reviewed paper

Developing a Technological Innovations Framework for Energy Security: a Case of City Power, Johannesburg

Nkosingizwile Mazwi Mchunu, Trynos Gumbo, George Onatu

Nkosingizwile Mazwi Mchunu, University of Johannesburg, Department of Urban and Regional Planning; Johannesburg, South Africa)
(Prof. Trynos Gumbo, University of Johannesburg, Department of Urban and Regional Planning; Johannesburg, South Africa)
Dr George Onatu, University of Johannesburg, Department of Urban and Regional Planning; Johannesburg, South Africa)

1 ABSTRACT

Rapid urban growth in the world's cities, particularly in the Global South has placed unprecedented demand for energy supply that keeps vital urban energy systems functioning in order to support life and economic activities in urban areas. Cities are the net consumers of energy (electricity) and other life-supporting services, as a result they require proper planning and coordination to ensure the resilience and energy security of urban areas. South African Cities, have consistently been experiencing energy shortages through rolling blackouts that date back to 2008.The study aims to develop a holistic framework that informs appropriate innovations that enable the achievement of energy security at City Power in the City of Johannesburg. The work adopted a mixed methods approach that uses both quantitative and qualitative data. Specifically, data was collected through interviews, surveys and observations; reviews of published journals, journals reports and government policy documents. Descriptive statistics, content analysis, narrative analysis, and discourse analysis were used to sieve information from the data. The research findings reveal that residents of the City of Johannesburg are only able to access electricity for an average between 7-12 hours in a day due to energy shortages. The city of Johannesburg is experiencing vulnerability of energy systems in the form of energy blackouts as the result of energy power cuts at the City of Johannesburg. The work posits that, through an energy planning model, the City of Johannesburg, through its power utility City Power could plan for the mitigation of energy black outs through implementation of microgrid planning. Consequently, the study recommends that the City of Johannesburg follows the existing legal frameworks and other planning laws that are available to develop spatial plans for infrastructure development for renewable energy within its area of jurisdiction. The framework for sustainable energy (electricity) security in the City is developed by combining technological innovations with spatial planning.

Keywords: energy security, energy planning, spatial planning, cities, urban growth

2 INTRODUCTION

Rapid urban expansion in the world's cities is placing unprecedented demands on multiple life-supporting services like energy (Sperling & Burke, 2017). Whereby cities are the net consumers of energy and other life-supporting services, and that as a result requires coordination that takes into account urban systems that are critical to the future well-being of communities and ensures the resilience of urban areas. The first industrial revolution was a result of efficient energy consumption that was used to support the explosion of population growth during the 1700s in European cities. The cycle continues three centuries later, during the present era of the fourth industrial revolution, due to the absolute dependency on energy of contemporary society. The present and future of society are dependent on the ability of cities to have energy security.

The idea of energy security in the Republic of South Africa has been one of the issues facing the country, evident through power cuts that have lingered for 15 years and counting. South Africa has been experiencing a series of power cuts since 2008 due to the state-owned electricity utility Eskom's insufficient power generation capacity (Shapely & InglesiLotz, 2022:1). The existence of modern society is dependent on energy (electricity), whereby towns, rural areas, and cities require some sort of energy to enable communities to function across the full spectrum of various endeavours.

Energy security concerns are aligned with United Nations Sustainable Development goals with specific focus on Goal 7 (Affordable Clean Energy).The goal of affordable clean energy is interlinked with other Sustainable Development Goals as stated in the United Nations policy brief as it outlines the linkage between SDG 7 with other linkages namely: linkage between energy and education (SDG 4) "Energy is critical in ensuring schoolchildren's access to educational services such as information and communication technology (ICTs)." (UN Policy Briefs, 2022: 12) , linkage between energy and Gender equality (SDG 5) is due to "Due to their gender roles and responsibilities, women are disproportionately affected by unequal energy access,

and creating an enabling environment for women's participation in the energy sector includes gender responsiveness in energy planning, legislation, and regulation ” (UN Policy Briefs 2022: 37), and Linkage between energy and sustainable land use (SDG 15) “Renewable Energy land system interlinkages have four dimensions: sustainable natural resource management, efficient use of land and biomass resources, appropriate land system governance, and implications on land users' well-being ” (UN Policy Briefs , 2022: 47).

The question of energy security in South Africa has not received the attention that will bring about a sense of urgency; hence, energy issues have lingered for almost two decades. Apart from the intent by the state to provide a policy framework through the National Development Plan, according to the fourth chapter of the National Development Plan, "South Africa needs to maintain and expand its electricity, water, transport, and telecommunications infrastructure in order to support economic growth and social development goals" (NDP, 2030:163), Such acknowledgment was formally made in 2013 when the policy framework was made official; however, the expansion of energy generation has not materialized. The purpose of the study is to develop framework (Localised Energy Planning Model) for technological innovations for energy security in the City of Johannesburg.

