The Significant Role of ICT Growth and Innovation in Boosting Renewable Energy Sector Growth

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Research Project Submitted in Partial Fulfilment of the Requirements

for the Degree of Master of Business Administration

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DECLARATION

I hereby declare that the case study is based on my original work except for quotations and citations that have been duly acknowledged. I also declare it has not been previously or concurrently submitted for any other degree at Universiti Tun Abdul Razak (UNIRAZAK) or other institution.

Signature :

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Date :

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The Significant Role of ICT Innovation And Growth in Boosting Renewable Energy Sector Development in Malaysia

By

Syahrill Mat Shariff

February 2023

Low carbon footprint initiative has enticed world governments around the globe to mitigate climate change in their nation. As an economy vital component and the largest carbon emission contributor, the energy sectors had begun its transition to renewable energy source to support the policy makers and to reduce dependency on raising fuel price. Many countries within the globe have launched initiatives and effort to implement and promote renewable energy throughout their nation. However, the effectiveness and success of these implementations are likely to be influenced and dependence to many factors and variables such as technology research and advancement, people, government policy, economy, geographically and importantly the innovation of indirect or support technology especially in Information and Communication Technology (ICT) sector as the enablement factors to monitor, manage and sustain the renewable energy attractiveness and effectiveness. This study uses a dimension reduction factor and regression analysis to examine correlation and causality whether the Information and Communication Technology (internet and digitalisation) growth has improved 30 countries renewable energy development within the period of 2000–2019. The findings implies a positive correlation between ICT growth with renewable energy development. However, the analysis also pointed out that inside the development of ICT, there is a positive correlation exist between CO2 emission and renewable energy growth. Internet development has the potential to boost renewable growth and efficiency, reduce carbon emission and foster domestic economy. The internet has become an important driving force that promotes the intelligent development of environmental governance in many nations while strengthen the renewable energy ecosystem by promoting efficiency.

CHAPTER 1 : INTRODUCTION

1.1. Background

In most developing nations generally, the awareness of renewable energy is particularly increasing yet the countries concerned are mainly concentrated to reducing the conventional energy source usage within the economy related sectors. In conjunction, Malaysia's authority with the increasing of YoY energy consumption has joined the race in pursuing renewable energy alternative production. Fig.-1 below show Malaysia's three decades energy consumption from 1990 until 2018 by sectors.

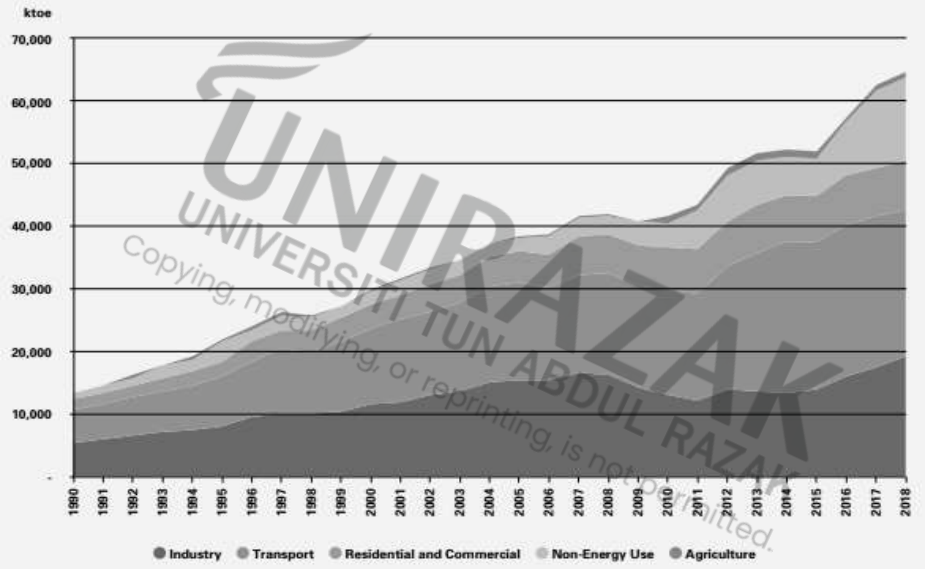


Figure 1 – Malaysia Energy Consumption by Sectors
Source: Suruhanjaya Tenaga

In the 8th Malaysia Plan, renewable energy policy has been crafted in the year 2000 and the "Five-Fuel Diversification Policy" and Special Committee on Renewable Energy (SCORE) enactment was implemented one year later indicated the set out of national's renewable energy journey with objective of reaching 5% production by 2005. The policy introduces fifth energy source in the nation's energy mix while the latter endorse rigorous practice of renewable energy in small scale projects. In pursuing the

energy transformation objective, Malaysia's law and policy maker has since promote, encourage, explore and endorse the importance of research and development (R&D) and innovation of renewable energy technologies both by international and local entity. The innovation policy and framework have to go beyond the renewable energy itself where it has to encompass the balance between various state of the art renewable energy technology and the support in harmonising these technologies efficiently and effectively in order to uniformly having a holistic view over private and public operation. An equilibrium between technology solutions and creating enabling environment for innovation has to be the government focus so that the private and public receives the right motivations. A stable long-term policy establishment are essential to attract engagement whilst establishing a sustainable renewable energy environment.

However, through state related utilities as vehicle company, the trek to meet the intended target has progressively from slow to none. The resolution then continued into 9th Malaysia Plan and further with the implementation of National Biofuels Policy (2006), National Green Technology Policy (2009) and New Energy Policy (2011). Fig.-2 below shows 2 decades summary of national energy production by source type.

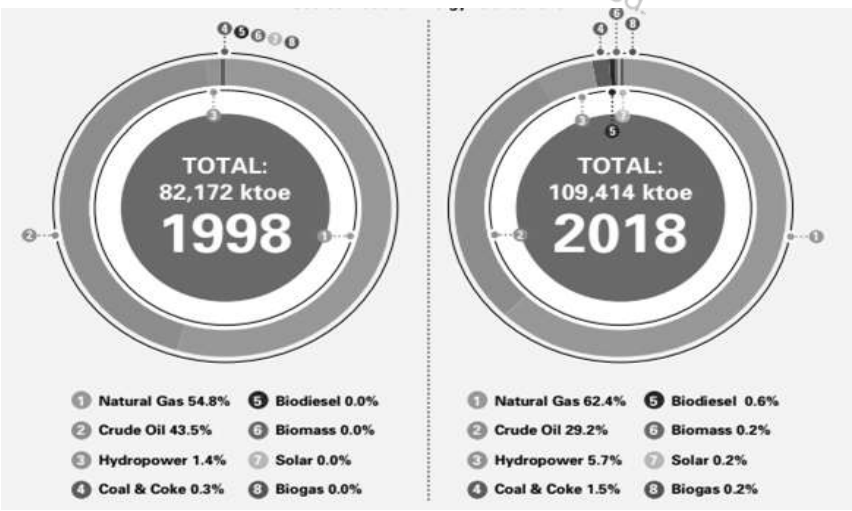


Figure 2 – Malaysia's Energy Production by Source
Source: Suruhanjaya Tenaga

Looking at the above scenario, it is determined that Malaysia's policy marker has come out short in meeting its two decades target.

1.2. Problem Statement

Development and innovation in renewable energy technology play an important role in the perspective of implementation and operating costs reduction and can lead to larger participation in renewable energy sector. Therefore, the aim of this research study is to analyse and examine the correlations between renewable energy growth, technology and ICT innovation. An empirical assessment was conducted in this research broad review of international journals with regard to renewable energy implementations, impacts and benefits to the country. In general, the findings show that renewable energy technology development and innovation led to cost reduction and optimise production in renewable energy sector. Furthermore, it is also learned that renewable energy technology development and innovation has positively benefits the economic growth and create sustainability in the country development such as energy security, resilient and socio-economic (Li Zhe, 2021; Miraj, 2022; Muhammad, 2021; Zahra Fotourehchi, 2017). By reducing greenhouse gas emissions while maintaining the same economic output target, increasing energy efficiency can, from the standpoint of terminal energy use, help to mitigate the effects of climate change (Yang et al., 2018). The understanding on how to effectively optimize the energy supply structure and improve energy efficiency however has become a major challenge for the authorities. In conjunction, rapid development of next-generation network information technologies such as big data, cloud computing, and mobile internet, ICT development shall play a greater role in enhancing renewable energy transformation and promoting the sustainable development of the world economy.

For better comparative purposes, this report narrows down and bring forth the data from the BRICS countries. BRICS countries are categorized as upper-middle-income economies and the fiscal development is at rapid pace in a way similar to Malaysia's economy that prominent in the demand for energy. Fig.-3 below illustrates the GDP of BRICS nations.

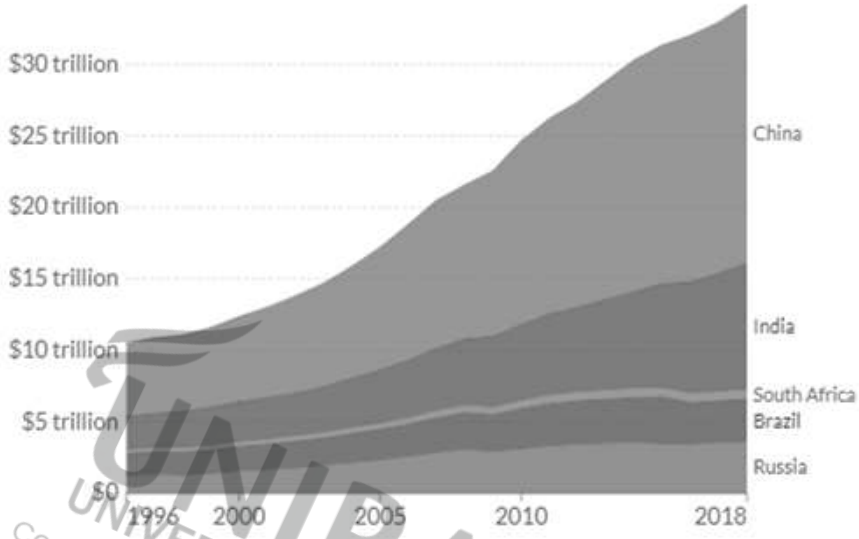


Figure 3 – BRICS Countries GDP From 1996 to 2018
Source: available online: https://ourworldindata.org/, accessed on 02nd Oct 2022

Next, looking at primary and renewable energy generation, the difference in primary fuel generation and the renewable energy generation appropriately shows the correlation between GDP growth and renewable energy. Fig.-4 below shows energy generation from fossil fuels and Fig.-5 illustrates the annual changes in renewable energy generation.

