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Cost of Production of Electricity: A Systematic Review.

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Abstract

Despite advancements in energy production technologies, renewable electricity remains more expensive to produce compared to conventional fossil fuels. This paper conducts a comprehensive review of methodologies used to estimate the cost of electricity production and the factors influencing these costs. A systematic literature review was employed to identify, select, evaluate, and synthesize relevant published and gray literature. The review reveals that less than half (43.8%) of the studies utilized the Levelized Cost of Electricity (LCOE) method for cost estimation, with only 14.5% focusing specifically on LCOE. Moreover, only 22.9% of the studies explored the factors determining the cost of electricity production. Key factors identified include operation and maintenance costs, project lifetime, technological advancements, fuel prices, and capital costs. Additional factors such as interest rates on capital and environmental charges were also noted. Notably, no studies examined the cost of electricity production through a theoretical framework at the firm level. This gap indicates a need for future research to incorporate theoretical perspectives, particularly focusing on technology investment and operational efficiency, to better understand their impact on electricity production costs.

Keywords: Cost of production, Electricity, Systematic review, Levelized Cost of electricity

Introduction

Clean, affordable and sustainable energy plays an essential role in socio-economic transformation (IRENA, 2015; UN DESA, 2020; Mulugetta et al., 2019; National Plannning Authority (NPA), 2020), and this is empathized in the Sustainable Development Goal 7 of the 2030 Agenda; access to affordable, reliable, sustainable and modern energy for all. Average cost of 1kWh of electricity to end user (Domestic consumption) in Uganda is US $ 0.170, still high, second to Tanzania (US $ 0.091) in East Africa, very far from the neighbouring countries like; Sudan (US $ 0.006), Ethiopia (US $ 0.006), DR Congo (US$ 0.061) (Global PetrolPirices, 2023). Kenya has the highest cost (US$ 0.177), followed by Rwanda (US $ 0.04) in East Africa. The high cost inhibits access to electricity, making the industrial and agricultural production less competitive. Usually, the price of a commodity is driven by the cost of producing it (Ricardo (1817). Therefore, the price of electricity majorly should depend on the cost of producing it. The cost of producing electricity stands as a pivotal factor influencing global energy policies (IRENA, 2020; Mccollum, 2018), economic strategies, and consumer dynamics (Sedai et al., 2020; Kumar & Rauniyar, 2018; Lekavičius et al., 2019; Olanrele, 2020). Besides, studies (Wang et al., 2022; Li et al., 2021; Can & Korkmaz, 2019; Silva et al., 2012; Pao & Fu, 2013) have emphasized that having clean energy is one of the important factors needed for social and economic development, and that energy and sustainable development are inseparable from one another. Understanding the multifaceted components contributing to the production expenses of electricity and methodologies to

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calculating the cost of production of electricity are essential in navigating the intricate landscape of energy generation. This critical subject encompasses various elements, from initial infrastructure investment and operational expenses to technological advancements and environmental considerations. Exploring the complexities and nuances of the cost of electricity production unveils insights that shape the energy industry, impact consumer pricing, and drive sustainable energy solutions in an evolving global landscape.

Studies have been done on the cost of production of electricity, majorly estimating the cost of production (Masum et al., 2020; Dinica, 2011; Tizgui et al., 2018; Soulouknga et al., 2020; Yuan et al., 2021; Shen et al., 2020; Rahman et al., 2018; Obi et al., 2017; Lai & McCulloch, 2017; De Roo & Parsons, 2011). Other studies reviewed the methods and approaches to estimating the cost of production of electricity (Levelized cost of Electricity (LCOE)) (Arrinda et al., 2020; De Roo & Parsons, 2011), estimated the unit production cost and carbon abatement cost of electricity from bioenergy (Masum et al., 2020) and a probabilistic approach to computation of the levelized cost of electricity. Although it appears to be no or few studies about the factors determining the cost of production, Tizgui et al. (2018) argued that factors like; the interest rate, the produced energy and the project lifetime, have a greatest effect on the estimated wind energy production cost. Others like; Discount rate, Capital cost, Fuel prices, technology lifetime, Capacity availability factor were found to contribute on the cost of production of electricity, in different technologies (Timilsina, 2021). Bartnik et al. (2018), studied the impact of technical and economic parameters on the specific cost of electricity production.

Electricity production cost comparison forms the foundation and bring about the awareness for investors and the countries to make preparations and decision-making for investments on any new power plant. Therefore, this study assesses the available factors determining and the methodologies used in estimating the cost of production of electricity by raising three questions: (i) what are the major factors that influence the cost of production of electricity? (ii) What are the theories and methodologies used in calculating the cost of production of electricity? (iii) What are the likely research gaps that need to be addressed? This review concentrates on these questions because there is scanty information/literature about the factors that determine and method of estimating the cost of production of electricity. If this issue about production cost is not well managed in the energy sector, the spread between the cost of production and the selling price will continue to remain obscure, particularly in energy sector. Therefore, this review provides a foundation to identify few factors determining and methods used to estimate the cost of production of electricity and provides the likely research gaps that need to be addressed in the future.

Materials and Methods

Systematic Review

This paper adopted a systematic review approach to analyse studies that have investigated about cost of production of electricity within the past 14 years (from 2010 to 2023). A systematic literature review methodology enables rigorous review of relevant literature (journal articles and grey literature) to address the research questions (Aveyard & Bradbury-Jones 2019). This approach briefly involves the formulation of a comprehensive review, with clear and rich literature searching strategy, a well-defined eligibility criterion for inclusion and exclusion of the studies. Eligible journal articles and relevant reports are then subjected to thorough review and

understanding to draw conclusions to answer the questions under study.

Material Collection
It is important to ensure that the right records and/or articles are selected for systematic literature review. To achieve the objective of this study, the process of identifying the content and/or materials for this review was guided by the following procedures:

Database Selection
In this study, database selection was based on those that provide metadata and abstracts, and have wide coverage of peer-reviewed academic literature. Metadata includes information on; year of publication, journal title, volume, and issue (or article identification number) and Digital Objective Identifier (DOI) number. Therefore, with those two reasons, Google scholar and Science direct were considered.