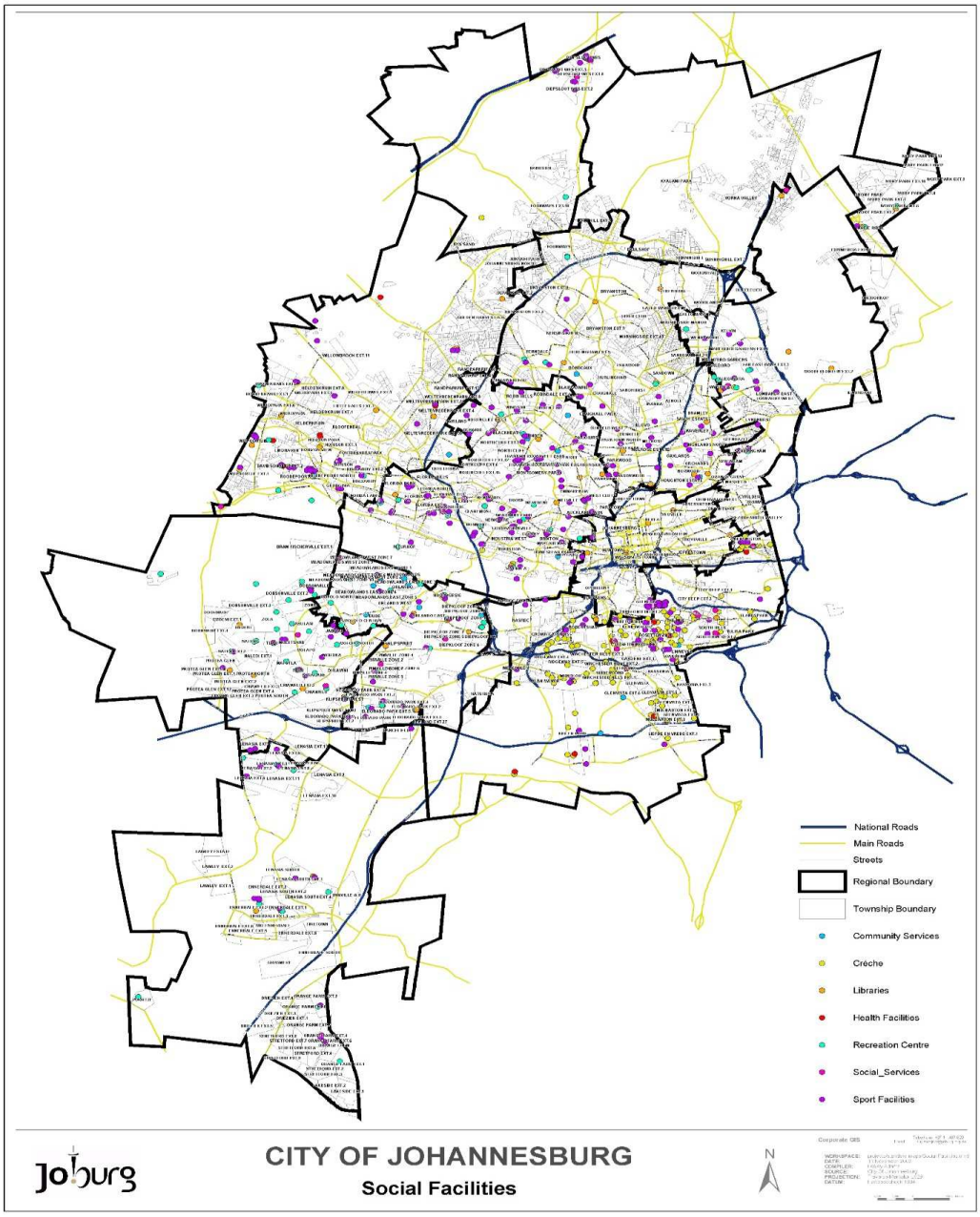
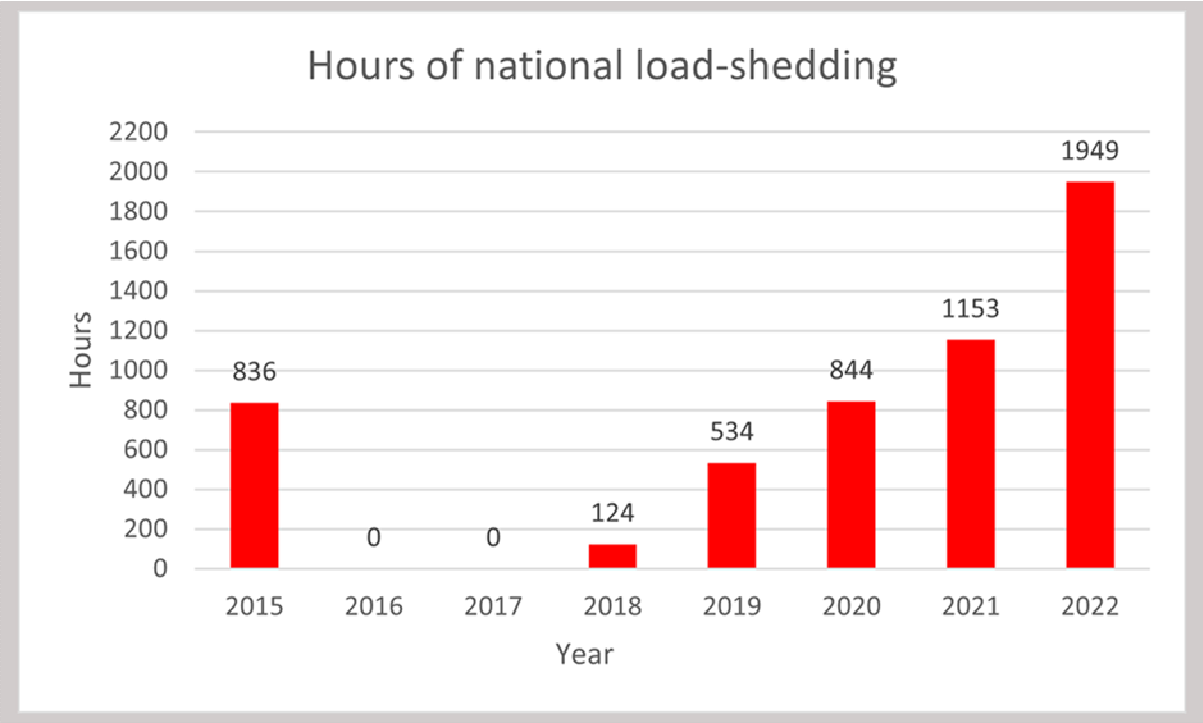


