# Impact of Renewable Energy Integration on Technology-Driven Sustainability in Sri Lanka within the Dynamic and Uncertain Global Environment, Marked by VUCA Elements.

Yasarathne, V[1], Pramudika, H[2], Fernando, M.T[3]

Blue Ocean Insights (Pvt) Ltd1[,2,3]
*vkumonline@gmail.com*, *pramudihansi@gmail.com*, *tajanmadhu@gmail.com*[1,2,3]

## ABSTRACT

This study aims to investigate the impact of renewable energy integration on technology-driven sustainability in Sri Lanka, particularly within the context of a dynamic and uncertain global environment characterized by VUCA elements (Volatility, Uncertainty, Complexity, Ambiguity). The research methodology involves conducting a thorough literature review to establish the empirical background. Primary data was collected through a structured questionnaire distributed to 160 respondents, including renewable energy users in the Anuradhapura and Mannar districts of Sri Lanka. Data analysis was performed using IBM SPSS, incorporating reliability testing, correlation analysis, and regression analysis. This study found that there is a significant positive impact of renewable energy integration on technology-driven sustainability. The study's findings align with existing empirical evidence and emphasize the significance of renewable energy integration in promoting technology-driven sustainability, even in the face of a VUCA global environment. This supports the study's hypothesis and contributes to the body of knowledge in this are by providing adequate evidence to support the fact that renewable energy integration positively and significantly impacts on technology driven sustainability within Sri Lanka. This research underscores the critical role of renewable energy integration in fostering technology-driven sustainability in Sri Lanka. It provides valuable insights for policymakers, business leaders, and stakeholders aiming to navigate the challenges posed by a dynamic and uncertain global environment while promoting sustainable practices. Furthermore, it contributes to bridging gaps in the existing research landscape and lays a solid foundation for future investigations in this domain.

**Keywords: Renewable Energy Integration, Technology-Driven Sustainability, Dynamic and Uncertain Global Environment, VUCA Elements**

## INTRODUCTION

The modern era which is attributed to high levels of volatility and uncertainty has raised the awareness of the concept of "sustainable development" on a global level. According to Manisalidis et al., (2020); Sunlu, (2003) the high level of environmental pollution, depletion of scarce resources, and continuous environmental changes have created a severe challenge to most of the nations around the world. Furthermore, it is visible that optimizing economic growth while increasing sustainability commitment is essential to achieve sustainable economic development. Several studies have been conducted by different scholars to identify the critical success factors in achieving sustainable economic development whereas it is visible that the concept of "VUCA" has been widely used to describe the modern contemporary environment (Schick et al., 2017). According to Lechner & Schlüter, (2023), VUCA can be identified as an acronym that describes volatility, uncertainty, complexity, and ambiguity. When considering further challenges in the VUCA environment, the prevailing global energy crisis can be recognized as a key issue faced by most countries (Schick et al., 2017). According to Allam et al., (2022); Bagchi & Paul, (2023), economic rebound followed by the cease of the Covid-19 pandemic outbreak and Russia Ukraine war have created a significant impact on energy markets whereas rising energy prices for crude oil have driven the global inflation rate by a considerable amount while creating adverse implications such as economic recessions to third world developing countries. With this context, a major concern has arisen regarding the utilization of alternative energy sources such as solar energy, wind energy, hydro-powered energy, and biomass, which are capable of providing sustainable and efficient solutions for the energy crisis.

When considering the economic context of Sri Lanka, it can be noted that throughout the past decade, the country had to undergo severe changes and uncertainties. For instance, the Covid-19 pandemic outbreak, the economic recession, and political instability followed by civil uprisings created severe economic depletions in terms of national GDP (George et al., 2022). Also, it can be further noted that the rising global energy crisis and the political mismanagement of the country created a catastrophic impact on Sri Lanka which led to a huge fuel crisis followed by power cutoffs and power shortages creating severe adverse implications and disruptions to both civil and corporate operations (Sharma et al., 2022). According to Weerasooriya et al., (2023), the major reason for this energy crisis faced by Sri Lanka was raised due to being highly dependent on fossil fuel products such as diesel and furnace oil for energy and electricity generation. The highly deviating global fuel prices followed by significant financial constraints led to creating constant supply disruptions, which can be identified as the root causes of the crisis accordingly.

Based on these facts, it can be argued that switching to renewable energy sources is the most optimum solution for the country in achieving sustainable development while minimizing the possible negative implications that may arise from the global energy market which is attributed to VUCA elements. In Sri Lanka, there are 9 thermal power stations, 15 hydropower electric stations, and 15 small-scale onshore wind farms whereas Thambapavani wind farm can be identified as the largest wind energy supplying station with 100-megawatt capacity. Meanwhile, solar energy production also has not been reached and practiced on a national level (George et al., 2022). For instance, according to Sayanthan & Kannan (2017), the inconsistencies and insufficient regulatory frameworks to support renewable energy can be identified as one of the key policy gaps that limit renewable energy integration in Sri Lanka. Hence, it is visible that there is a significant performance and policy gap in renewable energy production in Sri Lanka. Despite all the above facts, it is visible that many challenges are associated with renewable energy production and consumption. According to Eseosa & Ejiroro, (2020), adapting renewable energy sources is hurdled with a number of technical challenges such as issues related to national grid integration and high initial investment costs. A study conducted by Dasanayaka et al., (2022) identified that insufficiencies in the grid infrastructure to accommodate the efficient distribution of energy from renewable sources, shortage in skilled labor and lack of expertise knowledge on renewable energy integration also act as several major challenges that restrict renewable energy integration in Sri Lanka. However, it can be further noted that with continuous technological advancements happening throughout the world, adapting a multifaceted approach which is attributed to high technological integration is capable of providing more innovative solutions to overcome issues associated with renewable energy utilization (Dhanasekar et al., 2021).

Based on these facts, it can be argued that Sri Lanka possesses an unrealized and unattended solution for the existing energy crisis. However, to gain the full potential of renewable energy, it is required to create a viable policy and regulatory framework that facilitates and promotes both government and private sector interventions and initiatives in the renewable energy sector, which will enhance innovation and emergent technology integration accordingly. Through this study, the researcher aims to identify and assess the impact created by renewable energy integration on technology-driven sustainability in Sri Lanka. The study further attempts to provide viable solutions and recommendations based on the findings derived from the research study.

