The Impact of Non-Technical losses : A South African perspective compared to global trends

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***Abstract*—Global non-technical losses account for approximately $96 billion annually. The largest contributor to these losses is electricity theft which is attributed to access to electricity, affordability, socio-economic conditions and poor service delivery. South Africa is not excluded from this phenomenon, with electricity theft contributing to 10% of its total losses, highlighting its contribution of non-technical losses to global statistics of approximately 1.5%. Furthermore, the environmental impact resulting from fossil-fuel electricity generation in South Africa is on par 40% higher in global comparison and is highlighted to be the 14th largest emitter of greenhouse gasses globally, with non-technical losses compounding the situation. This paper discusses the impact of non-technical losses and highlights the South African perspective, compared to global trends.**

Keywords—Electricity theft, Health and Safety, Non-technical losses, Environmental impact and Economic impact

I. INTRODUCTION

Global utilities suffer commercial or alternatively defined non-technical losses of approximately $80-100 Billion per year [1, 2]. Non-technical losses (NTL) are quantified as losses, which are incurred because of poor administration, fraud, non-paying customers, and corruption, with the largest component attributed to electricity theft [3, 4, 5]. *Gratis* electricity is also considered an NTL and is defined as free electricity provided to support poor indigent communities and, in some instances, certain employees and organisations. [3, 6]. Technical losses on the other hand are losses that naturally occur within power systems due to energy dissipation, and these losses are generally quantified and mitigated for. The loss equation is then highlighted as below in equation 1. It has been argued in literature that the significant component of losses found within the overall loss equation is attributed to the sum of the NTL [5, 4].

$$\sum Total\ Losses = \sum TL + \sum NTL + \sum Gratis \qquad (1)$$

NTL have a direct impact on the economy, social wellbeing, safety of the population and environmental plethora as a result. In this paper, an overview of the impact NTL's has on the global situation will be discussed, and furthermore, the South African environment will be compared to these global trends.

The rest of this paper is organised as follows: Section II will highlight global trends, Section III will introduce a South African perspective, Section IV will provide for a comparative discussion and Section V contain the conclusion.

II. GLOBAL TRENDS

It is estimated that out of 20 trillion kW/h produced globally on an annual basis 1.4 trillion kW/h are lost due to the phenomenon of NTL [7], furthermore it would suggest that utilities would have to generate more capacity to offset these losses in order to sustain energy demand to their paying consumers. Figure 1 below [8], illustrates the combined global (TL and NTL) losses for the past 6 decades. This seems to highlight and that the combined losses are directly proportional to energy demand requirements and suggest no real diminishing of the overall losses. These losses therefore still form a significant part of the generated capacity.

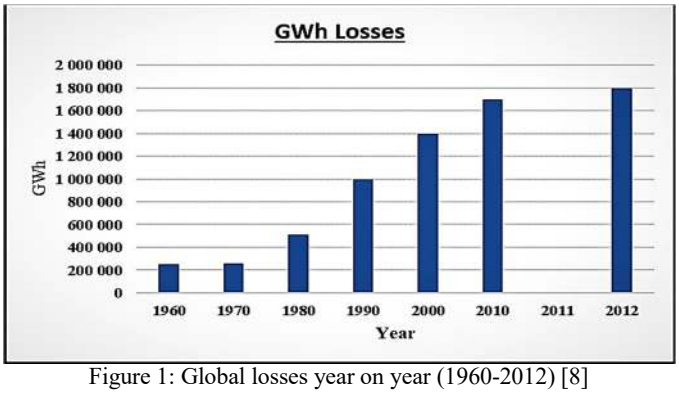

Figure 1: Global losses year on year (1960-2012) [8]

Figure 2 below [9], illustrates the losses per country and highlights the African continent as one of the regions where NTL's are still significantly ubiquitous. In 2004, it was estimated that in developing countries, the forfeited losses where 15% and that of developing countries were as much as 35% of the generated capacity [3]. However, in 2014, these losses have not diminished and have been on the increase as highlighted in figure 1 above.

