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Final Report

An Overview of Research on Energy Efficient Lighting in South Africa

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Acronyms

Acronyms	Meaning
AMEU	Association of Municipal Electricity Utilities
CEF	Central Energy Fund
CSIR	Council for Scientific and Industrial Research
DMRE	Department of Mineral Resources and Energy
DSI	Department of Science and Innovation
EEL	energy-efficient lighting
IESSA	Illumination Engineering Society of South Africa
LED	light emitting diode
MEPS	minimum energy performance standard
NDPW	National Department of Public Works
NMISA	National Metrology Institute of South Africa
NRCS	National Regulator for Compulsory Specifications
NRF	National Research Foundation
SABS	South African Bureau of Standards
SAIEE	South African Institute of Electrical Engineers
SANEDI	South African National Energy Development Institute

Content

An Overview of Research on Energy-Efficient Lighting in South Africa

The South African-German Energy Partnership, in collaboration with the South African-German Energy Programme (SAGEN), appointed SMEC South Africa to provide an overview of current energy-efficient lighting (EEL) research being carried out at South African universities and universities of technology, Eskom, public and private research institutions to determine common themes, identify possible gaps that may not be covered and compile a profile of EEL researchers actively working in the field. All of this would converge into recommendations on possible future focal areas for research on EEL in South Africa.

1. Aim of the project

The objective of the project is to provide an overview of the current research on EEL being conducted at South African universities and universities of technology, Eskom, the private sector, and other research organisations, culminating in a list of individuals and groups conducting research on the topic in South Africa. All EEL applications across all sectors have been covered by the research.

This information is required for SANEDI to establish an EEL platform that is envisaged to closely collaborate with the EEL industry and service providers in South Africa and identify additional gaps that may be present in current research.

2. Methodology

To achieve this goal, various data of qualitative nature were collected. The collection process included:

1. Conducting primary research in the form of questionnaires, and
2. Reviewing secondary research from relevant published publications.

The data collected had to be descriptive, and it had to be gathered by making observations based on the collected text. The approach was to preserve the perspective of participants as far as possible.

2.1 Data collection sources – published texts

Existing data selected were in the form of published texts collected from web search engines such as Google Scholar and ScienceDirect. The selection of these materials was refined by using key search terms relating to the goal of the research. Terms such as energy efficiency, lighting, and South Africa were used in addition to others. Exclusion criteria were texts published before 2015, to ensure that the data gathered were relevant and that the research was current.

Other relevant texts in the form of research and other articles were also collected from the archives of key stakeholders that included public sector and research facilities, academic institutions and the private sector (lighting manufacturers and suppliers).

2.2 Data collection process – questionnaires

Participants to answer the questionnaire were found and selected by contacting all key stakeholders mentioned in the section describing the aim of the investigation, and inquiring whether there was currently any research being conducted on EEL technologies.

The research was not limited to the listed parties. Other relevant organisations were also observed during the reviewing of secondary research in published publications, and notes were taken of authors and the institutions they represent. The same was done with regard to the primary research by asking all participants completing the questionnaire to provide the contact details of any peers who are also conducting research in the field. When contacting participants to ask them to complete questionnaires, an appointment letter from GIZ accompanied the questionnaire to highlight the purpose of the investigation and further motivate active participation from the respondents. A total of 95 individuals and organisations were contacted, as described in Appendix B: List of individuals/organisations contacted.

Where published publications were found, SMEC South Africa analysed the list of references to further expand the search. This led to a more complete search for academic papers and key authors. Researchers were contacted mainly via:

- Emails,
- Telephonic discussions, and
- Zoom/MS Teams meetings.

On November 1st and the 22nd, 2021, the final report was circulated to all questionnaire respondents with a request that they should confirm personal information, supply missing data and verify the research findings. Even after providing further opportunity for commentary, report authors received limited edits hence, certain profile photographs, biographies and NRF ratings are not incorporated in the report.

2.3 Data analysis

A thematic analysis was conducted of the selected literature and questionnaire responses. This included:

- Dividing the data into the defined categories of lighting;
- Examining the data to identify patterns and repeating ideas;
- Identifying gaps where no research is being undertaken; and
- Graphically representing the results based on an analysis of the received information.

3. Current EEL research in South Africa

The section below presents summaries of the completed (or partially completed) questionnaires that were returned.

3.1 Public sector and research facilities

The questionnaires received from researchers identified and contacted within this sector are listed in Table 3-1 below.

Table 3-1: List of researchers from public sector and research facilities

Institution	Researcher
ESKOM	André Blignaut
NMISA	Edwin Mofokeng Pieter du Toit
IESSA	Henk Rotman
SAEE Confederation	Thieda Ferreira

André Blignaut
Senior Advisor, Eskom

Biography

André Blignaut is a Senior Advisor at Eskom who has been involved in lighting design since 1986. He is a member of IESSA and is registered as an Accredited Lighting Practitioner. He has been lecturing for Eskom and IESSA since 2015 on all aspects of lighting. A former Development and Membership chairman of IESSA, Andre's area of speciality is lighting design and testing.

Are you currently involved with any research projects pertaining to EEL?

- Daylighting design
- Photometric measurement systems
- Lighting simulation
- Materials/Nanotechnology
- Lifespan, lumen maintenance/L70 (measurement)
- Standardised techniques for lifespan testing/ warranties/standards
- Colour shifts with ageing
- Improvements in energy efficiency
- Emission spectrum

Do you see any gaps where research should be conducted on EEL?

Not answered.

Which sector does your research fall under?

Not answered.

Which category does your research fall under?

Not answered.

To what type of lighting would you classify your research as being most relevant to?

- Retail and commercial
- Stadium/Sports lighting
- Public lighting
- Industrial
- Domestic

Please provide a short description of the focus of your research.

While not being involved in research as such, André specialises in the testing of luminaires for suppliers and manufacturers. He also presents courses to lighting engineers and designers from IESSA and Eskom, with energy efficiency being one of the main topics.

Please provide references to any other researchers/organisations in South Africa in the EEL research field.

Not answered.

Are you collaborating with any international institutions/universities?

Not answered.

Please provide a list of all recent (from 2015) published papers or articles of which you are an author.

- Light Output of 50 mm Diameter Light-Emitting Diode and Quartz Halogen Reflector Lamp Comparison.
- Mercury treatment techniques for compact fluorescent lamps.
- Published three standards for Eskom lighting installation:
    - Security Lighting for Eskom Applications
    - LED Street Lighting for Eskom Properties
    - Generation Power Station Lighting and Small Power Installation Standard

Edwin Mofokeng, Pieter du Toit
Scientists: Photometry and Radiometry, NMISA

Biography: Edwin Mofokeng

Edwin, who has been with NMISA since 2015, specialises in Photometry and Radiometry. A Spectrophotometry, LED radiometry and Photometry, Spectroradiometry and UV radiometry metrologist, Edwin is a convenor of the SABS TC64SC01 LED Working Group and a member of SABS TC64SC01 and SABS TC64SC02.

Biography: Pieter du Toit

Pieter, who has been with NMISA since 2015, specialises in Photometry and Radiometry. An LED radiometry, Spectroradiometry and UV radiometry metrologist, Pieter is the project leader for the maintenance of NMS for Radiometry and Spectroradiometry and NMISA's contact for its EMPIR project relating to the revision of LED standards.

Are you currently involved with any research projects pertaining to EEL?

Not answered.

Do you see any gaps where research should be conducted on EEL?

Not answered.

Which sector does your research fall under?

Not answered.

Which category does your research fall under?

- Photometric measurement systems
- Lifespan, lumen maintenance/L70 (measurement)
- Standardised techniques for lifespan testing/ warranties/standards
- Colour shifts with ageing
- LED chips
- Emission spectrum
- Uncertainty in photometric and electrical measurements
- Revision of standards for LED device testing (EMPIR)

To what type of lighting application would you classify your research as being most relevant to?

