

Smart Solar Street Lighting Systems for Resilient Urban Infrastructure: An Industrial Engineering Approach to Cape Town's Energy Security

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Abstract

South Africa's persistent load-shedding crisis, ageing electricity infrastructure, and rising tariffs necessitate sustainable alternatives for public lighting. This study presents a comprehensive techno-economic assessment of solar-powered street lighting systems in the Cape Town Metropolitan Area, focusing on optimising system design, evaluating economic viability, quantifying energy savings, and assessing technical suitability under local climatic conditions. Using quantitative data collection, DIALux lighting simulation, NASA climatology data, and financial modelling, the research evaluates the feasibility of replacing conventional 250W High-Pressure Sodium (HPS) streetlights with 174W solar-powered LED systems. The proposed configuration achieves 60.38% energy savings while complying with SANS 10098-1 public lighting standards. Economic analysis demonstrates strong feasibility, with an internal rate of return (IRR) of 15.51%, a net present

value (NPV) of R18.7 million, and a discounted payback period of 5.73 years over a 20-year assessment period. Sensitivity analysis confirms project robustness under varying electricity tariff escalation and battery pricing scenarios. The findings confirm that solar-powered LED street lighting is both technically viable and financially attractive, providing a resilient infrastructure solution that enhances urban energy security, reduces municipal electricity costs, and supports South Africa's renewable energy transition.

Keywords

Solar Street Lighting, Techno-Economic Assessment, Energy Security, LED Lighting, Renewable Energy

1. Introduction

South Africa faces an unprecedented energy crisis characterised by ageing coal-fired power infrastructure, frequent load-shedding, and rising electricity tariffs. The monopolistic national utility, Eskom, accounts for 95% of power generation, with coal contributing approximately 90% of electricity supply (Akinbami et al. 2021). This reliance on fossil fuels positions South Africa among the world's top ten greenhouse gas emitters, creating urgent imperatives for sustainable energy alternatives. Public lighting constitutes a substantial portion of municipal energy consumption. In Cape Town, street lighting accounts for 14% of the city's electricity usage, with over 120,000 luminaires ranging from High-Pressure Sodium (HPS), mercury vapour, metal halide, compact fluorescent lamps, and light-emitting diodes (LEDs) (City of Cape Town Open Data Portal 2023). The city's population has grown 29.31% between 2001 and 2011 and a further 27.23% from 2011 to 2021 (Western Cape Government 2021), placing increasing demands on public lighting infrastructure. Despite growing recognition of solar energy as a viable alternative, a significant gap remains in understanding the economic feasibility, technical viability, and potential societal impact of integrating solar powered lighting at scale in urban settings such as Cape Town. Decision-makers lack comprehensive, location-specific data on optimal system architectures, cost-effective comparisons with conventional grid-powered lighting, energy consumption patterns, and technical feasibility under Cape Town's unique Mediterranean-type climate characterised by winter rainfall and dry summers.

2. Literature Review

A solar-powered street lighting system comprises several interconnected subsystems: solar photovoltaic (PV) panels for energy generation, batteries for energy storage, charge controllers for power management, LED drivers for load regulation, and luminaires for light output. The two dominant silicon-based technologies are monocrystalline and polycrystalline panels, constituting over 95% of installed capacity (Asrori et al. 2020). Monocrystalline panels demonstrate superior efficiency in low-temperature, low-radiation conditions (below 500W/m²), while polycrystalline variants perform better in high-radiation, high-temperature environments (Benghanem et al. 2023). For Cape Town's climate, monocrystalline panels are recommended. Battery technology significantly influences system performance and economics. Lithium-ion batteries, particularly Lithium Iron Phosphate (LiFePO₄), offer superior characteristics including higher energy density (150-250 Wh/kg versus 30-40 Wh/kg for lead-acid), longer cycle life (1200-3200 cycles versus 500-800 cycles), and better cycle efficiency (80-90% versus 20-90%) (Dhundhara et al. 2018; Yoomak and Ngaopitakkul 2019). Despite higher capital costs, lithium-ion batteries are preferred for solar street lighting applications. Maximum Power Point Tracking (MPPT) controllers outperform Pulse Width Modulation (PWM) variants, achieving 93-98% efficiency through dynamic tracking of the solar panel's maximum power point (Majaw et al. 2018). MPPT controllers enable flexible system design and enhanced energy harvest, particularly in variable weather conditions. LEDs have revolutionised street lighting with luminous efficacy improvements to current levels exceeding 200 lm/W (Fryc and Listowski, 2025). LEDs offer superior colour rendering index (CRI > 80), instant on/off capability, dimmability, and operational lifetimes exceeding 50,000 hours which is way superior than conventional lighting (Fryc and Listowski, 2025).