Figure 2.1.1: City of Johannesburg Power Grid (Source: City Power Integrated Report 2021). (Source: City Power Integrated Report 2021)

3 BACKGROUND

Secondary data is the data that has already been collected through primary sources by other parties and made readily available for other researchers to use their own respective research projects. In the context of the current study as it is about studying energy security in the City of Johannesburg. It is important to give a background information about the source of electricity, in terms where does it comes from before spatial entity called City of Johannesburg could consume it for various purposes by all who live in the city. To present evidence about the energy security it is important to take into account the steps that precede the distribution of electricity in South Africa. Due to system of governance in the republic of South Africa that is made up of three branches of the state which are namely: National Government, Provincial Government and Local government, in this case the major source of electricity comes from the state-owned entity that operates to the national level. The entity is responsible for generating electricity from the national level through its network of power plants that are distributed in all nine provinces of South Africa. According to the Eskom's Integrated Results (2019), the total nominal capacity as of March 2019 amounted to 45GW.City of Johannesburg is situated in the Gauteng province and the city has its own electricity distribution network which is shown in figure 6.3.1. The network of the City of Johannesburg carries 12GW of electricity that runs the city and keeps urban energy systems running as well as the city functional according to City Power's report of 2021.The figure below shows the map of electricity distribution of the City of Johannesburg.

The comparison of the total energy capacity of the country compared to the one of the City of Johannesburg indicates that almost 25% of the national grid energy is consumed by the City of Johannesburg when it comes to ratio. The City of Johannesburg metropolitan municipality with its population size is bigger than other nation states in the globe and also in the African continent, whereby that alone creates a need for the city to place a strong emphasis on energy planning in light of the new policies that have been signed into law by the National government of South Africa that allows local governments to have their own generating capacities. Whereby the generating capacity begins with planning that is informed by sufficient data that put all the material factors into the table that shape the dynamic of the City. One of these dynamics is the demographic growth of the City of Johannesburg. The hypothesis of the study is that "as population of the spatial entity continues to growth, that puts pressure on the current energy capacity that needs to plan for future needs."



(EskomSePush, 2023).

There are numerous studies that have been attempted to uncover energy planning and security in the developing world in the global South. Where these studies have been conducted with an objective of

understanding the extent of energy security in developing nations including African continent. The current study focuses on the local government context regarding the energy security and subsequent development of technological innovations that are aimed towards improving the stable access to electricity in the City of Johannesburg. From the basis of that information the data will demonstrate the actual issue that are facing the City of Johannesburg when it comes to factors that contribute to energy security in the city, one of the issues among these are disruptions that are caused by power outages at the demand for energy outstrips the supply. At the core of energy security affecting the City of Johannesburg are power outages or energy blackouts that are known as load shedding, this is the phenomenon that has characterised South Africa. The figure 2.1.2 shows the number of load-shedding hours each year from 2015 to date, sourced from (EskomSePush, 2023).

4 CONCEPTUAL SYNOPSIS

One of the objectives of the new democratic dispensation in the republic of South Africa after 1994 was to transform spatial partners that were informed by the past spatial planning. There were various measures that were taken by the state in the interim like, which was the part of the freedom of movement in the country to live in cities because of pull factors in the urban areas. It was until 2013 where the law that governs the overall land use in all spheres of the government namely (a) Local government, (b) Provincial government and (c) National government. The passing of the Spatial Planning and Land Use Management Act 16 of 2013, did set up a legal framework that will guide spatial planning in the republic. Spatial transformation is informed by Spatial Development Frameworks (SDF) whereby according to section 12 subsection (1) of the SPLUMA Act states that “12. (1) The national and provincial spheres of government and each municipality must prepare spatial development frameworks that (a) interpret and represent the spatial development vision of the responsible sphere of government and competent authority; (b) are informed by a long-term spatial development vision statement and plan;(c) represent the integration 32 32 and trade-off of all relevant sector policies and plans;” (South Africa, 2013:21) .Spatial transformation follows the guide lines of the spatial development frameworks that are aligned from across all spheres of government, spatial transformation is a part of strategic spatial planning. Strategic spatial planning in the post-apartheid era has attempted to promote more compact and integrated cities, and to redress patterns of inequality of the past (Todes, 2012). One of the objectives of strategic spatial planning in the post-apartheid South Africa was and still is the spatial transformation of planning patterns of the past. There have been various reforms on the policies by South Africa government on energy security from 1994.Energy policy frameworks were aimed at improving energy security based on the expected economic growth and expansion of service deliver to previously disadvantaged groups. There are four key policy frameworks to be discussed namely: National Development Plan, Integrated Resource Plan, National Electricity Act 34 of 2008 and the amendment of National Electricity Act.