Energy-efficiency testing of all lighting and design of a stable, temperature-stabilised, current-controlled verification standard for industry.

Please provide a short description of the focus of your research.

Photometric and energy-efficiency measurements:

Development and maintenance of national measurement standard/facility for LED lighting, validated internationally. Development of measurement methods for accurate photometric and energy-efficiency testing of LED luminaires.

Potential impacts:

Expanding national testing/calibration capability and enabling adherence to legislation. Revised standards on LED measurement methods.

Are you collaborating with any international institutions/universities?

NMISA is currently participating in the EMPIR 19NRM02 project along with European NMIs, testing labs and manufacturers (https://www.ptb.de/empir2020/revstdled/home/).

NMISA is a member of the Consultative Committee for Photometry and Radiometry (CCPR) from the International Bureau for Weights and Measures (BIPM), which consists of internationally recognised scientists in the field from member countries. These scientific advisors are tasked with coordinating activities concerning measurement standards for photometric and radiometric quantities, the development of absolute radiometry and providing advice to the International Committee for Weights and Measures (CIPM) https://www.bipm.org/en/committees/cc/ccpr/

Henk Rotman
Gauteng Branch Chair, IESSA

Biography

Henk Rotman is the Gauteng Business Development Manager for Tridonic. He has also been the Chairperson of the Gauteng Branch of the Illumination Engineering Society of South-Africa (IESSA) since 2017. His passions in lighting are EEL and new lighting technologies. He is originally from the Netherlands, moved to South Africa in 2010 and has worked in various roles in the local lighting industry ever since.

Are you currently involved with any research projects pertaining to EEL?

Not answered.

Do you see any gaps where research should be conducted on EEL?

IESSA does recognise the need for ongoing technical research in the field of EEL, focused on increasing the efficiency of LEDs, drivers, lenses etc. and at the same time reducing the Lm/USD ratio, making EEL more affordable and hence removing one of the barriers to the implementation of EEL.

IESSA feels, however, that the research is already at a high level globally, and one can question whether additional research will yield significant results.

Solid state lighting as a lighting technology has reached a maturity level, enabling it to contribute greatly to the implementation of EEL.

In case additional research is being considered, IESSA would prefer that this research be directed towards market- and marketing-related issues, facilitating and accelerating the implementation of EEL.

According to Henk, IESSA has the impression that no further research is needed concerning the technology/science aspects of EEL, but research is needed concerning the marketing aspect.

"In the year 2006, the International Energy Agency estimated that the lighting share of global electricity consumption was 19%. In 2018, this was estimated to have dropped to 13%, and the IEA has set a target of 8% for 2030. IESSA has the strong perception that end-users and influencers think that by changing from traditional to any LED lighting they contribute to saving energy.

This is correct, but the efficiency of LED lighting is a clear case of good, better, best, with significant differences in efficiency between the various LED-based solutions. To reach the 8% target, the most energy-efficient LED lighting in combination with lighting controls must be used. Based on all this, IESSA suggests marketing research on EEL, focused on answering questions like, 'How to create awareness of differences in efficiency', 'What are roadblocks impeding the implementation of the most energy-efficient solutions, and how can they be removed?' etc. IESSA is available to play a supporting role in the preparation of the above-mentioned marketing research."

Which sector does your research fall under?

Not answered.

Which category does your research fall under?

Lighting components (LED modules and LED drivers).

To what type of lighting applicable would you classify your research as most relevant to?

Not answered.

Please provide references to any other researchers/organisations in South Africa in the EEL research field.

Not answered.

Are you collaborating with any international institutions/universities?

Not answered.

Thieda Ferreira
Secretary-General, SAEE Confederation

Biography

Thieda is the current Secretary-General of the SAEE Confederation. Her current duties at SAEEC includes the running of AGM and Board meetings, the training committee, advisory committee, South African Females in Energy Efficiency (SAFEE) Interest Group, Measurement and Verification Community of South Africa (MVCSA) Interest Group, finance committee as well as bookkeeping and relevant financial reports, company filing management, company documentation control and compliance requirements, international chapter compliance reporting to partners, international and local accreditations.

Are you currently involved with any research projects pertaining to EEL?

No current research into EEL.

Do you see any gaps where research should be conducted on EEL?

While not being involved in research as such, SAEEC Members would like to know the following:

- What's being done to address the disposal of the previous CFL rollouts (>65 million off)?
- How many of these CFL lamps have still not been replaced with LED?
- What percentage of lamps in the residential sector are still not LEDs?
- What is being done to increase awareness of efficient lighting in the residential sector?
- What percentage of lamps being sold in the SA retail market are still incandescent lamps? What is being done to manage this?
- What is the lever of understanding of EEL technology by facility managers and procurement managers?

Which sector does your research fall under?

Not answered.

Which category does your research fall under?

Not answered

To what type of lighting would you classify your research as most relevant to?

Not answered.

Please provide a short description of the focus of your research.

Not answered.

Please provide references to any other researchers/organisations in South Africa in the EEL research field.

Not answered.

Are you collaborating with any international institutions/universities?

Not answered.

What are your recommendations for EEL research?

Not answered.

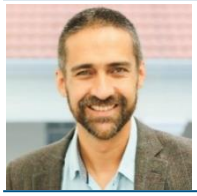
3.2 Academic institutions

The questionnaires received from researchers identified and contacted within this sector are listed in Table 3-2 below.

Table 3-2: List of researchers from academic institutions

Institution	Researcher
Stellenbosch University	MJ (Thinus) Booysen
University of the Free State	HC Swart
Nelson Mandela University	Ernest van Dyk
Central University of Technology	Stephen Tangwe
University of KwaZulu-Natal	Freddie Inambao
University of the Witwatersrand	Alex Quandt
University of Cape Town	Richard Larmour
Tshwane University of Technology	Olawale Popoola
	OD Dintchev
	Giscard Binini
University of South Africa	Mokhotjwa Simon Dhlamini
North-West University	Johan Rens
University of Johannesburg	Arnold de Beer

MJ (Thinus) Booysen
Professor: Department for Electrical & Electronic Engineering, University of Stellenbosch
NRF rating: C



Biography

MJ (Thinus) Booysen is a professor in the Electrical & Electronic Engineering Department at Stellenbosch University. He has been with Stellenbosch University since 2009 and his research is on the Internet of Things, with a focus on Smart Energy, Water and Vehicles (specifically its application to paratransit in Sub-Saharan Africa). He is also a founder of Bridgiot (Bridge-to-the-Internet-of-Things), and co-creator of Geasy and Count Dropula. He is the Director of the MTN Mobile Intelligence Lab and co-founder of the Stellenbosch Smart Mobility Lab. He is a Member of the Institution of Engineering Technology (MIET), a Chartered Engineer (CEng) at the Engineering Council (UK), and a Professional Engineer (PrEng) with the Engineering Council (SA). He has over ten years' international industry experience in the aerospace and automotive industries with companies that include SunSpace, Rolls-Royce, Boeing, BMW, and Jaguar Land Rover.

Are you currently involved with any research projects pertaining to EEL?

Not answered.

Do you see any gaps where research should be conducted on EEL?

Specifically in the power quality/factor, RF interference, Southern Hemispheric sunlight spectrum light quality. Also awareness.

Which sector does your research fall under?

Not answered.

Which category does your research fall under?

- Smart control & Building energy modelling
- Improvements in energy efficiency
- Behaviour change through smart metering and visualisation
- Solar power optimisation through load control

To what type of lighting would you classify your research as being most relevant to?

- Schools
- Public sector
- Renewable energy

Please provide a short description of the focus of your research.

- Energy efficiency in schools and public buildings, including energy efficiency, behaviour change, and renewable sources (http://thinus.co.za/research/schools/)
- Prediction of energy usage and energy modelling/simulation
- Carbon exchange, financial savings at schools, reducing carbon footprints.