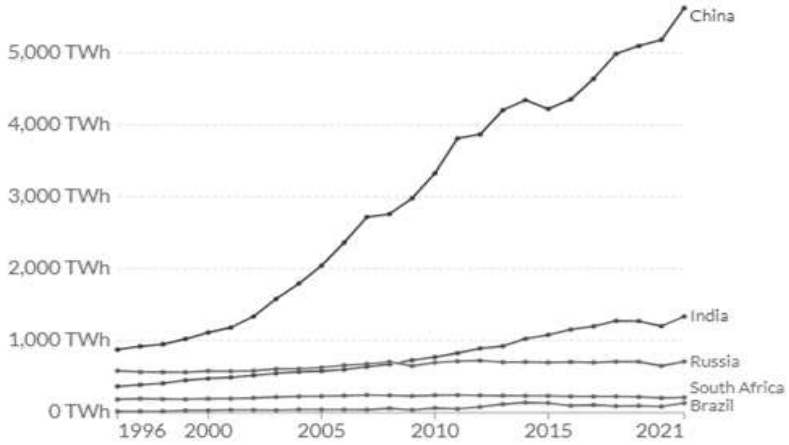


Figure 4 – BRICS Fossil-Fuels Energy Generation From 1996 to 2018
Source: available online: https://ourworldindata.org/, accessed on 02nd Oct 2022

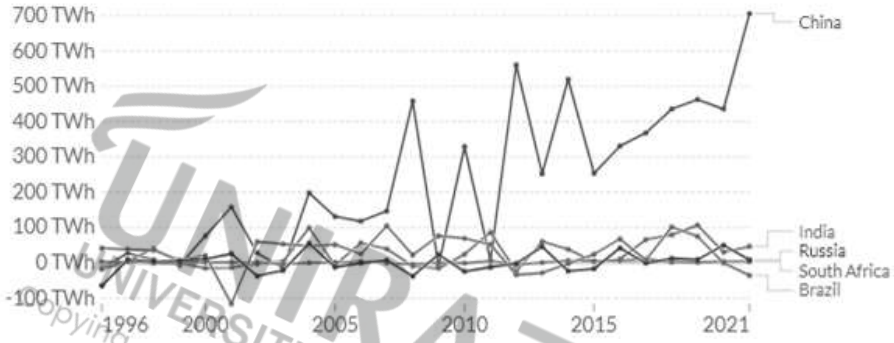


Figure 5 – BRICS Annual Change in Renewable Energy Generation
Available online: https://ourworldindata.org/, accessed on 02nd Oct 2022

It shows that fossil fuels remain as primary source of energy within the BRICS nations and except for China, the others BRICS countries renewable energy generation are yet to alleviate to significant level in line to respective GDP growth. The preliminary study has also discovered that mostly in the under-developed and developing countries, the absent of proper legal frameworks and support policy shall hindered and deterred renewable energy technology development and innovation program. In decade, the number of policy makers enforcing support policies has been increased more than triple from 48 countries in 2005 to 128 countries by 2017. The push of having these policies clearly magnifies the cruciality of government support in

nurturing renewable energy effort by lessening the barriers and obstacles to overcome difficulties facing the development.

Per se, Malaysian Government in line with its 8th Malaysia Plan (2000) has since put in place few policies and enactment to support the energy strategies in boosting the proportion of renewable energy. However, it demanded more than a decade time period and enforcement of additional policies for the renewable energy initiative to meet its target (2017) as illustrated in Fig.-6 below.

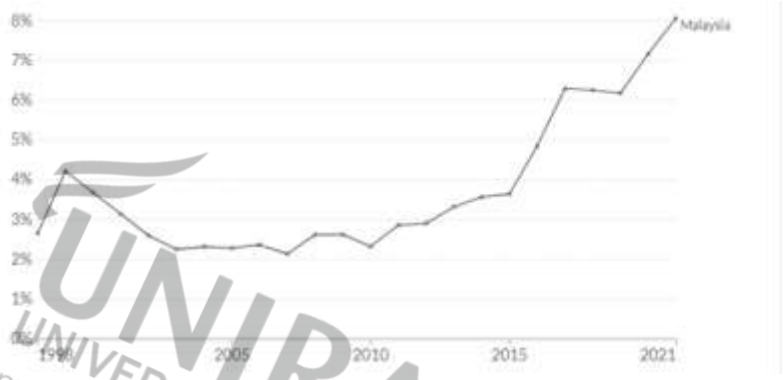


Figure 6 – Malaysia Share of Primary Energy From Renewable Source
Available online: https://ourworldindata.org/, accessed on 02nd Oct 2022

To-date, the contribution of renewable energy in Malaysia energy mix are less significant and mostly achievable through geographical advantage; hydropower is currently Malaysia's main renewable energy source in which translate to the reliance of government funding with mega hydro-power plant construction. Fig.-7 below demonstrate Malaysia's 2021 energy mix in comparison to its neighbouring country in the region.

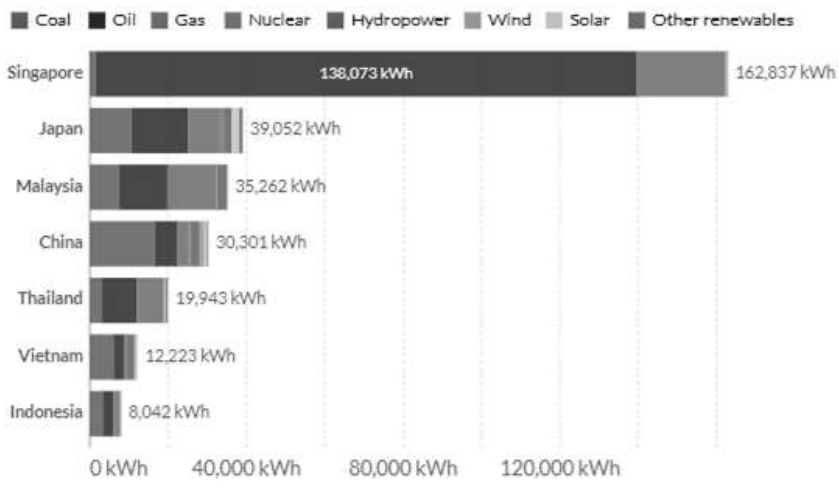


Figure 7 – Malaysia's Primary Energy Consumption by Source, 2021
Available online: https://ourworldindata.org/, accessed on 2nd Oct 2022

Ideally, the expansion of renewable energy program at national level will benefit both the lawmaker and the public across an all-inclusive program development whilst strengthen the domestic economy through supplementary income opportunity for the peoples. Despite decades of plans and efforts, the program lingered only among states related firms and less participation from private-public entities.

Furthermore, from the Fig.-8 below it is clearly indicated that with lack of international funding, the success of the program was solely dependence on government funding.

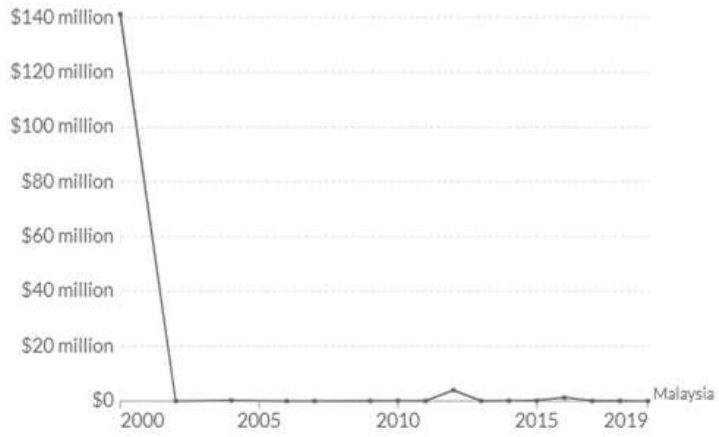


Figure 8 – Malaysia's International Finance Received for Clean Energy
Available online: https://ourworldindata.org/, accessed on 2nd Oct 2022

The national renewable energy target hugely achieved through Tenaga Nasional Berhad (TNB) hydropower facilities in which reflect the highly dependent on government financing. Hence, in general by successfully expanding the renewable energy program holistically throughout the nations, it shall lessen the government burden money-wise and being extended as a technique to explore multi-learning curve in defining the do's and the don'ts approach, efficient source, suitable technology and the right direction of the national sustainability development for energy and economic future.

1.3. Research Objectives

There are many research and studies investigating the development and innovation of renewable energy technology and its correlation in driving the renewable energy growth including the importance of support policy to foster the growth among private firms in Malaysia. However, there was lack of focus study to examine innovation and development of Information and Communication Technology (ICT) as support industry to drive the sustainability development of renewable energy and domestic economy. The key to achieving sustainable economic development lies in coordinating the interaction between economic growth, energy efficiency, and environmental pollution without harming the natural environment.

Grid reinforcement, energy storage, prosumer demand and supply management are the renewable energy variables that are today being incorporated within Malaysia's current peer-to-peer energy (P2P) trading infrastructure as shown in Fig.9 below. Through government link energy provider company (TNB), the framework has been implemented with various policies to entice and gain participation from private-public entities.

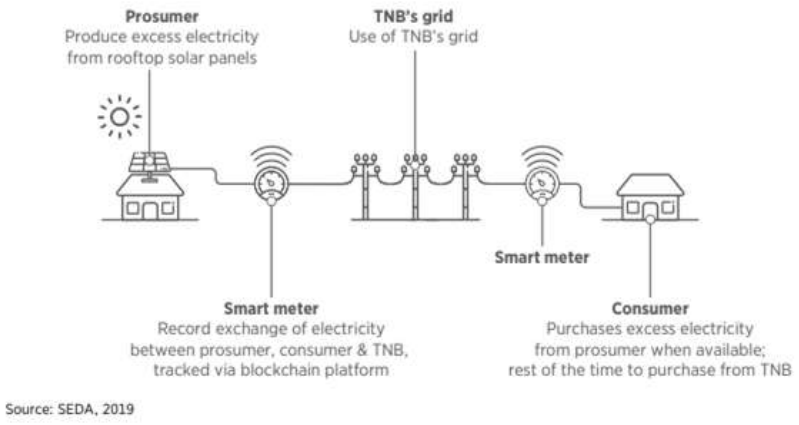


Figure 9 – Malaysia P2P electricity trading concept framework
Source: SEDA

However, in order to cater and incorporate increase shares of future renewable energy demands and growth, innovation such as digital system operations, innovative market and business model, prosumer demand and supply control and management are crucial in enabling a transparent, flexible, resilient and sustainable infrastructure. Hence, innovative development and innovation in ICT software stack namely digitalisation is vital in order to provide a more effective control and protection mechanism through integrative communication and distribution systems for all numerous devices and assets connecting to it.

