The successful implementation of LNG aggregation for market development

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Note: This is NOT a thesis (PhD only) and NOT a dissertation (Masters by 100% research only)

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ABSTRACT

In the context of the global transition towards sustainability, most countries still grapple with energy security issues and a heavy reliance on fossil fuels as an energy source. Natural gas is proposed as a significant source of energy within global future efforts to diversify the energy system. The development of the natural gas market is therefore imperative to achieve the global energy transition goals as LNG has been identified as an ideal transitionary fuel (Hafeznia, Pourfayaz, & Maleki, 2017; Mohammad, Mohamad Ishak, Mustapa, & Ayodele, 2021; Safari, Das, Langhelle, Roy, & Assadi, 2019). This research report assesses the types of LNG aggregation implemented by countries and the effectiveness of the implementation of LNG aggregation as an energy policy instrument. The determinants of the identified criteria, based on the 4-As framework, were collected, and normalised via the unitization method. Multi-criteria analysis was utilized for the aggregation of the determinants, allowing for the analysis of the function which, in this research report, is the success of LNG aggregation implementation as energy policy. The analysis provides for the top performing country based on the indicators identified for each criterion of the 4As framework, from which, the success factors of LNG aggregation are unpacked.

Sixty-four countries are identified as trading in LNG, of which, eleven were identified as having implemented LNG aggregation strategies. The criteria of the 4A's framework, affordability, availability, acceptability, and applicability, are utilised to define a set of indicators which allowed the eleven countries to be ranked based on a performance score.

The United States, ranking first, implements a block aggregation strategy which has been complimented by the country's success factors. The country has a mature legal environment which has provided reassurance to the global market and resulted in the attraction of investment, transforming the country into a net exporter of energy. The United States has flexibility in its policies which allowed for the production of non-conventional Shale gas. Russia, ranking second, implements single buyer and brokerage aggregation strategies which has enabled the country to become a significant participant within the global LNG market. This successful implementation of the aggregation strategy is underpinned by the vertical integration of the state-owned gas company. The third ranked country, Trinidad and Tobago, has successfully implemented a single buyer, single seller aggregation strategy which allowed the infant market to develop over time. The country strives towards the ease of doing business for global participants, provides

government support and the ability to absorb market fluctuations.

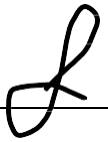
Lastly, Singapore implements a single-buyer aggregation strategy. The success factors, of which, have been the countries complimentary incentives for investment and trade, government support, policy driven incentives, a well-developed legal system and agility within policy.

KEYWORDS

Liquified Natural Gas, Aggregation, Energy, Natural Gas, energy security, energy mix.

DECLARATION

I, Letitia Anthia Moodley, declare that this research report is my work except as indicated in the references and acknowledgements. It is submitted in partial fulfilment of the requirements for the degree of Master of Management in Energy Leadership at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in this or any other university.

Name: Letitia Moodley Signature: 

Signed at …Durban……

On the 27th day of August 2024

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LIST OF ACRONYMS

bcf	Billion cubic feet
bcm	Billion cubic meters
CTL	Coal-to-Liquids
EMA	Energy Marketing Agency
EPC	Engineering Procurement and Construction
FSRU	Floating, Storage and Regasification Unit
GACN	Gas Aggregation Company of Nigeria
GTL	Gas-to-Liquids
IEP	Integrated Energy Plan
IGUA-SA	Industrial Gas Users Association South Africa
IPP	Independent Power Procurement
IRP	Integrated Resource Plan
KZN	KwaZulu-Natal
LNG	Liquified Natural Gas
MPRDA	Mineral and Petroleum Resources Development Act
Mtpa	Million tons per annum
NDP	National Development Plan
NERSA	National Energy Regulator South Africa
PPA	Power Purchase Agreement
RMIPPPP	Risk Mitigation Independent Power Producer Procurement Programme
ROMPCO	Republic of Mozambique Pipeline Company
SA	South Africa

CHAPTER 1. INTRODUCTION

1.1 Purpose of the study

This quantitative research report has assessed the types of LNG aggregation implemented, and the effectiveness of the implementation of LNG aggregation as an energy policy instrument, utilised to grow the LNG market. The determinants of the identified criteria, based on the 4-As framework, were collected, and normalised via the unitization method. Multi-criteria analysis was utilized for the aggregation of the determinants allowing for the analysis of the function, which in this research report, is the success of LNG aggregation implementation as energy policy. The overall performance score is then utilised to rank the countries from which the top four performers are assessed to identify the attributes of successfully implementing an LNG aggregation strategy.

1.2 Context of the study

Global natural gas trade can be traced back to the mid-twentieth century with the globalisation of natural gas markets beginning around the 1960s (Economides & Wood, 2009). The discovery of geographically spread gas pockets sparked the extensive investment in gas pipelines and LNG import terminals which allowed for off takers, not located in close proximity to the gas find, to purchase natural gas as LNG. As with all natural resources, not all countries are endowed with an abundance of natural gas which creates a gap in the possible positive impact that natural gas can have on a country's energy market and incorporation of renewable sources of energy. A possible solution to address the issue of supply shortages is the importation of LNG for supply to various end users, including gas to power plants, within several countries (Safari et al., 2019).

In many countries, industrialisation has been pursued in the absence of consideration of the impacts of the resources utilized on the environment. As a result, developed countries have achieved tremendous economic growth in exchange for environmental degradation which has impacted developing countries the most. There has been a global drive towards diversifying the global energy system to incorporate renewable sources of energy, however, natural gas is required to address the intermittency issues that arise from renewable energy (Kates, 2000). Research indicates that there must be a shift towards cleaner sources of energy and this must be done in a manner that is just (Marais, Burger, Campbell, Denoon-Stevens, & van Rooyen, 2021) There is therefore an increasing need for countries to transition to low cost, high efficiency energy systems that encompass the changes that are needed to reduce the global carbon footprint (NPC, 2030). Sufficient

literature highlights the possible role of LNG as a significant contributor toward a just transition and explains how this can be achieved within the set timeframes (Marais, Burger, Campbell, Denoon-Stevens, & van Rooyen, 2022).

The ability to transport natural gas, in the form of LNG, has enabled the establishment of the global LNG market that exists currently (Gałczyński, Ruszel, Turowski, Zajdler, & Zawisza, 2017). As the global LNG market has developed, countries which have identified significant LNG deposits have invested in upstream and midstream LNG activities which have enabled the export of natural gas and domestic supply. Countries that had not identified sufficient deposits to meet the country's demand, invested in import infrastructure which enabled the importation of natural gas as LNG (Gałczyński et al., 2017).

Technological advancements within the non-conventional sources of natural gas, such as Shale gas, have shifted the trade positions of certain countries, however, other countries have not participated in the natural gas market on a sufficient scale to allow the development of the LNG market (Wood, 2012). LNG aggregation has been utilised to develop the LNG market within several countries to differing degrees (Gkonis & Psaraftis, 2009). Globally, technological advancements arise daily and can often augment entire sectors. The development of the LNG sector will allow for significant investment into Research and Development (Strauss, 2008) for not only LNG in isolation but its integration into the implementation of renewable energy projects. The implementation of a natural gas aggregation strategy in certain countries, and the resultant development of the sector, would allow for the transfer of skills in this area of expertise (Energy, 2017).

The use of LNG comes with inherent risks which are exacerbated by global and national politics. The ongoing debate about the future of natural gas, recent phenomena such as the European energy crisis, and the global drive towards decarbonizing economies in a just manner, have all added to the negative sentiment around LNG as a source of energy. Several global phenomena, such as the Russia-Ukraine war, the Covid-19 pandemic and the resultant supply crunch, has impacted the demand and supply of natural gas and its prices which has impacted the sentiment around gas as a source of energy in the most recent years (Zakeri et al., 2022). The future of Natural Gas as a significant source of energy is widely debated as the LNG market has experienced supply constraints which have been exacerbated by the Russian invasion of Ukraine, leading to the energy crisis experienced by Europe (Zakeri et al., 2022).

Contrary to the stance against LNG for the future, there is a multitude of research, such as (Aïssa et al., 2023), (BP, 2022) and (Shell, 2022) that point to the relevance of LNG in the global energy system. Country specific LNG market development varies in accordance with the requirements of each country and its alignment to the transition towards net-zero. The need for energy security has been emphasised by the macroeconomic impacts on the global energy system, with countries considering natural gas as a viable addition to the energy mix, aiding in the transition towards net-zero (Zakeri et al., 2022).

The intersection faced by LNG must be unpacked to identify a viable solution to the reservations that several countries have against incorporating LNG into the energy mix (Feder, 2019). Policy certainty is required to ensure the development of the market and to attract investment into the ancillary infrastructure required, ensuring the required growth of the LNG market in various countries (Aleluia, Tharakan, Chikkatur, Shrimali, & Chen, 2022).

According to (IEA, 2022), LNG is the main form of gas traded globally with trade projected to reach 600 bcm by 2025. The current weak economy, coupled with a wanting regulatory environment within the natural gas sector in several countries, serves as an impediment to investment within the sector which is exacerbated by high capital costs (Roberts, 2019). Global phenomena such as the COVID-19 pandemic and the resultant impact on economic activity have constrained energy demand in 2020. Despite the aforementioned constraints and challenges, energy markets, and consequently the global economy, have experienced a revitalization once COVID-19 restrictions were lifted and economic activity resumed (Shell, 2022).

A stabilising model implemented in the natural gas sector, such as an LNG aggregation model, would assist in attracting investment and increasing participation within the sector. The increased participation would assist in growing the sector, relieving some of the strain on the fiscus of countries and fast-tracking global energy initiatives (Yuniza, Widyaparaga, Wicaksono, & Krisnadevi, 2016).

Literature points to the importance of LNG within the transition of economies to Net Zero Emissions as the recent years and global phenomena have emphasized the interconnection of energy systems and the respective sources of energy (Safari et al., 2019). Despite the risks associated with utilizing LNG as a source of energy, the sector's outlook remains bullish. The advantages of LNG as a source of energy can assist to shift economies to lower-emitting, higher efficiency energy systems, which is especially true

for developing countries (Shell, 2022). The associated risks, however, must be mitigated to ensure the successful growth of the sector (U.S.Department_of_Energy, 2017).

LNG as a source of energy cannot be implemented successfully without the consideration and involvement of the surrounding communities. Communities are increasingly holding market participants to account within the gas industry as the market continues to grow. It is therefore imperative for operators to perform a reference point analysis of the community from the onset of a project to ensure that communities are not left worse off due to the implementation of the project. In certain countries, it is compulsory to not only ensure that the communities are not negatively impacted but to ensure the betterment of surrounding communities by ensuring that projects include local content (U.S.Department_of_Energy, 2017).

To ensure that the transition to Net Zero is achieved with LNG as a significant complimentary resource to new renewable capacity, any LNG aggregation strategy must incorporate positive social impacts for surrounding communities. There are, generally, two beneficiaries of the value derived from the implementation of an aggregation system, system value and private value. Private value is realized when the implementation of an aggregation system yields an increase in value for a single entity or small group of agents. System value is derived when the entire energy system yields an increase in economic efficiency. The latter is preferred as private value may be derived at the expense of the economic efficiency of the energy system which may negatively impact the relevant communities (Kerscher & Arboleya, 2022).

Additionally, the market dynamics of LNG plays a crucial role in LNG aggregation. New supply and demand markets are increasingly being identified which compliments the pursuit of new technologies to improve the competitiveness and agility of LNG as a source of energy (Feder, 2019). Theoretically, the limitations presented by the imperfect energy system may be rectified once global policies and technologies catch up with the current transformation that the energy system is grappled with (Burger, Chaves-Ávila, Batlle, & Pérez-Arriaga, 2017).