Please provide references to any other researchers/organisations in South Africa in the EEL research field.

- Frans Rossouw, OrbitX
- Jason Samuels, GreenX

Are you collaborating with any international institutions/universities?

Yes, Reutlingen University and TU Munich.

What are your recommendations for EEL research?

Not answered.

Hendrik C Swart
Professor of Physics/SARChI chair, University of the Free State
NRF rating: B1

Biography

Hendrik C Swart is a professor of Physics at the University of the Free State. He brought luminescence materials to South Africa in the beginning of 1996 after a highly productive sabbatical spend in the lab of Paul Holloway, Florida University, Gainesville. This laid the foundation for his subsequent research at the UFS and was one of the most exhilarating times of his academic career. His research led to the establishment of a strong group working on luminescent materials and to the establishment of several smaller groups all over South Africa.

Are you currently involved with any research projects pertaining to EEL?

Not answered.

Do you see any gaps where research should be conducted on EEL?

Taking the research done to practical applications.

Which sector does your research fall under?

Not answered.

Which category does your research fall under?

- Materials/Nanotechnology
- Improvements in energy efficiency
- LED chips
- Emission spectrum

To what type of lighting would you classify your research as being most relevant to?

- Domestic
- Phosphors for improving solar cell performance and LEDs

Please provide a short description of the focus of your research.

LEDs and solar cells:

He has led research on the degradation of phosphors for field emission displays, as well as developing materials for nano solid-state lighting. He has been key in the development of processes to synthesise and deposit thin films of various types of semiconductors nanoparticles to enhance the colour, luminescent intensity and lifetime of such displays. He has established a National Nano Surface Characterisation Facility (NNSCF) containing state-of-the-art surface characterisation equipment. A research chair in Solid State Luminescent and Advanced Materials was awarded to him by the South African Research Chairs Initiative (SARChI) at the end of 2012, which was renewed for another five years at the end of 2017. The focus of his research group is the improvement of luminescent materials for applications in flat panel displays, solar cells, solid state lighting, dosimetry, and thermometry.

Potential impacts:

Energy-saving solid state lighting and improvement of solar cell performance

Please provide references to any other researchers/organisations in South Africa in the EEL research field.

- Ernest van Dyk, Nelson Mandela University

Are you collaborating with any international institutions/universities?

Yes, Ghent University, Bucharest University, Nagpure University, etc.

What are your recommendations for EEL research?

Device fabrication in the near future.

Ernest van Dyk
Professor of Physics, Nelson Mandela University
NRF rating: C

NELSON MANDELA UNIVERSITY

Biography

Not provided.

Are you currently involved with any research projects pertaining to EEL?

Not answered.

Do you see any gaps where research should be conducted on EEL?

Not answered.

Which sector does your research fall under?

Not answered.

Which category does your research fall under?

- PV materials and devices
- CPV project involving refractive and reflective light harnessing as applicable to large-area lighting

To what type of lighting would you classify your research as being most relevant to?

Not answered.

Please provide a short description of the focus of your research.

- PV materials, devices and systems
- PV reliability
- PV energy-yield studies

Please provide references to any other researchers/organisations in South Africa in the EEL research field.

- HC Swart, UFS
- Martin Ntwaeaborwa, UJ

Are you collaborating with any international institutions/universities?

Not answered.

What, in your opinion, are the research gaps concerning EEL research in South Africa which is not already mentioned above?

Not answered.

What are your recommendations for EEL research?

Not answered.

Stephen Tangwe
Senior Energy Engineer and Research Fellow, Central University of Technology (Free State)

Biography

Stephen Tangwe (ORCID ID: https://orcid.org/0000-0002-6936-9629 and Scopus Author ID: 56241790900) holds a PhD in engineering and is a chartered engineer and a research fellow. He is a Certified Measurement and Verification Professional and an ad hoc UFH Eskom M&V engineer affiliated with the Institute of Technology, University of Fort Hare. He is a full-time member of the international institution of mechanical engineers and served as volunteer member on the executive board of the institution of mechanical engineers in the southern African region. He is an energy expert and a seasoned reviewer of series in accredited peer review journals.

Are you currently involved with any research projects pertaining to EEL?

Not answered.

Do you see any gaps where research should be conducted on EEL?

Not answered.

Which sector does your research fall under?

Not answered.

Which category does your research fall under?

- Lighting simulation
- Surge protection
- Lifespan, lumen maintenance/L70
- Standardised techniques for lifespan testing/ warranties/standards
- Improvements in energy efficiency
- Smart control

To what type of lighting would you classify your research as being most relevant to?

- Retail and commercial
- Public lighting
- Traffic signals
- Industrial
- Domestic

Please provide a short description of the focus of your research.

Energy savings and lighting quality:

Stephen's research focused on performance monitoring and model development to predict the performance of EEL in the residential, industrial and public sectors.

Potential impacts:

Reduction of energy and cost of electricity

Reduction of carbon footprints, and environmental conservation

Please include/share any other information you think would be valuable for this project.

Creating a network for collaborative research and development on EEL between academic researchers and ESCOs operating in this field.

What, in your opinion, are the research gaps concerning EEL research in South Africa which is not already mentioned above?

Development of a standard methodology to compute savings and mathematical models to predict the techno-economic potentials of EEL technologies.

What are your recommendations for EEL research?

It is worth expanding the research base aspect of EEL research, as the energy savings from this technology are reported without following standard measurement and verification protocols, especially by ESCOs.

Freddie Inambao
Professor: School of Engineering, University of KwaZulu-Natal

Biography

Not provided.

Are you currently involved with any research projects pertaining to EEL?

Not answered.

Do you see any gaps where research should be conducted on EEL?

Not answered.

Which sector does your research fall under?

Not answered.

Which category does your research fall under?

Not answered.

To what type of lighting would you classify your research as being most relevant to?

Not answered.

Please provide a short description of the focus of your research.

- The improvement of health, wellbeing and productivity through the adequate use of lighting.
- Internal lighting that provides an illuminance level appropriate to the tasks undertaken, demonstrated through a lighting design strategy that provides illuminance levels (lux) in accordance with any other relevant standard.
- External lighting that is designed to provide illuminance levels that enable users to perform outdoor visual tasks efficiently and accurately, especially during the night.
- Lighting design concepts: EEL design focuses on methods/principles and materials that improve both the quality and the efficiency of lighting. Freddie's research is also devoted to barriers preventing the adoption of energy-efficiency measures for buildings.
- Future of lighting research: For lighting research to have a future, it is necessary for it to be influential.
- Some expectations to cover: Covering all areas of lighting, including daylighting design; interior and lighting design; lighting energy consumption; lamp, luminaire and lighting system design; photometric measurement systems; lighting simulation; the full range of psychological and physiological responses to lighting conditions; lighting quality.

Please provide references to any other researchers/organisations in South Africa in the EEL research field.

Not answered.

Are you collaborating with any international institutions/universities?

Not answered.

Please include/share any other information you think would be of value in this research.

Advance detailed auditing of lighting for commercial and industrial sectors.

What, in your opinion, are the research gaps concerning EEL research in South Africa which is not already mentioned above?

Not answered.

What are your recommendations for EEL research?

Not answered.

Alex Quandt
Professor of Physics, University of Witwatersrand
NRF rating: B2

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Biography

Alex Quandt is a professor of theoretical solid state physics at the University of the Witwatersrand (Johannesburg). His research comprises theory and materials simulations with the focus on photovoltaics and optics/photonics. He is a focus area coordinator of CoE Strong Materials and deputy director of ARUA CoE Materials, Energy and Nanotechnology.

Do you see any gaps where research should be conducted on EEL?

Research must be intimately linked to renewable energy technologies and run alongside the long overdue implementation of smart power grids.

Which category does your research fall under?

- Materials/Nanotechnology
- Improvements in energy efficiency

To what type of lighting would you classify your research as being most relevant to?