In conjunction, incorporating Artificial Intelligence (AI) and Machine Learning (ML) shall deliver a smarter grid in managing the complexity and dynamic of the renewable energy infrastructure network while enabling a safe and reliable operations through big data analysis and analytic algorithm. Features such as real-time and historical energy consumption, capacity forecasting, predictive maintenance, time-based energy trading, autonomous profile and performance evaluation can be incorporated in the smart grid capability. Consequently, ICT innovation facilitate unique technologies hybridisation and optimise load sharing while providing

centralisation dashboard for decision-making and audit purposes through the virtual layer platform or virtual renewable energy providers as depicted in Fig.10 below.

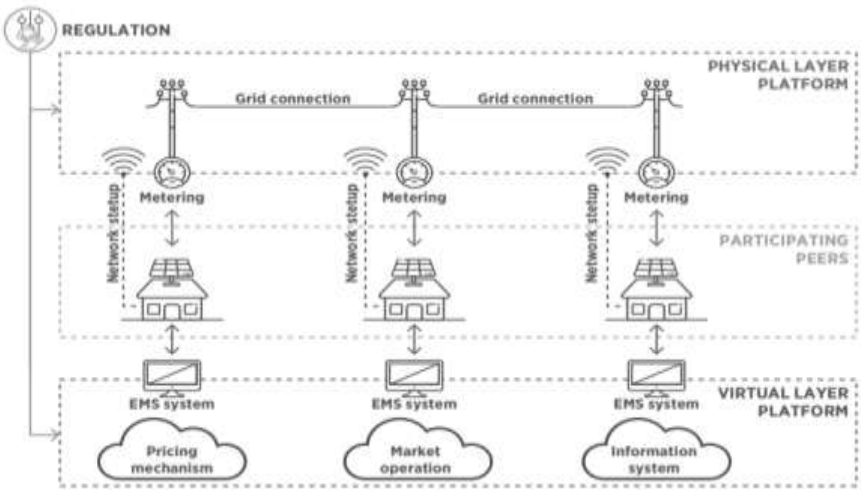


Figure 10 – Physical and Virtual Layer Platform if a P2P electricity network
Source: Tushar, 2020

1.4. Research Significant

This paper aims to investigate the correlation of ICT development and growth in helping to boost national energy program. The contribution of this research study can best benefit the policymaker through systematic review of current renewable energy initiative, status and progress. The study outcome will provide clearer picture and understanding of driving forces, gap and limitation in current program. Meanwhile, the systematic review of successful drivers in similar countries as research output will present the policy and law makers with proven alternative and solutions to adapt and enhancing the national renewable energy initiatives. Furthermore, this research shall be looking into how the expansion of ICT innovation can support and boost Malaysia's renewable energy sector holistically and the outcome will be vital in resolving the framework and roadmap in pursuing the program future success. In addition, independent review from the academic perspective is unbiased and disparate from any profit intention purpose. significant of study

CHAPTER 2 : LITERATURE REVIEW

Most of the articles and publications that have been observed were mainly discussing about renewable energy technology from the perspective of the renewable energy generation and efficiency. In relation, it was also discovered that renewable and sustainable source of energy are generally feasible and viable by individual level and the cost has become lower and lower over the year. However, there was lack of research journals that been focusing on promoting and supporting renewable energy open system to ease the control, management and forecasting of dynamic energy system. Independent entities participation can be crucial to the government in dispensing capital cost to determine best practices (sources, area) instead of exclusive banking on single entity provider handling the national interest flexibility and alternative in the long run. By way of thorough execution, nursing and supervising program, the initiative is vital to expand learning curve while simultaneously creates supplement income group among the publics and cultivating national sustainability economy progress. This programme can lead to lessening interdependency to environmental economy factors in a whole. Therefore, with research questions broaden as below, this report is intended to discover more on how ICT development and innovation can benefit and boost Malaysia's renewable energy framework and encourage renewable energy production by dependent entities (firms and individual) and in the long run can positively impact and contribute to the nations' sustainability economy growth.

2.1. Information and Communications Technology as Booster Variable

In the existing literature reviews, many concerns have been addressed to investigate relationships between renewable energy consumption, carbon emissions, GDP, FDI, information communications and technology and environmental quality. However, most of the research focus on investigates the direct causality of each variable in relation to environmental quality and others mainly discussing the relations in perspective of one country (Bassem et. al, 2022) or single region (To Trung Thanh et. al, 2022). Therefore, this research shall investigate the impact of ICT as boosting variable (moderator) for other influencers (GDP, CO2 and technology innovation) in their relation to energy output. Information and Communication Technology (ICT) by far has gone through rapid development and innovation in comparison to other sectors. Digitalisation of human life due to data-driven advancement has ease the way people live, trade, travel and socialise. ICT has become vital support industry for many other and change the landscape of world communication, economy, and transport. Hence, similarly energy system around the globe will follow and adopt many benefits of ICT for a better and effective digital solution improving the efficiency and reliability of its operation. Continuous demand for energy in dissent to the scarce resources for fossil fuel and its negative impact to the climate call for a more robust, flexible and resilient renewable energy system. Exploring and exploiting the renewable characteristic of the nature has resulted to many developments and innovation of renewable energy technology however, various manufacturer, technologies and origin has made the interoperability between multi-system especially in relation to prosumer and P2P infrastructure an essential.

ICT through software and application innovation and growth will substantially cause a direct, indirect and complementary effect to the energy sector; the manufacturing and use of ICT equipment possess direct energy consumption,

indirectly ICT application in multi-sectors promote energy efficiency and reduce consumption, and complementary the rebound effect of ICT helps to increase the intelligence of the transmission system and improve its energy efficiency from a micro perspective whilst play an important role in alleviating the energy and environmental problems faced by many countries (Zia, 2016; Amin and Rahman, 2019). Even though Usman et al. (2020) in his research found India was the only country in South Asia that has achieved energy efficiency improvements due to the increased use of ICT (1990 to 2018), ICT in a whole has made a positive contribution to the economic growth of South Asian countries.

However, some studies have pointed out the causality between ICT development and energy consumption (Saidi et.al, 2019; Salahuddin and Gow et.al., 2016; Lange et al., 2020) found that the higher the level of ICT development or digitalization represented by the amount of internet access and the number of mobile phone users, the higher the level of power consumption and no correlation with carbon emission. Nonetheless, others researcher indicated that reduced energy consumption is achievable as a result of efficiency through implementing ICT innovation in application, infrastructure and system optimisation (Moran et al., 2016; Bastida et al., 2019; Vlasov et al., 2019 & Murshed et.al., 2020). In conjunction, this research will be taking both broadband and mobile subscription as elements of ICT growth in determining the effect and impact it have on the energy output.

In conclusion, earlier research offers a theoretical foundation for the examination of the connection between internet growth and renewable energy efficiency, but there are still certain gaps that need to be filled. The majority of studies currently available focus on examining how the internet or information and communication technologies affect energy use or environmental damage. Thus, this

paper shall also be employing the technology innovation variable in the panel data factor analysis to examine the direct and mediator effects of each independent variable to the dependent energy efficiency. ICT today has been deployed and integrated in wide area of industries and economy sectors making shifting rapidly from offline to online upholding the era of digitalisation. Due to its increasingly valuable roles in modernisation and improve human efficiency, it is crucial to investigate the effect it can bring to energy sectors and adopt application as much as possible.

2.2. ICT Innovations - Variable Renewable Energy (VRE)

The key success factors for P2P electricity trading environment are the reliability of the overall energy system, good customer service, the availability of a conducive regulatory framework and a reliable grid. With smart or digitalisation of energy grid, EMS insert the virtual layer platform, the variable renewable energy at the top (Fig.10) as integral part for peers interaction, control and management. Smart grid ability to integrate and manage VRE energy are vital element for the energy system flexibility and resiliency in long term. The landscape of innovation and flexibility to accommodate prosumer and high share of VRE are emerging and globally implemented identified as suite of 30 such innovations across four key dimensions of energy systems as illustrated in Fig.11 below (IRENA, 2019a).

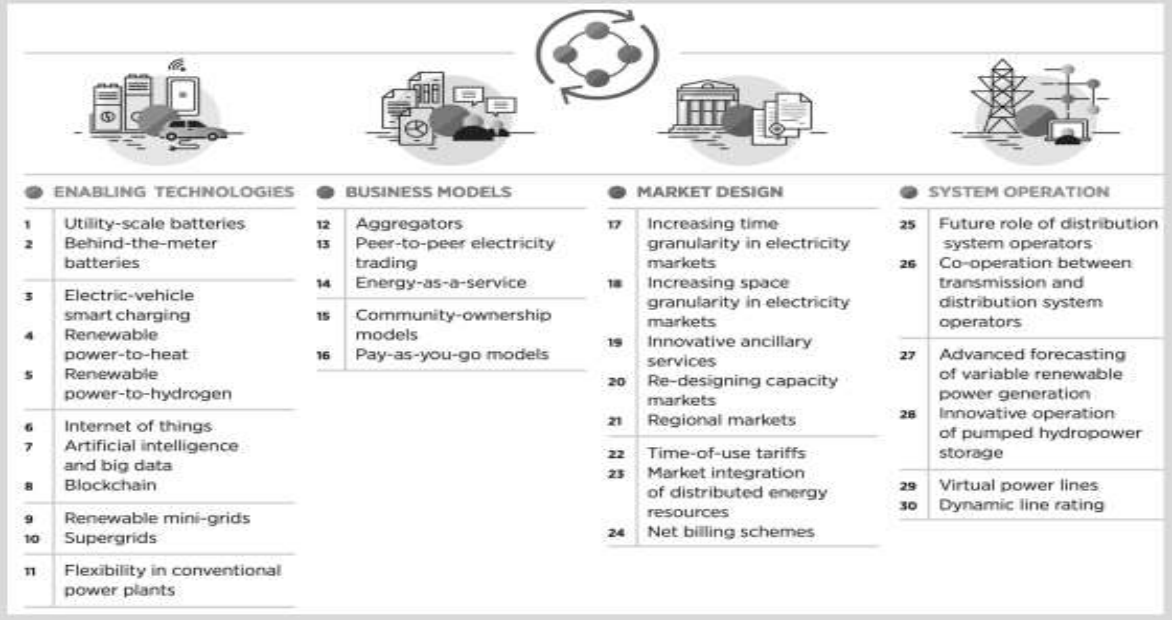


Figure 11 – The Landscape of Innovation to Integrate VRE
Source: IRENA, 2019

2.3. Digitalisation - Energy Management System (EMS)

In line with the VRE share grows, ICT innovations become the key to unlocking synergies and reducing overall system costs. The benefits will depend on aspects such as the rate of electricity demand growth, the level of existing grid interconnectivity and the spread of domestic natural resources, among others. The ICT innovation benefits can be summarized as the following;