The gas aggregation model, in most countries, is barely assessed as a viable model to be implemented to source LNG and develop the LNG market. The importation of LNG is an ideal transitionary source of energy which facilitates a just transition, preserving jobs with an easy augmentation of diesel and coal-fired power plants. LNG is a viable alternative to other sources of energy as it is readily available, transportable and can be introduced as an immediate solution to supply constraints. To achieve the

aforementioned just transition with an increased role of natural gas, there must be seamless coordination between demand and supply and the incorporation of renewable energy sources (NBI, 2022).

The legal environment is equally important to ensure the successful implementation of LNG aggregation. The requirement for the regulation of a sector arises because of the failure of the market participants within such a sector to regulate themselves. Regulation, when efficiently introduced, provides structure for the sector allowing for an increase in investor sentiment and a reduction of risks (Weems & Hwang, 2013). The LNG market, in many countries, has not fully developed due to the lack of structure and investment within the country for the importation of LNG. The European Commission proposes that customer participation within the energy market is minimized due to a lack of an efficient regulatory framework (Kerscher & Arboleya, 2022).

A significant obstacle in LNG sector growth is the existence of effective policies and the relevant frameworks to define the LNG objectives of government and address the issues of LNG affordability and LNG deliverability, to enable the growth of the sector. An effective policy must ensure that the prices of gas are such that there is equitable access to LNG which must be in line with government objectives. To ensure the deliverability of LNG, policies must be attractive to investors and facilitate the ease of doing business to enable the establishment of the necessary infrastructure (U.S.Department_of_Energy, 2017). LNG aggregation can be utilised to address both the deliverability and affordability of LNG (Burger et al., 2017).

Aggregators are widely defined depending on the national policies and legislature that exist which differ globally (Burger et al., 2017). Aggregation can be utilized to structure a country's gas sector, however, there is no single fit model for its successful implementation as the type and degree to which it is implemented will vary depending on the implementing country's dynamics and legal framework. (Roberts, 2019).

1.3 Research problem

The problem that this research report addresses is the difficulty for countries that do not have a developed LNG market to incorporate LNG into the countries' energy mix, given the complexities that arise with the energy source. To address these complexities and enable countries to ensure energy security, assistance is required to establish the LNG market and ensure seamless coordination between demand and supply. This assistance can be introduced as an LNG aggregation strategy. In the absence of such a

strategy, the complexities that exist with the implementation of LNG as an energy source may prevent the market from developing to a significant degree to allow the introduction of natural gas into a country's energy mix (U.S.Department_of_Energy, 2017).

LNG has been identified as a key source of energy to aid the global shift towards net zero emissions as the source is easily transportable and can be utilised to address the intermittency issues of implementing large scale renewable energy, allowing greater incorporation of renewable sources of energy into the global energy mix (Dorsey-Palmateer, 2019). The energy source is ideal for having lower emissions and higher efficiency than its hydrocarbon substitutes. For countries that do not have significant proven reserves of natural gas, or where there are barriers to the production of proven reserves, importing LNG may be a viable solution (Islam, 2023).

Given the importance of future natural gas and the role of LNG in the global economy, the successful implementation of an LNG aggregation model is key. Due to the complexities that are associated with LNG and the unique regulatory, geographical, economic and infrastructure nature of regions, there is no one size fits all aggregation strategy. The diverse types of LNG aggregation should be assessed to identify the more successful strategy given a set of factors.

1.4 Research questions

1. What are the main types of LNG aggregation?
2. Which countries have implemented LNG aggregation?
3. Which countries have been most successful in implementing LNG aggregation and what are the success factors of LNG aggregation?

1.5 Significance of the study

The energy supply shortage, arising due to recent global phenomena, coupled with the environmental crisis, and increasing pressure to decarbonize the world's energy system have brought the current energy systems into question. The challenges faced have emphasized the need for dependable, lower-emitting sources of energy that will assist with the transition to a net-zero economy. One such source is natural gas which is, in certain instances, identified as a green source of energy as it is a far lower emitter of greenhouse gases than its substitute hydrocarbons (Safari et al., 2019). This theory,

however, is often disputed with a strong stance against the addition of any fossil fuel capacity (Bugaje, Dioha, Abraham-Dukuma, & Wakil, 2022).

Research indicates that there must be a shift towards cleaner sources of energy, and this must be done in a manner that is just (Marais et al., 2022). Sufficient literature highlights the possible role of LNG as a significant contributor toward a just transition and how this can be achieved within the set timeframes (Bistline & Young, 2022; Marais et al., 2022; Safari et al., 2019).

The risks associated with LNG as a source of energy, the reservations that countries have as pertains to the future of LNG, and the balancing of the market, must be addressed to enable the development and growth of the LNG market globally. The implementation of LNG aggregation as an energy policy instrument is a viable solution to address the aforementioned issues. Unfortunately, LNG is not yet traded in the global market at the scale of its alternative fossil fuels which results in the requirement for assistance do develop the Market (Feder, 2019).

One complexity with LNG as an energy source is the geographical dispersion of the hydrocarbon which results in certain regions being resource rich whilst others have scarce deposits resulting in the need to import the molecule as LNG. This leaves the country susceptible to price fluctuations, being a price taker. An additional complexity is the capital intensity required for the extraction of natural gas in the upstream sector as well as the transportation, import and export infrastructure required (Rawat & Garg, 2021).

The misalignment of demand and supply is also seen as a complexity as supply is generally constrained (Simmer, Pfoser, Aschauer, & Schauer, 2015). Economies of scale are required to ensure that the supply of LNG can be secured at an affordable price over a sustainable period, which usually requires an anchor off taker (Appios, 2013). The lack of well-structured regulations and policy specific to LNG and natural gas may add to the complexity of developing the LNG market in countries with a nascent market (Knowles, 2003).

The aforementioned complexities can be addressed by implementing an aggregation strategy as has been implemented successfully by several countries over the years (Weems & Hwang, 2013). The geographic, economic, and regulatory disparities that exists between countries prevents the development of a single aggregation strategy as a best fit for all countries (Roberts, 2019). Research signifies that there is a gap in

existing literature on the successful implementation of LNG aggregation and which types have been the most successful. This study aims to address this gap thus providing a guideline for countries with nascent or non-existing LNG markets, given the role of LNG in the future global energy systems as a clean source of energy and the complexities in establishing the LNG market within a country (Brown, Wang, Sovacool, & D'Agostino, 2014; Najm & Matsumoto, 2020; Roberts, 2019; Wood, 2012).

This study unpacks LNG aggregation, identifies the countries that implement LNG aggregation and identifies the key requirements to its successful implementation. The study provides a valuable addition to academic research and beyond as it assists countries to identify whether LNG aggregation is a viable option and what the success factors of LNG aggregation are.

1.6 Delimitations of the study

This research report focuses on natural gas as a source of energy, more specifically, LNG as a form of natural gas. Available data on LNG importing countries is analysed to establish which of these countries have implemented LNG aggregation. The 4-As framework is utilised as the four main criteria to assess the effectiveness of LNG aggregation implementation as an energy policy instrument. A quantitative analysis of the determinants of each criterion is then assessed utilising a multi-criteria analysis for the year 2019.

The determinants of the identified criteria based on the 4-As framework are collected and normalised via the unitization method. Multi-criteria analysis is utilized for the aggregation of the determinants, allowing for the analysis of the function which, in this research report, is the success of LNG aggregation implementation as energy policy for market development. The analysis identifies the top performing country within each criterion for further discussion. The overall performance score is utilised to rank the countries from which the top four performers are assessed to identify the attributes of successfully implementing an LNG aggregation strategy.

1.7 Definition of terms

Natural gas is a fossil fuel found in pockets beneath the earth's surface in conventional and unconventional forms (Alejandro Alonso, 2012). Conventional gas has been extracted for decades as readily available and mined from porous rock (Alejandro Alonso, 2012). Unconventional gas, such as shale gas, is extracted utilizing advanced

technologies and consists of coal bed methane and shale gas (Alejandro Alonso, 2012). Coal bed methane is a form of natural gas that is entombed in coal beds. Natural gas can be extracted between coal beds whilst mining coal. Shale gas is found in sedimentary rock and requires hydraulic fracturing to extract the natural gas (Guo & Ghalambor, 2014).

One of the forms of natural gas is Liquified Natural Gas (LNG). LNG is the liquified state of natural gas which renders the gas nontoxic and nonflammable. The Gas reaches its liquid state when cooled to minus 162 degrees Celsius which reduces the volume of the gas by up to 600 times. This enables the transportation of natural gas over a long distance in a manner that is safe and easily transportable. Once at its destination, the gas is regasified and utilized for electricity generation, mobility, or piped to end users (Shell, 2022).

To ensure the successful development of the LNG market within a country, an LNG aggregation strategy may be implemented. Aggregation, in the context of this research report, is the implementation of a regulatory model which stipulates the requirement of an intercessor between sellers and buyers of natural gas, which pools gas demand and sources supply in a manner that allows equitable access to natural gas. The implementation of this model allows for stability within the sector and ensures the security of supply, addressing perceived risks within the sector and attracting multiple participants, thus growing the sector (Roberts, 2019).

The incorporation of LNG within energy systems may assist a country in achieving a transition to a lower emission economy in a just manner. A Just Transition, in the context of this study, refers to the transition to a net zero economy in a manner that is inclusive and takes into account the surrounding communities (NBI, 2022).

1.8 Assumptions

The research assumes that LNG is a viable source of energy that is required as a complementary energy source to Renewable energy. The requirement for LNG and the relevant LNG aggregation strategy is on the assumption that there will be no ground-breaking technological development in energy storage that will allow for the widescale use of renewable energy and the large-scale storage of such to address intermittency issues. Although many countries have identified proven natural gas reserves, an assumption is made that LNG importation is the most immediate solution which is easily implementable as a transitionary source of energy.

1.9 Structure of the report

Chapter 1 is the introduction of the research report on which the report is premised and provides an overview of the context, significance, and definitions of the report.

Chapter 2 is the literature review which analyses the literature that exists as pertains to the energy supply constraints within the country, the role of natural gas and the possible need for a gas aggregation strategy.

Chapter 3 is the research methodology which explains the methodological approach of the research report as qualitative research which includes a case study.

Chapter 4 is a presentation of the findings following the methodology followed in chapter 3.

Chapter 5 discusses the aforementioned findings.

Chapter 6 concludes the report and makes recommendations. Chapter 7 provides a reference list utilised within the research report

CHAPTER 2. LITERATURE REVIEW

2.1 Introduction

This literature review explores publicly available data, scholarly articles and other existing literature as pertains to the global LNG market. The GIIGNL Annual Report (2022) provides a list of LNG importing countries which are analysed to identify which of these countries implement LNG aggregation. The 4-As framework is utilised as the four criteria for which the relevant determinants of LNG aggregation are assessed via a multi-criteria analysis.

2.2 Definition of topic or background discussion

Aggregation is subjectively defined across nations, transforming through time and market anomalies. Juris (1998) explains that an aggregator assumes the role of an intermediary between producers and consumers, this enables the aggregator to pool the demand of smaller and larger market participants to source supply at fair transmission costs, arbitraging to take advantage of price variances (Juris, 1998a).

Kerscher and Arboleya (2022) define aggregators as market participants who generate value from bundling demand and supply. It is further deduced that the future role of aggregators in aiding the transition to net zero economies is almost certain if the technical, regulatory, and economic barriers to aggregation can be addressed (Kerscher & Arboleya, 2022).