- Retail
- Street lighting
- Traffic signals
- Industrial & Domestic
- Automotive

'Primarily our research is in combination with photovoltaics and energy storage technologies.'

Please provide a short description of the focus of your research.

Simulating energy and optical materials and the development and application of simulation methods for semiconductor devices like solar cells and LEDs. This involves light-conversion technologies based on rare earth ions; the simulation of augmented solar cells featuring photonic crystals, waveguides and plasmonic nanoparticles; and the simulation of energy storage solutions like batteries and supercapacitors.

Focus aspects:

- Device simulations
- Materials simulations
- Theory and numerical studies of light-matter interactions

Potential research impact:

- Identification of new materials and new device features
- Simulation of working devices

Are you collaborating with any international institutions/universities?

Yes. CNR-IFN Trento (Italy), University of Dresden (Germany)

What, in your opinion, are the research gaps concerning EEL research in South Africa which is not already mentioned above?

Some of the solid-state lighting technologies are not very well suited for the dire situation found in countries like SA, where there is load shedding and frequent power outages. In the long run there will be an urgent need for domestic off-grid technologies that combine solid-state lighting with renewable energy production and storage technologies.

What are your recommendations for EEL research?

From an industrial side, there should be a certain focus on developing the local beneficiation industry regarding LEDs and other lighting technologies. South Africa has remarkable mineral resources when it comes to rare earth ions.

Another interesting idea is that parallel to the dissemination of state-of-the-art lighting technologies, there could be a programme to train unskilled workers in the townships to refurbish broken LEDs and other devices, thereby providing them with a possible source of income.

Richard Larmour
Researcher: Department of Electrical Engineering, University of Cape Town

Biography

Richard Larmour holds an MSc. Eng (Energy Studies) from the University of Cape Town, has over 10 years of experience in Energy Efficiency & Demand Side Management, and currently resides in UCT's Department of Electrical Engineering.

Are you currently involved with any research projects pertaining to EEL?

Residential electricity modelling project, undertaken for SANEDI 2020-2021.

Do you see any gaps where research should be conducted on EEL?

Residential sector surveys are required to determine the following across all income groups:

- What stock is in place in terms of quantities and technologies?
- What are the actual hours of usage per technology per income group?

Which sector does your research fall under?

Not answered.

Which category does your research fall under?

- Energy efficiency
- Demand-side management
- Measurement & verification
- Residential electricity consumption

To what type of lighting would you classify your research as being most relevant to?

- Domestic

Please provide a short description of the focus of your research.

Residential electricity consumption. Installed technologies, stocks & lighting hours across income groups. Impacts include refining estimates of residential lighting electrical energy – current and future projected.

Please provide references to any other researchers/organisations in South Africa in the EEL research field.

Not answered.

Are you collaborating with any international institutions/universities?

Not answered.

Please include/share any other information you think would be valuable to this project.

The use of dimmers for existing fittings needs to be reviewed. Also, accelerated development of dimmers for LEDs is needed. From a life cycle and global perspective, the potential for immediate energy savings may be greater than a step change of end-use technology.

What, in your opinion, are the research gaps concerning EEL research in South Africa which is not already mentioned above?

Not answered.

What are your recommendations for EEL research?

Not answered.

Olawale Popoola
Professor: Centre for Energy & Electric Power, Tshwane University of Technology

Tshwane University of Technology
We empower people

Biography

Olawale Popoola is a lecturer and author with diverse experience in the electrical / power industry and education sector. Author and co-author of numerous scientific publications as well as reviewer for different journals, Olawale's research interests include energy management, energy and behaviour, renewable and sustainable energy, the application of power electronics in power systems, and new materials. Furthermore, innovative product development in new materials and load management with the emphasis on proficient operation/utilisation, effective management, affordability, cost savings, etc. are some high points in his career.

Are you currently involved with any research projects pertaining to EEL?

Not answered.

Do you see any gaps where research should be conducted on EEL?

- Lighting profile development with particular reference to computational intelligence (machine learning), based on behavioural tendencies
- The current impact of lighting technologies on buildings and their contribution to indoor environmental quality

Which category does your research fall under?

- Lighting simulation
- New materials/nanotechnology for lighting – new field
- New materials/nanotechnology – power conductors, devices, energy storage etc.
- Smart control (digitalisation/machine learning)

To what type of lighting would you classify your research as being most relevant to?

- Building – Domestic & commercial

Please provide a short description of the focus of your research.

The field of energy and the social science disciplines need to be pooled for better impact in terms of energy management and demand-side initiatives. The research focus includes factors associated with social values and norms to address energy profile development, innovative products for energy management, and the efficient utilisation of renewable systems based on user profiles and activities, addressing implementation challenges associated with the affordability of solar PV systems by households with the emphasis on low-income earners and rural areas. Off-grid stand-alone renewable systems and integration of (hybrid and non-hybrid) architecture for rural area activities.

Lighting aspect focus:

1. Residential lighting load profile: The use of modelling (machine learning) to explore the intricacies associated with lighting usage in relation to dynamic occupancy in a quantitative framework
2. Computational intelligence modelling based on variables interlinked with behavioural tendencies for energy usage profiling

Potential research impact:

Substantiation of the need for natural lighting (daylight), socioeconomics and demographics in load profile development and their inevitable impact on behaviour around energy usage

Are you collaborating with any international institutions/universities?

1. Covenant University, Nigeria
2. University of Nsukka, Nigeria
3. University of Ibadan, Nigeria
4. Nottingham Trent University, Nottingham, United Kingdom (looking forward to joint papers in future)
5. University of Wolverhampton, Wolverhampton, United Kingdom (looking forward to joint papers in future)

OD Dintchev
Professor: Centre for Energy & Electric Power, Tshwane University of Technology

Tshwane University of Technology
We empower people

Biography

O.D. Dintchev is a professor at the Centre for Energy & Electric Power of the Tshwane University of Technology. He is a Certified Energy Manager (CEM), Certifier for Measurement and Verification Leader (CMVP) with extensive energy-related experience of over 40 years.

Are you currently involved with any research projects pertaining to EEL?

Not answered.

Do you see any gaps where research should be conducted on EEL?

There is not enough information and awareness campaigns to educate the South African community. Campaigns should be selective to capture the diverse profiles of the population groups.

Which category does your research fall under?

- Improvements in energy efficiency

To what type of lighting would you classify your research as being most relevant to?

- Retail and commercial
- Public
- Domestic
- Rural/Low-income homes

Please provide a short description of the focus of your research.

R&D activities on the entire process for optimising lighting energy efficiency in buildings in South Africa by involving digital technologies:

- Developing of digital design tools and applications for lighting projects
- Remote monitoring and evaluation of lighting in buildings and other municipal initiatives
- Digitalising and applying of efficient blockchain technologies in the evaluation and capture of carbon credits resulting in energy-efficient innovative building lighting projects.

Please provide references to any other researchers/organisations in South Africa in the EEL research field.

- Prof. EL Meyer, UFH

Are you collaborating with any international institutions/universities?

Yes. College of Engineering and Technology, University of Derby.

Please include/share any other information you think would be valuable to this project.

Prof. Dintchev's R&D is in the areas of the design, monitoring, performance evaluation and capturing of energy & environmental savings resulting from innovative lighting technologies used in buildings. These are based on advanced digitalised and blockchain technologies.

His R&D team believes that this unique approach will lead to the expansion of lighting energy efficiency benefits not only to building owners, but also to the very occupants/people working in the buildings. In this way, the lighting energy efficiency will be everybody's business.

What, in your opinion, are the research gaps concerning EEL research in South Africa which is not already mentioned above?

Not answered.

What are your recommendations for EEL research?

Relevant scientific research, combined with R&D for commercialisation, monitoring and evaluation and with dissemination (inclusive) of the results of innovating, efficient and environment–friendly lighting systems.