Solar panel output peaks at 25°C, with temperature deviations reducing performance in accordance with manufacturer specifications (Mahmood and Majeed 2022). Cell temperature (T_{cell}) can be modelled as $T_{cell} = T_{NOCT} + (T_{amb} - T_{amb_{NOCT}}) \times (G/G_{NOCT})$, where T_{amb} is ambient temperature, G is solar irradiance (W/m²), and NOCT is nominal operating cell temperature (Filho et al. 2025).

Dust accumulation significantly reduces PV efficiency through limited sunlight penetration (Salamah et al. 2022). Said et al. (2026) identified wind, humidity, air pollution, and site characteristics as key factors influencing soiling rates. Regular cleaning is essential for maintaining performance (Kalam et al. 2020). Optimal tilt angle approximates site latitude, with Hertzog and Swart (2018) recommending latitude $\pm 10^\circ$ for South African conditions. In the southern hemisphere, panels should face due north.

Payback period findings vary significantly across geographical contexts. Al-Kurdia et al. (2015) reported 3.15 years for solar-powered LED lighting in Jordan, whilst Katyara et al. (2018) observed 5.384 years in Pakistan. Energy savings of 35-50% have been documented in Angola and Jordan (Orejon-Sanchez et al. 2021; Al-Kurdia et al. 2015). However, Karmiathi et al. (2018) reported negative NPV in Indonesia, highlighting the importance of location-specific analysis. The existing literature reveals significant gaps: limited studies in Southern African urban contexts, insufficient integration of lighting simulation into solar PV design, a lack of standardised economic assessment frameworks, and inadequate consideration of site-specific meteorological conditions. This research addresses these gaps through a comprehensive techno-economic assessment tailored to Cape Town's unique characteristics.

3. Methods

3.1 Research Design

Figure 1 illustrates the five-phase research methodology employed to evaluate smart solar street lighting for Cape Town. The framework progresses sequentially from literature review (establishing theoretical foundations and research gaps) through data collection (manufacturer specifications, NASA solar data, Eskom tariffs) to lighting simulation (DIALux modeling for 1km dual carriageway, SANS10098-1 compliance, 43m pole spacing optimisation).



Figure 1. Adopted methodology structure diagram

System design (Phase 4) engineers component integration: 520Wp monocrystalline panels, 24V 100Ah LiFePO₄ batteries (22% redundancy), MPPT controllers (20A, 97% efficiency), and adaptive dimming (100%/70%/50%/100%), achieving 18.3% energy reduction. Economic analysis (Phase 5) applies 20-year discounted cash flow (NPV: R18.7M, IRR: 15.51%, payback: 5.73 years) with sensitivity analysis (8%–13.12% tariff scenarios). The iterative refinement loop ensures simulation results inform design adjustments, balancing technical performance, financial viability, and resilience for industrial engineering decision-making.

3.2 Lighting Simulation

DIALux simulation software was utilised to model lighting performance for a 1km dual carriageway (two lanes per side, 3.7m lane width, 1.5m median) representing typical Cape Town arterial roads. Input parameters included mounting height (10m), boom tilt angle (10°), light overhang (1.5m), and maintenance factor (0.80), per SANS10098- 1 and EN13201:2015. The Philips BRP384 LED 320/757 174W DM A5 luminaire was selected to replace conventional 250W HPS lamps.

3.3 Solar Resource Assessment

NASA online platform provided climatological data for Cape Town coordinates (-33.89°S, 18.53°E). Monthly averaged irradiation values were obtained, with the lowest irradiation month (June, 4.05 kWh/m²/day) used as the design basis to ensure year-round system reliability.