Burger et al. (2017) define aggregation as the collaboration of several agents acting together as a single entity engaging wholesale and retail markets. As a regulatory model, it may be more beneficial to have a single large aggregator which is sufficiently regulated for market development and to maximize economies of scale (Burger et al., 2017).

Wang et al. (2015) classify aggregators as commercial, demand or production aggregators. Commercial aggregators are responsible for ensuring a balance between supply and demand within the market. Demand aggregators form an intermediary between smaller consumers and other market participants, whereas a production aggregator pools smaller producers for economies of scale (Wang et al., 2015).

Globally, countries are expected to augment their energy systems to minimise the negative impact currently inflicted on the environment (Davis et al., 2018). The

Augmentation of a country's energy mix must be done in a manner that is just, given the issues of poverty, unemployment and inequity that are faced globally by developing countries. Additionally, a country's energy supply constraints must be taken into consideration when diversifying its energy mix (Obobisa, 2022).

It is often highlighted that transitioning towards solely utilising renewable sources of energy in the short term is unfeasible given the intermittent issues that arise from using such sources of energy. It is therefore important to consider utilising a transitionary source of energy that is reliable and readily available, such as LNG (Mohammad et al., 2021). The development of the LNG sector and its incorporation into the global energy system requires the implementation of a regulatory model such as LNG aggregation which will assist with mitigating the risks associated with LNG usage and the disadvantage of its incorporation into the global energy system (Aleluia et al., 2022).

There are studies that dispute the future of LNG, however, even these studies contradictorily highlight the feasibility of LNG as a source of energy where the LNG demand is anchored by large scale gas to power plants such as three GW and above (Adam et al., 2022).

2.3 Unpacking the main types of aggregation

Although LNG aggregation is defined and interpreted varyingly across countries, as discussed in subsection 2.2., this research report focuses on LNG aggregation as defined by Roberts (2019). LNG aggregation is a regulatory model which regulates the intermediary, or aggregator, position between demand and supply, pooling supply, or demand to ensure economies of scale. LNG aggregation has a range of implementations and could range from brokerage between supply and demand to market manipulation. In rare instances, the security of the natural gas supply may occur naturally. Unfortunately, for LNG this is often not the case and a regulatory model such as LNG aggregation may require. (Roberts, 2019).

There are several reasons for the implementation of LNG aggregation which could differ globally. In countries with a strained fiscus, such as some developing countries, the lack of infrastructure could inhibit the growth of the sector. The introduction of an intermediary with the responsibility to reinvest in infrastructure or attract investment could structure the sector for growth (P. Turner & A. Barker, 2013). The complex and time-consuming contracting process for LNG can be addressed by establishing an aggregator for, mostly, standard contracts (Das, 2017).

As LNG is a relatively new source of energy for some countries, the regulation and policies surrounding it could be inadequate and the implementation of an LNG aggregator as a regulatory enabler of the market will assist to fill the gaps in regulations (Massol & Tchung-Ming, 2010). If the market is left unaggregated, an imbalance in prices may occur as customers willing and able to pay higher gas prices will always be the customer of choice, leaving other customers with supply constraints. The implementation of a gas aggregation strategy could result in the harmonization of imbalanced LNG pricing (P Turner & A Barker, 2013).

An aggregator that forms a fundamental component of the contracting between supplier and buyer may assume the default credit risk associated with purchasing LNG and as such promote supply to the customer or region. By pooling demand and supply through an aggregator, the imbalance in bargaining power may be rectified by Introducing an aggregation model which provides surety of contracts and demand for LNG, thus encouraging further exploration of natural gas fields (Weems & Hwang, 2013).

Although there are several purposes for, and advantages of, the implementation of an LNG aggregation strategy, there are several disadvantages that need to be managed. The incorrect selection of the relevant aggregation structure may result in the structure having a negative outcome. To mitigate this possibility, the correct form of aggregation must be applied to the country or region in question and must be specific to the dynamics of that country. It may also occur that the correct structure was implemented, however, it was implemented incorrectly resulting in a mismatch between market participants. This can be mitigated by having an implementation guideline for the aggregator and having an independent third party for disputes, should they arise. As with any agent, there is the risk of manipulation by a third party depending on the structure of the aggregation strategy. The risk of aggregation becoming a pseudo regulation must be mitigated by developing the correct policies. In some instances, aggregation is a temporary measure to ensure the development of the market. Once the market is developed, the aggregator must be repurposed as the aggregation strategy should be utilised as a transitionary measure (Roberts, 2019).

There are many forms of aggregation, for this research report, five main types will be considered. The first type is brokerage aggregation where the aggregator is the intermediary between demand and supply and assists with contracting, however, the contractual agreements are signed directly between buyer and seller. In this instance, the aggregator assumes a portfolio management role and may facilitate a bank account

for the deposit of funds, but this is merely in an attempt to facilitate credit, the aggregator does not provide credit guarantees (Juris, 1998a).

Secondly, is the single buyer model aggregation strategy in which the aggregator will buy from a supplier as the key buyer and sell to a customer as the key supplier. This assists in aggregating downstream demand which can be disjointed. In this type of aggregation, the aggregator assumes the risk of credit defaults and the responsibility of securing sufficient credit to conclude purchases which may require government support. The risk associated with ensuring that sellers follow through with their obligations also rests with the aggregator in this model. The aggregator will incur transaction costs, but these are offset by the profit generated from arbitrage (Burger et al., 2017).

The third form of aggregation involves a block aggregator where several suppliers or several purchasers pool demand and supply to establish bargaining power (Kerscher & Arboleya, 2022). An additional form of aggregation involves a governmental aggregation strategy where the purpose of the aggregator is to act as a regulator for increased governmental control within the LNG sector (Roberts, 2019). Lastly, for the consideration of this report, is price consolidating aggregation. This type of aggregation is implemented to facilitate symmetrical prices where all consumers pay the same price for LNG which will encourage fair distribution and access to LNG by all participants (Roberts, 2019). The five types of aggregation are summarized in table 1 below.

Table 1 Types of LNG Aggregation

#	Aggregation Type	Description	Source
1.	Brokerage aggregation	The aggregator facilitates contracts between buyers and sellers but does not assume any risk or contract directly with the buyer or seller	(Juris, 1998b) and (Roberts, 2019)
2.	Single Buyer model	The aggregator acts as the key buyer/seller, purchasing/selling LNG from one or more suppliers/buyers and selling/buying to/from consumers/buyers as the key seller/buyer. The aggregator assumes the supply and demand side risks.	(Burger et al., 2017) and (Juris, 1998b)

3.	Block aggregation	Suppliers pool supply capacity to form an aggregator that sells Blocks of LNG to consumers. Inversely it could also be the aggregation of demand to purchase a block of LNG to supply many consumers	(Kerscher & Arboleya, 2022)
4.	Governmental aggregation	An aggregator is established to act as a regulator for increased government control	(Roberts, 2019)
5.	Price consolidation	Aggregator facilitates symmetrical prices.	(Roberts, 2019)

Table 1: (Burger et al., 2017); (Juris, 1998b); (Kerscher & Arboleya, 2022) and (Roberts, 2019)

2.3.1 *Proposition one*

There are five main types of LNG aggregation as summarised in Table 1.

2.4 Countries implementing LNG aggregation

The GIIGNL Annual Report 2022 provides a list of LNG import and source countries as depicted below:

Table 2 LNG Importing countries				
#	County	$10^6 m^3$ liquid	10^6 T	Global Share
LNG Import Sources				
1	Gibraltar	0.14	0.06	0.0%
2	Colombia	0.10	0.04	0.0%
3	Israel	0.41	0.18	0.0%
4	Egypt	0.12	0.05	0.0%
5	Myanmar	0.49	0.22	0.1%
6	Sweden	0.83	0.36	0.1%
7	Malta	0.66	0.29	0.1%
8	Norway	0.50	0.22	0.1%
9	Finland	0.47	0.20	0.1%

10	Jamaica	1.24	0.52	0.1%
11	Canada	1.16	0.50	0.1%
12	United States	0.99	0.42	0.1%
13	Panama	0.47	0.21	0.1%

LNG Importing countries				
#	County	$10^6 m^3$ liquid	10^6 T	Global Share
14	Norway	0.53	0.24	0.1%
15	Mexico	1.42	0.61	0.2%
16	Croatia	2.76	1.20	0.3%
17	Lithuania	2.60	1.12	0.3%
18	UAE	2.66	1.19	0.3%
19	Cameroon	2.69	1.20	0.3%
20	Greece	3.73	1.64	0.4%
21	Puerto Rico	3.51	1.52	0.4%
22	Dominican Republic	3.41	1.47	0.4%
23	Malaysia	4.73	2.02	0.5%
24	Argentina	5.79	2.52	0.7%
25	Peru	5.68	2.55	0.7%
26	Equatorial Guinea	6.20	2.72	0.7%
27	Poland	6.49	2.83	0.8%
28	Singapore	7.19	3.12	0.8%
29	Chile	7.27	3.14	0.8%
30	Indonesia	7.58	3.31	0.9%
31	Belgium	7.54	3.32	0.9%
32	Angola	8.17	3.63	1.0%
33	Portugal	9.25	4.11	1.1%
34	Bangladesh	11.52	5.10	1.4%
35	Kuwait	11.99	5.34	1.4%
36	Netherlands	12.94	5.64	1.5%
37	Brunei	12.28	5.59	1.5%
38	UAE	13.10	6.02	1.6%
39	Trinidad and Tobago	14.51	6.19	1.7%
40	Thailand	14.78	6.55	1.8%
41	Italy	15.59	6.88	1.8%
42	Egypt	15.23	6.56	1.8%
43	Brazil	16.19	7.01	1.9%
44	Pakistan	18.45	8.19	2.2%
45	Papua New Guinea	17.84	8.30	2.2%

46	Turkey	22.68	9.99	2.7%
47	Russia	22.56	10.15	2.7%
48	Oman	22.26	10.22	2.7%
49	UK	25.04	11.04	3.0%
50	Algeria	26.19	11.78	3.2%
51	France	27.84	12.34	3.3%
52	Spain	31.34	13.82	3.7%
53	Indonesia	31.49	13.82	3.7%
54	Nigeria	36.35	16.42	4.4%
55	Taiwan	43.43	19.44	5.2%
56	Russia	44.53	19.46	5.2%
57	India	53.63	24.02	6.5%
58	Malaysia	56.78	24.94	6.7%
59	South Korea	105.59	46.92	12.6%
60	United States	155.09	67.03	18.0%
61	Japan	166.21	74.35	20.0%
62	Qatar	172.18	76.96	20.7%
63	Australia	177.24	78.52	21.1%
64	China	180.12	79.27	21.3%

***Table 2*: (GIIGNL, 2020)**

The GIIGNL (2022) provides a list of sixty-four countries that either import LNG or are a source of LNG for the importing countries which are ranked in ascending order from least global share. For this report, and to refine the aforementioned list to focus on significant participants within the LNG market, all importers, and sources of LNG with a volume of LNG that is less than $7x10^6m^3$, will be excluded from the list of countries under review. This exclusion reduces the list to thirty-seven countries, for which the existing literature and public information will be assessed to establish whether the country has implemented an LNG aggregation strategy. There are several lists such as within the BP Statistical Review of World Energy (2022), however, the GIIGNL serves as a major source of data for most reports and presents an all-encompassing list. Table 3 below outlines the countries that have implemented LNG aggregation strategies as assessed from the countries provided within Table 2.

One of the countries that implement LNG aggregation is Singapore. The country

introduced BG Singapore Gas Marketing Pte, which is a multinational company, as its LNG aggregator within Singapore. The aggregation strategy adopted a single buyer model in which the aggregator was regulated to aggregate demand, up to a maximum of three million tons per annum, to build the LNG market within the country. This emphasises the transitionary role of aggregation (Dodge, 2020).