The structure of this research study includes 05 chapters, namely, Introduction, Literature Review, Methodology, Analysis and Findings, and Conclusion. This study will also provide better insights for the policymakers and related authorities of the country. Furthermore, according to Ranathunga, (2023) it can be noted that there is a huge research and an empirical gap in the relevant context. This research study will bridge this empirical and practical gap by providing a solid foundation and insights for future endeavors as well. On the other hand, the future implications of this research study will provide insights into the energy security, energy independence, and optimized sustainability commitment that could be achieved through renewable energy along with the economic advantages as well.

## LITERATURE REVIEW

### Renewable Energy

The term “renewable energy” can be defined as energy that is derived from natural resources and possesses the capability of replenishing itself in comparison to high consumption (El-Sayed & Fitzsimmons, 2023; Strielkowski et al., 2021). There are many types of renewable energy sources. Solar energy, wind energy, biomass energy, and geothermal energy can be identified as some key renewable energy sources available and widely utilized in the modern world.  The concept of renewable energy has become a major topic of concern within most of the nations around the world. The unpredictable price fluctuations faced by the global energy market have been the key reason for this increasing awareness of renewable energy (Maksimtsev et al., 2022). Furthermore, it is visible that the contemporary global environment marked with VUCA elements has created a severe impact on the global energy industry. The impact created on global energy prices subsequently after the COVID-19 pandemic outbreak and the Russia-Ukraine war can be provided as a couple of classic examples of these unpredictable uncertainties. Apart from that it can be further noted that several sustainability-related factors have driven the rising awareness and preference towards renewable energy. For instance, the most commonly used non-renewable energy sources such as fossil fuel, coal, and crude oil are highly subjected to increasing depletion rates while the production process of pure energy using these sources leads to omitting greenhouse gases such as carbon dioxide which are capable of creating severe negative implications on global temperature levels and ecosystems simultaneously (Nunes, 2023). With this context, it can be noted that a large number of countries are considering and adapting renewable energy to gain more economic and environmental benefits while gaining a higher level of energy independence from non-renewable energy sources.

### Renewable Energy Integration

The term “renewable energy integration” can be defined as the process of interconnecting the produced renewable energy into the national energy grid in a manner that achieves the continuity of effective, efficient, cost-beneficial, and cleaner energy production (Alabbasi et al., 2022). Due to being a major concern around the world, many trends have arisen related to renewable energy integration. For instance, it can be noted that over the last five years, renewable energy utilization and capacity have increased by significant amounts around the world, specifically in the solar energy production and consumption sector (El-Sayed & Fitzsimmons, 2023; Halkos & Gkampoura, 2020). Furthermore, it can be noted that increased adoption of solar energy has facilitated technology-driven innovations within the industry leading to create more cost-effective and efficient energy generation models, which in turn have enhanced the investments accordingly. When elaborating further, the invention of highly advanced energy storage systems and smart grids is emerging within the industry which has led to enhancing and optimizing the reliability of renewable energy integration to the national grid (Salmerón-Manzano et al., 2023). Wide adaptation of Distributed Energy Sources (DERs) can be identified as another emerging trend related to renewable energy integration. DERs can be identified as small-scale energy generation units such as; rooftop solar panels and small-scale wind generation turbines (Facchini, 2017). According to Salmerón-Manzano et al., (2023) the increase in the adaptation of DERs on a global scale has enabled energy consumers to meet their energy requirements by themselves while gaining the capability to feed any excess energy to the national power grid.

Apart from these rising trends, it can be noted that many advantages are associated with renewable energy integration. For instance, Liu, (2014); Žarković et al., (2022) renewable energy integration has a significant positive impact on the environment because solar, wind, and biomass reduce greenhouse gas emissions substantially. Furthermore, according to a study conducted by Nugroho et al., (2017) on renewable energy in Indonesia, it was identified that increased renewable energy integration is capable of enhancing air quality while depleting environmental pollution by significant amounts. Another key advantage associated with renewable energy integration is the capability of attaining a higher level of energy security and independence. According to Belrzaeg & Ahmed, (2023), increasing renewable energy integration enables an economy to diversify the energy mix by enhancing local energy productions through DERs, which on the one hand reduces the dependency on fossil fuel, and on the other hand creates high energy stability by depleting the possible vulnerabilities associated with energy disruptions in a centralized grid. Furthermore, developing the renewable energy industry has a significant impact on the economy as the country gains the capability to get rid of unnecessary price fluctuations associated with crude oil while gaining the capability to support the local community through job creation (Gupta et al., 2023).

Despite having many environmental and economic advantages, it can be noted that the process of renewable energy integration is associated with several challenges and limitations. For instance, according to a study conducted by Ayamolowo et al., (2020), it was identified that effective renewable energy integration processes are constantly hurdled with constant frequency instabilities and deviations in frequency rate of change. A study conducted by Gupta et al., (2023) also provides adequate evidence to support this fact as through this study, it was identified that the process of predicting renewable energy and identifying the frequency rate changes is highly challenging. Apart from these technical challenges, the inadequacy of a proper policy and regulatory framework has been identified as another key challenge associated with renewable energy integration. According to Belrzaeg & Ahmed, (2023), inconsistency and lack of proper regulatory and policy frameworks can be identified as one of the major limitations visible within developing countries in the renewable energy integration process.

Furthermore, according to a study conducted by JANJIC et al., (2015) on the topic of renewable energy integration in smart grids, it was identified that four key factors, namely, customer satisfaction, technology, cost, and environmental impact act as indicators or drivers that influence on the adaptation of the renewable technology integration process. The study was conducted as a multi-criteria assessment using the fuzzy analytical hierarchical process whereas the results indicated that customer satisfaction level has the highest level of impact on renewable energy integration whereas environmental impact reduction, technology, and cost reduction factors have the next influential impact respectively. According to a study conducted by Malik et al., (2020), it was identified that customer satisfaction and environmental impact have a significant impact on renewable energy integration and purchase intentions. The study was conducted as a quantitative cross-sectional study using a sample size of 354 respondents in Maudurai district in India to identify the renewable technology integration selection criteria in the British Colombian region of Canada whereas the results indicated that key indicators in the relevant context can be segregated into 04 categories, namely, technical, environmental, economic, and social. The study further indicated that customer satisfaction, related costs, and impact on the environment were the major factors that created a substantial impact on renewable technology integration accordingly.