3.4 System Sizing

Daily Energy Requirement: With dimming profile (100% 6-10 pm, 70% 10 pm-2 am, 50% 2-4 am, 100% 4-6 am) for 12-hour nightly operation:

$$E_{\text{daily}} = (174W \times 100\% \times 4h) + (174W \times 70\% \times 4h) + (174W \times 50\% \times 2h) + (174W \times 100\% \times 2h) = 1705.2Wh \quad (1)$$

Solar PV Sizing:

$$W_{\text{peak}} = E_{\text{daily}} / (\eta_{\text{battery}} \times \eta_{\text{controller}} \times PSH \times MF) = 1705.2 / (0.995 \times 0.97 \times 4.05 \times 0.85) = 513Wp \quad (2)$$

Selected: 520Wp monocrystalline panel (2 per pole)

Battery Sizing:

$$C_{\text{battery}} = E_{\text{daily}} \times N / (V_s \times DoD \times \eta_{\text{output}}) = 1705 \times 1 / (24V \times 0.9 \times 0.97 \times 0.995) = 82Ah \quad (3)$$

Selected: 24V 100Ah LiFePO₄ battery (2 per pole).

Charge Controller:

MPPT type with integrated LED driver, 20A capacity, 97% efficiency

3.5 Economic Analysis Framework

Financial metrics calculated include Net Present Value (NPV), Internal Rate of Return (IRR), and Discounted Payback Period. Key assumptions are shown in Table 1 below.

Table 1. Key modelling assumptions

Assessment period (years)		20 years
Discount rate (%)		8.25%
Electricity tariff escalation (%)		10.56%
Annual Operation and Maintenance costs		2% of capital cost
Installation costs		10% of capital cost
Component Lifespan	LED luminaires	100,000 hours, no replacement
	Batteries	2000 cycles, replaced in years 6,12 and 18
	Controller	Replaced in year 16

3.6 Sensitivity Analysis

Scenario analysis examined variations in electricity tariff escalation (8%, 10%, 10.56% base, 13.12%) and battery pricing (10%, 15%, 20% reduction) to assess economic robustness.

4. Data Collection

This research employed a comprehensive multi-source data collection framework designed to ensure accuracy, reliability, and relevance for the techno-economic assessment of solar-powered street lighting systems in Cape Town. The data collection strategy integrated primary and secondary sources across four key domains: technical specifications, meteorological conditions, economic parameters, and infrastructure characteristics. This multi-faceted approach enabled robust system design, accurate financial modelling, and contextually relevant feasibility analysis.

4.1 Primary Data Sources

Primary technical and cost data were collected directly from manufacturers, suppliers, and distributors operating in the South African market. A systematic survey of available solar lighting components was conducted between September 2023 and March 2024, encompassing:

Solar PV Panels: Technical specifications, including peak power (Wp), efficiency ratings, temperature coefficients, nominal operating cell temperature (NOCT), physical dimensions, and warranty terms, were obtained from datasheets of five major suppliers (ARTsolar, Tenesol, Canadian Solar, JA Solar, and Trina Solar). Pricing data were collected through direct quotations and verified against current market rates from wholesale distributors.

Battery Systems: Lithium Iron Phosphate (LiFePO₄) battery specifications, including nominal voltage, rated capacity (Ah), depth of discharge (DoD), cycle life, operating temperature range, and safety certifications, were compiled from manufacturers including Pylontech, Freedom Won, Blue Nova, and local distributors (Geewiz, Solar Warehouse). Price quotations included battery management system (BMS) integration and warranty conditions.

Charge Controllers and LED Drivers: Maximum Power Point Tracking (MPPT) charge controller specifications, including maximum input voltage/current, conversion efficiency, load control capabilities, and communication protocols, were collected from manufacturers (SRNE, Victron Energy, Morningstar, Steca). Combined charge controller-LED driver units were specifically evaluated for integrated system compatibility.

LED Luminaires: Comprehensive photometric data for LED street lighting luminaires were obtained from Philips Lighting, BEKA Schröder, and Regent Lighting Solutions. Key parameters collected included luminous flux (lumens), luminous efficacy (lm/W), correlated colour temperature (CCT), colour rendering index (CRI), beam angle distribution, ingress protection (IP) ratings, and LM80 test reports for lumen maintenance.