Indonesia has been threatening to implement a gas aggregation strategy to regulate the market for several years which was solidified when the draft oil and gas market regulation was introduced. The further regulation of the gas aggregator was to address the disparity between demand and supply as a broker aggregator (Yuniza et al., 2016).

The Netherlands implements aggregation as a price consolidating aggregation model, however, there is a new law being implemented that explicitly defines aggregation (Sáez Armenteros, de Heer, & Bjørndalen, 2022).

All types of aggregation are implemented within France to differing degrees although demand side participation is only allowed for secondary markets. Regulation only considers generation enhancement as a demand response (Sáez Armenteros et al., 2022).

A governmental aggregation model was implemented to grow the natural gas market within Nigeria. The Gas Aggregation Company of Nigeria (GACN) was introduced as an aggregator in 2010 with no contractual dealings with buyers and sellers, instead, the GACN assumes a brokerage position between parties who eventually reach an agreement to buy or sell with each other. There is a stipulation, however, of a percentage for Domestic supply referred to as the Domestic Supply Obligation. This aggregation model has not reached its required level of success, which can be attributed to the lack of clear policy around the natural gas sector. Acting as a broker, GACN does not provide mitigation of credit risk or surety of supply (Roberts, 2019). The lack of regulatory and government support within the country's aggregation efforts has exacerbated the increasing risk of capital-intensive investment in the extraction of natural gas and the ancillary infrastructure required to sufficiently develop the natural gas market (Roberts, 2019).

The United Kingdom is one of the first countries to implement an aggregation model which was implemented to grow the sector and ensure that the relevant infrastructure required was developed independently of government intervention. The British Gas Corporation (BGC) was established to fill this role. There are lessons to be learnt from

this implementation as the BGC assumed a monopolistic role of developer, owner, and operator of the country's national transmission system (Heal, 1990). Similarly, the National Gas Company in Trinidad and Tobago was implemented as the sole distributor of gas as a strategy to grow the gas market. A single buyer/seller aggregation strategy was adopted as a gas aggregation strategy (Roberts, 2019).

Russia implements its aggregation strategy through, the majority state owned company, Gazprom which has been the topic of debate with the European Union due to the monopolistic nature of the company. The business model of Gazprom is a hybrid between a broker aggregator and a single buyer or seller model. The company is able to perform a portfolio management role but simultaneously participate in transactions. The company holds significant assets across the LNG value chain and aims to ensure the availability of capital expenditure for the growth of the gas market for the betterment of the country (Mandal, Semerdzhian, Leader, & Haigh, 2013).

The United States permits aggregators to purchase LNG for on selling purposes which allows these block aggregators to conduct arbitrage to exploit profits existing for different regions (Corbeau, Braaksma, Hussin, Yagoto, & Yamamoto, 2014).

Japan consists of around ten aggregators whilst China has three national oil companies that aggregate as per the single buyer model (Corbeau et al., 2014). Table 3 summarises the aggregation strategy that each of the eleven countries implements or has implemented.

Table 3 Countries that have implemented LNG aggregation strategies

#	Country	Aggregation strategy	Reference
1.	Singapore	Single-buyer aggregation	(Dodge, 2020)
2.	Indonesia	Broker Aggregation	(Yuniza, Widyaparaga, Wicaksono, & Krisnadevi, 2016)
3.	United Kingdom	Governmental aggregation	(Heal, 1990)
4.	United States	Block aggregation	(Corbeau, Braaksma, Hussin, Yagoto, & Yamamoto, 2014)
5.	Netherlands	Price consolidating aggregation	(Sáez Armenteros, de Heer, & Bjørndalen, 2022)
6.	Trinidad and Tobago	Single buyer/seller aggregation	(Roberts, 2019)
7.	Russia	Single buyer and brokerage aggregation	(Mandal, Semerdzhian, Leader, & Haigh, 2013).

8.	Japan	Broker aggregation	(Corbeau, Braaksma, Hussin, Yagoto, & Yamamoto, 2014)
9.	France	Multiple	(Sáez Armenteros et al., 2022)
10.	Nigeria	Governmental aggregation	(Roberts, 2019)
11.	China	Governmental aggregation	(Corbeau, Braaksma, Hussin, Yagoto, & Yamamoto, 2014)

Table 3: (Corbeau et al., 2014), (Dodge, 2020), (Mandal et al., 2013), (Roberts, 2019), (Sáez Armenteros et al., 2022), (Heal, 1990; Yuniza et al., 2016)

2.4.1 *Proposition 2*

There are eleven countries assessed which have implemented or are currently implementing an LNG strategy as outlined in Table 3.

2.5 The success factors of implementing LNG aggregation

2.5.1 *Proposition 3*

The 4-As framework, affordability, availability, applicability, and acceptability, was utilised to identify indicators to assess the success of LNG aggregation implementation. The criteria and indicators are defined within Table 4.

The demand for natural gas has increased given the advantages of its utilization relative to other fossil fuels. The cleanliness and versatility of natural gas, whilst remaining controllable, makes it an ideal transitionary fuel to achieve the global goal of net zero carbon emissions (Safari et al., 2019). Despite its suitability, and unlike other main sources of energy such as oil, LNG is not traded in the global market at the same level. Market phenomena such as the revolution of shale gas, has distorted markets and resulted in the increasing need for LNG aggregation as an energy policy to assist countries to develop the LNG market. Due to the constant fluctuations in the LNG market, the introduction of LNG aggregation as an energy policy to structure the sector is required (Kumar et al., 2011). The introduction of energy policy is conventionally aimed at addressing several issues, most importantly, energy security, energy intensity and environmental issues. All of which are encompassed within the 4-As framework.

The 4-As framework is quoted extensively in various literature since its introduction in 2007 (APERC, 2007; Brown et al., 2014; Yao & Chang, 2014). The definition of the four As framework was premised on the initial definition of energy security as a sustainable supply of energy at an affordable price (Yergin, 1988). Bielecki (2002) defines energy security as a sustainable source of energy at fair prices and emphasised energy security as a key consideration for policymakers to consider (Bielecki, 2002). Alternatively, Winzer (2012) defines energy security as being subjective to each country and defined by the relevant policies and characterizes energy security according to the risks faced by the specific market. The broadly defined concept of energy security emphasises its multi-faceted nature (Winzer, 2012).

The 4-As encompasses affordability, availability, acceptability, and applicability each with indicators for quantitative analysis (Yao & Chang, 2014). The indicators, according to Yao and Chang (2014), include oil and natural gas as sources of energy in the definition, however, for this report, only the indicators relating to LNG will be considered to address the research questions.

The indicators considered for affordability pertain to how well the population can afford LNG which includes the cost of LNG. Availability refers to the ability of LNG to be available or be utilised. The identified descriptive indicators of availability include natural gas reserves, production, reserve to production ratio, exports, imports, and reserve to consumption ratios. For acceptability, the variables used are in line with environmental stewardship as defined by Brown et al. (2014) as environmental sustainability. The Acceptability criteria refer to the environmental impact of the source of energy and is described by the incorporation of LNG into the countries' electricity generation and the relevant CO_2 emissions variables. The indicators considered for applicability are energy intensity and the relevance of the source to the country's dynamics which are defined by Yao and Chang (2014). The energy intensity variable is reflective of the energy efficiency of a country which is indicative of the level of technological advancement within that country, measured by the consumption of LNG per US dollar of GDP (Yao & Chang, 2014) The LNG import dependence ratio of each of the identified countries will be utilised and is regularly quoted in literature when defining energy security. Additional variables used to describe the applicability criteria are; excess LNG, LNG consumption, the share of LNG in the country's energy mix and LNG consumption. A summary of the variables is detailed in Table 4: (Brown et al., 2014), (PSA, 2021) and (Yao & Chang, 2014) below.

Table 4 The Criteria of successful LNG aggregation based on the 4A's framework				
#	Criteria	Description	Indicator	Reference
1.	Affordability	How well the population or consumers can afford the price of LNG	1.1 Cost of LNG imports LNG prices	(Brown et al., 2014)
2.	Availability	The ability for LNG to be available and used	2.1 Natural Gas Production 2.2 Natural Gas Reserves 2.3 LNG Exports 2.4 NG Reserve to Production ratio 2.5 LNG imports 2.6 Natural gas reserve to consumption ratio	(PSA, 2021) and (Yao & Chang, 2014)
3.	Acceptability	Environmental sustainability	3.1 CO2 emissions from natural gas 3.2 Share of gas fired energy out of total electricity generation	(Brown et al., 2014)
4.	Applicability	Economic and energy efficiency	4.1 Share of LNG in the country's energy mix 4.2 Excess Natural Gas 4.3 Consumption 4.4 Electricity generation from natural gas 4.5 LNG import dependence ratio 4.6 LNG consumption per GDP	(Yao & Chang, 2014)

Table 4: (Brown et al., 2014; PSA, 2021; Yao & Chang, 2014)

2.6 Conclusion of Literature Review

2.6.1 *Proposition 1*

There are five main types of LNG aggregation as summarised in Table 1.

2.6.2 *Proposition 2*

There are eleven countries assessed which have implemented or are currently implementing an LNG strategy as outlined in Table 3.

2.6.3 *Proposition 3*

The 4A-s framework is utilised to analyse the success of energy policy implementation as it assesses the affordability, availability, acceptability, and applicability of such a policy. For the purposes of this study the descriptive variables identified are as pertains to LNG and the implementation of LNG aggregation as an energy policy instrument. The assessment allows for the identification of key considerations for the successful implementation of LNG aggregation. The variables analysed are as per Table 4. Table 5 below presents an overview of the research propositions.

Table 5 Consistency Table

RQ #	**Research Question**	**Prop #**	**State Proposition**
1	What are the main types of LNG aggregation?	1	There are five main types of LNG aggregation as summarised in Table 1.
2	Which countries have implemented LNG aggregation?	2	There are eleven countries assessed which have implemented or are currently implementing, an LNG strategy as outlined in Table 3.

3	Which countries have been most successful in implementing LNG aggregation and what are the success factors of LNG aggregation?	3	The 4A-s framework is utilised to analyse the success of energy policy implementation as it assesses the affordability, availability, acceptability, and applicability of such a policy. For the purposes of this study the descriptive variables identified are as pertains to LNG and the implementation of LNG aggregation as an energy policy instrument. The assessment allows for the identification of key considerations for the successful implementation of LNG aggregation. The variables analysed are as per Table 4.

CHAPTER 3. RESEARCH METHODOLOGY

3.1 Research approach

As detailed within the literature review of this research report, authors such as (Brown et al., 2014) and (Yao & Chang, 2014) have identified variables that are applicable to each facet of the 4-As framework. This research report will follow a quantitative approach by imposing a multi-criteria analysis utilising the four As, affordability, availability, acceptability, and applicability, of the 4-As framework as the relevant criteria. The indicators utilised are as identified to be suitable for LNG aggregation as an energy policy. The purpose of assessing the effectiveness of LNG aggregation as an energy policy is to identify the success factors of its implementation to enable countries to develop or grow their natural gas markets.

Data pertaining to the identified variables was normalized and assessed according to their rank within each criterion. The success factors of the top four best performing countries, based on the holistic performance score, are thereafter discussed. The indicators successfully incorporate annualized data from 2019. The specific period was selected as it will eliminate the skewed data brought about by the 2019 COVID pandemic and the war between Ukraine and Russia. The indicators are as outlined in Table 4.