4.1 National Development Plan 2030

The National Development Plan is one of the unique policy frameworks as it attention not only focuses on the domestic affairs of South Africa, instead the policy looks at the orientation of South Africa as global player in the rest of the world as the phenomenon of globalization takes place in the wake of global economic recession of 2008.From that standpoint, there was an understanding that International and regional developments affect the republic of South Africa in multifaceted ways. Due to positive implications of globalization for South Africa’s development, notwithstanding several notable risks (NDP, 2030:30).One of the key objectives of the National Development Plan is to “ to invest in a strong network of economic infrastructure designed to support the country's medium- and long-term economic and social objectives” Through “maintenance and expansion of electricity, water, transport and telecommunications infrastructure in order to support economic growth and social development goals” (NDP, 2030:158).These policy objectives are meant to increase the capacity of South African Infrastructure in terms of its ability to support economic growth , where the key infrastructure items that is constantly being highlighted in these policy frameworks is the issue of energy security.

4.2 Integrated Resource Plan

Electricity demand trends in South Africa as projected in the period between 2010 and 2030 continues to be visible with the current more supply of energy that continues to fall under strain due to constant power cuts

taking place in the South African energy grid. Ateba, (2019) attributes the South Africa's industrial decline and dwindling economic growth prospects are directly associated with decreasing electricity poor accessibility, as the industrial sector is the main economic contributor to South Africa's GDP. Much of the issues that are affecting the aggregated economic prospects of the country includes the insufficient supply of energy that is necessary to support economic growth of South Africa. One of the issues that were accentuated by integrated resource plan was the issue of increasing the available supply of electricity by to ensure the equilibrium between the available energy supply and the demand of for electricity in South Africa. The emergence of integrated resource plan (IRP) came as the electricity capacity plan which a sole objective to provide an indication of the country's electricity demand, how this demand will be supplied and what it will cost (Govender and Dempster, 2019).Over time between the promulgation of the policy back in 2019 up to today, South Africa has suffered worst energy blackouts in its history as the country has endured almost 100 consecutive days of load-shedding between October 2022 and the 6th of February 2023 (Naidoo, 2023).The efficacy of the Integrated Resource Plan according to the studies that have been published and reports that emerges seems to paint a picture that is completely different from the original intent of the policy to guide the measures to energy security.

4.3 The National Electricity Act 34 of 2008

The formulation of the Act was an attempt to bridge the gap between, fragmented development of energy laws in the new South Africa and regulation on the one hand and environmental law on the other is influencing against the adoption of a sustainable energy system in South Africa (Murombo, 2015).One of the key objectives of the act is to ensure that diverse energy resources are available to bring about the sustainable energy mix in South Africa, through quantities that are both sustainable quantities and at affordable .The objective is aligned with the wide definition of energy security that revolves around 4As which are namely: physical availability; economic affordability; accessibility from a socio-political standpoint; and environmental acceptability (Fang, 2018).One of the key aspects of the act is to " to provide for energy planning, increased generation and consumption of renewable energies", as the study seeks to examine energy security from planning standpoint within the local government context.

4.4 The amendment of National Electricity Act 34 of 2008

The amendment of the National Electricity Act 34 of 2008 represented a major shift in the energy planning ethos of the local government, meaning that the local governments are provided an opportunity under law to participate in the energy generation initiatives within the areas that fall within their jurisdiction. Under chapter 5 Section (4) states that "Regulation 5 of the Regulations is hereby amended by the addition of the following sub regulation: "(3) A municipality. As an organ of state, may apply to the Minister to procure or buy new generation capacity in accordance with the Integrated Resource Plan. The amendment represents the alignment between the objectives of the National government and local government to pursue energy self-sufficiency. The act was amendment in the year 2020 to accommodate municipalities with the provision in the law. Thus, creating the grounds for the study to be conducted that will enable energy planning that will address energy security concerns in the City of Johannesburg. The amendment represents the current state of the situation in terms of major regulations that are governing electricity in South Africa.

5 RESEARCH METHODS

5.1 Research Design

The case study design was adopted for the research as it is profoundly relevant in offering a targeted and in-depth exploration of the intricacies and challenges within a specific context of the city. By focusing on City Power in Johannesburg, the case study provides a nuanced understanding of the local dynamics, regulatory frameworks, and collaborative efforts in the pursuit of energy security. This approach allows for a detailed examination of the practical implications of technological innovations within the unique urban landscape of Johannesburg. The case study design enables the identification of context-specific barriers and opportunities, fostering a more comprehensive and tailored framework for advancing energy security through technological innovations. Moreover, the insights garnered from this case study are not only valuable for City Power, but also serve as a rich source of lessons and recommendations with broader applicability for other urban energy contexts, contributing to the advancement of sustainable energy practices on a larger scale. 20

5.2 Research approach

The research adopted a mixed-methods approach as the methodology was deemed highly relevant due to the multifaceted nature of the established research questions. By combining both qualitative and quantitative methods, this approach provided a comprehensive lens through which to examine the complex interplay of technological innovations and energy security in a real-world urban setting. The qualitative element of the work allowed for an in-depth exploration of contextual nuances, capturing the perspectives of key stakeholders, and elucidating the intricate dynamics within City Power. On the other hand, the quantitative element assisted with facilitating the gathering of empirical data from the respondents, thus enabling the measurement of the impact of technological innovations on energy security metrics. The mixed methods approach not only enhanced the robustness of the study, but also ensured a more holistic understanding of the factors influencing the success of the proposed framework. The approach enables the synthesis of qualitative insights with quantitative data to produce a well-rounded examination of the critical issues surrounding technological innovations for energy security in the specific case of City Power, Johannesburg.