Journal Selection
In this study, emphasis was majorly put on journal that were peer reviewed. Therefore, mainly peer reviewed articles were used for content collection. Furthermore, journal impact and cite factor were used to identify credible journals from which the articles and records were extracted. Gray literature was searched separately using Google chrome search engine. In total, three (3) Reports from reputable and credible organizations, Electricity Regulatory Authority (ERA), Ministry of Energy and Mineral Development in Uganda (MoEMD) and International Energy Agency, were considered and included in the dataset.

Content/material Collection
In this study, the search was done using the following Key search expressions; “Cost of production”; “Cost of production of electricity”; “Electricity generation” AND “its cost”; “Electricity” AND “cost of production”; “Cost of producing electricity in emerging economy”; “Factors determining the cost of production”; “Factors determining the cost of production of electricity”. The search included other “Allintitle” search operators to capture a wider number of articles and records on Cost of production of electricity in emerging economy.

The Criteria for Exclusion and Inclusion
Inclusion criteria. All articles published between 2010 and 2023 were considered and included for synthesis in this study. Articles written in English were specifically considered since the researcher is more familiar with English language. Book chapters on cost of production were also considered in this study review. Exclusion criteria. Articles with the abstracts and executive summaries not well satisfying the purpose of the study were excluded. Articles whose content were not relevant and not in line with the study objectives, and published in any language not English were not included, articles investigating the cost of transmission, distribution of electricity were not considered since the researcher was interested in the generation of electricity. Conference papers and working papers were also not included in this review.

Review and Analysis of Articles
In this study, a total of 48 articles were included for the final review, with adversity of research and analytic approaches about the cost of production of a product/service like electricity in emerging economy. These articles were studied and data was extracted and analysed accordingly.

Key Research Questions of the Paper

i. What are the common factors that determine the cost of production of electricity?
ii. What theories and methodologies are applied to study cost of production of electricity?
iii. What are the likely research gaps that need to be addressed in the future?

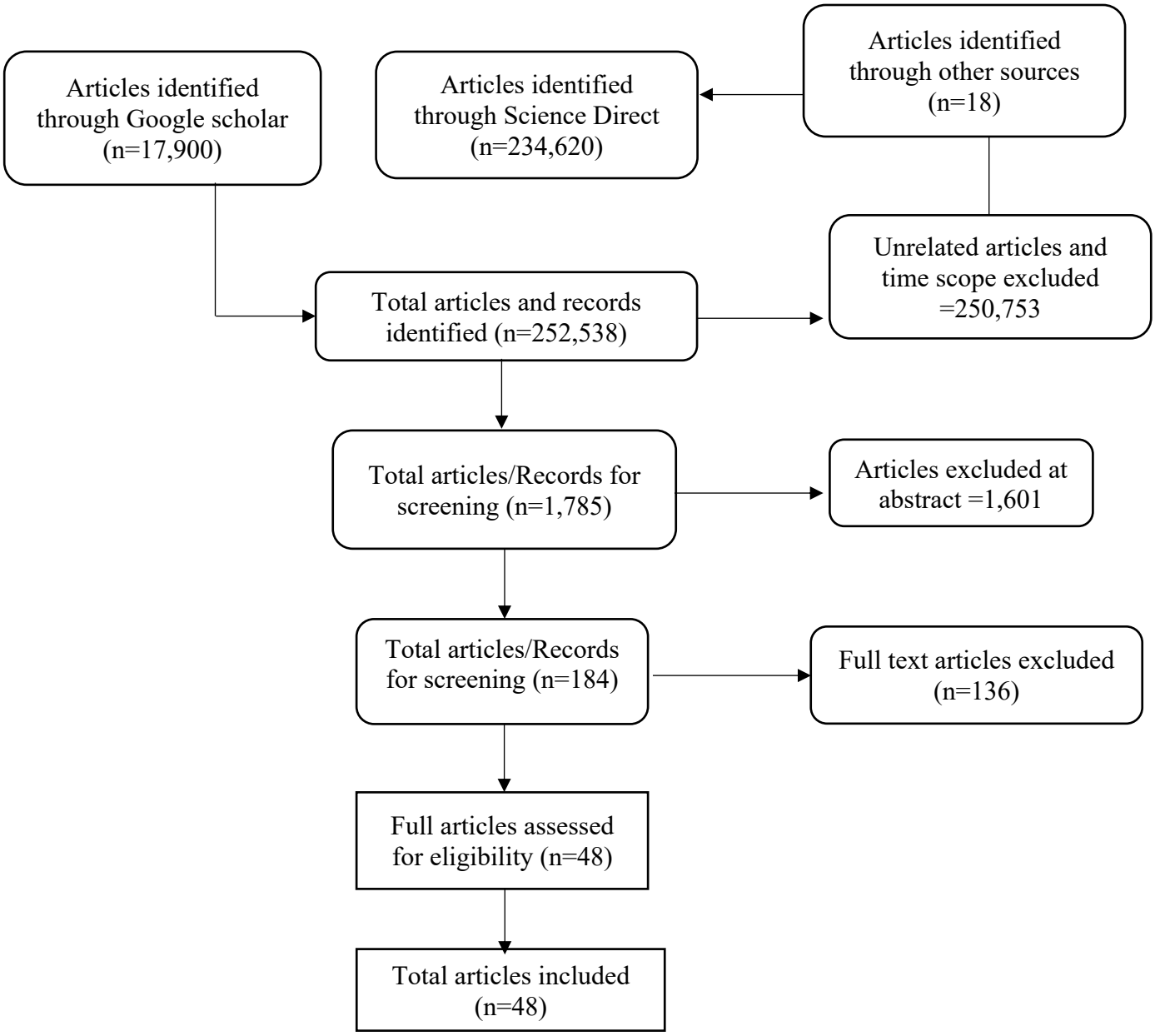

Figure 1: Flowchart showing article selection criteria for the study

Results and Discussion

Journal Coverage by Region

The study employed systematic review of literature on articles that studied about the factors influencing Cost of Production and estimation of cost of production of electricity techniques. The information about region/continent from which the research was undertaken is shown in Figure

1. It is indicated that 35% of the articles came from Europe, followed by North America (19%). The study did not get any article form the South America while the study picked 7 (15%) articles from Asia continent. 8% of the articles reviewed came from Africa and 4% of the articles came from Occenia. The results show that Europe and North America dominated research on cost of production of electricity. This observation may be due to the fact that in Europe and North America regions are the regions with the highest clean energy development and consumption as compared to Africa, still more in using unclean energy fuels and traditional fossil fuels (Coal, Natural Gas, Crude Oil).