3.2 Research design

This report follows a quantitative method whereby the data collected, as per Table 4, is segregated into stimulants, which are beneficiary variables and destimulants, which are non-beneficiary variables (Jonek-Kowalska, 2022). Multi-criteria analysis is utilized for the aggregation of the variables allowing for the analysis of the function which, in this research report, is the success of LNG aggregation implementation as energy policy. The below function, Equation 1, is utilized to conduct the analysis.

$$Fw = \sum mi = Wi \times fi(x)$$

$$_i \ where \ \ Wi \varepsilon [0; 1] i \sum^m = wi = 1 - weight \ of \ criterion$$

$$f_i(x) = functions \ which \ describes \ criteria$$

Equation 1 (Jonek-Kowalska, 2022)

The data collected is normalized, an invariant point of reference is assumed, and zero unitization is utilized wherein each of the variables has an equal weight of one (Jonek-Kowalska, 2022). The countries identified are as per the types of LNG aggregation identified from reviewed literature as summarised in Table 1: (Burger et al., 2017); (Juris, 1998); (Kerscher & Arboleya, 2022) and (Roberts, 2019). The list of variables selected are as per Table 4: (Brown et al., 2014; PSA, 2021; Yao & Chang, 2014). A holistic assessment performance score is thereafter calculated for each country which will be utilized to allocate a rank of the performance of each of the eleven countries in terms of LNG aggregation implementation as an energy policy instrument. The rank will be used to identify the best performing country in each criterion of the 4-As framework for further discussion, and the overall rank allows for the identification of the top four performing countries to highlight the LNG aggregation success factors.

3.3 Data collection methods

The data for the stimulant and destimulant variables of each criterion were collected from publicly available secondary data for each of the eleven countries from the World Bank Datasets, the International Energy Agency Datasets, and country specific information where required. This was collected for 2019 (Bank, 2019; IEA, 2023).

3.4 Population and sample

3.4.1 *Population*

The report analyses the list of LNG aggregation countries as identified in Table 2: (GIIGNL, 2022). This country list was refined by reviewing the available literature and reports of each of the listed countries to identify the countries which have implemented LNG aggregation.

3.4.2 *Sample and sampling method*

This research report analyses the refined list of countries which implement, or have implemented, LNG aggregation strategies as per the LNG aggregation types listed in Table 1: (Burger et al., 2017); (Juris, 1998); (Kerscher & Arboleya, 2022) and (Roberts, 2019). Data was collected for the list identified for each of the indicators of the criteria of energy security as defined in Table 3: (Brown et al., 2014), (PSA, 2021) and (Yao & Chang, 2014), for 2019. The year 2019 was selected to exclude the distorting effects that the global phenomena such as the COVID pandemic and the war between Ukraine and Russia, had on energy data.

3.5 The research instruments

Data was collected for the applicable variables of the selected countries and a multi-criteria analysis was utilized to calculate a performance score for each of the four criteria and an overall performance score for each country which was utilized to rank the countries from which the top four countries are utilized to provide a list of LNG aggregation success factors.

The multi-criteria analysis is utilized for the aggregation of the variables allowing for the analysis of the function which, in this research report, is the success of LNG aggregation implementation as energy policy.

$$Fw = \sum_{mi} = Wi \times fi(x)$$

$$where\ Wi \in [0; 1] i \sum_{i}^{m} = wi = 1 - weight\ of\ criterion$$

$$f_i(x) = functions\ which\ describes\ criteria$$

(Equation 1 (Jonek-Kowalska, 2022)

The data collected is normalized, an invariant point of reference is assumed, and zero unitization is utilized wherein each of the variables has an equal weight of one (Jonek-Kowalska, 2022).

3.6 Procedure for data collection

An analysis was conducted of the refined list of countries which implement, or have implemented, LNG aggregation strategies as per the LNG aggregation types listed in Table 1: (Burger et al., 2017); (Juris, 1998); (Kerscher & Arboleya, 2022) and (Roberts, 2019). Data was collected for the list identified for each of the indicators of the 4As criteria as defined in Table 6: (Brown et al., 2014), (PSA, 2021) and (Yao & Chang, 2014) below, which exhibits the calculation or units of the relevant variables.

Table 6 Indicator definitions

#	Criteria	Description	Indicator	Calculation/unit	Reference
1.	Affordability	How well the population or consumers can afford the price of LNG	1.1) Cost of LNG imports	1.1 USD per million BTU	(Brown, Wang, Sovacool, & D'Agostino, 2014)
2.	Availability	The ability for LNG to be available and used	2.1) Natural Gas Production 2.2) Natural Gas Reserves 2.3) LNG Exports 2.5) NG Reserve to Production ratio 2.6) LNG imports 2.7) Natural gas reserve to consumption ratio	2.1 bcm 2.2 bcm 2.3) million m3 2.4) natural gas reserves/production = number of years 2.5) million m3 2.6) natural gas reserves/consumption = number of years	(PSA, 2021) and (Yao & Chang, 2014)
3	Acceptability	Environmental sustainability	3.1) CO2 emissions from natural gas 3.2) Share of gas fired energy out of total electricity generation	3.1) MTPA 3.2) % of CO_2 emissions	(Brown et al., 2014)
4	Applicability	Economic and energy efficiency	4.1) Share of LNG in the country's energy mix 4.2) Excess Natural Gas 4.3) Consumption	4.1) % 4.2) (import + production-export) million cubic meters 4.3) bcm 4.4) TWh	(Yao & Chang, 2014)

			4.4) Electricity generation from natural gas 4.5) LNG import dependence ratio 4.6) LNG consumption per GDP	4.5) imports *100/production+imports-exports) (percentage) 4.6) cubic meters of LNG consumption per $GDP	

Table 6: Criteria (Brown et al., 2014), (PSA, 2021) and (Yao & Chang, 2014).

The data for the energy security indicators was collected from the World Bank, International Energy Agency, and country specific data, where necessary.

3.7 Data analysis and interpretation

The variables were identified as either stimulant or destimulant variables and normalized following the zero-unitization method. A multi-criteria analysis was conducted on the relevant data to calculate a performance score for each country. The performance score was then utilised to rank the countries for each of the four criteria and provide an overall score which is indicative of LNG aggregation as an energy policy instrument. The ranked data was used to identify the top four most successful countries in implementing LNG strategies which was used to identify the success factors in LNG aggregation implementation.

3.8 Limitations of the study

- There is limited information available for certain countries identified;
- The number of countries that are importers of natural gas and have successfully implemented a gas aggregation strategy is limited;
- The study focuses on 2019 which is a period in which most data is readily available, it excludes the impact of the COVID-19 pandemic, and it excludes the supply chain crisis felt due to the war between Ukraine and Russia.

3.9 Validity and reliability

3.9.1 *External Validity*

Calder et al. (1982) define external validity as the degree to which the research is

generalizable to other contexts globally. This research report was crafted to form a guideline for the successful implementation of LNG aggregation by countries and is not specific to a single country. The requirements of a country and the success in the implementation of LNG aggregation differs depending on the legal, political, economic, and environmental dynamics of the country at hand (Burger et al., 2017). This research report is, therefore, meant to be modified depending on the country in focus.

3.9.2 *Dependability*

Utilising multiple sources of data as indicated in the tables within this research report addresses the issue of dependability as detailed in (Kaman & Othman, 2016) as the ability to conduct the same study and yield similar results.

3.9.3 *Objectivity OR confirmability*

An audit trail of information obtained is incorporated into the report as sources of information are referenced (Lee, Mishna, & Brennenstuhl, 2010).

3.10 Ethical considerations

The research report does not include any human respondents. The data collected is from publicly available resources that are not restricted and require no permission.

Table 7 Consistency: research questions, propositions, data collection and data analysis

RQ #	State Research Question or Objective	Prop	State Proposition	Data collection detail	Data analysis method
3	Which countries have been most successful in implementing LNG aggregation and what are the success factors of LNG aggregation?	3	The 4A-s framework is utilised to analyse the success of energy policy implementation as it assesses the affordability, availability, acceptability and applicability of such a policy. For the purposes of this study the descriptive variables identified are as pertains to LNG and the implementation of LNG aggregation as an energy policy instrument. The Assessment allows for the identification of key considerations for the successful implementation of LNG aggregation. The variables analysed are as per Table 8: (Brown et al., 2014), (PSA, 2021) and (Yao & Chang, 2014).	Data for each of the eleven countries is collected from the World Bank datasets, the International Energy Agency datasets and from country specific data where required. This data was collected as per the variables in Table 8.	• Multi-criteria analysis • Normalization

CHAPTER 4. PRESENTATION OF RESULTS

4.1 Introduction

The data collected for the variables identified were collected as per Table 7: (Brown et al., 2014), (PSA, 2021) and (Yao & Chang, 2014). A multi-criteria analysis was conducted on the data for eleven countries. The resultant performance scores were utilised to allocate a ranking order. The four criteria were ranked separately for further discussion whereafter the overall rank was allocated which identified the top four performing countries.

4.2 Results pertaining to question 3.

Table 8 The values of the evaluated criteria before normalization

Country Name	LNG prices (USD/million BTU)	Natural Gas Production (bcm)	Natural Gas Reserves (bcm)	LNG Exports (million m3)	NG Reserve to Production ratio (number of years)	LNG imports (Million m3)	Natural gas reserve to consumption ratio (Number of Years)
Criteria	**Affordability**	**Availability**					
Destimulant (1-(x-min/range)) or Stimulant (x-min/range)	destimulant	Stimulant	Stimulant	Destimulant	Stimulant	Stimulant	Stimulant
China	6,2	170,8404605	8398,55	0,343758	49,18108	4952721	28,18738
France	5,5	0,02102	8,89518	0,874324	423,17	2203852	0,2107
Indonesia	8,5	65,32698365	1429,548	35,04	21,89227	8,25	33,62715
Japan	9,3	2,828	20,906	3,13E-05	7,3925	4185466	0,20003
Netherlands	5,5	26,91478568	129,9304	0	4,829523	1198117	3,632561

Nigeria	3,2	47,63383261	5472,98	45,95	114,9457	0	6,105
Russian Federation	6,4	656,3730971	37556,74	41,2	57,2429	348389	87,48453
Singapore	4,3	0	0	0,2501	0	424859	0
Trinidad and Tobago	9,68	33,4069854	289,5635	29,11	8,671436	0	17,15144
United Kingdom	4,47	37,84826955	186,9793	0,595177	4,942334	1840221	2,491065
United States	7,1	897,1236613	12618,71	77,61	14,07171	2949766	15,35235
Max	9,68	897,1236613	37556,74	77,61	423,17	4952721	87,48453
Min	3,2	0	0	0	0	0	0
Range	6,48	897,1236613	37556,74	77,61	423,17	4952721	87,48453

Criteria	**Acceptability**		**Applicability**					
Country Name	CO2 emissions from natural gas (MTPA)	share of gas fired energy out of total electricity generation (%)	Share of LNG in the country's energy mix (percentage)	Excess Natural Gas (import + production-export) million cubic meters	LNG Consumption (bcm)	Electricity generation from natural gas (TWh)	LNG import dependence ratio (imports*100 /production+imports- exports) (percentage)	cubic meters of LNG consumption per $GDP
Destimulant (1-(x-	Destimulant	stimulant	stimulant	stimulant	Stimulant	Stimulant	Stimulant	Stimulant

min/range)) or Stimulant (x-min/range)								
China	630,1714	3,116	7,713569	170979,8	298,0809	232,5	0,08167	0,024358
France	86,35643	6,949896	15,98093	34,17568	42,20427	39,31	68,78942	0,016342
Indonesia	87,91035	21,09468	18,11063	65300,19	42,52979	62,32	0,012634	0,041884
Japan	224,2301	38,05958	21,03181	170,01	104,5133	377,65	5,670762	0,02145
Netherlands	72,47401	58,51877	37,56241	26927,96	35,78345	70,65	0,048908	0,043083
Nigeria	35,10478	71,24802	10	47587,88	18,8279	22,55	0	0,050108
Russian Federation	803,8632	45,61293	53,2756	656356,7	429,4782	485,13	0,003781	0,272094
Singapore	20,88846	95,38165	37,456	7,57	12,12981	49,36	103,4167	0,037448
Trinidad and Tobago	36,4165	85,18518	90,50234	33377,88	16,88992	7,36	0	0,764976
United Kingdom	159,3209	40,59692	35,54824	37878,04	75,09191	130,58	0,080178	0,028467
United States	1673,999	38,19775	32,015	897048,5	822,2891	1585,81	0,000268	0,0422
Max	1673,999	95,38165	90,50234	897048,5	822,2891	1585,81	103,4167	0,764976
Min	20,88846	3,116	7,713569	7,57	12,12981	7,36	0	0,016342
Range	1653,11054	92,26565	82,788771	897040,93	810,15929	1578,45	103,4167	0,748634

Source ((BP, 2022; GIIGNL, 2020; IEA, 2022, 2023)

Table 8 provides an overview of the data collected and cleaned for the purposes of this research report. The data presented represents the values of each criterion before normalization.