Giscard Binini
Engineer: Centre for Energy and Electric Power, Tshwane University of Technology

Tshwane University of Technology
We empower people

Biography

Giscard Binini is an engineer who has been part of the Centre for Energy and Electric Power for the last 10 years, where his contributions are to conduct energy-related research for Eskom, IDM and the DMRE on various energy-efficiency and renewable energy programmes in metropolitan and local municipalities.

Are you currently involved with any research projects pertaining to EEL?

Not answered.

Do you see any gaps where research should be conducted on EEL?

Not answered.

Which sector does your research fall under?

Not answered.

Which category does your research fall under?

- Lighting simulation

To what type of lighting would you classify your research as being most relevant to?

- Retail and commercial
- Public

Please provide a short description of the focus of your research.

Giscard's current research on lighting is focused on the statistical modelling of lighting usage for commercial, retail and public applications for the purpose of accurately predicting the energy savings due to lighting retrofitting initiatives, in addition to identifying optimal LED replacement options.

Aspects of this focus include the power consumption, luminosity, lifespan, cost, and compatibility of LED replacement options for various applications.

He is also interested in gaining a better understanding of the impact and limitations of LED lighting replacement in energy and costs saving initiatives in South Africa.

Please provide references to any other researchers/organisations in South Africa in the EEL research field.

Not answered.

Are you collaborating with any international institutions/universities?

Not answered.

What, in your opinion, are the research gaps concerning EEL research in South Africa which is not already mentioned above?

Not answered.

What are your recommendations for EEL research?

The creation of a national research database focused on efficient-lighting studies.

Mokhotjwa Simon Dhlamini
Professor of Physics, University of South Africa
NRF rating: C2

Biography

Mokhotjwa Dhlamini is a professor of Physics at the University of South Africa and a C2 NRF-rated researcher. He has supervised about 20 postgraduate students to completion in the field of Solid-State Physics. He has published more than 100 journal articles in high-impact international journals with an h-index of 22 and i10-index of 48.

Are you currently involved with any research projects pertaining to EEL?

Not answered.

Which sector does your research fall under?

Not answered.

Which category does your research fall under?

- Materials/Nanotechnology
- Emission spectrum
- Development of materials; single white light-emitting phosphor for WLED

To what type of lighting would you classify your research as being most relevant to?

- Domestic (homes and offices)

Please provide a short description of the focus of your research.

Development of cost-effective high luminous phosphor materials for phosphor-converted white light-emitting diodes (WLEDs).

Focus aspect:

Development of a single-phased white light-emitting phosphor for white light-emitting diodes (WLEDs)

Research impacts:

- The research would have a socio-economic impact on society since cost-effective WLED bulbs/devices will be produced
- Young researchers and postgraduate students are involved in this project, so an increase in human capital development

Please provide references to any other researchers/organisations in South Africa in the EEL research field.

- Martin Ntwaeaborwa

Are you collaborating with any international institutions/universities?

Not answered.

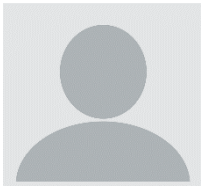
What, in your opinion, are the research gaps concerning EEL research in South Africa which is not already mentioned above?

Single-phased phosphor materials emitting white light with good quantum efficiency is still a challenge in this space. There are also issues of thermal quenching that is negatively affecting several materials in this application. Low colour rendering index is also a challenge in the commercially available WLEDs.

What are your recommendations for EEL research?

Not answered.

Johan Rens
Professor: School for Electrical Engineering, North-West University



Biography

Not provided.

Are you currently involved with any research projects pertaining to EEL?

Not answered.

Do you see any gaps where research should be conducted on EEL?

Not answered.

Which sector does your research fall under?

Not answered.

Which category does your research fall under?

Not answered.

To what type of lighting would you classify your research as being most relevant to?

Not answered.

Please provide a short description of the focus of your research.

- Validation of LED lamp nameplate ratings: colour, lumens, apparent power – a comparative study between what is available in South African retail
- Additional detail: Total active and total reactive power consumption, current harmonic phasor (magnitude and phase angle), compatibility to voltage waveform distortion and magnitude variation – a comparative study between suppliers
- Susceptibility to voltage flicker, that is the transfer of visible flicker – a comparative study between suppliers
- Supraharmonic components in load current – a general study to better understand the significantly reduced lifespan of LED lamps compared to their claimed lifespan, especially where significant grid-connected rooftop PV exists which also produces supraharmonics.

Please provide references to any other researchers/organisations in South Africa in the EEL research field.

Not answered.

Are you collaborating with any international institutions/universities?

Not answered.

What, in your opinion, are the research gaps concerning EEL research in South Africa which is not already mentioned above?

Not answered.

What are your recommendations for EEL research?

Not answered.

Arnoldus de Beer
Senior Lecturer, University of Johannesburg

Biography

Arnoldus de Beer is a senior lecturer at the University of Johannesburg. He obtained a PhD in electrical and electronic engineering from RAU in 1994 and has about 15 years' experience in the industry. He joined UJ in 2007. He is a iNarte Certified Electromagnetic Compatibility Engineer in the USA. He has done extensive research on the effects of LED lamps on power line communication (PLC).

Are you currently involved with any research projects pertaining to EEL?

Arnold is not involved directly in energy efficiency but rather in research on the electromagnetic compatibility (EMC) of new-generation lamps and lighting. This includes the power electronics that make the lighting work.

Do you see any gaps where research should be conducted on EEL?

Efficient lighting can cause electromagnetic interference (EMI). Basically, it can "pollute" the electricity grid. Research in South Africa is necessary in this area.

Which sector does your research fall under?

Not answered.

Which category does your research fall under?

- Surge protection
- Electrical emission spectrum

To what type of lighting would you classify your research as being most relevant to?

Not answered.

Please provide a short description of the focus of your research.

Electromagnetic compatibility of all sorts of power electronic devices, including modern lighting systems

Lighting aspect focus:

Designing for EMC; this includes lighting power converters and general power electronics

Potential research impacts:

Without EMC, large-scale lighting would electrically pollute the grid, rendering power line communication ineffective. It can furthermore cause failures in all sorts of equipment (other than the lighting equipment).

Please provide references to any other researchers/organisations in South Africa in the EEL research field.

Not answered.

Are you collaborating with any international institutions/universities?

Yes. Aalborg University in Denmark – largest power electronics research group at a university in the world.

What, in your opinion, are the research gaps concerning EEL research in South Africa which is not already mentioned above?

The role of power electronics in modern lighting systems.

What are your recommendations for EEL research?

Between the power grid and the lamps that produce lighting are the power electronics drivers for the lamps. These drivers have a given efficiency and characteristics. This should be thoroughly investigated.

3.3 Private sector

The questionnaires received from researchers identified and contacted within this sector are listed in Table 3-3 below.

Table 3-3: List of researchers from the private sector

Institution	Researcher
GreenX	Jason Samuels
OrbitX	Frans Rossouw
Genlux Lighting	Sello Joseph Tsoai
Bergstrom Lighting	Graham van den Berg
Beka Schréder	Gordon Arons
LED Light Consult SA (PTY) LTD	Paul Nel

Jason Samuels
Managing Director, GreenX Engineering

Biography

Jason Avron Samuels is the Managing Director of GreenX Engineering. He has an undergraduate degree in electrical and electronic engineering and a master's degree in electrical engineering, and is currently pursuing doctoral studies on South African schools' energy usage – which he has handed in for examination. He is focused on engineering solutions in the education and energy sectors. Research interests include renewable energy (solar PV), smart metering data analysis (IoT) and trends, and energy efficiency – all in the context of schools' energy usage in South Africa.

Are you currently involved with any research projects pertaining to EEL?

Not answered.

Do you see any gaps where research should be conducted on EEL?

Not answered.

Which sector does your research fall under?

Not answered.

Which category does your research fall under?

- Lighting simulation
- Improvements in energy efficiency

To what type of lighting would you classify your research as being most relevant to?