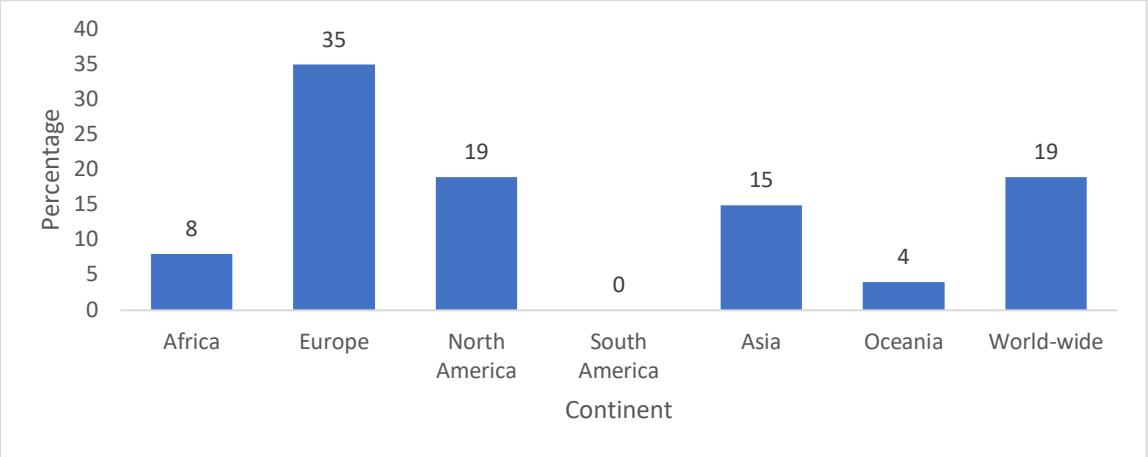

Figure 1. Showing journals by Continent

Journal Articles by Year

The study went ahead to look at the distribution of the articles by period (3 years). From Figure 2, study results have shown that there is an increasing trend of total number of articles researched for different periods since 2010 to 2021. This means that the topic "Cost of production" of a commodity/service like electricity is taking the debate in current years. There were few articles considered in the year period 2022-2023. This could have been due to the small period and that may be, some articles were not yet published.

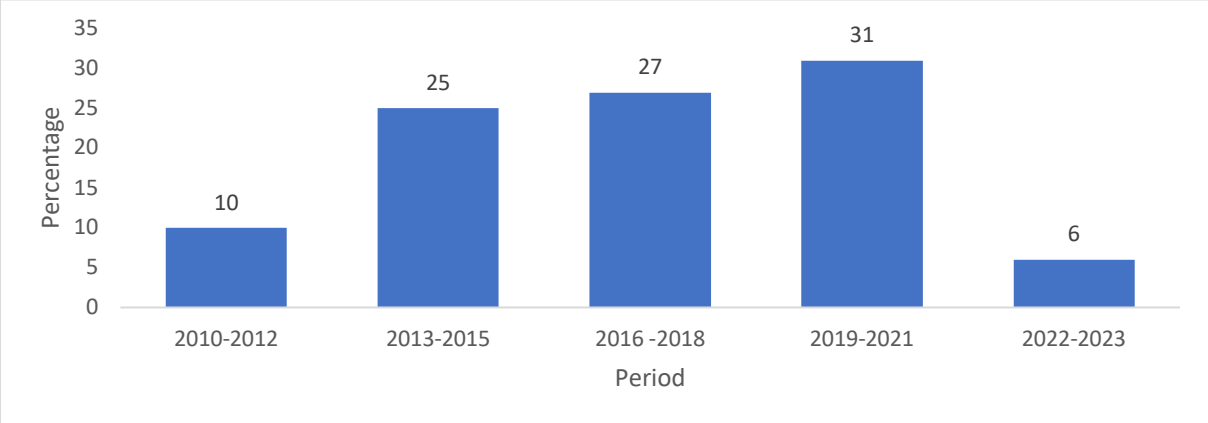

Figure 2. Showing the article by period

Research Articles Undertaken by Country

In terms of counties, as shown in Table 1, considering the period of study, studies about the cost of production were carried out world-wide (24%) topped the chart followed by studies carried in US.A (19%). Other than being part of the North American economies, where majority of people rely much on clean energy (renewable energy), it should be noted that understanding the cost of production of product or service is very important for any business in production of goods/services (Schröder et al., 2013; Wenbin, 2021; Rosnes & Vennemo, 2012). In Africa, only two specific countries; Chad and Morocco, had done some study about the cost of production of a commodity/service but not sufficient enough for generalizations. This could mean that in Africa, may be, many countries have not yet exploited or discovered their renewable energy potentials. About 15 countries had one article published within the period of study while the rest had at least more than one paper published during the same period. The results has shown that there is little or scanty literature on the cost of production, and specifically cost of production of electricity in African setting.

Table 1. Summary of articles by country

No.	Name	Frequency	Percent (%)	No.	Name	Frequency	Percent (%)
1	US.A	9	19	12	China	3	6
2	Poland	1	2	13	Morocco	1	2
3	World-wide	11	24	14	India	1	2
4	Georgia	1	2	15	Indonesia	2	4
5	Sweden	1	2	16	Island	1	2
6	Romania	1	2	17	Bulgaria	1	2
7	Spain	2	4	18	Great-Britain	1	2
8	Switzerland	1	2	19	Iran	2	4
9	U.K	4	9	20	Portugal	1	2
10	Australia	1	2	21	Ireland	1	2
11	Chad	1	2	22	Covered Africa	2	4
	Total	33			Total	14	

Summary of Articles by Journal Type

The study analyzed the distribution of the articles by journal type. The results in table 2 have indicated that within the period of study, the majority (12.5%) of the articles reviewed were obtained from the journal of "Energy", followed by the articles from "Renewable and Sustainable Energy Reviews" (10.4%), then conferences/working papers/series (8.3%). Other journals had at least more than one article within the period of study included; Energies, Energy Economics, Energy Policy, Renewable Energy, and Grey literature. Other journals had only one article picked form the particular journal.