Table 9 Values after normalization, the affordability criteria

Country Name	LNG prices (USD/million BTU)	Rank
	Destimulant	
Nigeria	1	1
Singapore	0,984567901	2
United Kingdom	0,804012346	3
France	0,645061728	4
Netherlands	0,645061728	5
China	0,537037037	6
Russian Federation	0,50617284	7
United States	0,398148148	8
Indonesia	0,182098765	9
Japan	0,058641975	10
Trinidad and Tobago	0	11

Source (Own work)

Table 9 provides an overview of the affordability of LNG within the eleven countries and ranks them based on the per US Dollar price of 1 British Thermal Unit of LNG.

Of the eleven countries analysed, Nigeria was ranked first in terms of affordability based on the LNG prices indicator. The country has identified approximately 206 trillion cubic feet of natural gas making it the largest gas reserve in Africa and one of the ten countries with the largest reserves globally (Ugolo & Iwegbu, 2023).

Singapore, ranked second in terms of affordability, is described as having a more progressive LNG market in the country's pursuit of the Asian LNG Hub and deregulated prices to ensure affordability. Singapore was able to reach its, close to, optimal strategy of LNG pricing given its historical implementation of an LNG aggregation strategy to develop the market (Mak, 2016).

The United Kingdom, ranking third, is a mature and liberalized market which has been able to leverage its domestic demand for LNG and its strategic location for LNG landing, to establish bulk LNG import infrastructure. The country has been successful in pooling domestic and European demand to establish its LNG market (Nikhalat-Jahromi, Angeloudis, Bell, & Cochrane, 2017).

France has ranked fourth in terms of the affordability of LNG, which may be attributed to the country's historical investments within the LNG value chain and market development within the country (Dorigoni & Portatadino, 2008).

Table 10 Values after normalization, the availability criteria

Country	Natural Gas Production (bcm)	Natural Gas Reserves (bcm)	LNG Exports (million m3)	NG Reserve to Production ratio (number of years)	LNG imports (Million m3)	natural gas reserve to consumption ratio (Number of Years)	holistic assessment performance score	Rank
Destimulant = 1-((x-min)/range) or Stimulant	Stimulant	Stimulant	Destimulant	Stimulant	Stimulant	Stimulant	Stimulant	

(x-min/range)								
Russian Federation	0,731641718	1	0,530859425	0,13527164	0,070342949	1	3,468115733	1
United States	1	0,335990557	1	0,03325309	0,595584932	0,175486455	3,140315034	2
China	0,190431339	0,223622977	0,0044293	0,116220621	1	0,32219845	1,856902688	3
France	2,34304E-05	0,000236846	0,01126561	1	0,444978023	0,002408426	1,458912336	4
Nigeria	0,053096172	0,145725641	0,592062878	0,271630078	0	0,069783766	1,132298536	5
Indonesia	0,07281826	0,038063687	0,45148821	0,051733984	1,66575E-06	0,384378244	0,99848405	6
Japan	0,003152297	0,000556651	4,03299E-07	0,017469339	0,845084147	0,002286461	0,868549298	7
Trinidad and Tobago	0,037237882	0,007710028	0,375080531	0,020491613	0	0,196051119	0,636571173	8
United Kingdom	0,042188464	0,004978582	0,007668818	0,011679311	0,371557574	0,028474349	0,466547098	9
Netherlands	0,030001199	0,003459576	0	0,011412725	0,241910861	0,041522324	0,328306685	10
Singapore	0	0	0,003222523	0	0,085782946	0	0,089005469	11

Source (Own work)

To assess the availability of LNG within the eleven countries, natural gas production, reserves, LNG imports and exports, reserves to production and consumption are utilised as indicators.

Although monopolised by two large LNG players, Russia ranked first in terms of the availability of LNG. The government of Russia has embarked on a political drive to ensure the growth of the LNG export market despite the disruptions to the global LNG market following the Russian-Ukraine conflict (Henderson & Yermakov, 2019).

The United States, ranking second for LNG availability, has been at the forefront of the LNG evolution with the discovery, and extraction, of Shale gas which changed the dynamics of the LNG market globally. The discovery caused a shift from the original objective to facilitate for LNG import capacity to the production of natural gas with the new abundance of the fossil fuel (Shakya, Li, & Etienne, 2022).

China, a significant consumer of natural gas ranked third in terms of LNG availability within the country. The country's energy requirements increase rapidly at a rate of more than 10% per annum with natural gas contributing towards its energy mix. Although the country has significant natural gas reserves, natural gas production is less than demand which results in the country importing LNG. The country has had several developments along the LNG value chain with technological advancements in Mobility and investments in import and reticulation infrastructure (Lin, Zhang, & Gu, 2010).

Similarly to the affordability criteria, France was ranked fourth for the availability of LNG within the country.

Table 11 Values after normalization, the availability criteria

Country	CO2 emissions from natural gas (MTPA)	share of gas fired energy out of total electricity generation (%)	Performance Score	Rank
Destimulant = 1-((x-min)/range) or Stimulant	Stimulant	stimulant		

(x-min/range)				
United States	1	0,380225469	1,380225469	1
Singapore	0	1	1	2
Russian Federation	0,473637256	0,460593189	0,934230445	3
Trinidad and Tobago	0,009393225	0,889487908	0,898881133	4
Nigeria	0,008599739	0,738433209	0,747032948	5
Netherlands	0,031205143	0,600470164	0,631675307	6
Japan	0,123005471	0,378727945	0,501733415	7
United Kingdom	0,083740583	0,40622832	0,489968903	8
China	0,368567573	0	0,368567573	9
Indonesia	0,040542897	0,194857783	0,23540068	10
France	0,039602899	0,041552799	0,081155698	11

Table 11 presents the assessment of the acceptability of LNG within a country utilising LNG CO_2 emissions and LNG's contribution to the country's electricity generation. The United States and Russia ranked first and third respectively in terms of the acceptability of LNG within the country. Russia and the United States are significant producers of

natural gas with the objective of further expanding the LNG markets within each country (Economides & Wood, 2009).

Similarly to the affordability criteria, Singapore has ranked second for the acceptability of LNG, although the country is not a natural gas producer, the country has incorporated LNG into its energy mix and future energy system plans (Mak, 2016).

Trinidad and Tobago ranked fourth for the acceptability of LNG within the country. The country has implemented a heavily subsidized structure for fuel and electricity consumption which has led to the high acceptance of LNG (Khan & Khan, 2020).

Table 12 Values after normalization, the applicability criteria

Country	Share of LNG in the country's energy mix (percentage)	Excess Natural Gas (import + production - export) million cubic meters	LNG Consumption (bcm)	Electricity generation from natural gas (TWh)	LNG import dependence ratio(imports*100/production mports-exports) (percentage)	cubic meters of LNG consumption per $GDP	Holistic assessment performance score	Rank
Destimulant = 1-((x-min)/range) or Stimulant (x-min/range)	stimulant	stimulant	Stimulant	Stimulant	Destimulant	Destimulant		
United States	0,293535352	1	1	1	2,59146E-06	0,034540243	3,343050315	1
Russian Federation	0,55034071	0,731682477	0,515143621	0,302683012	3,65608E-05	0,341624879	2,45648339	2
Trinidad and	1	0,037200432	0,005875524	0	0	1	2,058048085	3

Tobago								
Singapore	0,359256825	0	0	0,026608382	1	0,028192682	1,429030018	4
France	0,099860898	2,96594E-05	0,037121663	0,020241376	0,665167425	0	0,83739315	5
China	0	0,190595796	0,352956627	0,142633596	0,000789718	0,010707502	0,712655368	6
Japan	0,160870138	0,000181084	0,114031267	0,234590896	0,054834103	0,006823094	0,586302712	7
United Kingdom	0,336213124	0,042217104	0,077715705	0,078063923	0,000775291	0,016196165	0,566153437	8
Netherlands	0,360542144	0,030010214	0,029196283	0,040096297	0,000472922	0,035719744	0,511009713	9
Indonesia	0,125585401	0,072786668	0,03752346	0,034818968	0,000122166	0,034118141	0,319926933	10
Nigeria	0,027617646	0,053041404	0,008267621	0,009623365	0	0,045103482	0,158625647	11

Table 12 presents the assessment of the applicability of LNG within the eleven countries utilising the share of LNG in the energy mix, excess natural gas, LNG consumption, electricity generation and import dependence.

The United States, Russia, Singapore and Trinidad and Tobago ranked first to fourth respectively which reflects the LNG markets within each country as the aforementioned countries have ranked within the top four for more than one of the criteria, applicability, acceptability, affordability, and availability.

Table 13 Values of the criteria after normalization, holistic assessment performance score

Country Name	LNG prices (USD/million BTU)	Natural Gas Production (bcm)	Natural Gas Reserves (bcm)	LNG Exports (million m3)	NG Reserve to Production ratio (number of years)	LNG imports (Million m3)	natural gas reserve to consumption ratio (Number of Years)
Criteria	**Affordability**	**Availability**					
Destimulant (x/max) or Stimulant (min/x)	destimulant	Stimulant	Stimulant	Destimulant	Stimulant	Stimulant	Stimulant
United States	0,398148148	1	0,335990557	1	0,03325309	0,595584932	0,175486455
Russian Federation	0,50617284	0,731641718	1	0,530859425	0,13527164	0,070342949	1
Trinidad and Tobago	0	0,037237882	0,007710028	0,375080531	0,020491613	0	0,196051119
Singapore	0,984567901	0	0	0,003222523	0	0,085782946	0
China	0,537037037	0,190431339	0,223622977	0,0044293	0,116220621	1	0,322198 45
Nigeria	1	0,053096172	0,145725641	0,592062878	0,271630078	0	0,069783766

France	0,645061728	2,34304E-05	0,000236846	0,01126561	1	0,444978023	0,002408426
United Kingdom	0,804012346	0,042188464	0,004978582	0,007668818	0,011679311	0,371557574	0,028474349
Netherlands	0,645061728	0,030001199	0,003459576	0	0,011412725	0,241910861	0,041522324
Japan	0,058641975	0,003152297	0,000556651	4,03299E-07	0,017469339	0,845084147	0,002286461
Indonesia	0,182098765	0,07281826	0,038063687	0,45148821	0,051733984	1,66575E-06	0,384378244