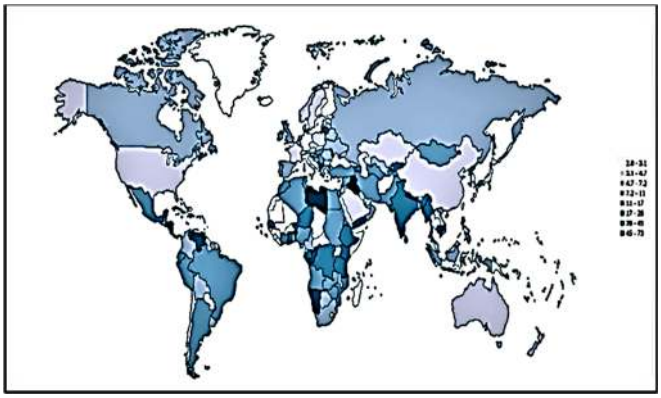

Figure 2: World Losses per country [9]

Literature highlights that Sub-Saharan African utilities present large inefficiencies and in 2009, it was recorded that on average; only 50% of generated electricity supply was paid for [4]. Nigeria contributed the largest portion of these inefficiencies of which only 25% of the generated capacity was paid for, whilst Botswana, considered the best performing utility, recorded losses at 10% [4]. During the same period, the loses reported for South Africa were at 15% [4], and in 2017 these losses were further reported to be in the order of 9.15% as per the Eskom Integrated report for 2018 [10], highlighting a marginal reduction in a period of almost 10 years. In a World Bank, report for 2016 it is

highlighted that out of 39 countries investigated only 19 countries collected enough revenue to sustain operational costs [11]. Figure 3 below highlights the cost recovery for these 39 countries [11].

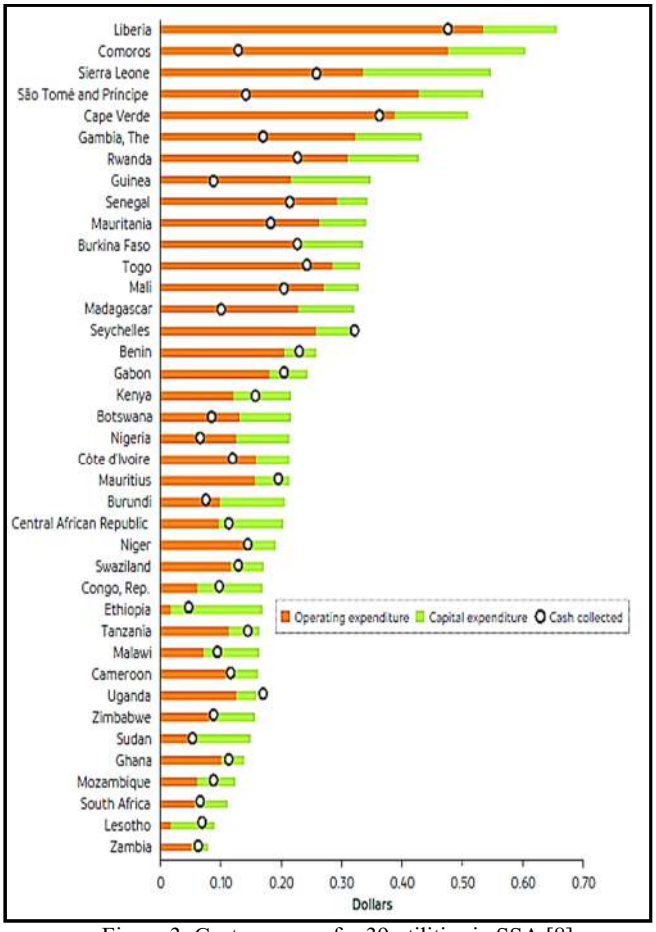

Figure 3: Cost recovery for 39 utilities in SSA [8]

Access to electricity as recorded in 2015 according to the World Bank, is on average 88% [12], and that the sub-Saharan African continent inclusive of some Southern Asian countries still face significant challenges to correct this. Figure 4 (2016) below highlights the global access to electricity and indicates clearly the prevalence of the problem [12]. Energy access in the sub-Saharan African region is still very problematic and it is estimated that only 1 out of 3 people have access to electricity, highlighting that approximately 633 million are still without electricity within this region [11, 13]. The current world demographics for 2018 constitutes a global population of approximately 7.7 billion people with an annual growth rate of 1.09% [14].

The sub-Sharan African continent however, accounts for just over a billion people with a growth rate of 2.66% down from 2.75% in 2015. This growth rate still signifies a higher rate than that of global trends and it is considered the fastest growing population in the world [15].