### Technology Driven Sustainability

Over the last two decades, the concept of sustainability has emerged with higher intensity throughout the world while creating significant influence on corporate and consumer behaviors

(Sumanasiri, 2020). According to Kuhlman & Farrington, (2010), sustainability can be defined as the process of compensating both individual and corporate requirements, needs, and demands without compromising the resource requirements of future generations. Also, it can be noted that sustainability has created a significant impact on consumer behaviors. Meanwhile, Yener & Secer, (2023) revealed that modern customers show a higher awareness and preference towards sustainable products whereas the sustainability commitment of organizations has a significant impact on consumer purchase intentions. Furthermore, according to Imppola, (2020), it is visible that environmental, social, and resource-related issues are increasing at an alarming rate within almost all countries, especially among developing countries, leading to the requirement for sustainability more vital. Based on these data it can be argued that sustainability has become a global phenomenon.

However, when considering further it can be noted that technology has played a critical role in achieving sustainability. When elaborating further, it can be noted that continuous technological advancements that keep occurring on a global scale have caused the emergence of emergent technologies such as Artificial Intelligence (AI), Blockchain, Internet of Things (IoT), Virtual Reality (VR), Robotics, etc. which are attributed with largely unrealized and unidentified potentials at present (Rotolo et al., 2015). Cascio & Montealegre, (2016) highlight that the enhancement of technological initiatives has created several positive implications for both business and human life. For instance, it is visible that increasing technological initiatives are capable of enhancing innovations while creating positive implications for overall productivity and efficiency. Similarly, it is visible that increasing technological advancements have created positive implications on the sustainability aspects as well. For instance, according to Vacchi et al., (2021), new and emerging technological initiatives have provided more innovative and effective solutions to overcome environmental, social, and economic challenges and limitations associated with sustainability. Some of these initiatives can be further explained as follows.

**Utilizing Big data and AI for energy management**

Big data indicate huge clusters of data that are attributed to very high volumes, velocities, and varieties (Rawat & Yadav, 2021). With the capability to capture these large clusters of data relevant to energy consumption in household and corporate contexts, it is possible to identify the patterns in energy consumption more precisely and accurately. This can be used to reduce unnecessary energy consumption and overutilization of units (Gupta et al., 2023). Furthermore, narrow AI applications and machine learning can be used to analyze these big data and conduct predictive analysis which enables the policymakers and related authorities to predict the energy demands more accurately and precisely, which in turn optimizes technology-driven sustainability (Hannan et al., 2021).

**Emergence of technologically innovative initiatives and appliances**

Due to the rapid advancements in technology, new appliances and innovative initiatives keep emerging in the energy industry which are capable of creating significant positive implications on energy utilization. For instance, it can be noted that energy storage devices have achieved transformational modifications with the inventions of supercapacitors and thermal energy storage devices which are capable of storing more energy with enhanced life spans that facilitate renewable energy integration (El-Sayed & Fitzsimmons, 2023). Furthermore, according to Belrzaeg & Ahmed, (2023), the inventions and constant innovative initiatives that keep occurring in smart grids have created more resilience, advanced, and efficient renewable energy integration processes that guide toward technology-driven sustainability.

Many studies have been conducted by different scholars to identify the key indicators related to technology-driven sustainability. According to a study conducted by Alabbasi et al., (2022) on the sustainability indicators in Bahrain's renewable energy integration and power generation context, it was identified that there are 19 key indicators of sustainability which can be categorized into 04 main dimensions, namely, technical, economic, social and environmental aspects. The study was conducted as a systematic approach which analyzed the frequencies of the indicators using a sample of 73 prior research studies.

Similarly, according to a study conducted by Mainali (2012) on Renewable Energy Based Rural Electrification in Nepal, it was identified that factors such as energy availability, efficiency, cost of capital, operations and maintenance cost, employment productions, and emission of $CO_2$ act as some key indicators related to sustainability through renewable energy integration. Furthermore, a study conducted by Liu, (2014), supports these facts by identifying time, efficiency, associated cost, level of social acceptance, and impact created on the environment ($CO_2$ emission, carbon footprint, etc.) as the key indicators that can be utilized to assess the sustainability on renewable energy integration context.

### Impact of Renewable Energy Integration on Technology-driven sustainability

Several studies have been conducted by different scholars and researchers in different contexts to distinguish the impact created by renewable energy integration on sustainability aspects. Kilinc-Ata & Tanriover, (2017) identified that renewable energy integration is capable of increasing the sustainability index in Turkey. Furthermore, adapting renewable energy is capable of creating a significant impact on sustainability aspects. Similarly, according to a systematic review conducted on 177 filtered articles by Al-Shetwi, (2022), it was identified that renewable energy integration has a significant impact on creating numerous positive economic and environmental implications including the enhanced sustainability commitment. Meanwhile, renewable energy integration has a substantial positive influence on sustainability (Sebestyén, 2021). However, the study further identified that some of the renewable energy sources such as wind turbines can adversely affect natural ecosystems through sound pollution and by hindering the bird immigration processes.

When summarizing all the above literature findings, it can be noted that there is adequate evidence to support the fact that renewable energy integration is highly advantageous, and is capable of creating a number of environmental as well as economic advantages. However, prior studies that have been conducted on the relevant context further suggest that technical challenges such as constant changes in frequency rates along with inadequate policy and regulatory frameworks act as key constraints towards renewable energy integration. Despite these challenges and restraints, it is further visible that technology plays an integral part of renewable energy integration while emergent technology concepts such as AI and Big data are used for effective energy management on a global context. Finally, upon the conclusion of all these facts, it is visible that there is adequate evidence to prove that technology plays a pivotal role in integrating renewable energy to achieve a higher level of sustainability.

## RESEARCH METHOD

### Conceptual Framework and Variable Operationalization

The conceptual model and the framework of the study, which has been developed based on the key findings derived from the literature review, which indicate that renewable energy integration possesses a positive impact on technology-driven sustainability (Sebestyen, 2021). The model is prepared based on the two variables discussed through literature analysis, namely, renewable energy integration and technology-driven sustainability. Furthermore, the visual presentation of the conceptual framework depicts that it is assumed that there is a relationship in between these two variables accordingly.