Supporting Components: Additional component data collected included solar mounting structures, PV cabling (4mm² specifications), battery enclosures, pole mounting brackets, and surge protection devices. Installation hardware specifications and pricing were obtained from local suppliers and hardware distributors.

Component specifications and pricing were obtained from manufacturer datasheets and supplier quotations (Table 2). Cape Town Open Data Portal provided existing public lighting inventory data. NASA database supplied 30-year climatological data (1980-2009) for solar resource assessment.

Table 2. System Component Costs

Component	Quantity	Unit Cost (R)	Total (R)
BRP384 LED 174W Luminaire	2	3,317.61	6,635.21
520Wp Monocrystalline Panel	2	1,629.55	3,259.10
MPPT Controller with LED Driver	2	1,726.61	3,453.21
25.6V 100Ah LiFePO ₄ Battery	2	9,385.00	18,770.00
4mm ² PV Cable (12.5m)	2	180.00	360.00
Battery Box	2	430.50	861.00
2-Panel Mounting Bracket	1	3,500.00	3,500.00
Total per Pole			36,838.52

5. Results and Discussion

5.1 Lighting Design Results

DIALux simulation confirmed the 174W LED luminaire achieves required illuminance levels with 43m pole-to-pole spacing, compared to 30m for 250W HPS lamps (Table 3). For a 1km stretch, 23 poles (46 luminaires) are required versus 33 poles (66 luminaires) for HPS, representing 30% reduction in infrastructure requirements.

Table 3. Lighting Design Specifications Comparison

Parameter	LED System	HPS System
Luminaire Power	174W	250W
Lumen Output	32,000 lm	30,000-32,000 lm
Luminous Efficacy	183.9 lm/W	120 lm/W
Pole Spacing	43m	30m
Poles per km	23	33
Luminaires per km	46	66
Power Consumption per km	8,004W	16,500W

5.2 Solar Resource Assessment

Cape Town receives average daily irradiation ranging from 4.05 kWh/m² (June) to 7.36 kWh/m² (January) (Table 4). The 4.05 kWh/m² minimum guided system design ensures reliable winter performance.

Table 4. Monthly Averaged Irradiation (kWh/m²/day)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
7.36	7.34	5.73	5.79	4.37	4.05	4.40	4.77	5.83	6.66	7.11	7.21

5.3 Energy Consumption Analysis

With dimming profile implementation, daily energy consumption per luminaire is 1.705 kWh, resulting in annual consumption of 28,630 kWh/km compared to 72,270 kWh/km for HPS—a 60.38% reduction in energy demand.

5.4 Economic Analysis Results

Capital Investment: Total capital cost for 1km installation is R847,286, with installation costs of R84,729 bringing initial outlay to R932,015. Financial Metrics: The project demonstrates strong economic viability (Table 5):

Table 5. Project Feasibility Determination

Metric	Criteria	Value	Discounted Payback Period	Verdict
NPV	>0 = feasible	R18,707,815	5.73 years	Feasible
IRR	>8.25% = feasible	15.51%	5.73 years	Feasible

Figure 2 illustrates the discounted cumulative cash flow trajectory for the 1-kilometre smart solar street lighting installation over the 20-year project lifespan. Positive cash flow begins in year 6, with cumulative savings reaching R3.03 million by year 20. The graph demonstrates three distinct phases of the investment lifecycle:

Initial Investment Phase (Year 0): The project requires an upfront capital outlay of R 932,015, representing the combined costs of 23 pole-mounted smart lighting systems (R 847,286) and installation (R 84,729).

Recovery Phase (Years 1-5.73): During this period, accumulated energy cost savings progressively offset the initial investment. The payback period of 5.73 years—marked by the red data point where the curve crosses the zero line—indicates that the system recovers its capital cost in less than 6 years, or 28.6% of the total assessment period.

Value Generation Phase (Years 6-20): Following payback, the system generates positive cumulative cash flows that escalate exponentially, reaching R 3.03 million by Year 20. This growth reflects the compounding effect of electricity tariff escalation (10.56% annually) and the avoidance of grid-dependent operational costs.