- Interoperability
- Communication Reliability and Scalability
- Control and Management
- Operational Scalable and Flexible
- Profiling
- Capacity Monitoring and Forecasting
- Remote Monitoring
- Logging and Record
- Flexi Business Model and Tariff Rate
- Flexi Deployment

The VRE ensure reliability and resiliency through continuous real-time communication, prosumer data consumption and analysis. This is where the ICT innovation such as smart meters, mobility communication, remote monitoring (SCADA) and automation systems (network digitalisation through AI and Big Data) are essential in enabling platform-based business models with distributed ledger technologies such as blockchain able to reduce trading transaction costs (Internet of Things [IRENA, 2019d, 2019e, 2019f). Malaysia's P2P framework is built on the Power Ledger platform, which is also running trials in Australia, Japan, Thailand and the United States (US) (Ledger Insights, 2019).

2.4. Distribution System Operator (DSO)

In view of current national energy landscape, distribution operator namely TNB, SEB, NUR and SESB hold the DSO role. From the list, NUR is the only private entity with limited area of operation. In the future, DSOs will need to develop and adopt innovative systems to solve network constraint issues and to manage the injection of variable power through enhanced use of ICT innovation. The emergence of advanced digital technologies such as smart meter, smart sensor, IoT, cloud, big data and AI automation has unlocked new and efficient ways of managing the network. Grid networks encompass by such technologies are referred to as smart grids which able to facilitate greater communication between DSO and prosumer for example real-time exchange of data and information which is crucial for system operator.

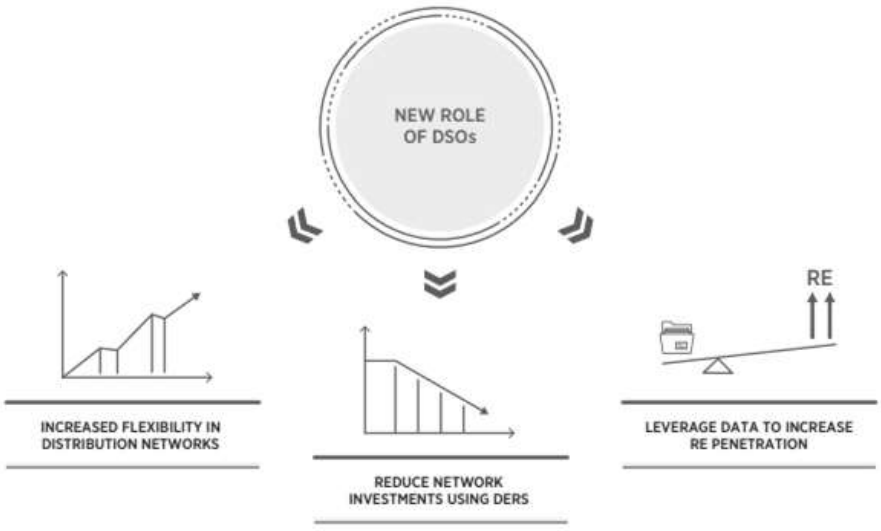


Figure 12 – The Landscape of Innovation to Integrate VRE
Source: IRENA, 2019

Digital media also play vital part for the DSO's new generation prosumer engagement i.e., real-time smartphone applications that allow consumption and real meter readings, manage accounts and bills (Endesa et.al., 2018; Iberdrola et.al, 2018).

2.5. Conclusion

It is widely believed that renewable energy policies could be leveraged to overcome the barriers hindering the growth of sustainable energy ecosystem and to gain competitiveness against conventional energy. Financial incentives namely taxes, feed-in tariff and loans play critical role in boosting renewable energy investments, developments and shifting consumption from conventional energy. In overall, researchers have acknowledged that feed-in tariff and renewable portfolio standard are the most prevalent policies to support the development of renewable energy.

From the literature reviews, it is concluded that renewable energy consumption has a foremost positive impact on economic growth if the existence of proper legal frameworks and policies to govern and pacify the investment and development are in

place. However, in order to provide access to millions of consumers, policy makers should not only focus solely on renewable energy technology related policy whereas ICT innovation also play a crucial role in creating and fashioning innovative business models that able to reduce operational costs, flexi payment opportunities and permit the use of data analytics and AI for efficient capacity scaling, VRE profiling and storage management while driving down the overall energy system cost. In view of growth, ICT enabling abilities are essential in managing renewable energy sources variable, fickle and disperse character and deliver deeper market penetration through ICT enabled real-time measurement, supply control and demand management. ICT's revolutionary has even now been observed in the transformation of smart grids across the world facilitating increase energy efficiency, cost effective and flexibility to accommodate and integrate future trend of VRE.

2.6. Research Questions

Start off with a brief overview on the induced innovation hypothesis, we show that policy intervention has been an effective tool to change relative prices, thus, incentivizing innovation, but that also various influencing factors are at play. The research aims in general to assess and identify important factors within renewable energy journey of multi-nations in the world and specifically to identify these factors positive correlation to renewable energy efficiency to be adopted by Malaysia's policymakers.

Further, from the broad research aim and conceptual framework, the objective is narrowed as per research questions below:

1) What is the main factor influencing the efficiency of renewable energy ecosystem?

2) Do domestic economic activities contribute to the development of sustainable renewable energy?

3) Does continuous innovation in renewable technology and ICT boost renewable energy establishment?

4) How does ICT sector growth influence overall renewable energy development?

5) Which segment or aspect of renewable development are prune to ICT development intervention?

2.7. Conceptual Framework

From the literature review and research objective, a conceptual framework has been developed and defined as below.

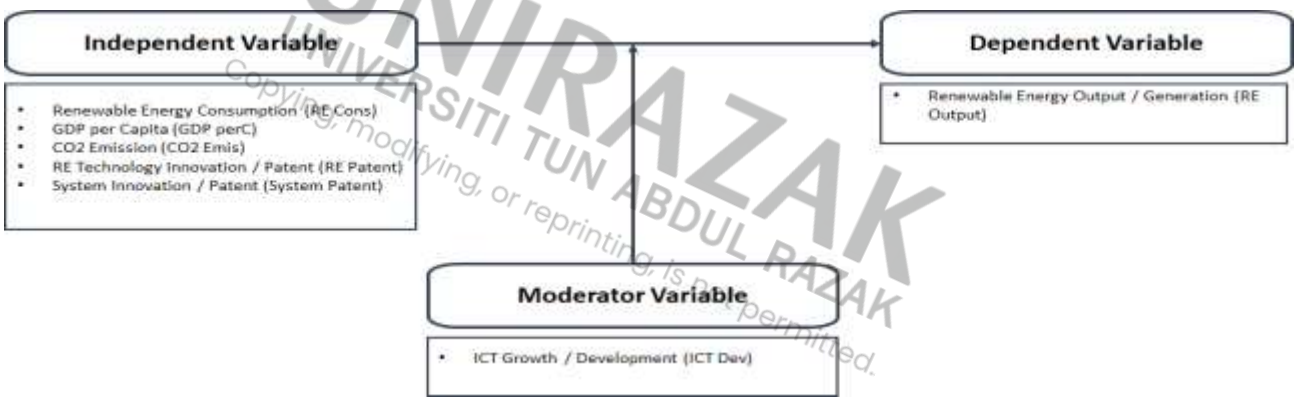


Figure 13 - **Conceptual Framework**

2.8. Theoretical Framework and Hypothesis

The theoretical framework in Diagram-1 below is developed to test the correlation and influence of independent variables to the dependent variable and to measure the impact of principal components causality using the Dimension Reduction analysis. The framework also will be applied to analyse the significant relationship

between independent and dependent variable and to identify which independent variable are positively significant to moderator variable.

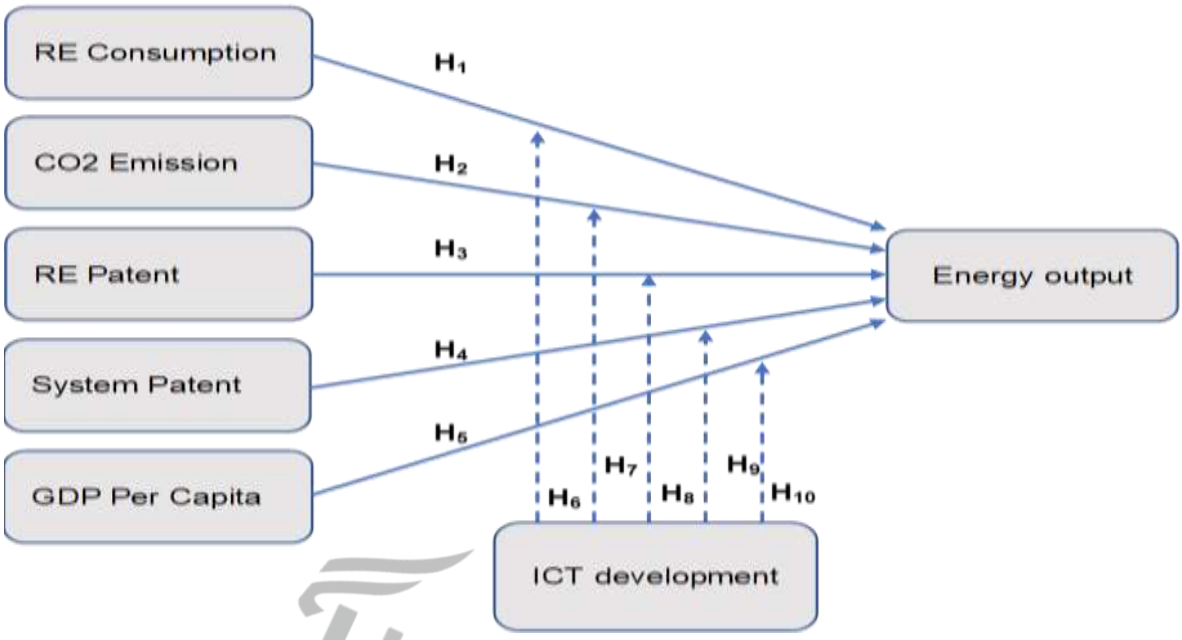


Figure 14 - Research Theoretical Framework

From the research framework, the possible hypothesis, H_0 of the construct are:

1) H_1 - There is a significant relationship between RE Consumption and RE Output;

2) H_2 - There is significant correlation between CO2 Emissions and RE Output;

3) H_3 - There is significant correlation between RE Patent and RE Output;

4) H_4 - There is significant correlation between System Patent and RE Output

5) H_5 - There is significant correlation between GDP Per Capita and RE Output

6) H_6 - ICT development significantly moderate the relationship between RE consumption and RE output.