The purpose of data analysis is to establish meaningful insights from raw data that has been collected with an objective of answering research questions as outlined as goals and objectives of the study, identify patterns that are reoccurring, and extract valuable information that will be useful to answering the questions. Since the study is a mixed methodology study, it has got both numerical and non-numerical data that has been obtained from the survey of participant that were sampled in the study. The study has three parts namely: (a) Demographic profile, (b) Public sentiment around energy security, and (c) Public opinion on possible solution for possible solutions for energy black outs.

6 RESULTS AND DISCUSSION

6.1 Demographic profile of participants

The 21st century is currently undergoing a significant majority of the world's population preferring to living in urban centres (Katleni et al.,2016). The City of Johannesburg with its large population is one of the major contributors to the Gauteng and South African economy, and its economic growth rate is larger than the national and provincial levels of government (Karuaihe, 2013). The city of Johannesburg offers insights with its demographic profile into urban governance and the interesting interaction between managing the demands for infrastructure in a rapidly urbanizing context of the spatial entity (Abrahams & Everatt, 2019). The city has the diverse population groups with different levels of social status and different participation levels on the economy. Demographic profile of the sample area shows the composition of participants that took part in the study, it is broken down into five key categories namely: economic status, citizenship, gender, marital status, and number of people in the household.

Economic status

The composition of participants that were sampled are 32% Self-employed, 32% employed, 14% unemployed and looking for employment, 12% not employed and not looking for employment and 10% was a subset of participants who indicated that they are still busy with their studies to get skills at different training institutions. The informal sector is distinguishing feature of emerging and developing economies, particularly in Africa and Latin America (Bargain and Kwenda, 2011). The inner city of the City of Johannesburg has huge number of people that are small business owners (Zulu,2020) that are self-employed, and another percentage is for people who are employed and working for someone else in different industries within the City of Johannesburg, followed by 10% of student population as the city has many training institutions for different skills. The massive growth of private student housing across cities globally including the developing world, and much of this has been attributed to the increased neo liberalisation and mainstreaming of higher education (Gregory & Rogerson, 2019) and other group is for people who are unemployed made up of those who are looking for work on the active basis and those that have given up on finding work opportunities. The high levels of unemployment in South Africa are a key concern for young people after leaving school. (Graham and Mlatsheni, 2015). Unemployment is responsible for increase in urban poverty in the post-apartheid period (Crankshaw, 2022).

6.2 Citizenship

The City of Johannesburg is made up of different nationalities within the City of Johannesburg as the city is understood as the cultural melting pot, (Harrison & Zack, 2012) meaning that the city is made up of different nationalities, whereby according to the surgery it shows the 66.7% majority by South Africans and 33.3% foreign nationals from the sample that was willing to participate voluntarily in the study. Earlier, in 2015, the United Nations had already projected out that population growth in the 21st century will be concentrated mainly in African continent (UN-DESA, 2015). Africa is experiencing unprecedented urban growth (Totafori, 2020).

6.3 Sex

Show the gender composition of the participants that is broken down between males and females, whereby males make up the majority of the participants with 58% and 42% females that took part in the survey.

6.4 Marital Status

This part refers to social composition of the participants, whereby singles make up the majority of the population by 64% followed by 34% and 2% of divorced. The data point helps to identify the family composition of participants who took part in the study.

6.5 Number of people in the household

Refers to the number of people within the household where each participant resides composition of the participants, whereby households with people from 2-5 represents the high number of households within the sample, followed by households with those households with 6-10 people within the households and these living alone.

6.6 Public sentiment around energy security

One of the strong sentiments that have been highlighted by the participants of the study with regards to energy security is the response around the number of hours in a day community have been without electricity is the financial implications of energy security that are high cost of living and high input cost of doing business. The data further suggest that in the year 2022 an equivalent of 82 days was lost due to power cuts as the result of energy blackouts as national energy grin was unable to sustain the supply of energy. The power cuts are also being experienced by the City of Johannesburg since it also gets electricity from state owned power utility ESKOM. The survey revealed that the communities are able to access electricity from 7-12 hours in a day by vast majority of households. And the mean or average number of days in which households without electricity is 6.97 days, meaning that there is a slow response in resolving electricity related disruptions that take place outside black outs alone. That on its own indicated the vulnerability of vital energy systems of the city in terms of unstable electricity grid.

6.7 Discussion

The use of solar energy and other renewable energy solutions has been suggested by communities as the initiatives that the City of Johannesburg could embark upon to stabilise the local energy grid of the municipality. Followed by the provision of free basic electricity for poorer households that are struggling to keep up with the steep electricity prices. There are deep concerns about the affordability of electricity in the future as the prices continue to climb. And the issue of vandalism has been highlighted as major concerns among communities that participated in the survey, meaning that some of the vulnerabilities in the energy systems are due to vandalism of the infrastructure.