**Figure 1: Conceptual Framework**

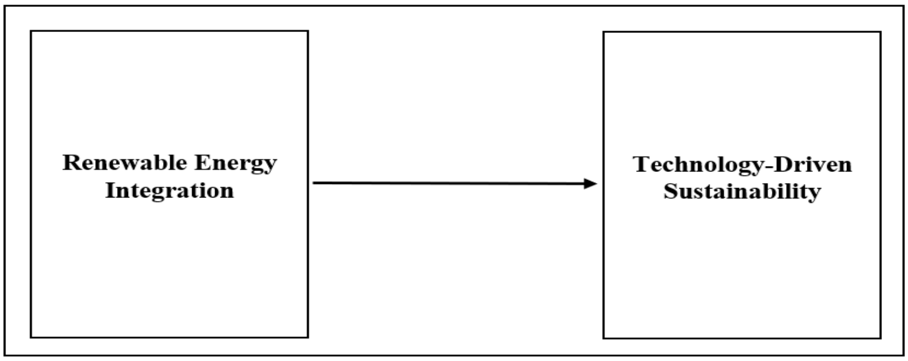


**Table 1: Variable Operationalization**

| Variable | Indicators | Sources | Measurement Scale |
|---|---|---|---|
| Renewable Energy Integration | Customer Satisfaction<br>• Quality and reliability<br>• Social benefits<br>Environmental Impact Reduction<br>• CO2 emission<br>• Environmental impact<br>Cost reduction<br>• Net present value<br>• Social benefits<br>Technology<br>• Voltage deviations<br>• Power losses | (JANJIC et al., 2015; Malik et al., 2020) | 1 – 5 Likert Scale |
| Technology Driven Sustainability | Technical<br>• Deployment time<br>• Efficiency<br>• Expert HR<br>• Installed capacity<br>• Reliability<br>• Potentials of resources<br>• Maturity<br>Economic<br>• Capital cost<br>• Operations and maintenance cost<br>• Electricity cots<br>• Economic contribution<br>• ROI | (Alabbasi et al., 2022; Liu, 2014; Mainali, 2012) | 1 – 5 Likert Scale |

| | | | |
|---|---|---|---|
| | • Levelized cost<br>Social<br>• Social acceptance<br>• Job creation<br>• Social benefits<br>Environmental<br>• CO2 emission<br>• Compliance with local conditions<br>• Land requirements<br>• Emission and pollution | | |

The operationalization table illustrates the indicators used to define the key variables that have been identified through the research model. When elaborating further it is visible that the independent variable "renewable energy integration" has been defined using 04 key indicators, namely, customer satisfaction, environmental impact reduction, cost reduction, and technology. Similarly, 04 key indicators have been used to define the dependent variable "technology-driven sustainability", which can be further identified as technical, economic, social, and environmental factors. The selection of these indicators that can be used to define the research variables is done through a comprehensive literature analysis whereas the selection criteria are confirmed upon the verification that there is adequate information to support the identified indicators. Also, the selection process is continued upon the reflection and consideration of the suitability and applicability of these indicators in the Sri Lankan context. It was further verified that the available indicators possess the capability of being assessed and are quantifiable. The questionnaire consists of 03 sections. The first part of the questionnaire addresses the basic demographic factors such as age, gender, and education level. The second part of the questionnaire assessed the independent variable "renewable energy integration" using 9 questions, while 17 questions were used in the third part of the questionnaire to assess the dependent variable "technology-driven sustainability", which are all formulated referring to the key indicators relevant to each research variable. Furthermore, the 5-point Likert scale is adapted to record and measure the responses for the dependent and independent variable criteria.

## Hypotheses

Upon the consideration of data derived from the literature review, "renewable energy integration" has been identified as the antecedent or the independent variable whereas "technology-driven sustainability" has been identified as the dependent variable of the research study. Based on these data, an alternative hypothesis and a null hypothesis are formulated in order to achieve the key objective of the study. The alternative hypothesis developed is named as H1, and the hypothesis is constructed to statistically assess the impact created by the independent variable (renewable energy integration) on the dependent variable (technology-driven sustainability). Furthermore, the conducted null hypothesis suggests that there is no statistically provable significant impact of the independent variable (renewable energy integration) on the dependent variable (technology-driven sustainability).

*Hypothesis 1 (H1): There is a significant impact of renewable energy integration on technology-driven sustainability.*

*Hypothesis 0 (H0): There is no significant impact of renewable energy integration on technology-driven sustainability.*

**Population and Sample Selection**

The population of the study includes renewable energy users, who are residing in Anuradhapura and Mannar districts. The key rationale used to select these two districts is the existence of relatively stable and more suitable weather conditions within these two districts which are much suitable for renewable energy integration, such as solar panels.184 questionnaires were distributed to the selected and identified sample of respondents which were distributed physically meanwhile only 160 valid responses were received.

## DATA ANALYSIS

### Demographic Factor Analysis

**Table 2: Gender Distribution**

| Gender | | | | | |
|---|---|---|---|---|---|
| | | Frequency | Percent | Valid Percent | Cumulative Percent |
| Valid | Male | 58 | 36.3 | 36.3 | 36.3 |
| | Female | 102 | 63.7 | 63.7 | 100.0 |
| | Total | 160 | 100.0 | 100.0 | |

The demographic analysis of gathered data represents that out of 160 respondents, the majority of the respondents are female with a frequency value of 102 and a percentage of 63.7 whereas 58 respondents are males which depicts a percentage value of 36.3%.

**Table 3: Age Distribution**

| Age | | | | | |
|---|---|---|---|---|---|
| | | Frequency | Percent | Valid Percent | Cumulative Percent |
| Valid | 21 - 30 Years | 16 | 10.0 | 10.0 | 10.0 |
| | 31 - 40 Years | 38 | 23.8 | 23.8 | 33.8 |
| | 41 - 50 Years | 64 | 40.0 | 40.0 | 73.8 |
| | 51 - 60 Years | 22 | 13.8 | 13.8 | 87.5 |
| | Greater than 60 Years | 20 | 12.5 | 12.5 | 100.0 |
| | Total | 160 | 100.0 | 100.0 | |

When considering the age distribution of the respondents, it is visible that a majority of 64 respondents with a percentage value of 40% are recorded to be “in between 41-50 years”, whereas the age group of “21-30yeras” represents the least number of respondents with a recorded frequency value of 16. The remaining age groups of “31-40 years”, “51-60 years” and “Greater than 60 years” have recorded frequency values of 38, 22, and 20 which represent 23.8%, 13.8%, and 12.5% out of the total 160 respondents respectively.