7) H_7 - ICT development significantly moderate the relationship between CO2 Emission and RE output.

8) H_8 - ICT development significantly moderate the relationship between RE patent and RE output.

9) H_9 - ICT development significantly moderate the relationship between System patent and RE output.

10) H_{10} - ICT development significantly moderate the relationship between GDPs Per Capita and RE output.

CHAPTER 3 : METHODOLOGY

3.1. Research Design

Diagram below illustrate the conceptual model for this research paper.

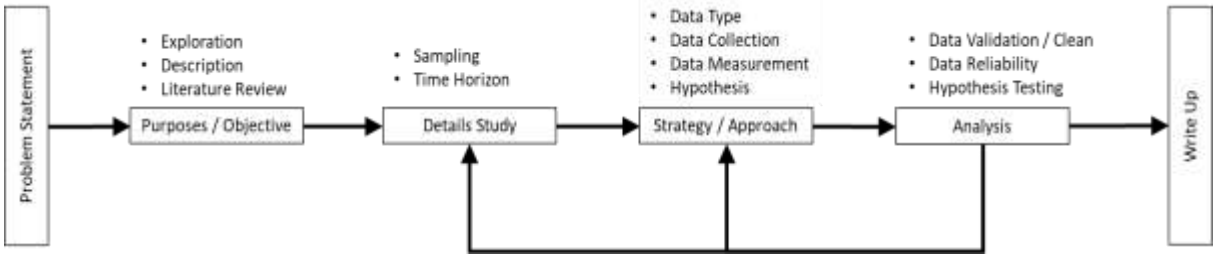


Figure 15 - **Conceptual Model**

This paper is centred on the theory of commonality and shared value behaviour and makes use of dimension reduction factor analysis in an effort to pinpoint the underlying variables, or factors, that account for the correlation pattern within the panel data observation harvested. This research proposal shall employ quantitative methods to investigate causality and outcomes using secondary data harvested from publicly available web pages. The secondary data consist of GDP per capita, ICT, renewable energy efficiency, carbon emission and technology & innovation patents. The study will take both developed and developing countries into scope.

Next, the research will employ linear regression analysis to investigate and identify which components and variables are significantly to ICT development mediator..

3.2. Data Collection and Sampling

The data for this study are sourced from The World Bank (databank.worldbank.org), Our World in Data (ourworldindata.org) and International Energy Agency (iea.org/data-and-statistics). This research shall consider the data from International Energy Agency members and ASIAN countries (total of 30

countries) giving the similarity of geographical and/or economic for the period of 2000 to 2019 in line with Malaysia's renewable energy program for effective comparison.

Table 1 - Panel data from IEA members and Southeast Asia countries.

Analysis	Population Sampling	Data Collection	Data Type	Population
Quantitative	• IEA members • Selected ASIAN countries	• Online data bank and statistic	Secondary	Non-random

The proposed theoretical framework for this research study consists of 5 independent variables and 1 dependent variable as explained in Table – 2 below:

Table 2 - **List of variables**

Variable	Adoption	Data Analysis
Dependent		
Renewable energy output / generation	Li Zhe (2021)	Renewable energy production (renewable energy Prod) defines the share of electricity generated from renewable sources out each country total energy output.
Independent		
Renewable energy consumption	Li Zhe (2021)	Renewable energy consumption (renewable energy Cons) is the share of electricity consume from renewable sources out of total electricity production.
Per capita Gross domestic product	Zahra (2017)	GDP per capita (GDP PerC) reflect the economic growth which is an important indicator of economic performance and a useful unit to make cross-country comparisons of average living standards and economic wellbeing.
Carbon Emissions	Miraj (2022)	Carbon emission (CO2 Emission) is the by-product which stemming from the burning of conventional fuels include carbon dioxide produced during consumption of solid, liquid, and gas fuels.
Technology Innovation	Jie Chen (2022)	Technology innovation defines the innovation of renewable energy technology and others related technology such as transmission systems, security and storage. This research takes renewable energy technology (Renewable Energy Patents) and system (System Patents) patents data into account. renewable energy Patents defines

		direct principal technology which are used to produce the energy from natural sources while System Patents define the innovation of complimentary
ICT Growth	Ahmed Usman et.al (20	ICT Growth is measured by mobile cellular subscriptions (MOB Subs – per 100 person) and internet users (INT subs – per 100 person).

3.3. Data Accessibility and issues

The panel data is harvested from publicly available data bank website and for that reason the data possess few issues regarding to authenticity, methodology used for data collection and its reliability. Adequacy, method of storage, safekeeping and transparency of the data are also pruned to validity uncertainty in which may affect the research outcome. In perspective of ethical conduct, the gathered data will only be used for comparative analysis purposes and would not be used to gain either economic leverage or being used to cause any impairment to others. In contrary, use of secondary data maximizes the value of data collection. The major benefit of using secondary data is the scale of data available in relation to scale, longitudinal and time period in which individual researchers would have a difficulty to collect. As doubtful as it may be, the data collection process by federal government usually involves specialisation, competence and integrity.

The major disadvantage however is the human error in processing and safekeeping the data that may lead to data insufficiency and disparate due to lack of understanding of the data itself, biased and integrity dispute. A related problem is that the variables may have been defined or categorized differently than when the primary data collection was executed.

3.4. Data Analysis Technique

Since this research employed free online data, the first step is to perform cross tabulation analysis to conform the correlation between variables in order to examine the association between the variables is statistically significant and to determine which variable may have the most impact on association. Next, factor analysis will help to understand how many factors are necessary to explain common arguments amongst a given set of variables and to eliminate any redundant variable in further regression analysis. Finally, linear regression model is to be run to identified and find a relationship between variables for hypothesis testing.

CHAPTER 4 : RESULTS AND DISCUSSION

4.1. Results Analysis

4.1.1. Descriptive Statistics Analysis

Table 3 - **Descriptive statistics**

	Mean	Std. Deviation	Analysis N
RE Prod	38.057	29.379	400
RE Cons	22.581	16.413	400
MOB Subs	98.435	33.589	400
INT Subs	19.421	13.807	400
CO2 Emis	7.830	4.623	400
GDP PerC	37335.073	16582.636	400
RE Patents	1837.908	5538.886	400
System Patents	1137.683	3812.661	400

From the descriptive statistics table above, it shows that GDP PerC (Mean = 37335) influence the renewable energy ecosystem the most.

4.1.2. Dimension Reduction Factor Analysis

Using SPSS tools below is the output of Principles Component Analysis and Factor Analysis.

Table 4 - **Correlation matrix**

Correlations	RE Prod	RE Cons	MOB Subs	INT Subs	CO2 Emis	GDP PerC	RE Patents	System Patents
RE Prod	1.000	0.834	0.136	0.187	-0.207	0.173	-0.182	-0.183
RE Cons	0.834	1.000	0.071	0.097	-0.389	0.014	-0.211	-0.214
MOB Subs	0.136	0.071	1.000	0.584	-0.049	0.379	-0.029	0.001
INT Subs	0.187	0.097	0.584	1.000	0.243	0.656	0.076	0.094

CO2 Emis	-0.207	-0.389	-0.049	0.243	1.000	0.596	0.114	0.102
GDP PerC	0.173	0.014	0.379	0.656	0.596	1.000	-0.163	-0.137
RE Patents	-0.182	-0.211	-0.029	0.076	0.114	-0.163	1.000	0.963
Storage Patents	-0.183	-0.214	0.001	0.094	0.102	-0.137	0.963	1.000
Sig. (1-tailed)		<.001	.003	<.001	<.001	<.001	<.001	<.001

The correlation matrix table shows that there is a correlation coefficient between single variable with others. The data set is a numeric data set (nominal type) and the objective mainly to test the factors component in boosting the renewable energy efficiency in the selected 30 countries. From the correlation matrix table, the results show positive and negative correlation exist between variables especially in relation to renewable energy Efficiency variables. The adequate correlation exists between variables make the data is suitable for data reduction analysis.

Table 5 - **Kaiser Meyer Olkin (KMO) and Bartlett's Test**

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.549
Bartlett's Test of Sphericity	**Approx. Chi-Square**	2388.268
	df	28
	Sig.	0.000

The KMO measures the sampling adequacy (which determines if the responses given with the sample are adequate or not) which should be close to 0.5 for satisfactory factor analysis to proceed. Kaiser (1974) recommends 0.5 (value for KMO) as a minimum (barely accepted), values between 0.7-0.8 are acceptable, and values above 0.9 are superb. Looking at the table below, the KMO measure is 0.549, which more than 0.5 and therefore can be barely accepted. The Bartlett's Test of Sphericity is significance (<0.12) which shows the correlation matrix is not an identity matrix.