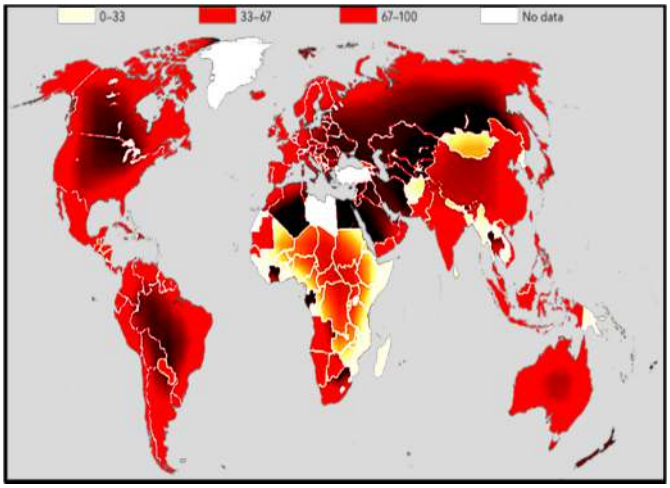

Figure 4: Global access to electricity (2016) [12]

According to [13, 11], the 633 million people without access to electricity in the sub-Saharan African region will increase to 823 million people by 2030, this due to the current population growth. With this population rate in mind and compared to the rate of infrastructure development and electrification, it is argued that the status quo will remain the same. Post 2030, this latter comparison is however expected to start correcting by 2040 due to renewed initiatives employed by utilities and governments worldwide.

In regions where electricity generation is largely dependent on fossil-fuels high losses tend to contribute to high greenhouse gas emissions [4]. Significant health risks due to poor breathing air, climate change, threat to food security, sea-level rise, floods and drought and diseases are all derivatives of the effect of burning fossil fuels in power plants [13]. The environmental impact because of these losses are significant and worth mentioning in this paper. It is estimated that the losses of 1.4 trillion kW/h represent carbon dioxide emissions of 1.2 trillion metric tons [7]. It is further suggested that by employing initiatives to reduce these emissions by 33% would yield a reduction in required capacity of 53 gigawatts [7]. This suggested reduced capacity is more than half of the total generated capacity of approximately 90 gigawatts in the sub-Sharan African region with more than half of this generated capacity found within South Africa [16].

As highlighted the largest portion of NTL are attributed to electricity theft. This phenomenon was first recorded in the *"Daily Yellowstone Journal of March 1886-People who steal Edison's electricity"* [17]. The act of electricity theft is generally attributed to the result of no or inadequate infrastructure, poor service delivery, high electricity tariffs and high unemployment [3, 18]. These illicit actions exacerbate the poor revenue collection initiatives within utilities and collectively affect the economy and the environment. It is furthermore recorded to be the third most stolen item, in comparison to motor vehicle and credit card theft [2]. Figure 5 below highlights the global perspective on where these illicit actions are prevalent [19]. From figure 5 below a clear comparison is drawn between developed and developing countries and seems to suggest that this phenomenon mostly occurs within developing countries.

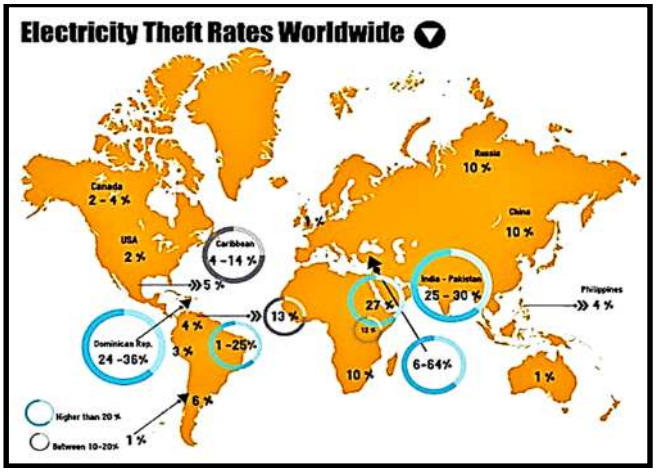

Figure 5: Electricity theft rates worldwide [19]