Table 2. Summary of articles by Journal type

	Journal Name	Frequency	Percent (%)
1	Energy	6	12.5
2	Renewable and Sustainable Energy Reviews	5	10.4
3	Conferences/Working papers/series	4	8.3

4	Energies	3	6.3
5	Energy Economics	3	6.3
6	Energy Policy	2	4.2
7	Renewable Energy	2	4.2
8	Grey articles/paper	2	4.2
9	Animal	1	2
10	Applied Energy	1	2
11	Biomass and Bioenergy	1	2
12	Energy Conversion and Management	1	2
13	European Journal of Health Economics	1	2
14	Gospodarka I Innowacje	1	2
15	Gray literature	1	2
16	Health policy	1	2
17	International Journal of Computer Integrated Manufacturing	1	2
18	International Journal of Energy and Environmental Engineering	1	2
19	International Journal of Energy Economics and Policy	1	2
20	International journal of hydrogen energy	1	2
21	Iranian Journal of Public Health	1	2
22	JAMAR	1	2
23	Journal of Economics and Business	1	2
24	Journal of Farm Management	1	2
25	Ocean Engineering	1	2
26	Procedia Manufacturing	1	2
27	Progress in Energy	1	2
28	Research in Social and Administrative Pharmacy	1	2
29	Solar Energy Materials & Solar Cells	1	2
	Total	48	

Estimating the Cost of Production of Electricity

From this study, 45.8% of the articles studied about cost of production of electricity using "Levelized cost of electricity (LCOE)" definition, estimation of Levelized cost of production of electricity and the associated components or reviewed literature about the Levelized cost of production of electricity identifying the cost components and methods of estimation. From the table 3, 25% of the studies looked at LCOE in all technologies by either, reviewing literature (3), reported about the LCOE in general in projects (2), calculated LCOE in renewable energy on country level (1), and LCOE as a guide (1). All the reviewers seem to agree that Levelized cost of electricity is the common method used to estimate the cost of production of electricity. In a study by Geissmann (2017), categorized the methods into two foundations of modelling LCOE; i) Using Societal point of view (includes external costs); ii) Business view (including accounting issues). Huang et al. (2012), categorized all the methods of estimating the production cost of a product/service into four categories; i) Intuitive techniques, ii) Analogical techniques, iii)

Parametric techniques and iv) Analytical techniques. This study by Huang went ahead to explain that all the estimations carried out before, had used analytical models. According to Table 3, it should be noted that most studies about estimation of levelized cost of production of electricity have been done in Solar energy generation (21%), followed by Wind energy generating technology (19%). Other authors reviewed the levelized cost of production of electricity in all energy technologies (25%). Obi et al. (2017) provided estimation of levelized production cost of electricity for various electrical energy storage systems, Soulouknga et al. (2020), evaluated the cost of producing wind-generated electricity and the electricity produced by different types of wind turbines using the Weibull distribution. Therefore, most studies have concentrated and provided the estimation methods of cost of electricity production in different energy technologies seem to miss on hydropower and geothermal technologies, with no clear picture on explaining the factors that determine the cost of production of electricity.

Table 3. Summary of articles carried out to calculate the LCOE by technology

Technology	Frequency	Percent (%)
All	7	25
Solar	6	21
Wind	5	19
Fossil fuels	2	7
Nuclear energy	2	7
Biomass	2	7
Fuel/battery cells	2	7
Storage systems	2	7
Hydropower	0	0
Geothermal	0	0
Total	28	100

Factors Determining the Cost of Production

Table 4. Summary of factors influencing Cost of Production of a Product/Service in general

	Methods	Frequency	Percent (%)
1	Operation &Maintenance cost	6	9
2	Capital costs	6	9
2	Operating time (Life cycles)	5	8
3	Fuel prices	5	8
4	Technology	4	6
5	Production/generation	4	6
6	Investment expenditure	3	6
7	Energy efficiency/tech level of production	3	5
8	Labour costs	3	5
9	Material cost/input prices	3	5
10	Environmental changes	2	3
11	Discount rate	2	3
12	Infrastructure/transportation	2	3

13	Load	1	1.5
14	Carbon dioxide emission costs	1	1.5
15	Backup costs for intermittent technologies	1	1.5
16	R&D Costs	1	1.5
17	Government subsides	1	1.5
18	Institutional factors	1	1.5
19	Resources factors	1	1.5
20	Location/Geographical	1	1.5
21	Cost of input	1	1.5
22	Fixed & variable costs	1	1.5
23	Variables costs	1	1.5
24	Internal production & management arrangements	1	1.5
25	Capacity availability factor	1	1.5
26	Heat rate	1	1.5
27	Shore distance	1	1.5
28	Grid Connection costs	1	1.5
	Total	**64**	**100**

According to the period of study, in table 4, it has indicated that the common factors that influence the cost of production of a commodity or service are majorly; Operation and Maintenance costs, Capital costs, Operating time, Fuel prices, technology, Production level, Investment costs, Energy efficiency and Labor costs. These factors were mention at least more than two time by different articles reviewed. Other factors mentioned are; environmental factors, Discount rate, and infrastructure factors. These results does not give the clear picture of the study because the factors mention to be common factors influencing the cost of production appear to be general, and the authors have no conclusive stand. Some studies were done in agricultural sector (Gulizahro Qakhkhorovna et al., 2022; Siagian et al., 2021; Harizanova-Metodieva & Ivanova, 2019; Boulton et al., 2017), others were carried out in health setting (Colla et al., 2015; Gregório et al., 2016; Hazra et al., 2018; Rajabi & Dabiri, 2012) while other articles came from engineering setting (Wenbin, 2021; Gelb et al., n.d.). Terzioglu and Chan (2013) reviewed theories and practices about the complexities of Service Costing. From the above studies, it is not clear to make conclusive remarks about the cost of production of product or services, thus, for electricity as a service. This leaves a gap, to explain what factors do influence the cost of production of a product/service as many authors were not considering all factors of production in their studies, depending on the study setting. Therefore, this study considered the papers that were specifically studying cost of production of electricity as a service to be able to make clear and on point conclusions. The results were as follows in the table 5.