**Table 4: Education Level Distribution**

| Highest Education Level | | | | | |
|---|---|---|---|---|---|
| | | Frequency | Percent | Valid Percent | Cumulative Percent |
| Valid | Ordinary Level | 6 | 3.8 | 3.8 | 3.8 |
| | Advanced Level | 17 | 10.6 | 10.6 | 14.4 |
| | Diploma | 73 | 45.6 | 45.6 | 60.0 |
| | Graduate | 50 | 31.3 | 31.3 | 91.3 |
| | Post Graduate | 14 | 8.8 | 8.8 | 100.0 |
| | Total | 160 | 100.0 | 100.0 | |

The majority of 45.6% of respondents have achieved the diploma level in education whereas 6 respondents have recorded possessing “ordinary level” with a percentage value of 3.8%, which is the least recorded frequency distribution of the current data set. Furthermore, it is visible that 17, 50, and 14 respondents have recorded possessing “advanced level”, “graduate” and “postgraduate” educational levels as the highest educational level respectively.

## Descriptive Statistics

**Table 5: Descriptive Statistics – Renewable Energy Integration**

| Renewable Energy Integration (RET) | Mean | Standard deviation |
|---|---|---|
| RET01 | 2.98 | 0.955 |
| RET02 | 2.99 | 0.935 |
| RET03 | 2.83 | 0.933 |
| RET04 | 2.99 | 0.925 |
| RET05 | 2.89 | 0.901 |
| RET06 | 2.86 | 1.033 |
| RET07 | 2.81 | 0.746 |
| RET08 | 2.98 | 0.876 |
| RET09 | 3.13 | 0.862 |

For the independent variable "renewable energy integration" it can be noted that the mean values of all the recorded data for the nine questions are between 2.5 and 3.4. This illustrates that the majority of the respondents have shown a neutral attitude toward the questions. Furthermore, it can be noted that the standard deviation values for all 9 statements are in between -2 and +2, hence it can be concluded that the data set is well within the acceptable range.

**Table 6: Descriptive Statistics – Technology-driven Sustainability**

| Technology Driven Sustainability (TDS) | **Mean** | **Standard deviation** |
|---|---|---|
| TDS01 | 2.54 | 0.861 |
| TDS02 | 2.42 | 0.865 |
| TDS03 | 2.6 | 0.899 |
| TDS04 | 2.56 | 0.916 |
| TDS05 | 2.46 | 0.831 |
| TDS06 | 2.56 | 0.963 |
| TDS07 | 2.56 | 0.943 |
| TDS08 | 2.69 | 1.127 |
| TDS09 | 2.54 | 0.875 |
| TDS10 | 2.46 | 0.653 |
| TDS11 | 2.88 | 0.819 |
| TDS12 | 2.62 | 0.8 |
| TDS13 | 2.93 | 0.802 |
| TDS14 | 2.39 | 0.817 |
| TDS15 | 2.99 | 0.85 |

| | | |
|---|---|---|
| TDS16 | 2.51 | 0.727 |
| TDS17 | 2.37 | 1.114 |

When considering the descriptive statistics of the independent variable. “technology-driven sustainability”, it can be noted that out of the 17 statements that are used to assess the dependent variable “technology-driven sustainability”, TDS02, TDS05, TDS10, TDS14, and TDS17 have the mean values which are lower than 2.5. Based on these facts it can be concluded that the majority of the respondents have not agreed with these statements. On the other hand, it is visible that the remaining 12 statements have a mean value that lies between 2.5 and 3.4, which indicates that the majority of the respondents have shown a neutral attitude towards these 12 statements. Furthermore, the standard deviation values derived from the analysis are between -2 and +2 for all 17 statements hence it can be concluded that they are well within the acceptable range.

**Reliability Test**

**Table 7: Reliability Statistics**

| **Reliability Statistics** | | |
|---|---|---|
| | Cronbach's Alpha | N of Items |
| **Renewable Energy Integration** | .922 | 9 |
| **Technology-Driven Sustainability** | .940 | 17 |

Cronbach’s Alpha test is used to assess the reliability of the instruments. The data derived from the analysis indicate that the Cronbach’s Alpha values for the independent and dependent variables are 0.922 and 0.940, which both are above the acceptable range of 0.7. Hence it can be concluded that there is a high level of internal consistency between the gathered data set and the instrument.

**Validity Test**

**Table 8: Validity Test**

| **KMO and Bartlett's Test** | | |
|---|---|---|
| Kaiser-Meyer-Olkin Measure of Sampling Adequacy. | | .834 |
| Bartlett's Test of Sphericity | Approx. Chi-Square | 3433.477 |
| | Df | 325 |
| | Sig. | .000 |

The validity of the data set is tested using KMO and Bartlett's test. The analysis data indicate that the sampling adequacy of the KMO test is at 0.834 which is in between the acceptable range of 0.7 and 1 whereas the significant value derived from Bartlett's test of Sphericity is at 0.000, Hence, it can be concluded that there is a high level of sample adequacy and the data set is valid.

**Correlation Analysis**

**Table 9: Correlation Analysis**

| Correlations | | | |
|---|---|---|---|
| | | REI | TDS |
| REI | Pearson Correlation | 1 | .534** |
| | Sig. (2-tailed) | | .000 |
| | N | 160 | 160 |
| TDS | Pearson Correlation | .534** | 1 |
| | Sig. (2-tailed) | .000 | |
| | N | 160 | 160 |
| **. Correlation is significant at the 0.01 level (2-tailed). | | | |

Pearson correlation is used to identify the correlation of the two variables whereas the data derived from the analysis indicate that renewable energy integration and technology-driven sustainability have a positive correlation value of 0.534. These data further depict that the two variables have a moderate positive inter-relationship of 0.534 or 53.4%.

**Multiple Regression Analysis**

**Table 10: Model Summary – Multiple Regression Analysis**

| Model Summary | | | | |
|---|---|---|---|---|
| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
| 1 | .534[a] | .286 | .281 | .53406 |
| a. Predictors: (Constant), REI | | | | |

The R square value depicted through the model summary table is 0.286. Hence it can be argued that 28.6% (R Square – 0.286) variances that occur in the dependent variable "technology-driven sustainability" can be explained using the independent variable "renewable energy integration".