III. A SOUTH AFRICAN PERSPECTIVE

A. Losses in South Africa-The economic Impact

Eskom, a state-owned enterprise and the largest electricity utility in the sub-Sharan African region, with an estimated generating capacity of 45.5GW, reports in their integrated report for 2018 that a total of 215.91TWh net energy was produced and 212.19TWh sold to its approximately 6.3 million customers [10]. The report further highlights that approximately 21.09TWh was lost which was attributed to technical and other losses and further shows that 496GWh was unaccounted for. From the figures presented then, it is thus deduced that the utility suffered total approximate losses of 21.5TWh, concluding total approximate losses of 10% of the delivered capacity. The Eskom rate per kWh as reported by Fin24 for 2018 [20], was at 89.13c/kWh. In highlighting the financial impact suffered by the utility, these losses on average would equate to approximately R19.1 billion annually in real terms or alternatively approximately R54 million rand per day. The significance of these losses highlights financial losses to the South African economy of approximately 0.4% of GDP (Gross Domestic Product) for 2018. These losses, which must be redressed, are then generically mitigated for through tariff increases exposing the already burdened economically active society and businesses to undue further tariff increases. Eskom states that these NTL's are mostly directly attributed to electricity theft and that it is not only contained to "townships" and occurs across all sectors of society [21]. The impact of these losses further exacerbates the fact that government now faces increasing difficulty to provide resources from the fiscus to employ allocated infrastructure funds to address backlogs in service delivery.

According to statistics South Africa [22], 58% of electricity distributed in South Africa is done by Eskom and the remainder 42% delivered by approximately 257 municipalities within South Africa. These municipalities which act as intermediaries between Eskom and the end user generated R22.5 billion in revenue from the sale of electricity between January and March for 2017 [23], and during the first quarter ending June 2018 this figure grew to R24.9 billion [24], thus an increase of 11% year on year. These municipalities apply higher tariffs to that of Eskom in order to attract profits from the sale of electricity. In fact, municipalities are much more reliant on the sale of electricity as this accounts for the largest part of their budget requirements, which in some cases accounts for than 40% of their budgeted revenue requirements [25]. Figure 6 below [22], highlights first quarter revenue collection for municipalities of South Africa.

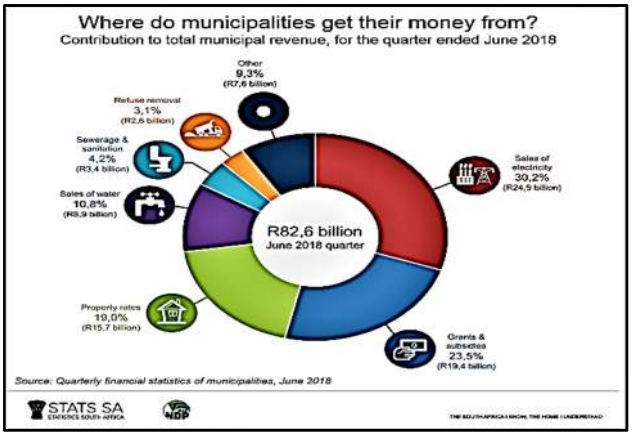

Figure 6: Municipality revenue from electricity sales [22]

As these municipalities are highly dependent of the sale of electricity to satisfy budget requirements, so too are they exposed to the proliferation of NTL's in the form of electricity theft and the provision of *Gratis* electricity. *Gratis* electricity *ceteris paribus* will also now contribute to increased NTL as the electrification programs in South Africa are realized. It is argued that improved access to electricity in communities where consumers cannot afford to pay for such services will increase NTL's and will now become the burden of the paying consumer through tariff increases and taxes. Although municipalities generate substantial revenue form electricity sales (on average 30.2%), the cost of procuring this electricity is also highlighted as the second largest expense (20.6%) next to employee costs (27.2%) [26]. With the prevalence on NTL's and the culture of non-payment amongst communities and businesses, these municipalities are currently exposed to defaulting on payments to Eskom, thus also now forced to address significant tariff increases and in so doing just creating further disruptions and constraints to the South African economy [27]. IOL News [28] highlights this where this debt is significant to the South African economy, as the current outstanding debt to Eskom is proportioned at R28 billion, escalating at R1 billion rand a month.

B. Contributing factors to electrcity theft and non-payment

It has been reported in literature [29] that Eskom on average, suffered NTL of approximately 7%, pre 2014. However, Eskom reports [30], that NTL have been reduced to 6.43% in 2016. Based on the losses presented in the latter, it would then suggest that more than 60% of the total losses suffered by Eskom still amount to values larger than R11 billion annually. The factors contributing to the theft of electricity and the culture on non-payment in South Africa are attributed to the following elements found within this environment. They are, access to electricity, the socio-economic situation, high tariffs and non-payment culture, corruption, poor service delivery and the implementation of

legislation [31, 18]. These various elements will be highlighted and unpacked for further discussion below.