Table 5. Summary of articles specifically about factors influencing cost of production of electricity

Author, Year	Article tittle	Findings	Limitations
1. (Bartnik et al.,	Analysis of the impact of	- The use of a particular technology determines the	The study was objective, using

2018)	technical and economic parameters on the specific cost of electricity production.	value of the investment needed for the construction of a power plant, its energy efficiency, internal electrical load of the power plant and its annual operating time. - The cost of production also dependents on the economic factors like; interest rate on the capital, fuel prices and environmental charges as well as, equally importantly, their variability in time. - Change in technology parameters cannot considerably reduce the specific production costs of electricity.	analytical models not subjective, using parametric models. The study did not establish the moderation role of technology advancement between factors and specific cost of production The results can only be generalized for developed countries not in developing countries.
2. (Sevencan et al., 2013)	Fuel cell based cogeneration: Comparison of electricity production cost for Swedish conditions	- The types of Fuel Cells that are investigated are proton exchange membrane FC and molten carbonate Fuel Cell. - Based solely on cost, Fuel Cells based cogeneration systems cannot compete with conventional systems. - To compete with conventional systems, the capital cost, lifetime and efficiency of Fuel Cells must be improved. - Creation a big market is essential to reduce capital costs and operation and maintenance (O&M) costs, the dominating parts of the overall costs according to the analysis.	This study is objective specific. Less effort was accorded to renewable energy technologies Did not consider labor cost and technology advancement effects on cost of production This study was more of analytical in estimation.

3. (Tizgui et al., 2018)	Estimation and Analysis of Wind Electricity Production Cost in Morocco	- The study found that; interest rate, the produced energy and the project lifetime, installed technology are the important factors influencing wind electricity production cost - The estimated energy cost is not very sensitive to the variation in operation and maintenance costs. - For all the studied wind farms, the obtained costs of producing one kWh of energy are less than the purchase tariff of electricity in Morocco and compare favorably with solar energy production cost in Morocco. Thus, wind energy is economically beneficial in Morocco.	Only looked at wind energy technology. The study used a small sample size of 9 wind firms Used analytical model (LCOE) to estimate the cost. The study never considered technology advancement moderation effect.
4. (Dinica, 2011)	Renewable electricity production costs. A frame work to assist policy-makers' decisions on price support.	- The study found that national-contextual factors also have a strong influence on production costs, such as geographic, infrastructural, institutional, and resource factors.	Only looked at wind power production-One specific study. This was a review of studies, thus, lacked empirical evidence. Study did not consider the moderation effect of technology on other factors. The study was done in western countries, leaving Africa not studied.
5. (Schröder et al., 2013)	Current and Prospective Costs of Electricity Generation until 2050	- The study provided various production cost estimates, including capital costs, fixed and variable operation & maintenance costs (O&M), and variable costs; - Other estimates like; plant availability, technical lifetime, and operational flexibility were	Did not provide the O&M cost estimates. The study lacked empirical evidence. It used literature

			provided	review for the estimates. The study only estimated costs but never accorded more efforts to find the factors determining cost production of electricity.
6. (Steffen & Waidelich, 2022)	Determinants of cost of capital in the electricity sector		- Drawing on the findings, the study indicates that policy decisions among countries can strongly influence the CoC of energy projects, though any potential intervention to alter the CoC needs to consider all relevant determinants across sectors and policy domains.	The study was looked at macro-level factors, putting less effort on micro-level (farm level). Only studied factors determining cost of capital, and left out other factors of production like labor, capital, and technology Review of literature: The study lacked empirical evidence.
7. (Johnston et al., 2020)	Levelised cost of energy, A challenge for offshore wind.		- The challenges include; Inconsistences in how costs are calculated for offshore wind, which can be attributed to several key factors. - Technology development or introduction of new technologies where manufacturers are bringing to market larger and more advanced turbines, affecting not just the initial costs but heavily influencing O&M costs. - Differences in national policies contribute to cost variation. - Strike price differences between the UK and other regions in Europe are likely to	The study was limited to developed country (UK) not in developing countries like in Africa. The study only looked at the challenges faced in calculating the LCOE in U.K The study was done in only wind technology (offshore) and less

			be influenced by a number of factors (feasible sites, connection charges, geographical differences including water depth and distance to shore)	effort is accorded to other technologies. Little or no effort is accorded to examine and identify empirically, the factors that influence the cost of producing electricity
8. (Timilsina, 2021)	Are renewable energy technologies cost competitive for electricity generation?		- The study found that for the lower range of capital costs, the LCOEs of renewable energy technologies, except concentrated Solar power and offshore wind, are lower than those of fossil fuel based technologies. This means that other technologies are cheaper than the fossil fuel technologies - Since the capital costs of biomass-based technology vary widely depending upon the feedstock type, the cost competitiveness of biomass with fossil fuels and nuclear depends on the type of feedstock. - The values of LCOE can change with change in the values of discount rate, overnight construction costs, O&M costs, fuel prices, heat rate, capacity availability factor, and economic life	This may not be generalized for developing countries since the study was done in developed country USA. Understanding and comparison of cost of electricity by technology is not enough in regards to reduce the cost of production, thus the price. Therefore, the need to understand the factors influencing the cost of electricity at firm level, may be inevitable
9. (Rogan et al., 2020)	Wind turbine cost reduction: A detailed bottom-up analysis of innovation drivers		- The study found that changes in materials (copper, fiberglass, and iron), labour (employee productivity), legal and financial costs contributed over 30% to the cost reduction of wind turbine prices over the period 2005–2017.	The study only concentrated on wind energy production cost. Yet there other energy technologies for