Table 6 - **Communalities**

	Initial	Extraction
RE Prod	1.000	0.797
RE Cons	1.000	0.865
MOB Subs	1.000	0.476
INT Subs	1.000	0.796
CO2 Emis	1.000	0.646
GDP PerC	1.000	0.853
RE Patents	1.000	0.969

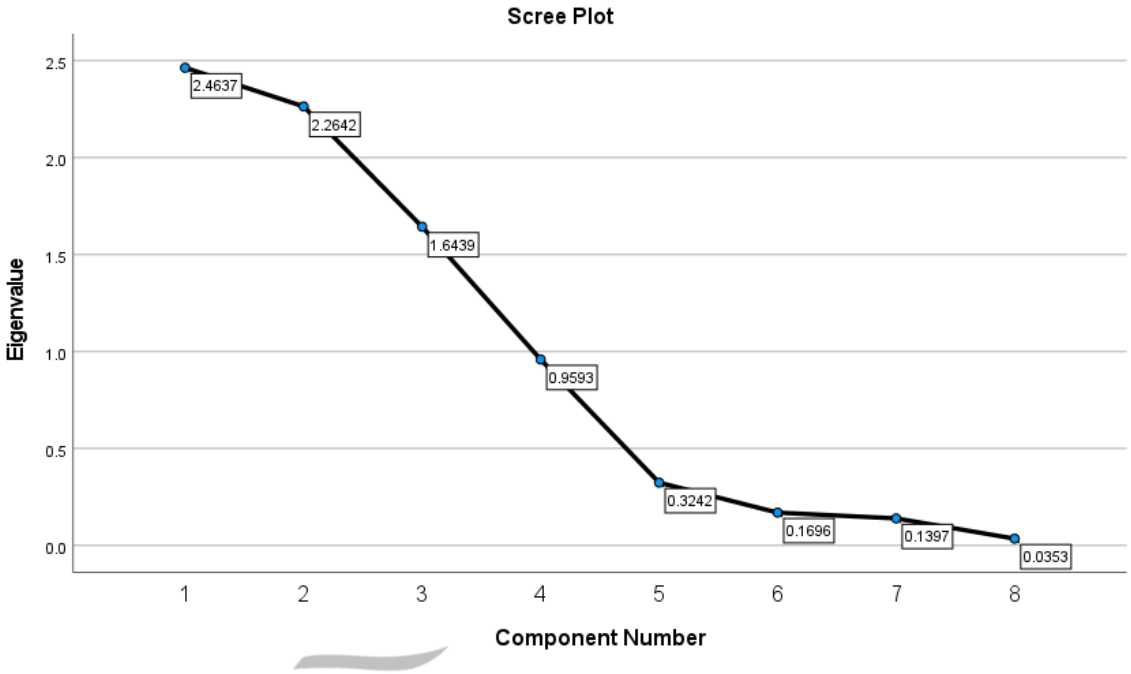
Communalities table represent the proportion of each variable's variance that can be explained by the factors. From the table the lowest extraction reading is 47.6% which is >40%.

From Total Variance Explained output, the result is summarized as follows;

Component / Factor	Eigenvalue	% Variance Explained	% Cumulative Variance Explained
1	2.464	30.796	30.796
2	2.264	28.302	59.098
3	1.644	20.549	79.648

From the above, the first three (3) factors have variances (eigenvalues) that are greater than 1. The eigenvalues change less markedly when more than 3 factors are used. In these results the scree plot started to form a straight line after the 4th component. Therefore, 1 - 3 factors appear to explain most of the variability in the data. The first three components accumulated to 74.648% adequate amount of variation explained in the data that hold significant variability of the data. The remaining factors accounted for a very small proportion of the variability and are likely inconsequential to the research objectives.

Fig – 13 - The Scree Plot



The scree plot is a graph of the eigenvalues against all the factors. The graph is useful for determining how many factors to retain. The point of interest is where the curve starts to flatten (Eigenvalues <1). It can be seen that the curve begins to flatten between factors 3 and 4. Note also that factor 4 onwards has an eigenvalue of less than 1, so only three factors have been retained.

Table 7 - **Component Matrix**

	Component		
	1	**2**	**3**
RE Prod	0.729		0.500
RE Cons	0.703		0.530
RE Patents	-0.682		0.632
Storage Patents	-0.670		0.636
INT Subs		0.780	
GDP PerC		0.778	
CO2 Emission		0.665	
MOB Subs		0.531	

Table 8 - **Rotated Component Matrix**

	Component

	1	2	3
GDP PerC	0.886		
INT Subs	0.878		
MOB Subs	0.657		
RE Cons		0.916	
RE Prod		0.850	
CO2 Emis	0.504	-0.626	
Storage Patents			0.979
RE Patents			0.978

From the above Component Matrix and Rotated Component Matrix the factors can be interpreted as follows:

- GDP PerC (0.886), INT Subs (0.878) and MOB Subs (0.657) have a large positive loading on factor 1. Thus, factor 1 can be regarded as economic sector that influence or impacted by the renewable energy growth.
- RE Cons (0.916), RE Prod (0.850) and CO2 Emission (-0.626) have a large positive loading on factor 2. Therefore, factor 2 is the renewable energy sector where energy production and consumption are the main factor and CO2 emission have the negative causality.
- System Patents (0.979) and RE Patents (0.978) have large positive loadings on factor 3. Factor 3 represent the renewable energy technology innovation which highly contribute to renewable energy development.

Together, all the three factors explain 79.648% of the variation in the data. It can be concluded from the analysis that the three principal components identified are vital for development focus, investment and capital injection to further develop the renewable energy sector.

4.1.3. Regression Analysis

Next, this research assessed the panel data using linear regression method to analyse the independent variables relationship with the dependent variable and the mediator effect on each of the relationship. In conjunction to factor analysis outcome, the CO2 Emission variable was excluded from this test.

Table 9 - **Descriptive Statistics**

	Mean	Std. Deviation	N
RE Prod	37.769	29.374	404
RE Cons	22.444	16.394	404
GDP PerC	37219.976	16617.688	404
System Patents	1127.629	3795.058	404
RE Patents	1823.500	5513.350	404
ICT_Dev	58.803	21.757	404

Table 10 - **Correlation Matrix**

		RE Prod	RE Cons	GDP PerC	System Patents	RE Patents	ICT Dev
Pearson Correlation	**RE Prod**	1.000	0.835	0.178	-0.180	-0.178	0.168
	RE Cons	0.835	1.000	0.019	-0.211	-0.208	0.089
	GDP PerC	0.178	0.019	1.000	-0.134	-0.159	0.511
	System Patents	-0.180	-0.211	-0.134	1.000	0.963	0.032
	RE Patents	-0.178	-0.208	-0.159	0.963	1.000	0.004
	ICT_Dev	0.168	0.089	0.511	0.032	0.004	1.000
Sig. (1-tailed)		<.001	<.001	<.001	<.001	<.001	<.001

Parallel to factor analysis output, the correlation matrix revealed significant correlation between all variables.

Table 11 - **Model Summary**

Model	R	R Square	Adjusted R Square	Sig. F Change

1	.851[a]	0.724	0.721	0.00055E-106
2	.851[b]	0.724	0.720	0.595373

Table 12 - **ANOVA**

Model		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
1	**Regression**	251628.324	4	62907.081	261.182	0.00055E-106[b]
	Residual	96101.360	399	240.856		
	Total	347729.683	403			
2	**Regression**	251673.483	5	50334.697	208.557	0.00083E-105[c]
	Residual	96056.201	398	241.347		
	Total	347729.683	403			

Table 13 - **Coefficients**

Model		**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**
		B	**Std. Error**	**Beta**		
1	**(Constant)**	-7.013	2.293		-3.058	0.002379
	RE Cons	1.498	0.048	0.836	31.039	0.00019E-104
	GDP PerC	0.000294	0.000	0.166	6.215	0.00013E-5
	System Patents	-0.000230	0.001	-0.030	-0.304	0.761609
	RE Patents	0.000270	0.001	0.051	0.516	0.606370
2	**(Constant)**	-7.659	2.597		-2.949	0.003379
	RE Cons	1.494421	0.049	0.834	30.671	0.0007E-103
	GDP PerC	0.000278	0.000	0.158	5.031	0.00074E-3
	System Patents	-0.000265	0.001	-0.034	-0.347	0.728670
	RE Patents	0.000283	0.001	0.053	0.534	0.590328
	ICT_Dev	0.022309	0.042	0.013	0.433	0.595373

With coefficient determination (R square) result of 0.724 (Model Summary Table), the independent variables explain 72.4% of the variability of dependent

variable. The independent variables statistically significantly predict the dependent variable with ANOVA F-ratio, F(4, 399) = 261.182, p < 0.001 for model 1 and F(4, 398) = 208.557, p < 0.001 for model 2, the regression model is a good fit of the data. However, looking at the coefficients table, only two independent variables are significant and the B value (Unstandardized Coefficients) for three out of five independent variables are zero. This shows no slope relations (changes) between the predictor and dependent implying the variable does not significantly predict the outcome.

This might the case of some predictors are correlated and carry the same information and therefore removing one predictor doesn't make any different, and the predictor is reported as not significant. Nevertheless, by running variable selection test with only one independent variable and mediator variable, a significant model is achieved as per below results.

Table 14 - **Model Summary**

Model	R	R Square	Adjusted R Square	Sig. F Change
1	.676a	0.457	0.456	0.00024E-73
2	.682b	0.465	0.463	0.004686

Table 15 - **ANOVA**

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	226281.738	2	113140.869	243.289	0.00024E-73[b]
	Residual	268331.786	577	465.046		
	Total	494613.524	579			
2	Regression	230152.315	3	76717.438	167.092	0.00077E-74[c]

	Residual	264461.209	576	459.134		
	Total	494613.524	579			

Table 16 - **Coefficient**

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-9.114	2.532		-3.599	0.000347
	RE Cons	1.133294	0.052	0.701	21.629	0.0002E-72
	GDP PerC	0.000554	0.000	0.360	11.104	0.00043E-22
2	(Constant)	-12.899	2.848		-4.529	0.000007
	RE Cons	1.134614	0.052	0.703	21.814	0.00033E-73
	GDP PerC	0.000469	0.000	0.304	8.085	0.00039E-11
	ICT_Dev	0.116967	0.041	0.103	2.839	0.004686

Selected only two independent and one mediator, the model gave coefficient determination (R square) of 0.457 where the independent variables explain 45.7% (46.3% with moderator model) of the variability of dependent variable. The independent variables statistically significantly predict the dependent variable with ANOVA F-ratio, $F(2, 577) = 243.289$, $p < 0.001$ for model 1 and $F(3, 576) = 167.092$, $p < 0.001$ for model 2, the regression model is a good fit of the data. The three variables (RE Cons, GDP PerC and ICT Dev) added statistically significantly to the prediction, $p < .05$.

4.1.4. Hypothesis Testing

From the regression model outcome, the research hypothesis can be concluded as below;

1) H_1 - From the regression analysis, the outcome gives RE Cons B value > 1 in all model coefficient. Therefore, the research fail to reject the null hypothesis and conclude that there is a significant relationship between RE Consumption and RE Output.