According to Statistics South Africa, general household survey for 2018 [32], access to electricity improved from 76.7% in 2002 to 84.7% in 2018. Eskom reports however in an IOL News publication [33], that access to electricity improved from 36% in 1994 to 90% in 2018. The report further highlights that only 80% of the population living in rural communities currently have access to electricity. The informal urban settlements which constitutes approximately 10% of the population still presents challenges in terms of the provision of electricity and it is argued that that due to these challenges and the slow pace of delivery, illegal connections are prevalent [18]. Therefore, access to electricity still presents a challenge to utilities and communities and allows the perpetuating of illegally connections to the existing power grid [5, 3, 18].

The socio-economic situation presents itself as direct consequence of the current high unemployment rates found within South Africa. The current employment rate according to Statistics South Africa is at a record high of 27.6% for 2019, 0.5% higher than indicated in the previous year within the same time period [34]. With the population in dire need of employment, migratory patterns occur between the nine provinces found within South Africa. Gauteng the smallest province in South Africa produces approximately 35% of the South African GDP [35], and therefore is perceived as an attractive economic haven. The result of these migratory patterns places severe strain on the current infrastructure and the ability of government to provide access to the basic human right needs of water, sanitation and electricity timeously.

Although the Gauteng and KwaZulu-Natal provinces represent the highest population percentages comparatively [36], the geographical areas are substantially different, with the Gauteng province approximately 5 times smaller than KZN, and thus the population densities are aggravated [36]. Figure 7 below [36], highlights the population densities per province. This situation now present informal settlements developing within the outskirts of the urban areas and as basic services are not available. The population now move to take matters into their own hands to ensure access to electricity by connecting illegally to nearby power grid infrastructure.

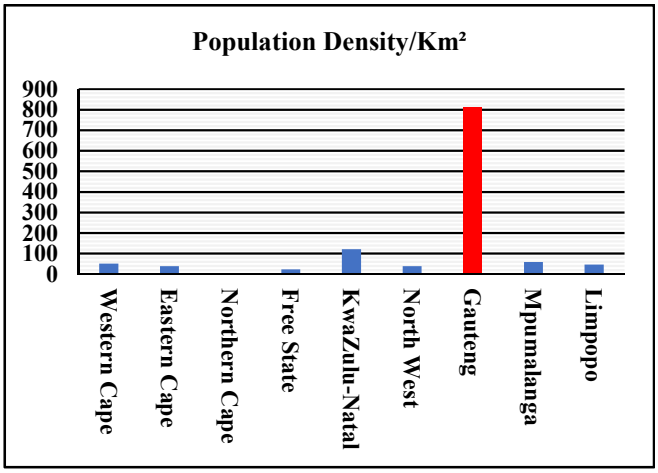

Figure 7: Density population per province [36]

High tariffs compound the effect off the NTL as the economically active population start finding it difficult to pay for these services due to affordability. The non-payment culture phenomenon cannot be viewed myopically and in isolation and must therefore be viewed from a collective economic perspective. Due to the current economic situation presented in South Africa the affordability issue is exacerbated by high taxes, population debt levels, food costs, transport costs, just to name a few. It is recorded by statistics South Africa that out of almost 58 million people [37], only 16.4 million people in the population (working age from 15-64 years old) are employed and that 6.2 million people are unemployed [38]. To indicate the disparity in terms of tax revenue collection from the 16.4 million people that are employed, R1216.5 billion rand was collected for 2018 and grew by 8.7% (R37bn) from the previous year [39]. Personal income tax was the largest component and amounted to 38.1% of the total revenue collected followed by VAT (value added tax) which amounted to 24.5% and further companies' tax of 18.1% [39]. Further statistics presented by the South African Revenue Services [39], highlights that only approximately 4.9 million people (30% of the working population) was subject to personal income tax. It is evident from this that almost R465 million was collected from 4.9 million out of a population of 58 million people through taxable income. VAT, on the other hand, affected the population employed and non-employed alike. From this, a clear picture is presented as to the burden the economic pressures places on the population from a taxation perspective, notwithstanding the effect of the population individual debt levels with high interest rates, as well as food and transport costs. This collective economic perspective thus suggests the increased prevalence of electricity theft and a non-payment culture,

Corruption plays a significant part in the poor administration of revenue collection. This is attributed to utility employees who connect electricity for communities illegally for personal financial gain [18], as well as extort monies from non-paying consumers who have connected illegally to the power grid and who face arrest and prosecution. These illicit actions are highlighted in an exclusive interview presented by an Eye Witness News (EWN) report in 2019 [40], where an Eskom employee revealed that more than half of Eskom employees are part of this connivance.

