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Sustainable Energy Planning and Modelling for Global South: A Case Study of the Federal Republic of Nigeria.

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ABSTRACT

This paper reviews the literature regarding the inherent limitations of Modeling practices for sustainable energy planning in the Global South (GS).GS is undergoing economic changes in its energy-setting socio-economic policies such as liberalisation, financial sourcing, and climate change implications of energy projects. Long-term energy planning lays the foundations for effective policies, investment strategies, and targets at the national or regional level. An astute and up-to-date master plan for energy development fosters predictable investment conditions. This makes it an essential prerequisite for scaling up renewable energy technologies. Active energy planning, built on quantitative setting Modeling and stakeholder consultations, allows policymakers to understand and explore the complexities and uncertainties of future energy system evolution. Modeling and simulation (M&S) is a well-known scientific technique that could analyse a system or predict its behaviour before physical construction. Despite being an established methodical tool in engineering, only a few review articles discussing emerging topics in M&S are available in the open literature, especially for renewable and sustainable energy systems. The International Renewable Energy Agency (IRENA) offers energy planning Support, as a guide, with a view to enhancing institutional capacity at the country level and strengthening each country's ownership of the planning process. The capacity to interpret key energy data into strong energy planning enables nations to develop all-inclusive national energy master plans and to frequently update these as the basis for comprehensive policies and investments. This paper examines the current Modeling and simulation of the energy sector with insights into the approaches, challenges, and prospects of certain selected and suitable energy systems. Additionally, it reveals the limitations of traditional planning tools such as optimisation, econometric, and general simulation models. The paper posits that traditional approaches are inadequate for SED in the GS due to its inherent weakness in guiding future policy decisions. In this work, the 7th SDG: Affordable and Clean Energy, is brought into focus. The paper addresses the Planning approaches, tools, framework, and techniques as revealed in the literature on energy Modeling and policy formulation. The aim is to enhance the country's capacity to analyse energy data and develop scenarios using Modeling tools for long-term energy planning. The additional tools to support energy planning may be selected according to each country's needs and existing Modeling expertise. Finally, areas that need further research and development in sustainable energy Modeling are highlighted.

Keywords: Sustainability, Energy Planning, Modelling, Global South.

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1. BACKGROUND TO THE STUDY

The COP26 conference 2021 held in Glasgow revealed an unprecedented participation of the various sectors. On the release of the Sixth Assessment Report of the IPCC, it has become clear that the combined effort of the public and private sector is required to keep global temperature from rising above 1.5 °C. As the engagement of various sectors increases, it is predictable that more and more corporations will have to commit to net-zero emission targets in the near future (Bowcott, 2021). Nations are expected to be committed to reducing and publishing their net-zero strategies by 2023.

While this is already a reality in the UK, where listed companies will have to publish their net-zero strategies, the call for the development of Corporate Contributions made by the WBCSD at COP26 also points in this direction (WBCSD, 2021). A key action a nation can take to directly reduce its carbon footprint is revisiting how it sources and produces energy. Previous studies have defined sustainable energy systems as structures that use energy sources that are expected to be depleted in a time frame relevant to the human race (Kreith & Krumdiek, 2013).

Energy is fundamental for any domestic and commercial activities, although its related emissions make up the lion's share of the carbon budget of most businesses, its development and sustainability are critical components in accomplishing the United Nations Sustainable Development Goals. Most countries in the (GS) are naturally endowed with diverse, renewable, solar, wind, hydro, and geothermal energy sources as the first step towards achieving global environmental sustainability. However, these sources can potentially provide both rural villages and urban cities with sufficient electricity. Literature has shown that meeting the global energy demands most sustainable has been a major challenge facing humanity since the beginning of the first industrial revolution.

There is a need to invest in renewable energy sources and end the reliance on non-renewable energy sources, which accounts for 70% of the total electricity generated in that region. However, access to electricity remains a key policy issue for most of the GS, and it is important to increase renewable energy use and improve access to electricity for all. This paper review literature, and case studies/reports on using sustainable energy tools such as for energy planning in the Global South. Proper energy planning facilitates and enables well-informed policymaking and, importantly, the achievement of key energy policy objectives. Besides, a robust national energy planning process, there is a need to align national and regional-level planning to enhance trade, efficiency, and security of energy supply and reap the benefits of economy-of-scale production.

2. STATEMENT OF PROBLEM

In the Global South, a large part of the population still lacks access to energy, which is crucial for poverty alleviation via the creation of employment and better health and education systems. The vast majority of cities around the globe are experiencing periods of elevated air pollution levels, that exceed international health-based air quality standards according to Kumar *et al*.,2013, but this is a global challenge, most of the highest air pollution levels are found in developing economies. They are expanding their economic activities with a parallel increase in demand for energy that is mostly met by unsustainable conventional sources.