2) H_2 – From dimension reduction factor analysis outcome, the rotated component matrix implied that there is a negative and positive correlation existed between CO2 Emission and RE Output. Hence, this research failed to reject the null hypothesis and conclude that there is significant correlation between CO2 Emissions and RE Output;

3) H_3 – The regression test failed to show significant correlation between RE Patent and RE Output with B = 0. Therefore, this research reject the null hypothesis and conclude there is no significant correlation between RE Patent and RE Output;

4) H_4 - The regression test failed to show significant correlation between System Patent and RE Output with B = 0. Therefore, this research rejects the null hypothesis and conclude there is no significant correlation between System Patent and RE Output;

5) H_5 - From the regression analysis, the outcome gives GDP PerC B value < 1 in all model coefficient. Therefore, this research rejects the null hypothesis and conclude that there no significant relationship between GDP per Capita and RE Output

6) H_6 - From the regression analysis, the outcome of Model 2 shows ICT development significantly moderates the relationship between RE consumption and RE output with incremental of B value from Model 1.

Therefore, this research failed to reject the null and conclude that ICT development do moderate relationship between RE consumption and RE output.

7) H_7 – CO2 Emission variable was not statically significant when being accounted for in the regression model. Therefore, this research reject the null hypothesis and conclude that ICT development not significantly moderate the relationship between CO2 Emission and RE output in multilinear regression model.

8) H_8 - From the regression analysis, the outcome of Model 2 shows ICT development not significantly moderates the relationship between RE Patent and RE output with incremental of B value < 1. Therefore, this research reject the null and conclude that ICT development do not moderate the relationship between RE Patent and RE output.

9) H_9 - From the regression analysis, the outcome of Model 2 shows ICT development not significantly moderates the relationship between System Patent and RE output with incremental of B value < 1. Therefore, this research rejects the null and conclude that ICT development do not moderate the relationship between System Patent and RE output.

10) H_{10} - From the regression analysis, the outcome of Model 2 shows ICT development not significantly moderates the relationship between GDPs Per Capita and RE output with incremental of B value < 1. Therefore, this research rejects the null and conclude that ICT development do not moderate the relationship between GDPs Per Capita and RE output.

CHAPTER 5 : CONCLUSION

Based on the factor analysis of 30 countries data from the period of 2000 to 2019, it shows that the is a positive correlation between ICT growth and technology innovation with renewable energy development. The internet and innovation within ICT and other support industries able to indirectly boost the development of renewable energy efficiency and sustainability. This will also increase the domestic economic growth apart from the reduction of carbon emission as the main motivation of implementing green energy program. However, the analysis also pointed out that inside the development of ICT, there is a positive correlation exist between CO2 emission and renewable energy growth. It is most probably due to the use of cooling system and energy consumption from conventional fuel for facility needs such as data centre for hosting purposes. To conclude this research findings, have some useful implication in crafting future renewable policy;

1) The research concludes that internet as part of ICT growth has a significant influence and impact on RE growth. Taking this into account, the government should intensify current internet development program to focus and drive ICT industries to incorporate renewable sector as part of its innovation. Attractive initiative and support policy need to be systematically crafted to entice participation among enterprises whilst develop local solutions, applications of internet technologies to increase efficiency and reduce cost. Furthermore, the lawmakers shall promote the development of ICT support technology and trade such as energy-saving products, integration and management system, security, automation and digitalisation.

2) The research results likewise suggest there is a small causality between renewable growth and economic factor where increase in renewable give a

slightly positive effect on GDP per capita. Thus, by formulating policy which will encourage public participant, a holistic sustainability ecosystem can be created where renewable activity (prosumer) shall create domestic economy opportunity and minimize the dependency to external.

5.1. Recommendation

ICT tools such as AI, Big Data analysis, digitalisation, smart sensing and control can lead to a more energy-efficient operation and business model. Through ICT integration, a more centralised or decentralised smart grid could be developed to best benefit the energy sector in the long run. Enablement of efficient transmission and supply chain networking are clearly the roadmap for future energy ecosystem. Therefore, based on the findings this paper suggests policy makers to formulate ICT driven policies and incentives in order to;

1) Trigger interest, investment and participation from international in general and local firms specially to be involved in driving the national energy sector.
2) Facilitate smart technology innovation to improve energy transmission and supply chain.
3) Attract independent prosumer participation with lowered technology and operating costs.
4) Facilitate off-grid ecosystem environment to reduce dependency on single entity producer and illuminate domestic and community economy.

5.2. Limitations and Future Research

This paper gives a first round discussion about the role of ICT from the perspective of internet growth and innovation in renewable energy growth yet the ICT development, innovation and growth are substantially subjective. Other assessment

involving further variables from wider industries especially in relation to R&D, investment and applications are essential. Even though the ICT mediator are found to be significantly boosting the relationship between the predictors and dependent, the result shows only 45.6% of the independent variables explain the regression model (B). The reason might be that they are others important predictors which are not included or being neglected in this research model such as:

- Public Awareness and Participation - Government policies and business decisions can be influenced by public opinion and awareness of renewable energy, which increases investment in this sector.
- Enabling Infrastructure - The adoption of renewable energy technology can be influenced by the availability and accessibility of enabling infrastructure, such as smart transmission and end users facilities.
- Technological availability and cost - The design and effectiveness of renewable energy generation may be considerably impacted by availability and affordability of the technology itself either by firms or individual.
- Weather or Environment Feasibility – The renewable energy technology or source dependent to geographical location.

These variables can play a significant role in the adoption and growth of renewable energy output. Furthermore, the panel data is primarily harvested from open access database which are available online for free and the issue with free data is that the reliability and validity are debatable. However, for preliminary discussion and guidelines the data is ample. Moving forward, having more reliable and high integrity data from known source would be crucial and more accurate meant for deeper analysis in future research.

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APPENDICES

APPENDIX A

Appendix

Literature Reviews

No	Year	Author	Title	Publication	Objective	Methodology	Dependent	Independent	Findings
1	2013	Felix Groba, Barbara Breitschopf	Impact Of Renewable Energy Policy And Use On Innovation - A Literature Review	German Institute for Economic Research	Comprehensive literature review highlighting numerous motivations and necessities underlying the introduction of renewable energy policies	Summary on methodological approaches to measure policy efforts and technological change respecting different impact levels and stages within the technological change process.	The impact of policies as well as the other driving forces aimed at fostering technological change of renewable energyTs	• Energy market failures • Energy market barriers • Government intervention • Impact environmental regulation on technological change	• The research findings show that environmental regulation and subsequent innovation can be advantageous. • Innovation can have effect on reducing technology costs, but also there are other factors can contribute to decreasing technology costs..
2	2019	Michael Grubb	Induced innovation in energy technologies and systems: a review of evidence and potential implications for CO2 mitigation	IOP Pubishing	Explore links between demand-drivers (both market-wide and targeted); indicators of innovation (principally, patents); and outcomes (cost reduction, efficiency, and multi sector / macro consequences).	Systematic and interdisciplinary review of empirical literature assessing evidence on induced innovation in energy and related technologies.	Relationship between renewable energy consumption and economic growth	• Innovation patents • Cost- reduction • Efficiency • Consequences	• Positive impacts in industry, electricity and transport sectors. • Technology costs decline with cumulative investment for almost every technology studied across all time periods. • Overall innovation is cumulative, multi-faceted, and self-reinforcing in its direction (path-dependent).
3	2015	Alberto Jánez ˜ Morán, Paolo Profaizer,	Information and Communications Technologies (ICTs) for energy	Elsevier	This paper was developed from the results obtained in the framework of the study "SMART 2013/0073 –	Data analysis of the main results of the pilot projects regarding the energy savings	Energy savings, Economic and Social analysis	• Projects' buildings details • Main system typologies	While complex systems are required in tertiary buildings, houses are usually equipped by

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		María Herrando Zapater, María Andérez Valdavida, Ignacio Zabalza Bribián	efficiency in buildings: Review and analysis of results from EU pilot projects		reducing energy consumption in buildings with ICT – analysis of data from EU pilot. projects" financed by the European Commission – DG Communications Networks, Content & Technology and executed by CIRCE.	achieved, an economic and social ana			localised systems adapted to one dwelling with simplified information and management possibilities.
4	2020	Steffen Langea, Johanna Pohlc, Tilman Santariusa	Digitalization and energy consumption. Does ICT reduce energy demand?	Elsevier	Investigates the effect of digitalization on energy consumption	The analysis combines empirical and theoretical findings from debates on decoupling energy consumption from economic growth and from debates on green IT and ICT for sustainability	Energy consumption	• Direct effects from the production, usage and disposal of information and communication technologies (ICT) • Energy efficiency increases from digitalization • Economic growth from increases in labour and energy productivities • Sectoral change/ tertiarization from the rise of ICT services	The findings concluded that digitalization can only boost sustainability when it fosters energy efficiency and sectoral change without promoting direct effects and economic growth.
5	2021	Qinghua Fu, Susana Álvarez-Otero, Muhammad Safdar Sial, Ubaldo Comite, Pengfei Zheng,	Impact of Renewable Energy on Economic Growth and CO2 Emissions—Evidence from BRICS Countries	MDPI	To examine correlation between impact of renewable energy on economic growth, CO2 emissions and sensitivity of CO2 emissions in five majors economic BRICS nations.	Application of econometric-based models • "Cross Dependency" test • Unit root test • "CIPS" (cross-sectional augmented IPS) to measure	Renewable energy impact on Economic Growth	• Renewable energy consumption • Reduce carbon emission. • Developed, developing and underdeveloped countries	

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		Sarminah Samad, Judit Oláh				contribution of renewable energy towards economic growth; AND • DOLS test (dynamic ordinary least square) • FMOLS (fully modified ordinary least square) for verification. Application of sensitivity analysis to gauge and regression model to identify the nature and magnitude of relationship between GDP growth and increase in CO2 emissions.			
6	2022	Miraj Ahmed Bhuiyan, Qiannan Zhang, Vikas Khare, Alexey Mikhaylov, Gabor Pinter, Xiaowen Huang	Renewable Energy Consumption and Economic Growth Nexus—A Systematic Literature Review	Frontiers	Systematic reviews the consumption nexus of renewable energy and economic growth.	Articles review	Renewable energy impact on Economic Growth	• Renewable energy consumption • Reduce carbon emission • Developed, developing and underdeveloped countries	
7	2022	Muhammad Khalid Anser, Muhammad Usman, Muhammad Sharif, Sana	The dynamic impact of renewable energy sources on environmental economic growth:	SpringerLink	Empirical analysis of renewable energy sources on Asian country economy.	Panel vector error correction model (PVECM) analysis for eight Asian countries data sets for the period	Sustainable economy development	• Biomass sources energy • Geothermal sources energy • Wind generation source energy	Biomass, geothermal, and wind power sources have a positive significant impact on the economic advancement with wind