		- Learning-by-deployment was the most important innovation driver, being responsible for half of the cost reduction.	electricity production The study concentrated on developed country (Island) ignoring the developing countries in Sub-Saharan Africa
10. (Bosch et al., 2019)	Global levelised cost of electricity from offshore wind	- This study presents a geospatially-explicit cost (LCOE) model to assess offshore wind energy potential, allowing comparison of costs between countries, and also across country offshore areas. - The average LCOE is 86 $/MWh, while the cheapest LCOEs (79 $/MWh) are located in the deepest available waters (> 55m) which have floating (TLB) foundations - Transmission costs, installation costs, and OPEX vary with distance to shore, while foundation costs and installation costs are dependent on water depth. - Annual energy production, CAPEX (capital expenditure) and WACC all have a significant impact on LCOE - OPEX (operating expenditure) reductions have the least influence on LCOE even though many studies show that significant opportunities are available to reduce OPEX.	The Study only estimated the levelized cost of electricity from offshore wind globally, yet there are other energy technologies The study was done on national level yet the individual firm production can explain the variability within the cost of production well. The study does not explicitly identify the factors influencing the cost of production
11. (Pillai, 2015)	Drivers of cost reduction in solar photovoltaics	The study found that the drivers of cost reduction in solar PV include; • Reduction in the price of inputs • improvements in technology, • increasing market penetration	Technology was considered important in cost reduction in solar PV

		of lower cost firms from China, • Increases in industry investment. These results suggest that government policies aimed at reducing the cost of solar panels should target technological advancements not only in the solar panel industry but also in other industries manufacturing the inputs and the capital equipment used in solar panel production.	The study considered only solar energy. Yet there are other energy technologies. This was done in developed countries leaving the developing countries.

From the table 5, it was indicate that very few authors had done studies on factors that determine the cost of production of electricity in energy sector in the period considered. For example, out of 48 articles, only 11 were tailored to understanding the factors influencing the cost of production of electricity. From the table above, only one article has been carried out in Sub-Saharan Africa, particularly, Morroco in the period of study (Tizgui et al., 2018) but only in Wind energy technology. Therefore, whereas some studies have been carried out about factors influencing the cost of production of electricity, very few have been from African continent. This argument is supporting the previous results (Figure 1). The results have indicated that there is need to conduct more studies to increase knew knowledge and literature on production cost of electricity, to bridge the lacuna on lack of literature, especially, in Sub-Saharan African context.

Table 6. Summarized factors determining cost of production of electricity

	Factors	**frequency**	**Percent (%)**
1	Interest rate on Capital,	2	6
2	Fuel prices,	3	9
3	Environmental charges	2	6
4	Capital cost	3	9
5	Operation and maintenance cost	4	12
6	Project Lifetime	4	12
7	Technology development	4	12
8	Energy produced	1	3
9	National contextual factors	1	3
10	Fixed and variable costs	1	3
11	Shore distance	2	6
12	water depth	2	6
13	Grid connection costs	1	3
14	Investment cost	1	3
15	Discount rate	1	3
16	Input prices	1	3
	Total	**33**	

From the Table 6, it is indicated that the commonly mentioned factors that influence the cost of production of electricity include;

- Interest rate on Capital,
- Fuel prices,
- Environmental charges
- Capital cost
- Operation and maintenance cost
- Project Lifetime
- Technology development

However, the study by Bartnik et al. (2018) claimed that the technology development parameters cannot influence the cost of production of electricity. From Table 5, studies (Bartnik et al., 2018; Seven can et al., 2013; Tizgui et al., 2018; Dinica, 2011) have indicated that labor cost was not explicitly considered independently to influence the cost production of electricity and no conclusion and ultimate agreement on the most important factors determining the cost of electricity production was made. Whereas Elia et al (2020) estimated the factors influencing the wind turbine cost reduction and Pillai (2015) investigated the drivers of solar PV cost reduction, it remains unknown on what are main factors that determine the cost of production of electricity and what models can be used to determine these factors. Most studies have been carried out on wind technology alone (Timilsina, 2021; Johnston et al., 2020; Bosch et al., 2019) while others looked at Solar energy technology alone (Pillai, 2015) and determinants of cost of capital (Steffen and Waidelich, 2022). Whereas Bartnik et al (2017) explained that the factors that determine the cost of production of electricity included; technology, interest rate on capital, fuel prices, environmental factors, operating time and energy efficiency, the study did not consider the labour cost**.** Other studies (Sevencan et al., 2013; Schröder et al., 2013; Dinica, 2011; Tizgui et al., 2018) did not consider technology change and labor costs explicitly, as important factors influencing the cost of production of electricity. Tizgui et al. (2018) did not find a significant effect of Operational and maintenance cost on cost of production of electricity. Therefore, these studies did not explicitly examine the effect of labour and technology advances, and the moderation role of technology change on the relationship between the factors mentioned and cost of production of electricity. The study has also found that no study has been anchored from the theoretical perspective by using the theories to explain the concept of cost of production of electricity at firm level. And very few are from African continent.

Conclusion and Recommendation

The study was based on a systematic literature review of article in the period of 14 years (2010 to 2023). In this study, it was found that studies about factors influencing the cost of production of electricity are still few/scanty (22%), thus no sufficient knowledge or literature is availble to explain the concept, especially in Sub-Saharan Africa (8%, where only four articles were from Africa (Table 1). None has been carried out in Uganda (Table 2) for the period of study considered in this study. The study has identified some common factors that influence the cost of production of electricity to be mixed and not well stipulated, such as; Interest rate on Capital, Fuel prices, Environmental charges, Capital cost, Operation and maintenance cost, Project Lifetime, Technology development, Energy produced and National contextual factors (Geographical location, infrastructure, Institutional factors, resource factors). The study also found that the all studies ignored or have not explained well the role of technology advancement, and it's

moderation role on the relationship between the factors and cost of production of electricity.
There is enough literature about estimation of levelized cost of electricity (LCOE) in most energy technologies but less effort has been accorded to estimate the LCOE for hydro power energy and Geothermal energy technologies and also in regions like South America, Africa and even in Asia (table 1). All the studies so far carried out about the cost of production of electricity, in the period considered under the study, have used the analytical models as opposed to parametric models.