These conventional energy sources (gas, coal, oil, etc.) are being depleted gradually and their prices are very volatile. GS is also characterised by low institutional quality and long procedural delays, as well as volatile investment needs due to corruption and classified interference (Bellakhal, 2019). The major energy issues in GS can be summarised as (1) Limiting the use of fossil fuels. (2) Migrating towards diversified renewable energy matrices. (3) Decentralising energy generation and distribution. (4) Low investment in low-carbon energy sources. (5) Policy and regulation. (6) Access issue. Overall, the rapidly changing environment highlights a number of issues for energy companies throughout the oil, gas, and electricity value chains as they think about their future business models

Inadequate responsiveness to population concerns is also a major contributing factor that can lead a nation to economic and social development, but GS has low political stability and poor democratic quality. Energy production and consumption have a greater impact on economic growth, (Adams, 2016), and the effect different macroeconomic factors have on environmental quality depends on institutional quality (Adams, 2016). The phenomenon of institutional stability of GS in the context of environmental quality and economic growth is still understudied and needs to be further explored, (Adams, 2018).

3. OBJECTIVE

The primary objective of this paper is to address the methodological approaches, planning tools, frameworks, and techniques as revealed in the literature on energy planning and formulation.

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4. LITERATURE REVIEW OF SUSTAINABLE ENERGY PLANNING AND MODELING

This section presents an overview of different reviews and surveys of energy system models and tools found in the literature. These are then categorised according to their respective focus areas and their review approach, to show existing gaps in the literature.

4.1 Energy Planning

As the discourse surrounding 100% renewable energy systems has evolved, several energy system modeling tools have been proposed to determine the technical feasibility and economic viability of fully sustainable, sector-coupled energy systems. While the characteristics of these tools vary among each other, their purpose remains consistent in integrating renewable energy technologies into future energy systems. Energy is one of the most vital features of urban growth and technological advancements. It is essential to human life as well as for every community, nation, or International organisation. Moreover, it is essential for all contemporary economic sectors and supports all economic activities (Atems, 2018).

Its production and consumption are connected to various environmental, social, and economic problems covering all three sustainability pillars, strategic and targeted energy planning is vital to the smooth shift towards a more efficient and greener society. But, there are a number of environmental, social, and economic apprehensions related to its production and consumption, with the global issue of climate change. According to Statista 2022 (Statista Primary Energy Consumption Worldwide, 2021), some nations' levels of energy consumption are disproportionately high in comparison to those of other nations around the globe.

The transition of the energy sector is one of the priorities of sustainable development (Radovanović, 2021) which aims at the management of financial, technological, institutional, natural, and social resources to meet the needs of current and future generations. United Nations (UN), in 2015 introduced a set of goals for sustainability, known as the Sustainable Development Goals (SDGs). SDG 7 includes three key targets, i.e., to ensure affordable and reliable access to modern energy for all, to increase the share of renewable energy in the energy mix globally, and to improve the global rate of energy efficiency improvement. At the same time, SDG 11 strives for sustainable cities and communities deeply linked with alternative sources of energy and adequate consumption patterns, which also correspond to responsible consumption and production (SDG 12) (Tsangas, 2022).

The principles and indicators usually used to assess the energy strategies, policies, or sustainable choice of energy sources are multiple and comprise, further the environmental issues, social characteristics as well as economic, political, and technical priorities. Sustainable energy approaches, until today, were considered to ensure the mitigation of the triggers of climate change and a transition to a clean energy future with a balance between the environment, society, and the economy, including fossil fuel use elimination, further deployment of renewable energy, and energy efficiency improvement (Wołowiec *et al*; 2022). Additionally, common social efforts and international cooperation are believed to have the capacity to lead to a clean energy system.

4.2 Current Approaches of Energy System Modelling.

With current emerging approaches in the decision-making process in energy systems, the choice of models or tools becomes pivotal. This paper focuses particularly on models relevant to national and international energy policy, with special reference to GS. It examined traditional, optimisation, general or multiscale, and econometric modeling.