According to the data it implies that entire country has experienced load shedding or energy blackouts for almost 2000 hours in 2022 meaning that if we divide number of our by a day which is made up of 24 hours we have = 1949 hours X (Day/24 hours) = 81 days in 2022 were equivalent to total darkness, 48 days in 2021, 35 days in 2020, 22 days in 2019.This means that out of 365 days a year the City of Johannesburg experienced an equivalent of 81 days of total darkness without any electricity. In light if the current situation with regards to energy security in the City of Johannesburg that continues to grow quite significantly in terms of population the current capacity will not be enough to satisfy the demand that comes with urban future growth. According to WorldData (2023) the South African electrical energy consumption per capita is at an average of 3.377kWh, from this information this means that in proportion to population growth of the

country as recoded from decade to decade the energy needs continue to grow. The specific reference to this growth phenomenon of population in the local government of the City of Johannesburg grew from 4.2 million in 2011 to 6.2 million people in 2022 which is information taken from Statistics South Africa from census data. This means that in the light of energy shortages that are currently being experienced by the city there has been and addition of 2 million people who need an average of 3.377kWh of energy on the daily basis. The table below shows the electrical energy consumption per capita of South Africa in comparison with USA (Data sourced from WorldData, 2023).

5.8.1. Energy consumption comparison Republic of South Africa compared to United States of America

Electricity	Total	South African electricity consumption per capita	USA electricity consumption per capita
Own consumption	202.29 bn kWh	3377.4 kWh	11695.27 kWh
Production	231.85 bn kWh	3870.99 kWh	12147.64 kWh
Import	7.82 bn kWh	130.61 kWh	184.37 kWh
Export	14.48 bn kWh	241.79 kWh	42.41 kWh

Source: (WorldData, 2023)

Emanating from the two data points from figure 6.3.1 and 6.3.2 it is evident that the ability of the City of Johannesburg to have energy security for the area that fall under its jurisdiction is a concern that needs to be addressed. As the city is currently being affected by external factors that directly affects how the city functions on being the phenomenon of population growth and the other variables being its dependency upon the capacity of the state-owned entity for its electricity. In this section we shall be presenting data points from other studies with specific focus on energy security and technological innovations in the urban context. This data will be presented in the form of codes that will be highlighted as key themes of the secondary data presentation namely: Technological innovations and energy security, Urbanisation rate and energy security, Industrialisation rate and energy security, Population growth and energy, Energy consumption security, Financial Development and energy security, Spatial trade-offs and energy security

6.7.1 Energy consumption security

Following the global pandemic in the year 2020 and 2021 that was followed by the return to normal business activities that require the use of electricity to boots strong economic recovery drive a rapid rebound in energy demand. Those energy demands raised concerns about energy security in the globe (Wang and Lee, 2020).With varying degrees of energy supply and demand all over the world as cities where beginning to return back to normal functioning this saw a shift on supply chain of energy products (EU Report, 2021).In the column released by Reuters (2021) “Worldwide energy shortage shows up in surging coal, gas and oil prices” according the publication prices for commodities began to climb as the world economy was beginning to open up and that directly raise concerns about energy security for cities that is being affected by global commodities markets. The figure 6.3.2.1 below shows the timeline for energy prices from year 2020 to 2021.

6.7.2 Technological innovation and energy security

The fourth industrial revolution has brought about an era known as Industry 4.0, and to keep up with this structural economic shift towards digitisation of various aspects of society through technological innovation, the role of innovation is being reinterpreted as a catalyst for digital transformation (Chen et al., 2021).These innovations have an effect in energy systems that are responsible for functioning of contemporary society through improvement that is driven by extensive knowledge of how systems work over the years. Improvements in energy use cannot be achieved without technological advances (Rip & Kemp, 1998). Technological Innovations bring about efficiency in the production and use of energy in general and its responsible for newer and greener modes of electricity generation and improving energy security overall through monitoring of the grid capacity (Rüßmann et al.,2015). With an intention of driving global development that sustainable, technological innovations have a significant role to play in improving how global cities consume energy. Technological advancement and development are regarded as the most significant and practical technique to increase energy consumption efficiency, storage efficiency and generation from sustainable sources that are renewable (Rae, 2012).