Recommendations

This study finds out that all studies about the cost of production of electricity included in this review were not anchored on any theory to explain the concept of cost of production of electricity and its underlying determinants at household level. Therefore, there is need to explain the factors that determine the cost of production of electricity using theories that capture important aspects in production process.
There is need to employ or adopted other methods to determine the factors of production cost of electricity and predicting the future costs for example using parametric models (regression models, very strong in both observed and latent variables)

References

Arrinda, M., Berecibar, M., Oyarbide, M., Macicior, H., Muxika, E., & Messagie, M. (2020). Levelized cost of electricity calculation of the energy generation plant of a CO2 neutral micro-grid. *Energy*, *208*, 118383. https://doi.org/10.1016/j.energy.2020.118383

Aveyard, H., Bradbury-Jones, C. (2019). An analysis of current practices in undertaking literature reviews in nursing: findings from a focused mapping review and synthesis. *BMC Medical Research Methodology,* Vol. 19(105); https://doi.org/10.1186/s12874-019-0751-7

Bartnik, R., Hnydiuk-Stefan, A., & Buryn, Z. (2018). Analysis of the impact of technical and economic parameters on the specific cost of electricity production. *Energy*, *147*, 965–979. https://doi.org/10.1016/j.energy.2018.01.014

Bosch, J., Staffell, I., & Hawkes, A. D. (2019). Global levelised cost of electricity from offshore wind. *Energy*, *189*, 116357. https://doi.org/10.1016/j.energy.2019.116357

Boulton, A. C., Rushton, J., & Wathes, D. C. (2017). An empirical analysis of the cost of rearing dairy heifers from birth to first calving and the time taken to repay these costs. *Animal*, *11*(8), 1372–1380. https://doi.org/10.1017/S1751731117000064

Can, H., & Korkmaz, Ö. (2019). The relationship between renewable energy consumption and economic growth: The case of Bulgaria. *International Journal of Energy Sector Management*, *13*(3), 573–589. https://doi.org/10.1108/IJESM-11-2017-0005

Colla, P., Hellowell, M., Vecchi, V., & Gatti, S. (2015). Ac ce p te t. *Health Policy*. https://doi.org/10.1016/j.healthpol.2015.08.018

De Roo, G., & Parsons, J. E. (2011). A methodology for calculating the levelized cost of electricity in nuclear power systems with fuel recycling. *Energy Economics*, *33*(5), 826–839. https://doi.org/10.1016/j.eneco.2011.01.008

Dinica, V. (2011). Renewable electricity production costs-A framework to assist policy-makers' decisions on price support. *Energy Policy*, *39*(7), 4153–4167. https://doi.org/10.1016/j.enpol.2011.04.021

Geissmann, T. (2017). A probabilistic approach to the computation of the levelized cost of electricity. *Energy*, *124*, 372–381. https://doi.org/10.1016/j.energy.2017.02.078

Gelb, A., Meyer, C. J., Ramachandran, V., & Meyer, C. J. (n.d.). *Can Africa Be a Manufacturing Destination ? Labor Costs in Comparative Perspective Working Paper 466 October 2017*. *October 2017*.

Gregório, J., Russo, G., & Lapão, L. V. (2016). Pharmaceutical services cost analysis using time-driven activity-based costing: A contribution to improve community pharmacies' management. *Research in Social and Administrative Pharmacy*, *12*(3), 475–485. https://doi.org/10.1016/j.sapharm.2015.08.004

Hazra, N. C., Rudisill, C., & Gulliford, M. C. (2018). Determinants of health care costs in the senior elderly: age, comorbidity, impairment, or proximity to death? *European Journal of Health Economics*, *19*(6), 831–842. https://doi.org/10.1007/s10198-017-0926-2

Huang, C. H., & Hou, T. C. T. (2019). Innovation, research and development, and firm profitability in Taiwan: Causality and determinants. *International Review of Economics and Finance*, *59*, 385–394. https://doi.org/10.1016/j.iref.2018.10.004

Huang, X. X., Newnes, L. B., & Parry, G. C. (2012). The adaptation of product cost estimation techniques to estimate the cost of service. *International Journal of Computer Integrated Manufacturing*, *25*(4–5), 417–431. https://doi.org/10.1080/0951192X.2011.596281

IRENA. (2015). Rethinking Energy: Renewable Energy and Climate Change. *Irena Publication*, 39. www.irena.org

IRENA. (2020). *The Renewable Energy Transition in Africa (KfW Development Bank, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, IRENA).*

Johnston, B., Foley, A., Doran, J., & Littler, T. (2020). Levelised cost of energy, A challenge for offshore wind. *Renewable Energy*, *160*, 876–885. https://doi.org/10.1016/j.renene.2020.06.030

Kumar, S. & Rauniyar, G (2018). The impact of rural electrification on income and education: evidence from Bhutan, *Rev. Dev. Econ.* Vol. 22 (3), pages 1146–1165.

Lai, C. S., & McCulloch, M. D. (2017). Levelized cost of electricity for solar photovoltaic and electrical energy storage. *Applied Energy*, *190*, 191–203. https://doi.org/10.1016/j.apenergy.2016.12.153

Lekaviˇcius V, Galinis A, & Miˇskinis V (2019), Long-term economic impacts of energy development scenarios: the role of domestic electricity generation, *Applied Energy*, Vol. 253, 113527.