Poor service delivery is highlighted in a study conducted in KwaXimba KZN [18], where it was cited that poor service delivery was earmarked as the second largest reason for electricity theft following economic conditions. Poor service delivery also attracts violence, protests and destruction of property as reported by [41], where illegal connections (done due to poor service delivery) are removed by utilities, therefore rallying the communities into disruptive and dangerous behavior.

Although South African legislation, historically, only covered illegal connections through municipal bylaw's and meter tampering by virtue of fraud convictions, the prosecution rate was not deemed effective enough and therefore allowed these illicit acts to continue. In 2015, South Africa introduced the *"Crime Matters Amendment Act"* (Act 85 of 2015) to address infrastructure crime

related incidents as well as to mitigate tampering on the networks [42]. This prosecuting tool has been employed but has had some difficulty in gaining traction in the implementation thereof by the South African Police Services. This is evident from *"Operation Khanyisa",* an awareness campaign initiated by Eskom in 2010 [43], where it is recorded in 2016 that although *"96% of South Africans knew electricity theft was wrong only 16% believed that they would get caught. A further 14% believed they would get prosecuted if caught".* This perception clearly highlights the effect current policing and legislation have on the population who partake in these illegal activities.

C. Health, Safety and Enviromental Impact

South Africa is understood to be the 14th largest emitter of greenhouse gasses (GHG) with an emission per capita benchmarked at 9.5 tonnes of carbon dioxide (CO_2) equivalent (tCO_2e) [44]. Although this represents less than half of that of the US, it is still well above the world average of $6.8tCO_2e$ [44]. The reason for South Africa's high emission statistics is due to its reliance on fossil fuels, especially coal to generate electricity. According to statistics South Africa [45], 88% of its electricity is generated by coal-fired power stations with coal reserves lasting for up to 256 years (as at 2014). The production of electricity using coal is still considered the least cost benefit and will therefore still be used as the primary electricity delivery mechanism for the foreseeable future. Although South Africa have embarked on alternative strategies in the form of renewable energies, more can be done in the reduction of GHG through the reduction of NTL's. It is argued that by reducing NTL's less coal will be burnt and thus reduce the greenhouse gas emissions.

Electricity theft contributes to serious health and safety concerns within communities where these illicit actions occur. The consequences of these actions do not just expose the individuals connecting illegally to electrocution, but more so the innocent community members such as children who are exposed to these illegal connections [18]. In 2016/2017 Eskom reported that at least 50 South African were killed nationwide due to illegal connections with a further 150 others injured [46]. Intervention in mitigating NTL's should therefore be prioritized not just to address the financial benefits in terms of revenue improvement, but due consideration should be afforded to the environmental aspects and more importantly the safety consideration of communities.

D. What can to be done to ameliorate NTL in South Africa

Deployment of SMART Technologies with intelligent data management algorithms in households and businesses should be the primary implementation strategy to address immediate revenue and cash-flow improvement. This will allow for more controlled mechanisms in the detection of NTL's at the customer point of supply (PoS). This strategy however, will still present some challenges to the *"backbone"* electrical infrastructure since SMART technologies deployed in households will only detect theft and tampering at the PoS. Illegal connections detection on the *"backbone"* infrastructure should therefore then be mitigated by suitable intelligent technologies to detect pilferage on the main infrastructure supply. It is also suggested that in areas where the cost to electrify out ways the revenue generated due consideration should be given to off-grid supply with the aid of renewable energy mini-plants. Although South Africa employs its "*Universal Access Program"* as part of its Integrated National Electricity Plan (INEP) more should be done to provide access of electricity to all at affordable tariffs. The use of adopted legislation and effective policing to address electricity theft should be based on a zero-tolerance approach and duly promulgated. Consideration should be afforded to the input costs (i.e. NTL) in the establishment of electricity tariffs and it is argued that NERSA should implement strategies to hold Eskom and municipalities accountable for the management of NTL's.