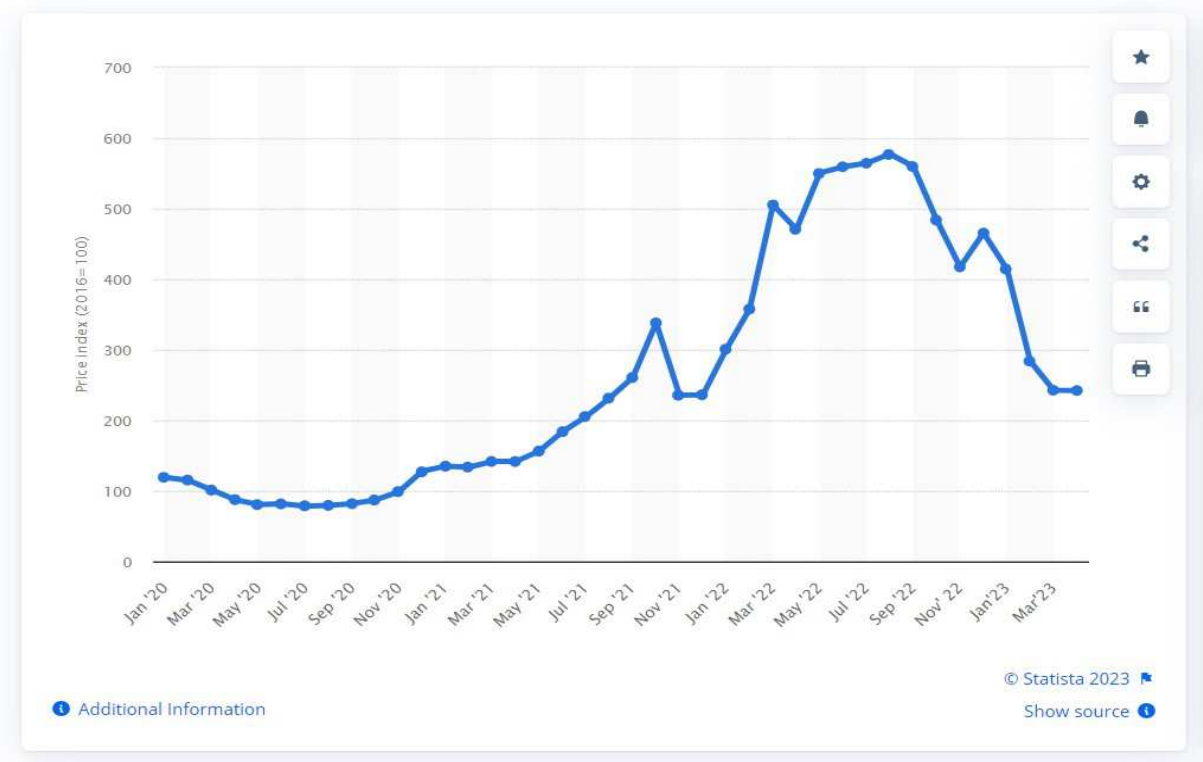


Figure 2.7.3 Coal Prices. Source: (EU Report, 2021)

6.7.3 Spatial Trade-offs and energy security

To achieve long-term carbon emission reduction targets, land-based, utility-scale renewable energy systems that generate power from solar or wind resources are emerging as a clear choice. Local governments are responding in kind by setting their own objectives and/or rules to help renewable installations succeed in their areas of responsibility (Guo et al., 2020).Against the of the demand for energy and related services grows to meet social and economic growth, anthropogenic greenhouse gas (GHG) emissions and the resulting atmospheric concentration have reached a historical high relative to pre-industrial levels (Change, 2014).The demand for land use in the urban areas like in the City of Johannesburg where there is a massive population growth due to urbanisation, massive demand for energy (electricity) that is necessary to urban systems and vital services of the city. This will create a competition between various land use requirements due to competing land use interest of the city. However, the need for the city to mitigate against the negative impact of energy blackouts to stable local electricity grid, the spatial trade-offs is one of the feasible solutions for the city to allocate land that would be dedicated for renewable energy and other technologies for stabilising the local grid of the City of Johannesburg municipality.

7 CONCLUSIONS AND RECOMMENDATIONS

The study has found that the city of Johannesburg is experiencing vulnerability of energy systems in the form of energy blackouts as the result of energy power cuts that have engulfed the entire country South Africa. In the year 2022, the country lost an equivalent of about 82 days without electricity as a result of energy blackouts. The study has discovered that through energy planning model for the City of Johannesburg, the city through its power utility City power could plan for mitigation of energy black outs through the implementation of microgrid planning to utilize technological innovations for energy storage sites to ensure that there is minimized number of hours parts of the city without energy. The role of technology in intervening in energy security would be to provide data centres that would be responsible for monitoring the capacity of the electricity grid in all 135 wards for the city of Johannesburg. The data from the database can be potentially useful in quantifying peak periods for electricity demand in each ward, and this was useful in determining the battery storage sites that could be appropriate for each site. The study suggests that through urban planning, the control of land use 89 is the foundation to strategically develop the technological infrastructure that supports energy systems of the City of Johannesburg with an aim of securing stable energy supply. Based upon the study conducted, this section outlines the recommendations that can be adopted by

the City of Johannesburg in terms of energy planning strategies that aimed at protecting the local electricity of the of the city grid from energy blackouts. By following the existing legal framework and other legislative mechanisms that are available to enable local governments to develop spatial plans that will enable the infrastructure development for renewable energy within the area that fall under the jurisdiction of the municipality.

The integration of energy planning into the scope of mainstream planning. The integration of energy planning into IDP (Integrated Development Planning) programmes of the municipality, the inclusion of energy planning into spatial planning by creating the spatial development frameworks that will designate certain land portions to support local energy grid.

Urban growth monitoring measures, by limiting low density developments. The pursuit of energy security in the city requires land resources in the same way the urban expansion does require land. In this way the municipality could avoid urban expansion by low density neighbourhoods as that will take up more land that could have been used for other purposes like grid scale technology and wind power sites.

Categorisation of vital energy systems that needs to be prioritized first, in order to inform the energy planning priorities that need to be attended first, due to limited resources when it comes to capital expenditure allocated to various infrastructure initiatives.