Li, Q., Cherian, J., Shabbir, M. S., Sial, M. S., Li, J., Mester, I., & Badulescu, A. (2021). Exploring the relationship between renewable energy sources and economic growth. The case of SAARC countries. *Energies*, *14*(3), 1–14. https://doi.org/10.3390/en14030520

Masum, M. F. H., Dwivedi, P., & Anderson, W. F. (2020). Estimating unit production cost, carbon intensity, and carbon abatement cost of electricity generation from bioenergy feedstocks in Georgia, United States. *Renewable and Sustainable Energy Reviews*, *117*(November 2019), 109514. https://doi.org/10.1016/j.rser.2019.109514

Mccollum, D. (2018). Affordable and clean energy: Ensure access to affordable, reliable, sustainable, and modern energy for all. *Atlas of Sustainable Development Goals 2018: From World Development Indicators*, 26–29. https://doi.org/10.1596/978-1-4648-1250-7_ch7

Mulugetta, Y., Hagan, E. Ben, & Kammen, D. (2019). Energy access for sustainable development. *Environmental Research Letters*, *14*(2), 20201. https://doi.org/10.1088/1748-9326/aaf449

National Plannning Authority. (2020). Third National Development Plan (NDPIII) 2020/21-

2024/25. *Uganda Vision 2040*, *Third*, 341. http://www.npa.go.ug/wp-content/uploads/2020

Obi, M., Jensen, S. M., Ferris, J. B., & Bass, R. B. (2017). Calculation of levelized costs of electricity for various electrical energy storage systems. *Renewable and Sustainable Energy Reviews*, *67*, 908–920. https://doi.org/10.1016/j.rser.2016.09.043

Olanrele, I. A (2020), Assessing the effects of rural electrification on household welfare in Nigeria. *Journal of Infrastructural Development*, 0974930619892742.

Pao, H. T., & Fu, H. C. (2013). Renewable energy, non-renewable energy and economic growth in Brazil. *Renewable and Sustainable Energy Reviews*, *25*, 381–392. https://doi.org/10.1016/j.rser.2013.05.004

Pillai, Unni (2015), Drivers of Cost Reduction in Solar Photovoltaics. *Energy Economics*, Vol. 50, Available at SSRN: https://ssrn.com/abstract=3862666

Rahman, S. M., Spalding-Fecher, R., Haites, E., & Kirkman, G. A. (2018). The levelized costs of electricity generation by the CDM power projects. *Energy*, *148*, 235–246. https://doi.org/10.1016/j.energy.2018.01.144

Rajabi A & Dabiri A (2012) Applying Activity Based Costing (ABC) Method to Calculate Cost Price in Hospital and Remedy Services. *Iranian Journal of Public Health*, Vol. 41,(4), pp 100-107.

Ricardo, David. 1817 [1966]. *On the Principles of Political Economy and Taxation*. London: John Murray. (Reprinted 1966 in The Works and Correspondence of David Ricardo, Vol 1: Principles of Political Economy and Taxation, edited by P. Sraffa. London: Cambridge University Press.)

Rogan, F., Elia, A., & Taylor, M. (2020). *Wind turbine cost reduction : A detailed bottom-up analysis of innovation drivers*. *147*(October). https://doi.org/10.1016/j.enpol.2020.111912

Rosnes, O., & Vennemo, H. (2012). The cost of providing electricity to Africa. *Energy Economics*, *34*(5), 1318–1328. https://doi.org/10.1016/j.eneco.2012.06.008

Schröder, A., Kunz, F., Meiss, J., Mendelevitch, R., & von Hirschhausen, C. (2013). Current and prospective costs of electricity generation until 2050. *Deutsches Institut Für Wirtschaftsforschung*, *68*, 1–81.

Sedai A. K, Nepal. R, Jamasb T (2020), Flickering Lifelines: Electrification and Household Welfare in India

Sevencan, S., Guan, T., Lindbergh, G., Lagergren, C., Alvfors, P., & Ridell, B. (2013). Fuel cell based cogeneration: Comparison of electricity production cost for Swedish conditions. *International Journal of Hydrogen Energy*, *38*(10), 3858–3864. https://doi.org/10.1016/j.ijhydene.2013.01.178

Shen, W., Chen, X., Qiu, J., Hayward, J. A., Sayeef, S., Osman, P., Meng, K., & Dong, Z. Y. (2020). A comprehensive review of variable renewable energy levelized cost of electricity. *Renewable and Sustainable Energy Reviews*, *133*(March), 110301. https://doi.org/10.1016/j.rser.2020.110301

Siagian, V., Resmayeti, Yuniarti, S., & Hidayah, I. (2021). Analysis of factors that influence production and cost of corn in Banten province. *E3S Web of Conferences*, *232*, 1–9. https://doi.org/10.1051/e3sconf/202123201007

Silva, S., Soares, I., & Pinho, C. (2012). The impact of renewable energy sources on economic growth and co 2 emissions - A svar approach. *European Research Studies Journal*, *15*(SPECIAL ISSUE), 133–144. https://doi.org/10.35808/ersj/374

Soulouknga, M. H., Oyedepo, S. O., Doka, S. Y., & Kofane, T. C. (2020). Evaluation of the cost of producing wind-generated electricity in Chad. *International Journal of Energy and Environmental Engineering*, *11*(2), 275–287. https://doi.org/10.1007/s40095-019-00335-y

Steffen, B., & Waidelich, P. (2022). *Determinants of cost of capital in the electricity sector Progress in Energy OPEN ACCESS*.

Terzioglu. B & Chan E.K (2018)Toward understanding complexities of service costing: a review of theory and practice. *Journal of Applied Management Accounting Research,* Vol. 11(2): page 29-45

Timilsina, G. R. (2021). Are renewable energy technologies cost competitive for electricity generation? *Renewable Energy*, *180*, 658–672. https://doi.org/10.1016/j.renene.2021.08.088

Tizgui, I., El Guezar, F., Bouzahir, H., & Vargas, A. N. (2018). Estimation and analysis of wind electricity production cost in Morocco. *International Journal of Energy Economics and Policy*, *8*(3), 58–66.

UN DESA. (2020). *Accelerating SDG 7 Achievement Policy Brief 6 Energy And SDG 10 Reduced Inequalities*.

Wang, Q., Dong, Z., Li, R., & Wang, L. (2022). Renewable energy and economic growth: New insight from country risks. *Energy*, *238*, 122018. https://doi.org/10.1016/j.energy.2021.122018

Wenbin, L. U. (2021). Study on Factors Influencing Production Cost of Prefabricated Components Based on AHP. *E3S Web of Conferences*, *253*, 1–4. https://doi.org/10.1051/e3sconf/202125302013

Yuan, X, Chen, L., Sheng, X. et al. (2021) Life Cycle Cost of Electricity Production: A Comparative Study of Coal-Fired, Biomass, and Wind Power in China. *Energies*, Vol. 14 (12). 3463. ISSN 1996-1073