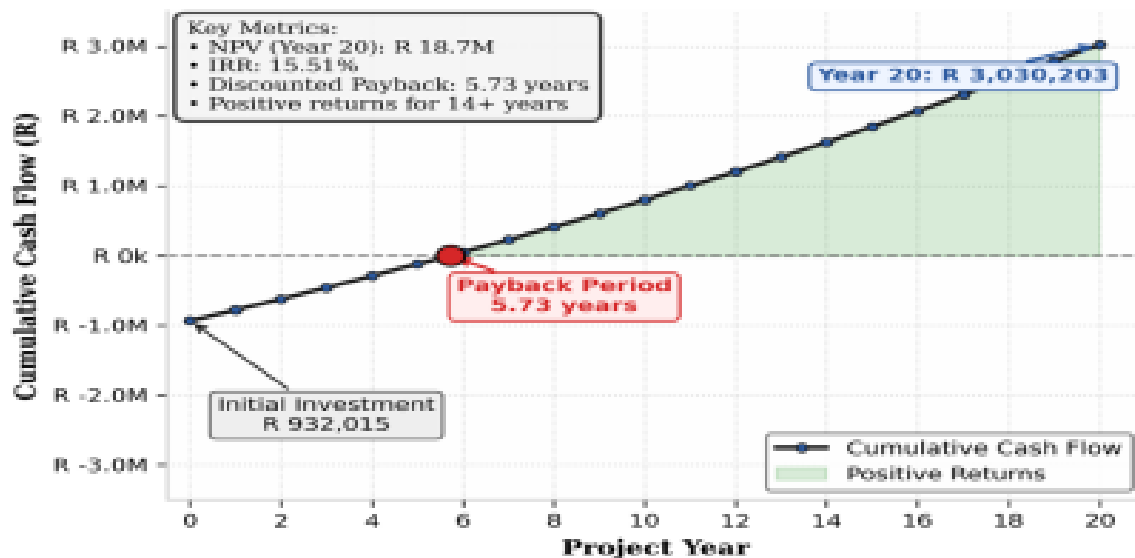


Figure 2. Cumulative Cash Flow over Project Lifespan

The shaded green region highlights the 14+ year positive returns period, during which the investment creates net value for the municipality. The embedded metrics box summarises key financial indicators: NPV of R 18.7 million, IRR of 15.51% (exceeding the 8.25% cost of capital), and the 5.73-year discounted payback period. This financial trajectory demonstrates that smart solar street lighting represents not merely a cost alternative, but a resilient infrastructure investment that generates escalating returns while eliminating load-shedding vulnerability—delivering both economic value and energy security for Cape Town's urban infrastructure.

Figure 3 illustrates the annual energy cost savings trajectory over the 20-year project lifespan, demonstrating how smart solar street lighting generates escalating financial returns through grid independence. Annual savings compound exponentially from R 182,414 (Year 1) to R 1.23 million (Year 20)—a 6.7-fold increase driven by electricity tariff escalation protection.



Figure 3. Annual energy cost savings trajectory

This growth pattern reflects a critical resilience attribute: while conventional grid-dependent systems face volatile, rising electricity costs (historically 10.56% annually in South Africa), the solar system delivers fixed-cost illumination post-deployment. Key milestones include R 272,552 (Year 5), R 450,236 (Year 10), and R 743,756 (Year 15), with total undiscounted savings reaching R 11.1 million—exceeding the initial R 932,015 investment by 12×. The trajectory underscores energy security value beyond conventional metrics. The system functions as a hedge against price volatility, converting unpredictable operational expenditures into predictable capital assets. For industrial engineering, this demonstrates that resilience investments generate time-compounding returns that traditional lifecycle analyses undervalue when focusing solely on static payback rather than dynamic, escalating benefits.

5.5 Sensitivity Analysis

Electricity Tariff Escalation: The project remains viable under all scenarios (Table 6). At 8% escalation (2.56% below base), IRR remains 12.61%—well above the 8.25% discount rate. At 13.12% escalation, IRR increases to 18.28% with payback reduced to 5.41 years.