4.3.1 Traditional Energy Modelling Approaches.

The development of energy sources that are renewable and sustainable is a critical component in achieving the United Nations' sustainable development goals (UN SDGGOAL7, 2017). Literature revealed that meeting the world's energy demands most sustainably has been a major challenge facing humanity since the beginning of the first industrial revolution (Moon, 2017). Thus, there is a need for a comprehensive understanding of sustainable energy systems and their interaction with the environment to optimise their design, operational sustainability, and economic feasibility. Modeling and simulation (M&S) have been defined in the past as the application of physical, logical, or mathematical models to describe a system an entity a phenomenon, or a process to develop data utilised for scientific and technical decision-making (Yoro *et al.;* 2021). Against this background, this paper assesses and updates the body of knowledge on the application of M&S techniques.

Chang et al;2021 presented literature on Trends in tools and approaches for modeling the energy transition. Olaniyi, 2014 describes the inherent limitations of a traditional modeling framework for sustainable energy development in a developing economy. This paper examines energy system models such as the Transition model, an optimisation- model, and energyPlan simulation tools, a simulation model. It further analyses different novel Modeling approaches used by modelers Scenarios built using the Systems Thinking (ST) model for the case of Nigeria, to examine the effects of multi and single-node structuring and the effects of the overnight energy transition analysed.

Yoro *et al*, 2021 maintained that M&S is the easiest and most cost-effective way to understand, improve, and design a system to achieve improved efficiency, safety, and environmental demands, however, to date, about 106 articles have been published on the application of M&S, which shows that the application of M&S in has not been adequately reported as presented in fig.1 below;

Figure 1: The Numerical Trend of Published from 1999-2021,
Source: Adapted from renewable and sustainable energy reviews, 2021

The numerical trend of published research on RSES from 1999–April 2021. Debnath & Mourshed, 2018, supported multi-criteria assessments of the impact of energy policies on the economy and environment because this is aimed at reducing greenhouse gas emissions while enhancing energy security. In contrast, most, if not all, developing countries are predominantly concerned with increasing energy access. Olaniyi, 2014 argues that traditional approaches are inadequate for Sustainable Energy Development (SED) in the Developing Economy (DE)due to their inherent weakness in guiding future policy decisions. Optimistion-based models may be suited for well-defined solutions, however, the macro-energy scene at a decision support level in most DE does not lend itself to simplified modeling techniques that are rooted in past algorithms. This paper favors the application of an integrated approach that considers energy demand and supply perspectives. Models used in policy analysis are of two categories (Figure 1) optimisation and simulation models (Olaniyi 2014). Simulation models can be further divided into three i.e. General Simulation, Econometric, and System Dynamics Modelling. The following gives a brief overview of these modeling approaches as identified in the literature.

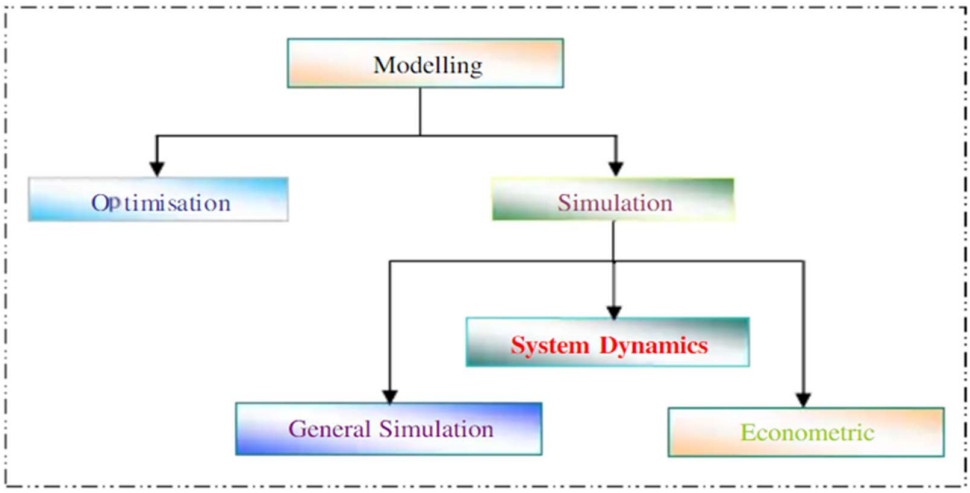

Figure 2 Generic Problem Structuring Modelling (Source: Adapted from Olaniyi, 2014)

4.4.1 Optimisation Modelling Approaches in Energy Planning

Imminent climate change impacts call for stronger energy system modeling approaches in order to design resilient communities. Researchers, policymakers, and energy planners utilise energy system simulation and modeling methods to support decision-making for long-term, sustainable energy planning. The paper strengthens resilience analysis approaches within the energy system optimisation model (ESOM) domain for urban energy system planning. The literature presents a variety of methods to assess energy system resilience. Operational cost increases during disruptions have been used to evaluate energy system resilience performance in different studies in the context of ESOMs (Ibanez et al; 2016).