Government buildings, specifically public schools. However, GreenX is expanding its research to other industries as well.

Please provide a short description of the focus of your research.

Jason's focus areas are public school energy usage and interventions regarding electricity. GreenX found that lighting was a big portion of public schooling expenses and replaced their lights with LED tech. It was also found that there was an energy disparity between affluent and poor schools.

Please provide references to any other researchers/organisations in South Africa in the EEL research field.

Not answered.

Are you collaborating with any international institutions/universities?

Not answered.

What, in your opinion, are the research gaps concerning EEL research in South Africa which is not already mentioned above?

- Smarter lighting system implementations in schools and passive lighting systems in South Africa schools, also expanding this to other energy items
- The impact of outside lighting systems in South African schools
- The modelling and data analysis of lighting systems/energy usage in South African industries
- The affluence-energy gap between public schools

What are your recommendations for EE lighting research?

- Expanding the sample set with regard to school-related lighting research and interventions, introduction of smart lighting systems in schools, extension into schools' lighting and electricity usage nationally
- Lighting usage and the reduction thereof elsewhere such as in hospitals, packhouses and public entertainment places
- Also, looking at the lighting manufacturing industry in South Africa.

Frans Rossouw
CEO, OrbitX (Pty) Ltd

Biography

Frans Rossouw is the CEO of OrbitX, which specialises in LED lights for commercial and industrial applications. In partnership with Azoteq, OrbitX developed LED lighting that supersedes currently available LED technology. Tested yearly against other LED technologies at the Hong Kong Lighting Fair, it still proves to be both unique and superior.

Three main features distinguish OrbitX Direct Drive LED lights, courtesy of the AC driver and the unique topology:

- Eight-year guarantee with a 10–30-year lifespan (up to 30 years in office environments)
- 40%-75% electricity savings due to low power consumption (and excellent power factor)
- No wi-fi or radio interference, which is a common, but relatively unknown weak point of traditional LED drivers

Are you currently involved with any research projects pertaining to EEL?

Not answered.

Do you see any gaps where research should be conducted on EEL?

More work is required to evaluate and promote the lifecycle costing of EEL.

Which sector does your research fall under?

Not answered.

Which category does your research fall under?

- Lighting simulation
- Materials/Nanotechnology
- Lifespan, lumen maintenance/L70
- Standardised techniques for lifespan testing/ warranties/standards
- Improvements in energy efficiency
- Emission spectrum
- Drivers
- Heatsink
- Smart control

To what type of lighting would you classify your research as being most relevant to?

- Retail and commercial
- Stadium/Sports lighting
- Public lighting
- Industrial

Please provide a short description of the focus of your research.

LED and driver longevity:

- Lifetime of driver
- Lifetime of LED (functional and light output)
- Energy efficiency
- Light quality (colour spectrum)
- Harmonics and RF emissions

Please provide references to any other researchers/organisations in South Africa in the EEL research field.

Not answered.

Are you collaborating with any international institutions/universities?

Not answered.

What, in your opinion, are the research gaps concerning EEL research in South Africa which is not already mentioned above?

Not answered.

What are your recommendations for EE lighting research?

Not answered.

Sello Joseph Tsoai
General Manager, Genlux Lighting

GENLUX LIGHTING
a lighting technology company
A division of
ACTOM (Pty) LTD

Biography

Sello Tsoai is the General Manager at Genlux Lighting. He is currently working on light improvement and energy efficiency.

Are you currently involved with any research projects pertaining to EEL?

Not answered.

Do you see any gaps where research should be conducted on EEL?

Not answered.

Which sector does your research fall under?

Not answered.

Which category does your research fall under?

- Lighting simulation
- Surge protection
- Heatsink
- Lens/Diffuser improvements
- Smart control
- Solar lighting

To what type of lighting would you classify your research as being most relevant to?

- Stadium/Sports lighting
- Public lighting
- Industrial

Please provide a short description of the focus of your research.

EEL development

Focus aspects:

Street lighting/Sports lighting/Exterior/Floodlight lighting

Potential impacts:

- Light improvements as well as energy efficiency
- Educating electrical contractors and consultants in the implementation of LED EEL.

Please provide references to any other researchers/organisations in South Africa in the EEL research field.

Not answered.

Are you collaborating with any international institutions/universities?

Not answered.

Please include/share any other information you think would be valuable for this project.

The SA market should be aware of inferior products that are being sold in South Africa without proper standard certifications or LOAs.

All imported lighting products should be tested and certified by the SA authorities to submit a proper standard certification.

What, in your opinion, are the research gaps concerning EEL research in South Africa which is not already mentioned above?

Not answered.

What are your recommendations for EEL research?

The use of South African manufacturers as much as possible with fair competition in the market, NOT those that import inferior products and sell into the SA market, which are not contributing to the economy of the country.

Graham van den Berg
Sales Manager/Designs Manager, Bergstorm Lighting

Biography

Graham van den Berg is a Sales & Designs Manager at Bergstorm Lighting, which is currently involved in the development of EEL for design and implementation into South Africa's commercial market. They currently work with both local and international component suppliers as well as local industrial designers.

Are you currently involved with any research projects pertaining to EEL?

Not answered.

Do you see any gaps where research should be conducted on EEL?

Not answered.

Which sector does your research fall under?

Not answered.

Which category does your research fall under?

- Daylighting design
- Lighting simulation
- Improvements in energy efficiency
- Heatsink
- Smart control

To what type of lighting would you classify your research as being most relevant to?

- Retail and commercial
- Industrial

Please provide a short description of the focus of your research.

High-efficiency luminaires with thermal management characteristics that allow for longer warranty periods

Focus aspects: Commercial/Industrial/Retail

Potential impacts: Better lifespan and serviceability of local luminaires.

Please provide references to any other researchers/organisations in South Africa in the EEL research field.

Not answered.

Are you collaborating with any international institutions/universities?

Not answered.

Please include/share any other information you think would be valuable for this project.

Not answered.

What, in your opinion, are the research gaps concerning EEL research in South Africa which is not already mentioned above?

Not answered.

What are your recommendations for EEL research?

Not answered.

Gordon Arons
Regional Manager, Beka Schréder Pty Ltd

Biography

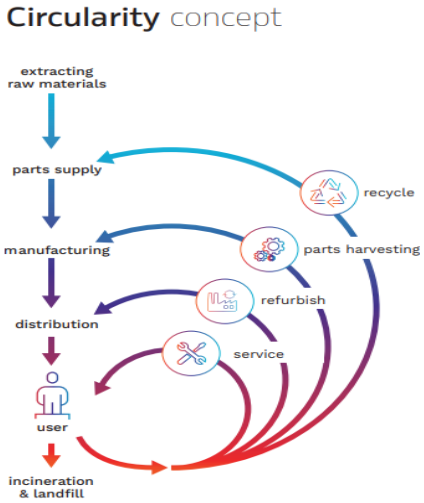
Gordon Arons is currently the Regional Manager (Northern Region) for BEKA Schréder Pty Ltd and is based at the Head Office in Olifantsfontein, South Africa. He started out with BEKA *Schréder* in May 2006 and has been with the company, now BEKA Schréder, for 15 years. Shortly after joining the company, the market started aggressively with LED exploration, which has grown into a formidable solution for lighting applications. He was privileged to walk the road with the technology from the beginning with a company that has a rich history of developing world-class lighting technology-based solutions for the market.

Are you currently involved with any research projects pertaining to EEL?

Not answered.

Do you see any gaps where research should be conducted on EEL?

- The emphasis is placed on energy-efficient lighting by providing numbers to attain, e.g., XX% saving must be reached.
- In applying 1 above, the focus is lost to "the right light" for projects.
- Company A and company B may have the same wattage but perform totally differently due to technologies used.
- Energy efficiency should not be based on wattage only but should be coupled with lumen output and "the right lighting" by means of a design from a qualified lighting designer.