**Table 11: ANOVA Table – Multiple Regression Analysis**

| ANOVA[a] | | | | | | |
|---|---|---|---|---|---|---|
| Model | | Sum of Squares | df | Mean Square | F | Sig. |
| 1 | Regression | 18.018 | 1 | 18.018 | 63.174 | .000[b] |
| | Residual | 45.064 | 158 | .285 | | |
| | Total | 63.082 | 159 | | | |
| a. Dependent Variable: TDS | | | | | | |
| b. Predictors: (Constant), REI | | | | | | |

The data derived from the ANOVA table indicate that the significant value of the analysis is at 0.000 while the F value is 63.174 which is greater than 1.96. Hence it can be argued that the overall model is significant.

**Table 12: Coefficient Table – Multiple Regression Analysis**

**Coefficients[a]**

| Model | | Unstandardized Coefficients B | Std. Error | Standardized Coefficients Beta | T | Sig. |
|---|---|---|---|---|---|---|
| 1 | (Constant) | 1.206 | .180 | | 6.720 | .000 |
| | REI | .472 | .059 | .534 | 7.948 | .000 |

a. Dependent Variable: TDS

The data derived from the coefficient table further depicts that the significant value is at 0.000 which is lower than 0.05. Hence, it can be concluded that the independent variable renewable energy integration has a 47.2% significant positive impact on the dependent variable technology-driven sustainability.

Upon the consideration of all these data, a regression equation can be formulated as follows.

$$\mathbf{Y = \alpha + \beta + \epsilon}$$

$$= 1.206 + 0.472 + 0.180 .$$

## DISCUSSION

When considering the empirical evidence that was assessed through the literature review, it can be noted that there is adequate evidence to support the fact that there is a positive relationship between renewable energy integration and sustainability. Renewable energy integration has a positive correlation and a significant impact on the Sustainability Index in Turkey (Kilinc-Ata & Tanriover, 2017). The study was conducted using Mean-Median Tests and Study Event methodology which was deployed using the data gathered through 50 organizations in Turkey that were included in the BIST Sustainability Index. The findings of the study confirmed that investors believe the renewable energy integration with corporate enterprises has a significant impact on sustainability and find them to be attractive in terms of investor's perspectives. Meanwhile, renewable energy integration has a positive correlation and a significant impact on environmental sustainability (Al-Shetwi, 2022).

When comparing these results against the data derived from the correlation analysis of the current study, it can be noted that there is a positive correlation of 0.534 or 53.4% between the independent variable (renewable energy integration) and the dependent variable (Technology-driven sustainability). When considering further, it is visible that the data derived from the current statistical analysis align with the empirical findings that were derived from the literature analysis. Hence by considering all these data, it can be concluded that renewable energy integration has a positive correlation with technology-driven sustainability.

When further considering the empirical data derived from the literature analysis, it can be noted that renewable energy integration has a significant positive impact on sustainability (Kilinc-Ata & Tanriover, 2017). According to Al-Shetwi, (2022), renewable energy integration is capable of creating a significant impact on sustainability. The study was conducted as a systematic literature review. The data required for the analysis were gathered from 177 research papers, journal articles, and other studies which were extracted from reliable literature sources. The findings of the study indicated that increasing renewable energy integration into the national electricity grid creates a significant influence on sustainability commitment accordingly. However, according to Sebestyén, (2021), it was identified that some renewable energy sources have a significant impact on the natural environment and ecosystems. The study was conducted using the multi-layer network-based impact assessment technique. The findings of the study indicated that renewable energy sources such as wind turbines have a substantial influence on flying animals and sound pollution. Also, it was identified that hydropower plants have a considerable impact on the water flow conditions while geothermal power plants create a considerable negative impact on soil and natural plants. The study further emphasizes that regulatory frameworks should be aligned more to positively influence the sustainability commitment using renewable energy integration.

When considering the results derived from the statistical analysis of the current study, it could be noted that the independent variable "renewable energy integration" had a significant positive impact on the dependent variable "technology-driven sustainability". (Sig -0.000). Based on these findings it can be noted that Hypothesis 1 of the study has been accepted, which assumed that "There is a significant impact of renewable energy integration on the technology-driven sustainability". When comparing this data against the empirical findings derived from the literature analysis, it can be noted that the results align with the majority of the findings which elaborates on the existence of a significant impact of renewable energy integration on technology-driven sustainability (Kilinc-Ata & Tanriover, 2017) (Sebestyen, 2021). By considering all these facts it can be finally concluded that renewable energy integration has a substantial impact on technology-driven sustainability.

Overall, it can be noted that this research study provides better insights into renewable energy integration within Sri Lanka. The key limitation of the study includes the limited sample size used to conduct the research analysis. However, it can be noted that this study provides a solid foundation for future researchers by bridging the research and empirical gap that exist within relevant research contexts.

## CONCLUSION

When considering the modern contemporary environments, it can be noted that all the nations are compelled to operate under highly dynamic environmental conditions which are constantly attributed to VUCA elements. Increasing regional political instabilities, possible pandemic outbreaks, and constant, extreme weather conditions can be identified as some root causes for this dynamic business environment which are marked with VUCA elements. With this scenario, most of the nations struggle to pursue both economic developments while increasing the sustainability commitment of the economy, as they seem to be mutually exclusive interests at a glance. However, with the rising energy crisis, renewable energy has proven to be a highly beneficial and efficient alternative that is capable of creating numerous positive implications for both economic development as well as the sustainability commitments of the country.

When considering the economic conditions of Sri Lanka, it is visible that the prevailing global energy crisis has created catastrophic implications for the Sri Lankan economy. The dependency on fossil fuel followed up with the sudden price fluctuations in the global energy market created severe energy shortages in terms of diesel and electricity to Sri Lanka, which in turn created long power cuts and transformational disturbances, These effects created severe negative implications on both household and corporate settings of the country. With this context, the significance of energy independence and energy security have become critical success factors for the country's economic development.

This study is conducted to investigate the impact created by renewable energy integration on technology-driven sustainability. The study was carried out as a quantitative analysis which collected data from a sample of 160 respondents to evaluate the impact created by renewable energy integration on technology-driven sustainability. The results indicated that renewable energy integration has a significant impact on technology-driven sustainability (Sig – 0.000) with a positive inter-correlation of 0.534. Based on these derived results it can concluded that there is adequate evidence to support the fact that there is a significant impact of renewable energy integration on technology-driven sustainability within Sri Lanka.