Energy planning must also address energy security and affordability in what is known as the energy trilemma (World Energy Trilemma 2016). Optimisation models have been the most used approaches for energy system analysis owing to the detailed techno-economic structure and the ability to analyse national policy (Burandt et al 2019). As a whole, the models reduce the total system cost, defined as the discounted cost of the area(s) over the time horison (Plazas-Niño et al; 2022). The models can include investment costs, operating and maintenance (O&M) costs of technologies, trading costs of energy commodities, penalties for the emission of CO2, and other costs. The objective function is constrained by various limitations, including maximum capacities, domestic energy potentials, operational life spans, phase-out plans, and emission limits, among others (Plazas-Niño et al; 2022).

4.4.2 General Simulation and Econometric Models in Energy Planning.

4.4.3 General Simulation Modelling/Multiscale system

The energy needs of a nation largely depend on the type of activities and processes conducted. In view of the growing phenomenon of electrification, the planning of the future electric system is central for many Nations. The interaction of multiple energy vectors represents an attractive opportunity to increase the performance of the system, in particular for distributed generation (Laveneziana, 2023).

General or multi-scale modeling is a new paradigm in engineering science with the key idea of connecting a network of models across different spatial and temporal scales such that information computed in one model can be used in another. The goal is to develop a high-fidelity model that correctly captures the overall system behaviour at a large scale by utilising information provided by higher-resolution models at smaller scales (Vlachos, 2005). The approach is called 'upscaling' because of the flow of information from smaller to larger scales with a matching reduction in degrees of freedom.

General simulation is a methodological approach that identifies the weak points of a system. General simulation systems engineering has been supported by recent advances in computational ability, with progress in parallel computing, as well as by improvements in experimental methods predominantly at finer scales (Horstemeyer, 2009). Floudas et al;2016 present an outlook of the prospects to apply multi-scale systems engineering at several time and length scales to address pressing energy and environmental issues, such as the generation of affordable energy in an environmentally sustainable way and ensuring future energy security (Floudas, 2016) Numbers of important design and operational problems in energy systems engineering necessitate multi-scale modeling with upscaling or downscaling approaches.

4.4.4 Econometric Modelling

Econometric modeling is defined as a combination of economic theory, mathematical tools, and statistical methods. This approach is econometrics was aimed at testing economic theory (estimation of economic relationships) using empirical evidence. Econometric models use regression of economic relations through statistical analysis of economic data, which has been widely applied to energy demand projections. Econometric models' projections are based on economic parameters (i.e. price, income, etc) and their causal effect on energy (Olaniyi, 2014). Its advantages include fewer data requirements than optimisation and general simulation models (Olaniyi, 2014). But, over the course of time, the requirements made of econometrics increased from pure hypothesis testing to the development of complex econometric models. Additionally, econometric energy models are open-ended, growth-driven macro-econometric models using/analysing time series data on a higher level of aggregation, e.g. output, etc. with no assumption of equilibrium, while cross-section and panel data tend to be applied more in micro econometrics (Greene, 2003).

A major disadvantage of this approach is its overreliance on data. To generate credible results, econometric models require huge amounts of data for fairly long time periods. There could be non-availability of data for the modelers in the case of small macro-econometric models, which will possibly be exacerbated in the case of multi-country analyses where data for some countries might not be available at all or not comparable due to national accounting or census differences (Andrea, et al; 2012). In this context, the credibility and adequacy of data represent additional uncertainties for model quality.

5. THE CHALLENGES OF MODELING APPROACHES AND THE NEED FOR ALTERNATIVE PARADIGMS

This paper summarises four model paradigms (1) Traditional Modeling (2) energy systems optimisation (3) Econometric modeling (4) General/Multi-scale modeling. It lays out challenges facing energy systems modeling: resolving time and space, balancing uncertainty, transparency, and reproducibility, developing methods to address the growing

complexity of the energy system, and integrating human behavior and social risks and opportunities. There are other significant challenges and shortcomings in energy modeling that this paper does not address, for instance, improving how models render technological learning (Kahouli-Brahmi, 2008). As a result, various concrete suggestions for modeling emerge. There is a need to rethink whether current methods are appropriate for twenty-first-century challenges. It is important to have a wide range of tools and methods available and to select from this repository when tackling a specific question.