Criteria	**Acceptability**		**Applicability**					
Country Name	CO2 emissions from natural gas (MTPA)	share of gas fired energy out of total electricity generation (%)	Share of LNG in the country's energy mix (percentage)	Excess Natural Gas (import + production - export) million cubic meters	LNG Consumption n (bcm)	Electricity generation from natural gas (TWh)	LNG import dependence ratio (imports*100 /Production mports-exports) (percentage)	cubic meters of LNG consumption per $GDP
Destimulant (1-(x-min/range)) or Stimulant (x-min/range)	Destimulant	stimulant	stimulant	stimulant	Stimulant	Stimulant	Stimulant	Stimulant
United States	1	0,380225469	0,293535352	1	1	1	2,59146E-06	0,034540243
Russian Federation	0,473637256	0,460593189	0,55034071	0,731682477	0,515143621	0,302683012	3,65608E-05	0,341624879
Trinidad and Tobago	0,009393225	0,889487908	1	0,037200432	0,005875524	0	0	1
Singapore	0	1	0,359256825	0	0	0,026608382	1	0,028192682

China	0,368567573	0	0	0,190595796	0,352956627	0,142633596	0,000789718	0,010707502
Nigeria	0,008599739	0,738433209	0,027617646	0,053041404	0,008267621	0,009623365	0	0,045103482
France	0,039602899	0,041552799	0,099860898	2,96594E-05	-0,037121663	0,020241376	0,665167425	0
United Kingdom	0,083740583	0,40622832	0,33621312	0,042217104	0,077715705	0,078063923	0,000775291	0,016196165
Netherlands	0,031205143	0,600470164	0,360542144	0,030010214	0,029196283	0,040096297	0,000472922	0,035719724
Japan	0,123005471	0,378727945	0,160870138	0,000181084	0,114031267	0,234590896	0,054834103	0,006823094
Indonesia	0,040542897	0,194857783	0,125585401	0,072786668	0,037523346	0,034818968	0,000122166	0,034118141

Table 14 Holistic assessment of performance score

Country	Holistic assessment performance score	Rank
United States	8,261738966	1
Russian Federation	7,365002407	2
Trinidad and Tobago	3,593500392	3
Singapore	3,502603388	4
China	3,475162666	5
Nigeria	3,037957131	6
France	3,022522913	7

United Kingdom	2,326681784	8
Netherlands	2,116053434	9
Japan	2,0152274	10
Indonesia	1,735910429	11

Source (Own Work)

Table 13 and 14 provides a summary of the overall assessment of the eleven countries using the assessment criteria of affordability, acceptability, applicability, and availability from the 4-As framework. The data has been normalised to allow for the analysis of the indicators selected for each criterion. The United States ranked first, Russia second, Trinidad and Tobago third and Singapore fourth.

The multi-criteria analysis provides an indication of which countries have been most successful at developing the LNG markets by utilising an LNG aggregation strategy which will be further discussed in Chapter 5.

4.3 Summary of results

The countries were ranked according to the holistic assessment performance score calculated after normalization which resulted in a rank for each criterion as follows.

Table 15 Summary of Results

	Affordability	Availability	Acceptability	Applicability	Overall Performance Rank
China	6	3	9	6	5
France	4	4	11	5	7
Indonesia	9	6	10	10	11

Japan	10	7	7	7	10
Netherlands	5	10	6	9	9
Nigeria	1	5	5	11	6
Russian Federation	7	1	3	2	2
Singapore	2	11	2	4	4
Trinidad and Tobago	11	8	4	3	3
United Kingdom	3	9	8	8	8
United States	8	2	1	1	1

Table 15 presents a summary of the eleven countries that were identified as participants within the LNG market by implementing an LNG aggregation strategy to develop or expand this market. For the affordability criteria, which utilised the per US Dollar LNG price for 1 British Thermal Unit of LNG, the top 4 ranking countries were Nigeria, Singapore, the United Kingdom, and France. The availability criteria utilised LNG production, reserves, imports, and exports to assess the availability of LNG in the eleven countries. The resultant top four ranking was Russia, United States, China, and France. The CO_2 emissions of each country and gas to power contribution to the countries' electricity generation were used as indicators to assess the acceptability of LNG within each country. The United States, Singapore, Russia and Trinidad and Tobago ranked top four in terms of the acceptability of LNG within the respective countries. For the applicability criteria, the share of LNG in the energy mix, excess natural gas, LNG consumption, electricity generation and import dependence were utilised as indicators to assess the applicability of LNG within each of the 11 countries. The United States, Russia, Trinidad and Tobago and Singapore ranked top four.

Overall, the four countries that were identified as the best performers in terms of the multicriteria analysis, utilising the 4-As framework are the United States, Russia, Trinidad and Tobago, and Singapore.

CHAPTER 5. DISCUSSION OF THE RESULTS

5.1 Introduction

Natural Gas, proposed as a future energy transition source, plays a key role in global future energy systems. Many countries have implemented an LNG aggregation strategy as an energy policy initiative to differing extents in order to develop the LNG market whilst other countries are yet to develop such a market. The development of the natural gas market is key to achieving the global energy transition goals as emphasised throughout literature (Hafeznia, Pourfayaz, & Maleki, 2017; Mohammad, Mohamad Ishak, Mustapa, & Ayodele, 2021; Safari, Das, Langhelle, Roy, & Assadi, 2019).

The nature of LNG is such that, in certain instances, assistance is required for the market to develop. This research report therefore assesses the types of LNG aggregation implemented by countries and the effectiveness of the implementation of LNG aggregation as an energy policy instrument. The determinants of the identified criteria based on the 4-As framework were collected and normalised via the unitization method. Multi-criteria analysis was thereafter utilized for the aggregation of the determinants, allowing for the analysis of the function which, in this research report, is the success of LNG aggregation implementation as energy policy. The analysis has provided for the top performing country within each criterion from which the success factors of LNG aggregation will be unpacked. The holistic performance indictor ranks the United States, Russia, Trinidad and Tobago and Singapore in descending order.

5.2 Discussion pertaining to research question 3.

5.2.1 *The United States*

In the last decade, the United States has become a significant player within the LNG market given its advancements in the extraction of Shale gas. The country has transformed from a net importer of energy to a net exporter on the basis of unconventional gas finds. Globally, the United States has the largest capacity to export LNG with the infrastructure to export almost 186 million cubic meters of LNG per annum (Globerman & Shapiro, 2003).

The United States' energy mix consists of a 32% share of LNG with the highest amount of excess supply and consumption of LNG out of the eleven countries identified and a

low energy intensity. The United States, which implements block aggregation, can meet its production and consumption requirements, at 2019 rates, for the next 14 and 15 years respectively (IEA, 2022).

Demand side block aggregation is utilised where aggregators purchase the majority of capacity in blocks to supply to end-users. The mature legal environment and policies, which are conducive to the global trade of natural resources, forms the platform for the successful implementation of LNG aggregation (Corbeau et al., 2014).

The governance structures in place in the United States guides all transactions towards good governance, compliance and transparency which are some of the attributing factors to successfully implementing an LNG aggregation strategy. The legal framework existing within the country coupled with agile policies allow some flexibility to be built into markets as is seen with the evolution of Shale gas. The Shale gas evolution allowed the United States to become a net energy exporter. This built in flexibility is an additional success factor that aided in the development of the LNG market within the United States to the level that is observed currently (Globerman & Shapiro, 2003).

The flexibility and regulatory nature of the US market has aided in the country's attraction of extensive investment globally, totaling $26.74 billion. The investment attraction into the Country's Shale gas value chain represents 20% of the country's total investment between 2008 and 2012 (Corbeau et al., 2014; Globerman & Shapiro, 2003).

5.2.2 *Russia*

In 2019, Russia had a prominent level of natural gas reserves, despite its successes in implementing the Single buyer and brokerage aggregation strategies, it manages to maintain high reserve to consumption and reserve to production ratios. These ratios indicate Russia's ability to meet its LNG requirements for the next 57 to 87 years to come (Mandal et al., 2013).

More than 50% of Russia's energy mix is attributed to natural gas with significant excess supply and a high consumption and generation of electricity from LNG. The country possesses a low Import dependence ratio and a low energy intensity (Mandal et al., 2013).

Historically, Russia implemented its aggregation strategy through a state-owned company, Gazprom. The business model of Gazprom is a hybrid between a broker aggregator and a single buyer/seller model. The company is able to perform a portfolio

management role but simultaneously participate in transactions. The company holds significant assets across the LNG value chain and aims to ensure the availability of capital expenditure for the growth of the gas market for the betterment of the country (Alex, 2023).

5.2.3 *Trinidad and Tobago*

Trinidad and Tobago is a country that is rich in hydrocarbons for which natural gas was utilised as a driver of industrialisation. Trinidad and Tobago implemented a national gas company, which acts as the single purchaser of LNG within the country. LNG aggregation was introduced to develop the commercial aspect of gas, adding significant value to the export of the commodity (Roberts, 2019).

The structure of the country's LNG sector and its integration of a historical LNG aggregation strategy has allowed for the development of the sector to become a significant contributor to the global LNG sector as a four bcf per day natural gas economy. The structure was reviewed through the country's gas master plan in 2015. The aim of LNG aggregation within the country is to attract investment into the downstream LNG market while increasing local content and supply competition. The aggregator is an intermediary for downstream supply, assuming the risk of the imbalance between prices and volumes. Additionally, the aggregator owns and operates the transmission section of the value chain providing bundled tariffs for downstream off- takers (Welsh, 2021).

The countries' advantageous location has contributed to its success as an LNG exporting country. The deliberate pursuit of a gas development strategy purposefully led to the introduction of LNG aggregation. The well-developed, stable, political environment within the country allowed for the successful implementation of an LNG strategy. The vertical integration within the LNG value chain has provided additional stability, improved investor sentiment, and increased the integrity of the LNG value chain (Welsh, 2021).

Trinidad and Tobago implements a single buyer/seller model of LNG aggregation which has resulted in a well-developed LNG market with over 90% of the country's energy mix consisting of natural gas. The country has an import dependence ratio of zero as the country is a net exporter of LNG (Roberts, 2019).

5.2.4 *Singapore*

Singapore enjoyed a secure supply of piped LNG from Indonesia in 2019 as a major importer of LNG. The country adopts a single-buyer aggregation model which allows for a single purchaser of LNG, reducing the middle-man costs. The country imposes relatively low taxes and duties on LNG (Mak, 2016).

The introduction of LNG aggregation within Singapore arose with the uncertainty around the future sustainability of the imported piped gas and the country sought to source LNG from alternative global suppliers. The issue faced at the time was the imbalance between supply and demand and its negative impact on the growth of the LNG market. To address the aforementioned issues, whilst exploiting its strategic advantages, Singapore introduced an exclusive LNG aggregator, BG Singapore Gas Marketing Pte Ltd. The Energy Market Authority of Singapore allocated 3 Mtpa to the aggregator to initiate the development of the LNG market within Singapore allowing until 2023 to execute its mandate (Barker, 2013).

The aim of Singapore's energy policy in terms of LNG aggregation was to infiltrate the LNG market and establish itself as a key LNG role player by taking advantage of the previous projected growth in demand. In addition to the projected market access, Singapore had the strategic advantage of an ideal geographical location being in close proximity to the targeted market and well positioned to offer products and services throughout the LNG value chain, creating an LNG hub. The country offered a well-developed business environment which was investment focused, with emphasis on the ease of doing business and offering prospective stakeholders several incentives. An example of which is the Global Trader's Programme. Government support and policy driven initiatives played a leading role in the development of Singapore as a significant LNG player despite the country not being a competitor in terms of proven natural gas reserves (Barker, 2013).