By considering all these facts it can be further concluded that this research study provides valid insights on the importance of enhancing renewable energy integration while elaborating on the unrealized potentials of renewable energy integration on the technology-driven sustainability. This information can be used by policymakers to stabilize the country by achieving a higher level of energy independence. For instance, government interventions and formulation of policies to promote renewable energy integration such as incentives driven up with feed-up tariffs, tax credits and formulation of green building codes can positively influence on technology driven renewable energy integration in Sri Lanka. When considering from the institutional perspectives, increased organizational commitments through increased R&D, establishment of technology incubators and creating public private partnerships to implement renewable energy integration projects will create substantial increase on effective adoption of technology driven renewable energy integration. Furthermore, the study bridges the existing research gap in the relevant context by providing a solid foundation for future researchers accordingly.

## REFERENCES

Al-Shetwi, A. Q. (2022). Sustainable development of renewable energy integrated power sector: Trends, environmental impacts, and recent challenges. *Science of the Total Environment*, *822*(May). https://doi.org/10.1016/j.scitotenv.2022.153645

Alabbasi, A., Sadhukhan, J., Leach, M., & Sanduk, M. (2022). Sustainable Indicators for Integrating Renewable Energy in Bahrain's Power Generation. *Sustainability (Switzerland)*, *14*(11). https://doi.org/10.3390/su14116535

Allam, Z., Bibri, S. E., & Sharpe, S. A. (2022). The Rising Impacts of the COVID-19 Pandemic and the Russia–Ukraine War: Energy Transition, Climate Justice, Global Inequality, and Supply Chain Disruption. *Resources*, *11*(11). https://doi.org/10.3390/resources11110099

Ayamolowo, O. J., Manditereza, P. T., & Kusakana, K. (2020). Exploring the gaps in renewable energy integration to grid. *Energy Reports*, *6*, 992–999. https://doi.org/10.1016/j.egyr.2020.11.086

Bagchi, B., & Paul, B. (2023). Effects of Crude Oil Price Shocks on Stock Markets and Currency Exchange Rates in the Context of Russia-Ukraine Conflict: Evidence from G7 Countries. *Journal of Risk and Financial Management*, *16*(2). https://doi.org/10.3390/jrfm16020064

Belrzaeg, M., & Ahmed, A. A. (2023). *A The Adoption of Renewable Energy Technologies , Benefits , and Challenges : Libyan Journal of Contemporary Academic Studies ةرصاعملا ةيميداكلأا تاساردلل ةيبيللا ةلجملا A The Adoption of Renewable Energy Technologies , Benefits , and Challenges : Mini-Re*. *July*, 7–11.

Cascio, W. F., & Montealegre, R. (2016). How Technology Is Changing Work and Organizations. *Annual Review of Organizational Psychology and Organizational Behavior*, *3*(June), 349–375. https://doi.org/10.1146/annurev-orgpsych-041015-062352

Dasanayaka, C., Perera, Y., & Abeykoon, C. (2022). Investigating the effects of renewable energy utilization towards the economic growth of Sri Lanka: A structural equation modelling approach. *Cleaner Energy and Technology, 6*, 1-14. doi:https://doi.org/10.1016/j.clet.2021.100377

Dhanasekar, R., Vijayaraja, L., Anandan, R., Gurusharan, G. M., Keerthana, M., & Mahalakshmi, E. (2021). Driving technology in the path of renewable energy-a review. *IOP*

*Conference Series: Materials Science and Engineering*, *1055*(1), 012148. https://doi.org/10.1088/1757-899x/1055/1/012148

El-Sayed, A. F. M., & Fitzsimmons, K. (2023). From Africa to the world—The journey of Nile tilapia. *Reviews in Aquaculture*, *15*(S1), 6–21. https://doi.org/10.1111/raq.12738

Eseosa, O., & Ejiroro, A. E. (2020). Challenges and Way Forward Of Renewables In Developing Energy Economy: Today And Tomorrow. *International Journal of Recent Engineering Science*, *7*(4), 14–19. https://doi.org/10.14445/23497157/ijres-v7i4p103

Facchini, A. (2017). Planning for the future. *Nature Energy*, *2*(8), 1–2. https://doi.org/10.1038/nenergy.2017.129

George, A. S. H., George, A. S., & Baskar, T. (2022). Sri Lanka's Economic Crisis: A Brief Overview. *Partners Universal International Research Journal*, *1*(2), 9–19. https://doi.org/10.5281/zenodo.6726553

Gupta, S., Gupta, P., Matapurkar, P., & Rajput, V. (2023). *Integration of Solar and Wind Energy : 10*(3), 605–609.

Halkos, G. E., & Gkampoura, E. C. (2020). Reviewing usage, potentials, and limitations of renewable energy sources. *Energies*, *13*(11). https://doi.org/10.3390/en13112906

Hannan, M. A., Al-Shetwi, A. Q., Ker, P. J., Begum, R. A., Mansor, M., Rahman, S. A., Dong, Z. Y., Tiong, S. K., Mahlia, T. M. I., & Muttaqi, K. M. (2021). Impact of renewable energy utilization and artificial intelligence in achieving sustainable development goals. *Energy Reports*, *7*(November), 5359–5373. https://doi.org/10.1016/j.egyr.2021.08.172

Imppola, J. J. (2020). Global economy and its sustainability in the globalized world. *SHS Web of Conferences*, *74*, 04008. https://doi.org/10.1051/shsconf/20207404008

Janjic, A., Savic, S., Velimirovic, L., & Nikolic, V. (2015). Renewable energy integration in smart grids-multicriteria assessment using the fuzzy analytical hierarchy process. *Turkish Journal of Electrical Engineering & Computer Sciences*, *23*(November), 1896–1912. https://doi.org/10.3906/elk-1404-287

Kilinc-Ata, N., & Tanriover, B. (2017). *A Quantitative Analysis of the Impact of Renewable Energy Deployment on Sustainability*. *December*, 309–321. https://doi.org/10.4018/978-1-5225-3147-0.ch014

Kuhlman, T., & Farrington, J. (2010). What is sustainability? *Sustainability*, *2*(11), 3436–3448. https://doi.org/10.3390/su2113436

Lechner, J., & Schlüter, N. (2023). Sustainable and Resilient System Development in a Vuca-World: an Empirical Study To Develop a Process Orientated Method of Risk and Technical Change Management in Automotive Industry. *Proceedings of the Design Society*, *3*(JULY), 3255–3264. https://doi.org/10.1017/pds.2023.326