Secondly, for effective systems management, there is the need to innovatively combine methods from different sources and from other fields. A successful application of this method will demonstrate its usefulness of the method, however, the need for deeper and more fundamental treatment of the complexity remains with much potential for further research (Anselim, 2019). For best practice, Modelers should adopt open code bases, but also, use techniques such as unit testing and integration testing to reduce the likelihood of hard-to-track errors in complex pieces of software, and can also avoid the trap of modeling what is easily quantifiable rather than what is the essential driving variables of the system.

6. METHODOLOGY

A systematic literature review was conducted on state-of-the-art energy resilience research using Scopus, Science Direct, Emerald Journal, and Web of Science articles for this study using a series of keywords. Planners can employ various approaches in analysing and testing system designs based on different resilience targets. However, this paper employed EnergyPLAN as a tool to address the energy challenges of the GS. EnergyPLAN is an energy system analysis tool created for the study and research in the design of future sustainable energy solutions with a special focus on energy systems with high shares of renewable energy sources. EnergyPLAN is intended to exploit the synergies enabled by including the whole energy system.

Hence, with EnergyPLAN, the user can take a holistic approach focusing on the analysis of the cross-sectoral interaction. For example, demand sectors, like buildings, industry, and transport, are linked with supply technologies through electricity, gas, district heating and cooling grids. By this, EnergyPLAN enables the analysis of the conversion of renewable electricity into other energy carriers, like heat, hydrogen, green gases, and electro fuels, as well as the application of energy efficiency improvements and energy conservation. As explained by Lund et al;2017, the purpose of EnergyPLAN is not to provide the basis for prescribing or predicting the future energy system but rather to form a basis for an informed, transparent, and conscious deliberation of potential development pathways for the energy system.

Energy models are used to project the future energy demand and supply of a country or region. They are mostly used in an exploratory manner assuming certain developments of boundary conditions such as the development of economic activities, demographic development, or energy prices on world markets. They are also used to simulate policy and technology choices that may influence future energy demand and supply, and hence investments in energy systems, including energy efficiency policies. The main guiding principle for the development and use of EnergyPLAN is to establish alternatives; and create a tool that would enable the consistent comparison of various alternative development strategies of the energy system.

6.1 EnergyPLAN Modeling Approach

EnergyPLAN represents analytical programming rather than establishing a series of balance equations that are solved numerically as in optimisation and equilibrium models. EnergyPLAN is based on a series of endogenous priorities within, e.g., power and heat production and pre-defined procedures for simulating the operation of units that are freely dispatchable. The approach is purely deterministic with no stochastic elements. It simulates user-defined systems and does not make endogenous system optimisation. EnergyPLAN should developed with the ability for the user to consider different energy system combinations in mind, and as a consequence, also with speed, user-friendliness, and ease of implementing changes in mind.

6.2 The Input and Output

Fig. 1 provides an overview of inputs as well as outputs of the model. EnergyPLAN comes with a graphical user interface in which the user can type in inputs and maintain an overview of the model.