8 REFERENCES

Sperling, J.B. and Berke, P.R., (2017). Urban nexus science for future cities: Focus on the energy-water-food-X nexus. Current Sustainable/Renewable Energy Reports, 4, pp.173-179.

Sehlapelo, T., & Inglesi-Lotz, R. (2022). Examining the determinants of electricity consumption in the nine South African provinces: A panel data application. Energy Science & Engineering, 10(7), 2487-2496.

Chalvatzis, K.J. and Rubel, K., (2015). Electricity portfolio innovation for energy security: The case of carbon constrained China. Technological Forecasting and Social Change, 100, pp.267-276.

Wang, J., Ghosh, S., Olayinka, O.A., Doğan, B., Shah, M.I. and Zhong, K., (2022). Achieving energy security amidst the world uncertainty in newly industrialized economies: The role of technological advancement. Energy, 261, p.125265.

South African Government. (2012). National Development Plan 2030. Pretoria: Government Printer.

Karunathilake, H., Prabatha, T., Sadiq, R. and Hewage, K., (2022). Overcoming the energy security challenges in developing countries. In Handbook of Energy and Environmental Security (pp. 61-88). Academic Press.

Chirisa, I. and Matamanda, A., (2019). Forces shaping urban morphology in Southern Africa Today: unequal interplay among people, practice, and policy. Journal of Urbanism: International Research on Placemaking and Urban Sustainability.

Batliwala, S. and Reddy, A.K., (1994). Energy consumption and population. Population: the complex reality.

Jewell, J., Cherp, A. and Riahi, K., (2014). Energy security under de-carbonization scenarios: An assessment framework and evaluation under different technology and policy choices. Energy Policy, 65, pp.743-760.

Clemente, I., (2021). Urban Events and the Soul of the City: The Poetic Political Tripartition of Urban Form. In Mapping Urban Spaces (pp. 76-85). Routledge.

Fainstein, S.S., (2014). The just city. International journal of urban Sciences, 18(1), pp.1-18.

Wang, J., Ghosh, S., Olayinka, O.A., Doğan, B., Shah, M.I. and Zhong, K., (2022). Achieving energy security amidst the world uncertainty in newly industrialized economies: The role of technological advancement. Energy, 261, p.125265.

Kok, P.C., Bouare, O. and O'Donovan, M., (2003). Post-apartheid patterns of internal migration in South Africa. HSRC Press.

Todes, A., (2012). Urban growth and strategic spatial planning in Johannesburg, South Africa. Cities, 29(3), pp.158-165.

Steyn, M., Tsekwa, J. and McEwen, H., (2017). “Whole masses of uncharted territory”: Metaphors, Internal Spatiality, and Racialized Relationships in Post-Apartheid South Africa. Critical Philosophy of Race, 5(2), pp.267-295.

South Africa (2013). Spatial Planning and Land Use Management Act 16 of 2013.Government Printer. Pretoria.

South Africa (1996). Constitution of the Republic of South Africa. Act 108 of 1996.Goverment Printer. Pretoria.

City Power Integrated (2021/2022). Annual Integrated Report. State Owned Enterprise. Government Printer. Johannesburg.

Ntombela, C., Masangane, W., Funke, N.S. and Nortje, K., (2013). ekhukhune District Municipality workshop proceedings: Wastewater treatment: Towards improved water quality to promote social and economic development.

Naidoo, N., Pearce, D., Visser, W., Crafford, J., Maila, D. and Harris, K., (2016). Implementation of effective wastewater charges by municipalities in South Africa: An investigation into the barriers and enablers. Report to the water research commission. Pretoria, South Africa: Water Research Commission.

Brew-Hammond, A., 2010. Energy access in Africa: Challenges ahead. Energy policy, 38(5), pp.2291-2301.

Gaede, J. and Meadowcroft, J., 2016. A question of authenticity: Status quo bias and the International Energy Agency's World Energy Outlook. Journal of environmental policy & planning, 18(5), pp.608-627.

Chen, M., Sinha, A., Hu, K. and Shah, M.I., (2021). Impact of technological innovation on energy efficiency in industry 4.0 era: Moderation of shadow economy in sustainable development. Technological Forecasting and Social Change, 164, p.120521

Karuaihe, S., (2013). The state of the economy: city of Johannesburg. Abrahams, C. and Everatt, D., 2019. City Profile: Johannesburg, South Africa. Environment and Urbanization ASIA, 10(2), pp.255-270.

Rip, A. and Kemp, R., (1998). Technological change. Human choice and climate change, 2(2), pp.327-399.

Rüßmann, M., Lorenz, M., Gerbert, P., Waldner, M., Justus, J., Engel, P. and Harnisch, M., (2015). Industry 4.0: The future of productivity and growth in manufacturing industries. Boston consulting group, 9(1), pp.54-89.

Rae, C. and Bradley, F., (2012). Energy autonomy in sustainable communities—A review of key issues. Renewable and Sustainable Energy Reviews, 16(9), pp.6497-6506.2

Dobravec, V., Matak, N., Sakulin, C. and Krajačić, G., 2021. Multilevel governance energy planning and policy: A view on local energy initiatives. Energy, Sustainability and Society, 11, pp.1-17.

Guo, J., Fast, V., Teri, P. and Calvert, K., (2020). Integrating land-use and renewable energy planning decisions: A technical mapping guide for local government. ISPRS International Journal of Geo-Information, 9(5), p.324.