Table 6. Sensitivity Analysis: Electricity Tariff Escalation

Metric	8%	10%	10.56% (Base)	13.12%
IRR	12.61%	14.89%	15.51%	18.28%
NPV (R)	12,918,362	17,332,537	18,714,675	25,908,317
Payback (years)	6.10	5.80	5.73	5.41

Battery Pricing: Battery cost reductions have a marginal impact on economic metrics (Table 7). A 20% battery price reduction increases IRR from 15.51% to 15.55% and NPV by 0.31%, indicating project robustness.

Table 7. Sensitivity Analysis: Battery Pricing

Metric	Base Case	-10%	-15%	-20%
IRR	15.51%	15.53%	15.54%	15.55%
NPV (R)	18,714,675	18,741,374	18,757,385	18,772,897
Payback (years)	5.73	5.72	5.72	5.73

5.6 Discussion

The results demonstrate that solar-powered LED street lighting is both technically feasible and economically viable in Cape Town. Key findings align with international studies while providing location-specific insights:

Technical Feasibility: DIALux simulation confirms compliance with SANS10098-1 and EN13201:2015 standards. The proposed configuration—520Wp monocrystalline panels, 24V 100Ah LiFePO₄ batteries, MPPT charge controllers with integrated LED drivers, and 174W LED luminaire achieves lighting levels equivalent to 250W HPS while consuming 60.38% less energy, consistent with Zima and Cieplucha's (2023) findings on LED superiority. The dimming profile extends battery life and reduces system costs, supporting Chiradeja et al.'s (2020) recommendations for adaptive lighting control.

Economic Viability: The 5.73-year payback period falls within the 3.15 - 5.9 year range reported in literature (Al-Kurdia et al. 2015); Katyara et al. 2018). The 15.51% IRR significantly exceeds South Africa's 8.25% cost of capital, indicating strong investment potential. A positive NPV of R18.7 million confirms long-term value creation. Rising electricity tariffs (an annual average of 10.56%) enhance relative competitiveness over time.

Sensitivity Analysis: Project viability persists under conservative tariff escalation scenarios (8%), addressing concerns about regulatory uncertainty. Minimal sensitivity to battery pricing reflects the technology's maturity and declining cost trajectory (Statista 2023).

Comparative Advantage: The 43m pole spacing versus 30m for HPS reduces infrastructure requirements by 30%, lowering capital costs and visual impact. This finding supports Yoomak and Ngaopitakkul's (2019) observations on LED distribution efficiency.

Contextual Factors: Cape Town's Mediterranean climate with winter rainfall coinciding with the lowest irradiation (June) necessitates a conservative design based on minimum solar resource. The selection of monocrystalline panels and the 1-day autonomy specification ensure year-round reliability.

5.7 Future work and limitations

The study has several limitations: reliance on simulated rather than measured performance data, assumption of stable component pricing over the assessment period, exclusion of smart grid integration benefits, and focus on technical economic factors without a detailed social impact assessment. Future research should address these limitations through pilot installations and longitudinal studies. Another key limitation is the exclusion of the high risk of theft and vandalism, which threatens the longevity of high-value components such as batteries and PV panels. Future research should investigate design-based strategies, including the technical integration of GPS tracking devices, low-power surveillance cameras, and tamper-resistant enclosures in the luminaire architecture. Furthermore, to mitigate the significant initial capital outlay of R932,015 per kilometre, future studies on innovative business models to preserve municipal cash flow are recommended. In addition, investigating the leasing of pole space for advertising boards offers a promising revenue generating stream; such income could be ring-fenced to ensure timeous operations, maintenance, and deployment of security personnel. Addressing these security and financial dimensions will be critical for transitioning from simulated feasibility to resilient, large-scale urban infrastructure.

6. Conclusion

This research demonstrates that solar-powered street lighting systems offer a technically feasible and economically viable solution to enhance urban energy security in Cape Town. All research objectives were achieved. This study provides the first comprehensive techno-economic assessment of solar street lighting specifically tailored to Cape Town's urban context. Key contributions include: integrating lighting simulation with solar PV design, location.

specific meteorological analysis, robust sensitivity analysis across multiple scenarios, and practical implementation guidance for municipal decision-makers. Municipalities can utilise these findings to justify solar lighting investments through quantified financial returns, optimise system specifications for local conditions, develop procurement frameworks that incorporate lifecycle cost analysis, and integrate solar lighting into broader urban resilience strategies. Recommended areas include pilot implementation with performance monitoring, integration of smart technologies (IoT sensors, remote monitoring, adaptive controls), social impact assessment (crime reduction, community safety perceptions), lifecycle environmental analysis, and innovative financing models (public-private partnerships, carbon credits). The transition to solar-powered street lighting represents a critical opportunity for South African cities to enhance energy security, reduce carbon emissions, and demonstrate leadership in sustainable urban development. This research provides the evidence base for informed decision-making, contributing to the broader discourse on renewable energy integration in African urban contexts.