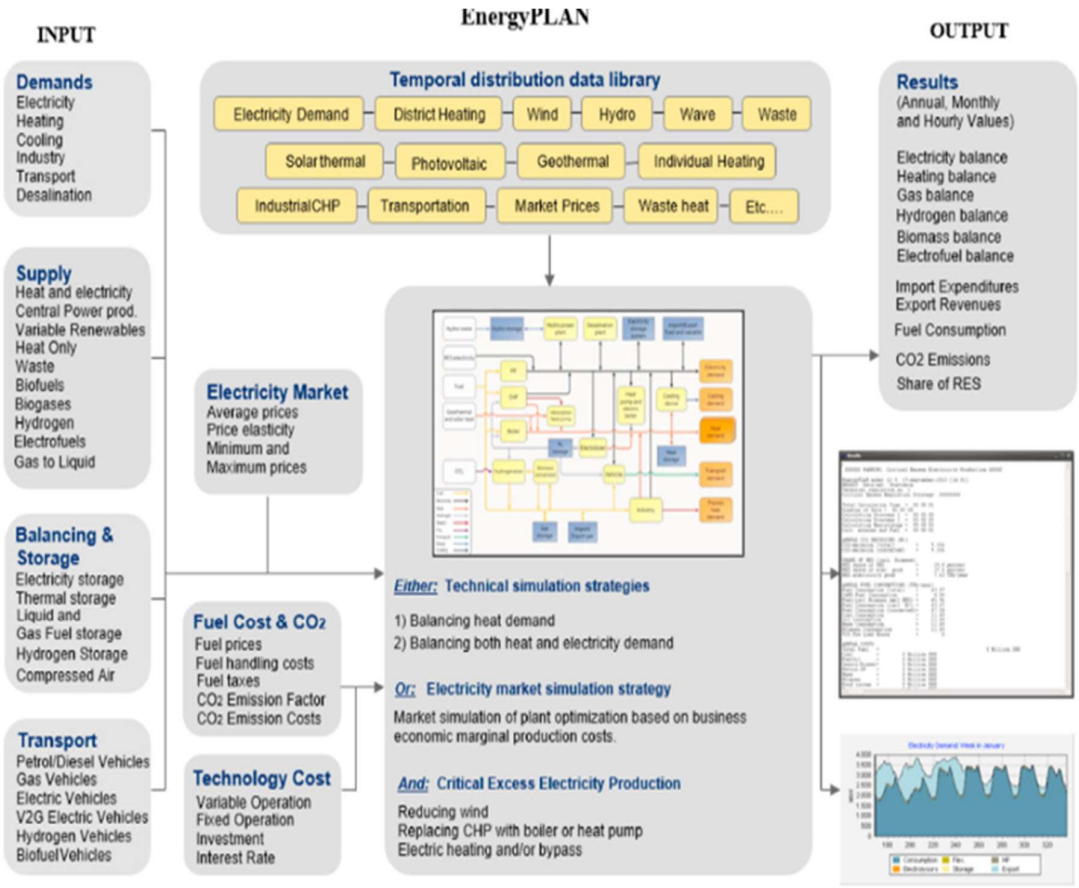

Figure 3 Data inputs and outputs of EnergyPLAN.
(Source: Adapted from smart energy system. Lund et al; 2021)

Figure 3 represents the structure of EnergyPLAN of the energy system, energy demand, energy production unit, and resources including conversion, simulation, and cost

7. The Research Design

Given the significance of the topic, the paper adopts a qualitative method to evaluate the framework in a transparent and arranged way concerning its suitability to tackle energy system modeling challenges. The field of energy system scrutiny is faced with the challenge of increasingly compound systems and their sustainable transition. The challenges are not only on a technical level but also linked to societal aspects. Energy system modeling plays a decisive role in this field, and model properties define how useful it is in regard to the existing challenges. Current main challenges and framework properties that potentially contribute to tackling these challenges are derived from a literature review.

8. FUTURE WORK

This work will provide important insights on state-of-the-art concepts, problems, and solutions on the application of sustainable technologies for clean and affordable energy generation. Future work will include. Developing effective national energy strategies to address concerns over energy resource availability, climate change, air quality, and energy security. GS communities are passing through different phases of economic growth in their development life cycle; its optimal energy plan and development strategy should entail holistic refinement as opposed to a static state-planning paradigm. Furthermore, there should be a development of a systemic tool that could sufficiently address the inherent dynamics of complex energy planning and policy formulation as currently witnessed in the DE given the current migration from central planning to market-based energy resource allocation commonly seen as energy industry liberalization and privatisation efforts.

9. DISCUSSION OF FINDINGS

The current paper was conducted on reviews of recent trends in energy systems modeling of the existing literature on the features and applications of energy modeling tools. It is revealed in the literature that existing models are not always adequate to deal with twenty-first-century energy systems, but they retain an important role and remain the basis for much analysis underpinning policy in many countries and regions. Literature also highlighted key issues and how the energy systems modeling society is addressing them, with higher resolution of space and time a particular concern at the moment. Many scholars have suggested a new classification scheme and categorise diverse modeling approaches. While some of these categories are explicit, other descriptive labels assigned to tools may fall within an overlapping spectrum which is harder to define.

10 CONCLUDING REMARKS

The sustainable generation of energy is a key test involving various stakeholders including government regulators, energy production and distribution firms, suppliers, and final consumers. With respect to the primary importance of energy to the modern economy, energy systems have been studied by scholars in both the Process Systems Engineering (PSE) and Energy Economics (EE) fields using modeling and simulation approaches with different nature of variables, theoretical underpinnings, level of technological aggregation,

spatial and temporal scales, and model purpose. A great number of energy models have been established in the past that come with various formulations with their applications. Grounded on the information gained from the in-depth literature review in this paper, it can be concluded that the principles of modeling and simulation could play a critical role in understanding the behaviour of clean energy and sustainable energy systems due to their beneficial properties. This paper has recognised that there is a shortage of scientific reports that apply these principles.

To fill this limitation, a comprehensive review of the literature in energy modeling was conducted and the following relevant conclusions were drawn.