IV. COMPARITIVE ANALYSIS

Table I below is provided for comparative representation. Recorded NTL's for South Africa are benchmarked at approximately 7% annually, which in financial terms translates to approximately $95 million. Compared to global trends this represent approximately 0.1% of overall global NTL's, however, still represents a significant impact on the South African economy. Global access to electricity as highlighted by World Bank statistics is defined as 88% for 2015 [12], and that of South Africa highlighted to be 84.7% for 2018 [32]. Electricity theft in South Africa is recorded to be in the order of 10% according to [19].From a global perspective the average electricity theft statistics are difficult to quantify due its heterogeneous nature. However, with South Africa representing 10% on average in comparison to developed countries (where NTL are between 1 and 5%) and in developing countries (where it can be as much as 50%) still seems to suggest that the figure presented is considered above the accepted norm. The global GDP as cited by KNOEMA was in the order of $84.8 trillion for 2018 [47]. With recorded global financial losses at approximately $96 billion [2], the global percentage loss of GDP yielded 0.113% and in comparison, the South African ratio translates into 0.4%, higher than the global norm. With a global population of 7.7 billion people [14], and the global financial losses at approximately $96 billion [2], the financial loss per capita is calculated based on the fraction of financial losses to the respective population data and highlights that South Africa presents statistics of approximately 13% compared to that of global trends. This suggest that financial losses suffered in South Africa because of NTL are significant in the comparative context. The percentage of NTL as compared to the overall losses in the South African context is tabled at approximately 7%, however the comparative losses from a global perspective (i.e.1.4TkWh out of 20TkWh) represent on average 7%. This seems to suggest that South Africa is on par with the global trend. Finally, the significance of the South African fossil-fuel electricity production policy is highlighted in the tonnes per CO_2 equivalent. The South African statistics are recorded as $9.5tCO_2e$ compared to the global trend of $6.8tCO_2e$ [44]. This highlights the environmental concern South Africa is faced compared to global trends. This comparative data suggest that South Africa is approximately 40% higher in CO_2 emissions as a

direct consequence of electricity generation by virtue of coal-fired power stations.

TABLE I-COMPARITIVE TABLE

Item	South Africa	Global
Financial Losses (NTL)	≈ $95m	≈ $96bn
Access to Electricity	84.7%	88%
% Electricity Theft	10%	≈ 1 to 50%
% Losses to GDP (USD)	0.4%	0.113%
NTL Financial Losses per Capita (USD)	≈ 1.66	≈ 12.5
% NTL of Total Losses	≈ 7%	≈ 7%
%CO2 Emissions	9.5tCO2e	6.8tCO2e

V. CONCLUSION

Total losses suffered by the South African economy in terms of generated electricity supply is in the order of 10%. This translates into approximately $1.4 billion in revenue losses annually compared to approximate world losses of $96 billion. These losses of $1.4 billion reflect approximately 0.4% of the South African GDP compared to 0.113% of world GDP losses and suggests a ratio of 3.5 times higher than global GDP. South African non-technical losses (as part of the overall loss equation) represents 7% of the total losses and in real revenue terms highlights these losses to be in approximately $95 million (R1.4bn) annually. Access to electricity in South Africa is benchmarked at almost 85% , still presenting a challenge in rural communities, however the largest catalyst for electricity theft is related to affordability and lends to economic migration patterns where the population migrates between provinces to seek employment, and therefore informal household dwellings are realized, perpetuating illegal connections and electricity theft. In an ailing economy with high tax burdens, high fuel costs, high electricity tariffs and a high unemployment rate the culture of electricity theft and non-payment is prevalent. These illicit actions further compound the problem in terms of health and safety in communities and greenhouse gas emissions for the country. It is therefore imperative that South Africa address this problem as a matter of urgency. The accomplishment of the mitigating strategy should address a collective outlook on how electricity is generated, distributed and sold to the end user. As part of the strategy legislation and the implementation thereof needs to be enforced with a zero-tolerance approach to create a law-abiding culture, which is currently lacking. Furthermore, the strategy must include job creation and the timeous completion of affordable electricity access to all, with the provision of improving the policy on *"Free Basic Electricity"* and address non-technical system losses through innovative means in order to reduce the cost of producing electricity, therefore improving tariffs to the consumer. It is suggested that the South African electricity regulator (NERSA) consider more stringent mechanisms for non-technical loss mitigation, which might include punitive and reward programs for loss management improvement.

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