To what type of lighting would you classify your research as being most relevant to?

BEKA *Schréder* constantly strives through regular product updates to provide the best and most energy-efficient solution to the various industries in most disciplines.

Ambiance, commercial, floodlighting, illumination, industry, road and urban as well as various lighting control systems

What are your recommendations for EEL research?

Concentrate on which parameters are used to determine EE.

"The right lighting" includes but is not limited to –

- Energy-efficiency benchmarks (watts per square meter) once a certified design is offered for evaluation purposes
- Uniformity in line with the relative SANS specifications

As for sustainability, BEKA *Schréder* focuses on a ***circular economy***. It is mainly defined in opposition to the traditional linear economy of "take, make and dispose". In a circular economy, products are part of a value network where they will be used for as long as possible.

After a careful analysis of the potential circularity of our luminaires, Beka decided to introduce a "circular lighting" product label. This label acts as a circular indicator for our customers.

Paul Nel
Director, LED Light Consult SA (Pty) Ltd

Biography

Paul Nel is a director at LED Light Consult and has been involved with lighting for close to 14 years. In his time in the lighting industry, he has worked for and gained knowledge and experience from two of the top manufacturers (GPL and LIA) respectively. LED Light Consult SA (Pty) Ltd was started and has continued their quest to deliver product and intel to the lighting industry.

Are you currently involved with any research projects pertaining to EEL projects?

Not answered.

Do you see any gaps where research should be conducted on EEL?

Not answered.

Which sector does your research fall under?

Not answered.

Which category does your research fall under?

- Daylighting design
- Surge protection
- Lifespan, lumen maintenance/L70
- Standardised techniques for lifespan testing/ warranties/standards
- Colour shifts with ageing
- Drivers
- Heatsink

Area of specialty: Smart LED lighting, automation and renewable energy solutions.

To what type of lighting would you classify your research as being most relevant to?

Industrial/Warehousing

Please provide a short description of the focus of your research.

Energy efficiency conversion: The conversion of outdated lighting technology to the latest LED solutions to achieve massive energy savings, be it for energy saving or to free the client's transformer up to expand their manufacturing/growing capacity

Potential impacts: Demonstrate how to achieve substantial energy saving from changing existing older technology to the latest technology available on the market

Please provide references to any other researchers/organisations in South Africa in the EEL research field.

Not answered.

Are you collaborating with any international institutions/universities?

Not answered.

What, in your opinion, are the research gaps concerning EEL research in South Africa which is not already mentioned above?

Daylight harvesting

What are your recommendations for EEL research?

Not answered.

4. Analysis of research

This section analyses the responses within questionnaires from potential researchers and the published papers surrounding EEL research conducted in South Africa.

The data gathered are grouped according to the sector, category and lighting application which the research is a function of.

- The data are classified according to the following sectors:
  - Public sector and research facilities
  - Academic institutions
  - Private sector
  - Other
- The data are classified according to the following categories:
  - Daylighting design
  - Photometric measurement systems
  - Lighting simulation
  - Materials/Nanotechnology
  - Surge protection
  - Lifespan, lumen maintenance/L70
  - Standardised techniques for lifespan testing/warranties/standards
  - Colour shifts with ageing
  - Improvements in energy efficiency
  - LED chips
  - Emission spectrum
  - Drivers
  - Heatsink
  - Lens/Diffuser improvements
  - Smart control
  - Other
- The data are classified according to the following lighting applications:
  - Retail and commercial
  - Stadium/Sports lighting
  - Public lighting (road lighting and high-mast area lighting)
  - Traffic signals
  - Industrial/Warehousing
  - Domestic
  - Other

Thereafter, the data are analysed by identifying trends and gaps in research on EEL in South Africa.

Appendix C: Data analysis shows the analysis of data in table format.

4.1 Analysis of questionnaires

The returned questionnaires could not be included in the main report in respect of personal data and these were submitted in a separate report to GIZ. The questionnaire template can be found in Appendix A: Questionnaire template.

4.1.1 Analysis per sector

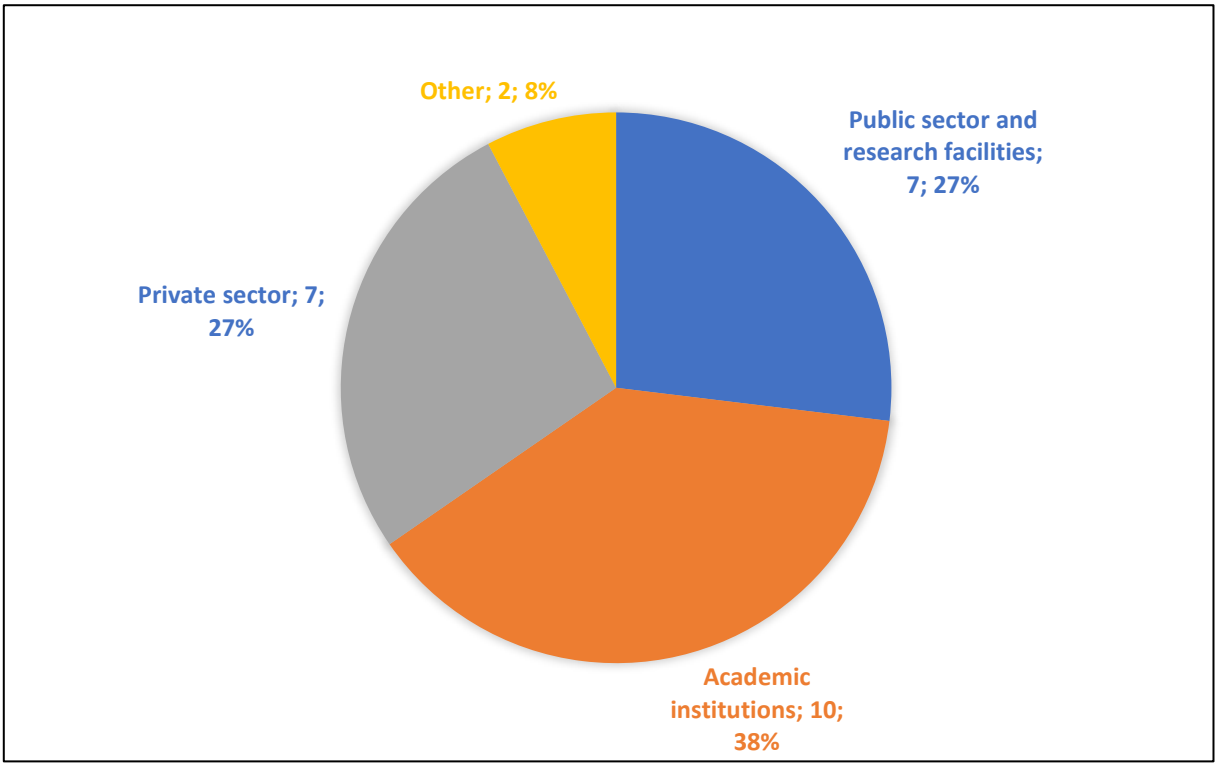


Figure 4-1: Graphical representation of research per sector based on questionnaire responses (total: 23)

From the above figure, 38% of research is being conducted by people working for academic institutions, 27% by the private sector and 23% by public sector and research facilities.

The "Other" category comprises two responses, one each from Prof. OD Dintchev and Mr Richard Larmour, pertaining to rural electrification and residential lighting, respectively.

4.1.2 Analysis per research category

From Figure 4-2, it can be seen that most research is being conducted on improvements in energy efficiency (14%), closely followed by lighting simulation (12%). Only one response received indicated that they were looking into lens/diffuser improvements.