- There is an increase in interest in renewable energy adoption, therefore the call for detailed energy planning for sustainable development.
- While modeling and simulation tasks can be simplified with the development of user-friendly software, model validation remains unanswered, and the principle, more time will be needed to analyse the model result.
- Power systems, electricity market modeling, and energy model optimisation methods could also be used in addressing the challenges in modeling and simulation.
- Uncertainty in modeling, difficulty, parameter ambiguity, and unavailability are the major challenges facing modeling and simulation in clean energy and sustainable energy systems. These challenges and other issues can be resolved by making a strong model assumption, model validation, and revalidation of model results in conjunction with other data.

From a broader perspective, there is a need for more data input, Data needs can vary largely according to the modeling. A model with high data needs depends on high quality and a large quantity of input data to provide reasonable outputs. The paper posits that the availability of advanced, but intricate, modeling functions could be a disadvantage rather than an advantage.

11 CONTRIBUTIONS TO KNOWLEDGE.

Addressing the gap in the existing body of knowledge, the information provided here can help the selection process at various levels of planning: from an initial screening of the tools, based on overall features, to the assessment of the availability of specific modelling functions. It is argued that the ranking of the tools proposed in this paper echoes their ability to fulfil the exact requirements laid out in this paper, rather than their overall capabilities.

REFERENCES

Adams, S. E.K.M. Klobodu, E.E.O. Opoku, 2016. Energy consumption, political regime, and economic growth in sub-Saharan Africa: Energy Pol., Vol. 96 pp. 36-44, 10.1016/j.enpol.2016.05.029.

Andrea Herbst, Felipe Toro, Felix Reitze, and Eberhard Jochem, 2012. Introduction to Energy Systems Modelling. Swiss Society of Economics and Statistics. Vol. 148 No.2.pp 111–135

Adams, S. P.K. Adom, E.K.M. Klobodu, 2016. Urbanisation, regime type and durability, and Environmental degradation in Ghana. Environ. Sci. Pollut. Res., Vol 23 pp. 23825-23839,
Adams, S. E.K.M. Klobodu, A. Apio, 2018.Renewable and non-renewable energy, regime

type, and economic growth. Renew. Energy, Vol 125, pp. 755-767, 10.1016/j.renene.2018.02.135.

Atems, B.; Hotaling, C. The effect of renewable and non-renewable electricity generation on economic growth. Energy Policy Vol 112, pp111–118.

Anselm, A.J. 2019. Challenges of Mega Cities: Lessons for Evolving Sustainable Nigerian Cities. Modern Economy, 10, 2031-2050. https://doi.org/10.4236/me.2019.109128

Bowcott, H. Pacthod, D. Pinner. D.2021. COP26 Made Net Zero a Cor Principle for Business Bellakhal, R. S. Ben Kheder, H. Haffoudhi, 2019.Governance and renewable energy investment in MENA countries: How does trade matter? Energy Econ., 84 (2019), pp 104541, 10.1016/j.eneco.2019.104541

Burandt. T., B. Xiong, K. Löffler, P. Oei Decarbonizing China' 's energy system – modeling the transformation of the electricity, transportation, heat, and industrial sectors Appl Energy, Vol 255 (20, pp. 113820, 10.1016/j.apenergy.2019.113820

Chang, M., Thellufsen, J. Z., Zakeri, B., Pickering, B., Pfenninger, S., Lund, H., & Østergaard, P. A. 2021. Trends in tools and approaches for Modeling the energy transition. Applied Energy, 290, 116731. https://doi.org/10.1016/j.apenergy.2021.116731

Debnath, K.B., Mourshed, M. Challenges and gaps for energy planning models in the developing- world context. Nat Energy 3, 172–184 (2018). https://doi.org/10.1038/s41560-018-0095-2.

Dagnachew AG, Lucas PL, Hof AF, Gernaat DE, de Boer H-S, van Vuuren DP, 2017. The role of Decentralized systems in providing universal electricity access in Sub-Saharan Africa—A model- based approach. Energy Vol.139: pp184–195.

Environment, United Nations SDG GOAL 7, 2017. Affordable and clean energy UNEP - UN Environ. Programme (2017).

Edenhofer O, Pichs-Madruga R, Sokona Y, Minx JC, Farahani E, Kadner S, Seyboth K, Adler A, Baum I, Brunner S, Eickemeier P, Kriemann B, Savolainen J, Schlömer S, von Stechow C, Zwickel T, 2014. Climate Change 2014. Mitigation of Climate Change. Working Group III contribution to the fifth assessment report of the intergovernmental panel on climate change. Cambridge University Press, New York.