The LNG aggregator managed to contract 2,7 Mtpa by February 2014 despite its allowance until 2023. The cap on the volume of LNG traded by the aggregator provided the country with flexibility and significant control over the LNG sector as the type of aggregation was able to be amended post the 3 Mtpa allocation (Roberts, 2019).

5.3 Assessment of the lower ranking countries

China, ranked fifth in terms of the holistic performance score, serves as an anomaly wherein the country has aggressively pursued industrialization of the past few decades which has rapidly increased the country's demand for energy. The country produces most of its LNG demand, however, increasingly imports LNG to meet its demands and invests in extraction activities in exporting countries. The country pursues a governmental aggregation strategy where the government controls the supply and sourcing of LNG and other sources of energy (Lin, Zhang, & Gu, 2010). Due to the size of the country's demand and economies of scale, the country is able to secure large quantities of LNG for domestic use (Lin, Zhang, & Gu, 2010).

Nigeria, ranked sixth based on the holistic performance score, introduced the Gas Aggregation Company of Nigeria (GACN) in 2010 which implemented a governmental LNG Aggregation model. The GACN assumed a brokerage role between sellers and buyers. The GACN implemented a domestic supply obligation which aimed at assisting in the development of the LNG market. The outcome, however, was unsuccessful which has been attributed to the lack of clear policies (Roberts, 2019).

France, ranked seventh according to the holistic performance score, implements multiple models of LNG aggregation (Sáez Armenteros et al., 2022). The French natural gas market, however, is well developed as the source of energy has been used within the country since the nineteenth century. The country was one of the first countries to utilizes natural gas that was extracted as it identified the possibility of the resource that was being burnt off as a byproduct of oil extraction activities in the United States (Beltran, 1992).

The United Kingdom, ranked eighth in terms of the holistic performance score, introduced the British Gas Corporation (BGC) as a single buyer/seller aggregator. The country was one of the first countries to implement an aggregation strategy which assumed a monopolistic role and provides lessons learnt pertaining to the introduction of aggregation strategies (Heal, 1990).

The Netherlands, ranked nineth in terms of the holistic performance score, has historically implemented a price consolidating aggregation (Bjørndalen, 2022). The Netherlands discovered natural gas field in 1959. The implementation of aggregation has been unofficially implemented over the years, however, in 2002 the revolution of the Dutch gas market commenced as the abuse of market power was evident within the market. The changes envisioned were staggered by internal conflict and the country grapples with the issue of liberalizing the market through privatization versus energy

security (Correlje, Van der Linde, & Westerwoudt, 2003).

Japan, ranked tenth as per the holistic performance score, implements a single- buyer aggregation model via the three national oil companies. The country significantly augmented its energy mix after the nuclear disaster faced by the country which led to the decommissioning of nuclear power plants. The country had to rapidly secure natural gas, for which its extraction activities could only provide 10% and therefore resorted to LNG imports. The country resorted to paying a premium to secure LNG supply (Corbeau, Braaksma, Hussin, Yagoto, & Yamamoto, 2014).

Indonesian government was obligated to intervene in the country's LNG market and implement a broker aggregation system to address the disparity between supply and demand. The country is yet to establish an efficient LNG market (Yuniza et al., 2016).

5.4 Conclusion

The discussions within subsection 5.2, based on the available literature and data, have led to the conclusion that there are several success factors that attributed to the successful implementation of LNG aggregation as an energy policy instrument to grow the LNG market within the four top ranking countries. Table 10 summaries the success factors as discussed within 5.2.

Table 16 Summary of LNG Aggregation Success Factors

Country	What makes successful an LNG aggregation strategy	Reference
Singapore	Complimentary incentives for development and trade	(Mak, 2016)
Singapore Trinidad and Tobago	Clear competitive advantage for the value chain component of the LNG sector to be located within the country	(Mak, 2016) (Welsh, 2021)
Singapore Trinidad and Tobago	Government Support and policy driven initiatives	(Mak, 2016) (Welsh, 2021)
Singapore	A well-developed legal system	(Barker, 2013)
The United	Good governance	(Globerman & Shapiro,

States		2003)
Singapore The United States Trinidad and Tobago	Agility built into policy	(Barker, 2013) (Corbeau et al., 2014) (Welsh, 2021)
Singapore Trinidad and Tobago	A drive towards the ease of doing business for foreign and domestic investment	(Roberts, 2019)
Trinidad and Tobago The United States	The ability to absorb market fluctuations that impact volume and prices	(Welsh, 2021) (U.S.Department_of_Energy, 2017)
Russia Trinidad and Tobago	Vertical integration along the LNG value chain	(Mandal et al., 2013) (Welsh, 2021)

This research report therefore proposes that LNG aggregation is a useful energy policy instrument when implemented to develop or grow the market. The type of LNG aggregation implemented depends on the current nature of the LNG market within the country and the ability of the economy to invest in capital projects or attract funding. Countries that have been the most successful at implementing LNG aggregation as an energy policy instrument to grow or develop the market, have implemented policies which result in the ease of doing business. These countries have focused on providing incentives for investment or government intervention. This implementation has resulted in the securing of supply and the attraction of investment into the capital intensive sector. These countries usually have well developed legal and governance systems. The type of aggregation implemented should be assessed according to the specific country in order to prevent market manipulation, monopolistic behaviour and to enable competition in the market.

CHAPTER 6. CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

This study provides an augmented method for assessing energy policy as LNG aggregation. The purpose of the study is to identify the key success factors for LNG aggregation to serve as a benchmark for other countries. Multi-criteria analysis was utilised to evaluate a set of criteria based on the 4As framework, affordability, acceptability, applicability, and availability. A set of indicators ranked eleven countries that were identified as trading in LNG and implementing LNG aggregation strategies.

6.2 Conclusion of the study

There are five main types of aggregation identified within this study. Brokerage aggregation wherein the aggregator facilitates contracts between buyers and sellers but does not assume any risk or contract directly with the buyer or seller. (Juris, 1998). Secondly, the Single Buyer model in which the aggregator acts as the key buyer or seller, who purchases or sells LNG from one or more suppliers/buyers and selling/buying to/from consumers/buyers as the key seller/buyer. The aggregator assumes the supply and demand side risks. (Burger et al., 2017). Thirdly, block aggregation where suppliers pool supply capacity to form an aggregator that sells Blocks of LNG to consumers. Inversely, it could be the aggregation of demand to purchase a block of LNG to supply to many consumers (Juris, 1998). Fourth is governmental aggregation in which an aggregator is established to act as a regulator for increased government control (Roberts, 2019). Lastly, is price consolidation in which the aggregator facilitates symmetrical prices (Roberts, 2019).

There are eleven countries found to either previously have implemented or are currently implementing LNG aggregation as an energy policy instrument which includes; China, France, Indonesia, Japan, Netherlands, Nigeria, Russian Federation, Singapore, Trinidad and Tobago, United Kingdom, and the United States.

The data collected were for the variables identified as descriptives of the criteria; affordability, availability, acceptability, and applicability. The analysis performed on the normalized data resulted in performance score calculations for each country which were thereafter ranked accordingly. For the affordability indicator, the top two performing countries were Nigeria and Singapore. In terms of gas availability, Russia and the United States were top performers. The countries within which LNG aggregation was most

acceptable, according to the acceptability criteria of the 4As framework, is the United States and Russia. For applicability, the United States and Singapore excelled. In terms of the overall performance of the eleven countries in implementing LNG aggregation, the United States was the best performer, however, its LNG aggregation was not analysed due to the shale gas evolution and distortions in the market. The second, third and fourth best performing countries are Russia, Trinidad and Tobago and Singapore, respectively.

The overall performance score was utilised to rank the countries from which the top four performers were assessed and the factors of successfully implementing an LNG aggregation strategy were summarised in table 10.

The performance scores allowed for the assessment of the top performing countries in which nine key considerations for the successful implementation of LNG aggregation were identified. The most successful implementation was in countries where there were either of several success factors. One such factor is the pre-existence of complimentary incentives for development and trade (Mak, 2016). Having clear competitive advantages for the value chain component of the LNG sector to be located within the country is a success factor to the implementation of LNG aggregation (Welsh, 2021). The existence of Government support and policy driven initiatives were clearly visible and the most successful LNG aggregation implementing countries exhibited a well-developed legal system and good governance (Barker, 2013). An additional success factor is the relevant energy policy with provisions for flexibility and an active drive towards the ease of doing business for foreign and domestic investment (Welsh, 2021). Success of LNG aggregation is seen in the ability of the aggregator to absorb market fluctuations that impact volume and prices (Globerman & Shapiro, 2003). An additional key component is vertical integration along the LNG value chain which seemed to contribute towards the successful implementation of LNG aggregation (Mandal et al., 2013).

6.3 Recommendations

It is recommended that countries consider LNG as a transitionary source of energy and a complement to renewable energy. Countries with underdeveloped or no LNG market should consider implementing LNG aggregation as an energy policy initiative after assessing the key considerations identified within this study as the success factors that the top four countries have implemented to grow the LNG market. There are several types of LNG aggregation strategies which can be implemented within a country, it is recommended that consideration be given to the nature of the country in question and

the level of advancement of the sector before concluding on a type of aggregation strategy to develop the LNG Market. The top four ranked countries implement different strategies.

The United States implements a block aggregation strategy which has been complimented by the country's success factors. The country has a mature legal environment which has provided reassurance to the global market and resulted in the attraction of investment, transforming the country into a net exporter of energy. The country has flexibility in its policies which allowed the production of non-conventional Shale gas. A similar approach may be recommended for countries with well developed economies that have proven reserves of LNG or have neighbouring countries that could result in access to piped gas for domestic supply (Corbeau et al., 2014).

Russia implements single buyer and brokerage aggregation which has enabled the country to become a significant participant within the global LNG market. The successful implementation of the aggregation strategy is underpinned by the vertical integration of the state-owned gas company. Global phenomena, however, has resulted in the requirement of the country to augment the strategy and allow for increased participation within the market. This type of strategy may be suggested for a country that has an LNG market that has become stagnant (Mandal et al., 2013).

Trinidad and Tobago has successfully implemented a single buyer, single seller aggregation strategy which allowed the infant market to develop over time. The country strives towards the ease of doing business for global participants, provides government support and the ability to absorb market fluctuations. After the market developed to a satisfactory level, the country augmented its strategy to allow for increased competition. This strategy may be advised for a country that is in its infancy stage with limited access to capital (Roberts, 2019).

Singapore implements a single-buyer aggregation model which has enabled the successful development of the LNG market (Dodge, 2020). The success factors of this aggregation implementation have been the countries complimentary incentives for investment and trade, government support and policy driven incentives, a well-developed legal system and agility. A similar approach could be followed by countries who do not have significant reserves of natural gas and are likely to rely on LNG imports for domestic supply. To ensure its success, the country clearly mapped out its competitive advantages for the location of the LNG value chain within its borders (Dodge, 2020).

6.4 Suggestions for further research

It is suggested that a follow up study is conducted to assess the sector and that LNG security is defined by variables using factor analysis to provide a true reflection of how LNG aggregation can be utilised to develop the LNG market within a country.

Further studies may be required to test the outcome of this research report as it is utilised to develop the LNG markets within a country.

The research report did not assess the impacts and changes resulting from the recent global phenomenon, such as the Russia-Ukraine war and the Covid-19 pandemic. Additional studies may be required to assess the impact of such phenomena on the implementation of LNG aggregation or the augmentation thereof.

Given the limitations of the sample size on the outcomes of the study, an analysis should be conducted on the entire population which will include all countries that import or export LNG.

A detailed analysis of the different market structures that exist in each country should be undertaken to assess the impact of each market structure on the implementation of LNG aggregation. The details should include the nature of the market in each country prior to aggregation implementation.

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