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Biographies

Silver Takudzwa Machisa holds a Master of Engineering in Engineering Management from the Department of Industrial and Systems Engineering at Cape Peninsula University of Technology (CPUT), Cape Town, South Africa. He is passionate about renewable energy and innovative technologies, with core expertise in energy efficiency, demand-side management, and energy wheeling. His research focuses on resilient infrastructure systems, renewable energy integration, and industrial engineering applications for sustainable urban development. His current research applies systems engineering methodology to optimise smart solar street lighting for urban energy security, combining technical simulation with multi-objective financial modelling. His research interests include distributed energy systems, infrastructure resilience optimisation, and smart city technologies for developing economies. Silver has presented his work at academic forums and is committed to advancing industrial engineering solutions that enhance urban sustainability and energy independence across African cities.

Bingwen Yan is the Head of the Department of Operations Management in the Faculty of Business and Management Sciences at CPUT. He holds a Doctor of Technology in Mechanical Engineering and has played a pivotal role in advancing higher education through his extensive contributions to teaching, learning, and curriculum development. Prof. Yan's research expertise spans industrial engineering, engineering management, operations management, and public administration. His scholarly work is widely recognised, with numerous publications in ISI- and DHET-accredited journals and presentations at reputable international conferences. In addition, Prof. Yan actively contributes to academic quality and research governance through his service on conference organising committees, his role as a peer reviewer for leading journals and conferences, and his work as an evaluator of NRF-funded research projects and grant applications. Prof. Yan is a registered member of the International Council on Systems Engineering (INCOSE) and remains committed to bridging academia and industry through active engagement in community-based initiatives and industrial collaborations.

Rumbidzai Muvunzi is a Senior Lecturer in the School of Mechanical, Industrial & Aeronautical Engineering at the University of the Witwatersrand (WITS), Johannesburg, South Africa. She holds a PhD in Industrial Engineering from Stellenbosch University, where her doctoral research focused on the application of additive manufacturing to improve the efficiency of hot-forming tools. She also holds a Master's degree and a Bachelor's degree in Engineering Sciences. She is a registered Professional Engineer (PrEng) with the Engineering Council of South Africa and a member of the Southern African Institute of Industrial Engineers (OMSIIE). Dr. Muvunzi's research interests span advanced manufacturing technologies, additive manufacturing, simulation and modelling, artificial intelligence and robotics in predictive maintenance, and sustainable manufacturing systems. She has been involved in international research collaborations and has published her work in accredited journals and conference proceedings. She was a recipient of the OWSD PhD Fellowship (2014-2019) and recently received the prestigious Thuthuka research grant (Post-PhD track) from the National Research Foundation (NRF).

Senthil Krishnamurthy is an Associate Professor of Power Systems at CPUT, Cape Town, South Africa, where he holds an Established Researcher NRF C2 Rating. He holds professional registrations as a Professional Engineer (PrEng) and memberships with the South African Institute of Electrical Engineers (SMSAIEEE) and the Institute of Electrical and Electronics Engineers (MIEEE). He serves as the Leader of the Centre for Intelligent Systems and Emerging Technologies (CSIET) and the Centre for Substation Automation and Energy Management Systems. His research expertise spans power systems engineering, intelligent control systems, substation automation, and emerging energy technologies. He has made significant contributions to advancing sustainable energy solutions through his leadership in research centres focused on intelligent systems and energy management. Prof. Krishnamurthy has extensive experience in electrical engineering education and in supervising research. His work integrates theoretical foundations with practical applications in power system modernisation and smart grid technologies. He is actively engaged in research that supports South Africa's energy transition, including renewable energy integration and intelligent energy management systems for industrial and commercial applications.