Floudas, C.A.; Niziolek, A.M.; Onel, O.; Matthews, L.R. 2016. Multi-scale systems engineering for energy and the environment: Challenges and opportunities. AIChE J. 2016, 62, 602–623

Greene, W. H. (2003), Econometric Analysis, Fifth Edition, New York University, Pearson Education, New Jersey.

Horstemeyer, M.F 2009. Multiscale Modeling: A Review. In Practical Aspects of Computational Chemistry; Springer: Dordrecht, The Netherlands, 2009; pp. 87–135. ISBN 978-90-481-2686-6

IRENA (2019) A new world. In: The geopolitics of the energy transformation. Masdar City Ibanez. S. Lavrenz, K. Gkritza, D.A.M. Giraldo, V. Krishnan, J.D. McCalley, A.K. Somani Resilience And robustness in long-term planning of the national energy and transportation systems. J. Crit. I Infrastructures, 12, pp. 82, 10.1504/IJCIS.2016.075869

Kumar, P., Hussin, J.M. Rahman, I.A. Memon, A.H., 2013.The way forward in sustainable construction: Issues and challenges. International Journal of Advances in Applied Sciences.

Kreith. F, Krumdieck, 2013.Principles of sustainable energy systems (second ed.), CRC Press (2013) ISBN-13: 978-1466556966.

Kahouli-Brahmi, S 2008.Technological learning in energy-environment-economy modelling: a survey Energy Policy, Vol. 36, pp. 138-162

Lund. H. F. Arler, P.A. Østergaard, F. Hvelplund, D. Connolly, B.V. Mathiesen, 2017.Simulation versusoptimisation: theoretical positions in energy system modeling Energies, Vol.10, pp. 1-17, 10.3390/en10070840

Lund, H., Thellufsen, J. Z., Østergaard, P. A., Sorknæs, P., Skov, I. R., & Mathiesen, B. V. 2021. EnergyPLAN Advanced analysis of smart energy systems. Smart Energy, 1, 100007. https://doi.org/10.1016/j.segy.2021.100007

Laveneziana, L., Prussi, M., & Chiaramonti, D 2023. A critical review of energy planning models For sustainable development at the company level. Energy Strategy Reviews, 49, 101136. https://doi.org/10.1016/j.esr.2023.101136

Moon. Y.B., 2017. Simulation modeling for sustainability: a review of the literature. International Journal ofSustainable Sustain Engineering Vol. 10, pp. 2-19

Plazas-Niño, F., Ortiz-Pimiento, N., & Montes-Páez, E. 2022. National energy system optimisation Modelling for decarbonization pathways analysis: A systematic literature review. Renewable and Sustainable Energy Reviews, Vol.162, pp112406. https://doi.org/10.1016/j.rser.2022.112406

Olaniyi, 2014. Addressing the inherent limitations of the traditional framework for sustainable

Energy development in a developing economy. Computing Information Systems Development Informatics and Allied Research Journal, Vol.5 No. 1.

World Business Council for Sustainable Development, 2021. “The Business Manifesto for Climate Recovery,” World Energy Trilemma 2016: Defining Measures to Accelerate the Energy Transition

Sangas, T, M., Papamichael, I., & Zorpas, A. A. 2023. Sustainable Energy Planning in a New Situation.Energies, Vol16 No4, pp1626. https://doi.org/10.3390/en16041626

Statista Primary Energy Consumption Worldwide in 2021, by Country. Available online: https://www.statista.com/statistics/263455/primary-energy-consumption-of-selected-] countries/

Radovanović, M.; Filipović, S.; Panić, A.A. Sustainable energy transition in Central Asia: Status and challenges.Energy Sustainability Society. 2021, Vol11, pp49.

Tsangas, M.; Zorpas, A.A.; Jeguirim, M.2022. Sustainable renewable energy policies and regulations, recent advances, and challenges. In Renewable Energy Production and Distribution; Academic Press: Cambridge, MA, USA; pp. 449–465.

Vlachos, D.G 2005. A Review of Multiscale Analysis: Examples from Systems Biology, Materials Engineering, and Other Fluid–Surface Interacting Systems. In Advances in Chemical Engineering;

Elsevier: Amsterdam, The The Netherlands. Vol. 30, pp. 1–61. ISBN 978-0-12-008530-9. Yoro, K. O., Daramola, M. O., Sekoai, P. T., Wilson, U. N., & Eterigho-Ikelegbe, O. 2021. Update on Current approaches, challenges, and prospects of modeling and simulation in renewable and sustainable energy systems.Renewable and Sustainable Energy Reviews, 150, 111506.] https://doi.org/10.1016/j.rser.2021.111506.