Liu, G. (2014). Development of a general sustainability indicator for renewable energy systems: A review. *Renewable and Sustainable Energy Reviews*, *31*, 611–621. https://doi.org/10.1016/j.rser.2013.12.038

Mainali, B. (2012). Analysis of Sustainability Indicators for Renewable Energy Based Rural Analysis of Sustainability Indicators for Renewable Energy Based Rural Electrification. *Tech4Dev, Technologies for Sustainable Development: A Way to Reduce Poverty, UNESCO-Lausanne, 29th May-31st May 2012, At UNESCO-Lausanne, Brundtland 1987*. https://www.researchgate.net/publication/321533771%0AAnalysis

Maksimtsev, I. A., Kostin, K. B., & Berezovskaya, A. A. (2022). Modern Trends in Global Energy and Assessment of the Ever-Increasing Role of Digitalization. *Energies*, *15*(22). https://doi.org/10.3390/en15228767

Malik, M. I., Ahmad, M., Hussain, A., Saleem, F., Durrani, M. K., Hyder, S., Qureshi, S. S., Imtiaz, S., & Malik, S. (2020). Renewable energy products and customer's purchase intentions having environmental concern. *International Journal of Energy Economics and Policy*, *10*(6), 14–21. https://doi.org/10.32479/ijeep.10427

Manisalidis, I., Stavropoulou, E., Stavropoulos, A., & Bezirtzoglou, E. (2020). Environmental and Health Impacts of Air Pollution: A Review. *Frontiers in Public Health*, *8*. https://doi.org/10.3389/fpubh.2020.00014

Nugroho, H., Fei-Lu, S., & Firmansyah. (2017). Developing renewable energy in developing countries: A lesson from Indonesia. *Energy Sources, Part B: Economics, Planning and Policy*, *12*(4), 318–325. https://doi.org/10.1080/15567249.2015.1072599

Nunes, L. J. R. (2023). The Rising Threat of Atmospheric CO2: A Review on the Causes, Impacts, and Mitigation Strategies. *Environments - MDPI*, *10*(4). https://doi.org/10.3390/environments10040066

Ranathunga, R. G. S. A. (2023). Potential Renewable Energy Sources in Sri Lanka. *J. Res. Technol. Eng*, *4*(2), 111–124.

Rawat, R., & Yadav, R. (2021). Big Data: Big data analysis, issues and challenges and technologies. *IOP Conference Series: Materials Science and Engineering*, *1022*(1). https://doi.org/10.1088/1757-899X/1022/1/012014

Rotolo, D., Hicks, D., & Martin, B. R. (2015). What is an emerging technology? *Research Policy*, *44*(10), 1827–1843. https://doi.org/10.1016/j.respol.2015.06.006

Sayanthan, S., & Kannan, N. (2017). Renewable energy resource of Sri Lanka! A review. *International Journal of Environmental & Agriculture Research, 3*(4), 80-85. Retrieved from https://ijoear.com/assets/articles_menuscripts/file/IJOEAR-APR-2017-19.pdf

Salmerón-Manzano, E., Alcayde, A., & Manzano-Agugliaro, F. (2023). Renewable Energy Predictions: Worldwide Research Trends and Future Perspective. *Lecture Notes in Electrical Engineering*, *956*(January), 93–110. https://doi.org/10.1007/978-981-19-6490-9_6

Schick, A., Hobson, P. R., & Ibisch, P. L. (2017). Conservation and sustainable development in a VUCA world: the need for a systemic and ecosystem-based approach. *Ecosystem Health and Sustainability, 3*(4). https://doi.org/10.1002/ehs2.1267

Sebestyén, V. (2021). Renewable and Sustainable Energy Reviews: Environmental impact networks of renewable energy power plants. *Renewable and Sustainable Energy Reviews, 151*(September), 111626. https://doi.org/10.1016/j.rser.2021.111626

Sharma, D. S., Anawade, P., Sahu, A., & Sharma, M. (2022). The economic crisis faced by island nation-Sri Lanka: An empirical study. *Journal of Contemporary Issues in Business and Government*, *28*(03), 2022. https://doi.org/10.47750/cibg.2022.28.03.074

Strielkowski, W., Tarkhanova, E., Tvaronaviˇ, M., & Petrenko, Y. (2021). *Renewable Energy in the Sustainable Development of Electrical*. 1–24.

Sumanasiri, E. A. G. (2020). Sustainability as an Important Tool in Organisational Management: A Review of Literature. *Journal of Scientific Research and Reports*, *September*, 11–33. https://doi.org/10.9734/jsrr/2020/v26i830293

Sunlu, U. (2003). Environmental impacts of tourism Local resources and global trades: Environments and agriculture in the Mediterranean region Bari : CIHEAM Options Méditerranéennes : Série A ENVIRONMENTAL IMPACTS OF TOURISM. *Séminaires*

*Méditerranéens*, *57*, 263–270. http://om.ciheam.org/article.php?IDPDF=4001977http://www.ciheam.org/%5Cnhttp://om.ciheam.org/

Vacchi, M., Siligardi, C., Demaria, F., Cedillo-González, E. I., González-Sánchez, R., & Settembre-Blundo, D. (2021). Technological sustainability or sustainable technology? A multidimensional vision of sustainability in manufacturing. *Sustainability (Switzerland)*, *13*(17). https://doi.org/10.3390/su13179942

Weerasooriya, K. A., Wanniarachchi, W. D. D. M., Nadeera, A. A. D. P., Kularathna, D. G. J. C., Godapitiya, M. V. N., & Silva, D. D. I. De. (2023). Addressing the Prevailing Energy Crisis in Sri Lanka: A Case for Cost-Efficient Energy Consumption. *International Journal of Recent Technology and Engineering (IJRTE)*, *12*(1), 102–109. https://doi.org/10.35940/ijrte.a7620.0512123

Yener, G., & Secer, A. (2023). *What Factors Influence Consumers to Buy Green Products ? An Analysis through the Motivation – Opportunity – Ability Framework and Consumer Awareness*.

Žarković, M., Lakić, S., Ćetković, J., Pejović, B., Redzepagic, S., Vodenska, I., & Vujadinović, R. (2022). Effects of Renewable and Non-Renewable Energy Consumption, GHG, ICT on Sustainable Economic Growth: Evidence from Old and New EU Countries. *Sustainability (Switzerland)*, *14*(15). https://doi.org/10.3390/su14159662