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		Bashir, Malik Shahzad Shabbir, Ghulam Yahya Khan, Lydia Bares Lopez	evidence from selected Asian economies			starts from 1990 to 2018.			power holds greater impact.
	022	Jie Chen, Fan Su, Vipin Jain, Asma Salman, Mosab I. Tabash, Akram M. Haddad, Eman Zabalawi, Alaa Amin Abdalla. Malik Shahzad Shabbir	Does Renewable Energy Matter to Achieve Sustainable Development Goals? The Impact of Renewable Energy Strategies on Sustainable Economic Growth	Frontiers	Investigates the association between various renewable energy sources and economic growth in selected Asian nations	Heterogeneous approach for panel data and second generational tools for econometrics	GDP per capita	• Total nation output per capita. • Capital stock per capita. • Technology	The outcomes confirm the significant positive impact of renewable energy sources to economy growth.
8	2020	Noor Faezah Khairudin	Renewable energy development in Malaysia: Communication barriers towards achieving the national renewable energy target	Open Access	Thorough examine the perceptions and understandings on the communication barriers towards renewable energy development in Malaysia.	Review Study	National renewable energy development failure	• Perception and understanding on communication barriers	Political berries and knowledge barriers were found was found as major contribution to the failure of renewable energy development.
9	2012	Sumaini	Barriers and challenges for developing renewable energy policy in Malaysia	IACSIT	Explains four main barriers that prevent developing renewable energy policy in Malaysia.	Systematic review of journals	renewable energy Policy development in Malaysia	• Financial, • Market, • Administrative, and • Sociocultural	Explains four main barriers that prevent developing renewable energy policy in Malaysia

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10	2022	To Trung Thanh, Le Thanh Ha, Hoang Phuong Dung, Tran Thi Lan Huong	Impacts of digitalization on energy security: evidence from European countries	Springer	To analyse relationship between digitalization and the security of the energy system.	Empirical analysis of nexus of digital transformation and energy security (ES) of international sample from 27 European countries over 2015 to 2019	Influence of digitalization on energy security	• GDP per capita (constant 2010 US dollar) • Share of trade values to GDP (TRADE) • Ratio of net inflows of FDI and GDP (FDI) • contribution of the industrial sector to GDP	The scaleup of digitalization could reduce the amount of carbon dioxide emission and foster the sustainable development of the energy system in the long run. Therefore, continuous investment in digital transformation across sectors is deemed to be beneficial to energy security.
11	2022	Muhammad Zeeshan, Jiabin Han, Alam Rehman, Irfan Ullah, Muhammad Mubashir	Exploring the Role of ICT and Renewable Energy in Environmental Quality of South-East Asian Emerging Economies	Frontiers	To investigate how information communication technology (ICT) and renewable energy relates to environmental quality in South-East Asia	Six SEA annual data (2000 – 2018) analysis using Panel Quantile Regression, and Dynamic Fixed Effect estimation technique	Environmental performance	• ICT Composite Index • Energy consumption • Population growth • GDP • C02 emission	The tremendous growth in ICT, advanced technologies, and renewable energy have significantly contributed to environmental sustainability across the globe.
12	2021	Anam Azam, Muhammad Rafiq, Muhammad Shafique, Jiahai Yuan, Sultan Salem	Human Development Index, ICT, and Renewable Energy-Growth Nexus for Sustainable Development: A Novel PVAR Analysis	Frontiers	Analyse the association between ICT, renewable energy, economic growth, and human development	Empirical analysis of 30 developing countries CO2 emissions and remittances from 1990 to 2017 using panel vector autoregressive model (PVAR)	Correlation between ICT, renewable energy, Human Growth and Economic development.	• ICT • renewable energy • Human Growth • GDP • Co2 Emission	The causality findings discovered that economic growth, remittances, and CO2 emission Granger cause to human development index. The empirical findings suggest that policymakers and government officials should make ICT-related policies more effective in terms of economic growth to

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									stimulate human development
13	2021	Elena G. Popkova, Agnessa O. Inshakova, Aleksei V. Bogoviz, Svetlana V. Lobova	Energy Efficiency and Pollution Control Through ICTs for Sustainable Development	Frontiers	To prove the necessity for a more thorough consideration and more active use of the modern ICTs for the technological support for the practical implementation of the SDGs' ecological block in the aspect of the increase of energy efficiency and environmental pollution control.	Regression Analysis	To determine regression equations that reflect the positive influence of ICTs on energy efficiency and environmental pollution control.	• Energy efficiency • Environment pollution • ICT potential factors	ICT is a promising tool for the practical implementation of the environmental block of the SDGs, stimulating energy efficiency and improving environmental pollution control.
14	2022	Yi Niu, Xiangyi Lin, Hongyun Luo, Jianhua Zhang, Yinghuan Lian	Effects of Digitalization on Energy Efficiency: Evidence From Zhejiang Province in China	Frontiers	To study and determine rapid digitalisation development in Zhejiang effect into energy efficiency and practical implications for improving regional energy efficiency in the digital era – estimation effect and assess the relationship between digitalization and energy efficiency.	Regression Model Analysis	Energy efficiency	Digitalisation Index • Physical foundation • Participant • Medium • Pathway	The ridge regression estimation results show that digitalization has a positive effect on energy efficiency - Network infrastructure, communication service development, information technology industry development, and digital technology innovation have various degrees of positive contribution to energy efficiency.
15	2022	Michelle Antretter, Matthias Kühnbach, Kaspar Knorr,	Digitalisation of Energy Flexibility	Fraunhofer	Analysing digital flexibility solutions; linked to demand side response (DSR) as significant part of the system's flexibility needs and Its complementation to other, non-digital flexibility	Identification and Analysis of use and business cases	Amount of flexibility provided to the energy systems	• DERMS • VPP • Energy sharing & P2P • District heating & cooling • BEMS • HEMS	Recommendations on flexibility use cases

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					solutions and could enable a more economical renewables-based power system.			• Industrial Hybrid Heating • Residential Heat Pumps	
16	2022	Birgit BEN YEDDER, Staffan VOWLES	Digitalisation of the energy system; A thematic collection of innovative EU-funded research results	Cordis EU	Explores how EU-funded research projects are paving the way for digital solutions to build a more secure and diversified energy supply, all while improving efficiency and resilience, reducing emissions and providing citizens with innovative energy services.				
17	2022	Teresa Pakulska, Małgorzata Poniatowska-Jaksch	Digitalization in the Renewable Energy Sector—New Market Players	MDPI	The empirical analysis to identify a framework "digital compass" of business models in renewable energy in renewable energy within a group of solar and wind energy start-ups, operating in energy storage and supply industries.	The research algorithm applied here enabled the identification and classification of startup business models based on secondary data using R software.	Framework digital compass for renewable energy business models.	• Digital technologies • Customer orientation • Delivery of value and revenue stream.	In conclusion, the expansion of digital technologies in renewable energy leads to a more dynamic energy transformation as well as to a proliferation of entities that apply new business models. Still, the extent of these changes is slow and also conditioned by certain non-technological factors - business models in renewable energy are deeply rooted in the frameworks of politics and regulations.
18	2020	Dr. Piyush Verma, Dr. Romanas Savickas, Mr.	Digitalization: enabling the new phase of energy efficiency	UNECE	To "explore the role of digitalization and increased use of big data and geo-spatial data in provision of	Report article			Digitalization of the energy system brings enormous potential to accelerate effort to achieve carbon

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		Stefan M. Buettner			energy services" - examines the role of digitalization and how it can help improve the efficiency of the overall energy system, while aiming to provide a clear, concise and balanced view on the matter to policymakers and other stakeholders				neutrality enabled by advances in data, analytics and connectivity, and it can greatly increase the overall efficiency of the energy infrastructure and the energy use at a significantly reduced cost.
19	2020	Moritz Loock	Unlocking the value of digitalization for the European energy transition: A typology of innovative business models	Elsevier	To identify potential that digital technology and business model innovation have to address bottlenecks and understand the consequences of digitalization on business model innovation in the energy domain - to encourage and enable the active participation of citizens that consume and produce energy.	Conventional case-study analysis – In-depth data analysis of EU EMPOWER Project data	Digitalization-based business model innovation	• Qualitative industry data: Industry reports, expert presentations at workshops, annual reports of European utility companies • Quantitative industry data: energy production capacity over time from different technologies such as wind, solar, market and trade volumes	The insights provide further implication for how digital technology and business model innovation affect the governance of sustainable energy transitions and the empowerment of prosumers.
20	2018	Xiaoyong Zhou, Dequn Zhou, Qunwei Wang	How does information and communication technology affect China's energy intensity? A three-tier structural decomposition analysis	Elsevier	To examine the effect of ICT on China's energy intensity change from a production perspective for the period of 2002 – 2012.	Three-tier structural decomposition analysis (SDA) approach on a basis of production theory framework of how ICT affects production structure and energy consumption.	Changes in energy intensity	• Energy efficiency change in ICT industry • Final demand change for ICT products • ICT input change • Substitution between ICT and KLEM • Technological change of ICT.	ICT positively affected China's energy intensity in many ways and shows remarkable effect on China's production structure and sectoral energy consumption.

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21	2022	Le Thanh Ha	Are digital business and digital public services a driver for better energy security? Evidence from a European sample	Springer	The impacts of the digital transformation process in the business and public sectors on energy security (ES).	Empirical methodology for comprehensive measures and databases to investigate the relationship between digitalization in business and public sectors and ES.	A nonlinear association between digitalization in the public sector and energy intensity and energy consumption, suggesting the acceptability and develop-ability of energy security can be enhanced if the digital transformation process achieves a certain level.	• Energy security • E-Commerce • CRP • Business cloud and mobility • GDP • Trade Share • FDI • Goverment	The use of modern digital technology such as big data, cloud computing is extremely important to ensure the security of the energy system, especially the availability of energy.
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