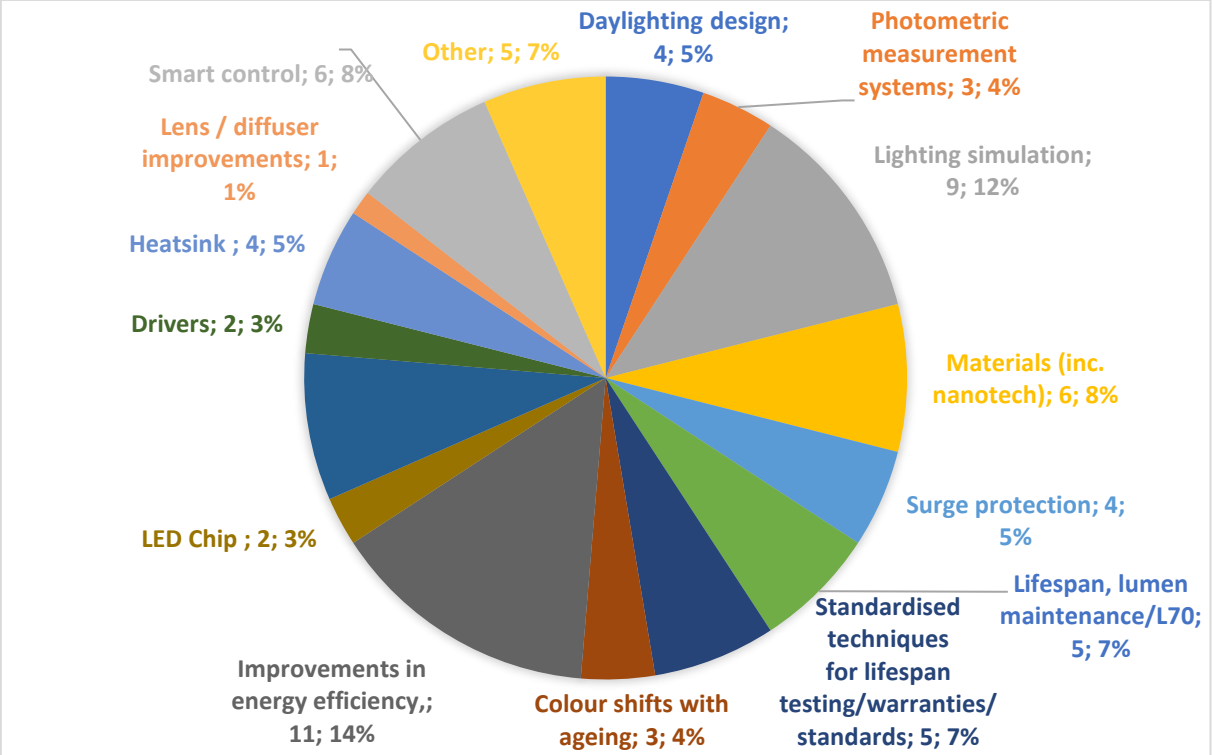


Figure 4-2: Graphical representation of research categories chosen (total: 23)

4.1.3 Analysis per lighting application

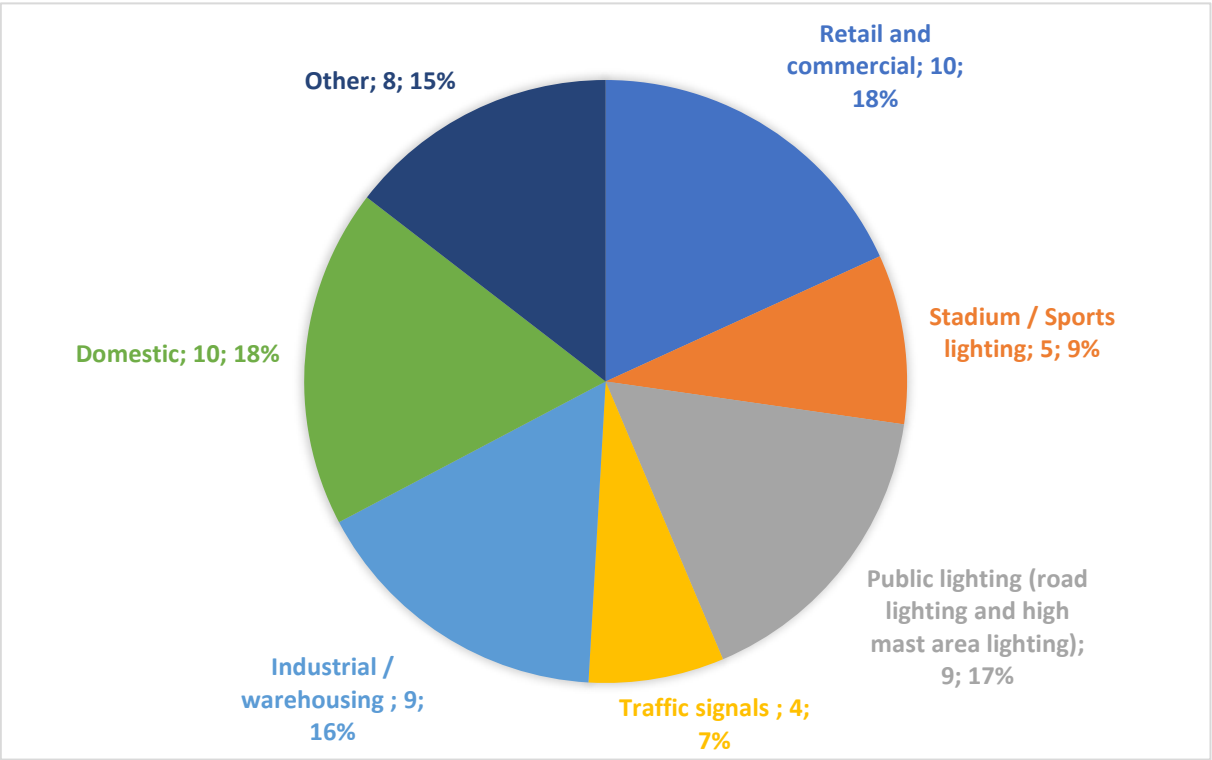


Figure 4-3: Graphical representation of lighting applications from questionnaire responses (total: 23)

From Figure 4-3 it can be seen that according to the questionnaires received, most lighting research relate to the *Retail, Commercial* and *Domestic* sectors (18%). Traffic signals show the least research in the industry, at 7%.

4.2 Publications

Table 4-1 provides an overview of the articles researched for this project.

Table 4-1: Overview of EEL publications reviewed for this project

	Article	Authors
A	Passive Solar and Conventional Housing Design: A Comparative Study of Daylighting Energy Efficiency Potential	Ochuko K. Overen, Edson L. Meyer and Golden Makaka
B	Maintenance optimization incorporating lumen degradation failure for energy-efficient lighting retrofit projects	Alice Ikuzwe, Xiaohua Xia, Xianming Ye
C	LED there be light: The impact of replacing lights at schools in South Africa	M.J. Booysen, J.A. Samuels, S.S. Grobbelaar
D	Smart streetlights using power line communication	P. du Toit; C. Kruger; G. P. Hancke; T. D. Ramotsoela
E	A Sensor for Monitoring the Lifespan of Colour-LEDs in Traffic Lights	C. E. Ngene; T. Shongwe
F	Influence of LED tubes on the throughput of an indoor broadband PLC channel	Arnold S. de Beer; Allan Emleh; Hendrik C. Ferreira
G	Light-years apart: Energy usage by schools across the South African affluence divide	M.J. Booysen, J.A. Samuels, S.S. Grobbelaar
H	Enhanced orange-red emission from KSrVO4: Sm3+ nanophosphor for possible application in blue light-emitting diode based white LED	OM Ntwaeaborwa and HC Swart
I	White light emitting LaGdSiO5:Dy3þ nanophosphors for solid state lighting applications	Simon N. Ogugua, OM Ntwaeaborwa and HC Swart
J	Advances in phosphors based on organic materials for light emitting devices	HC Swart
K	Structural, surface and luminescence properties of Ca3B2O6:Dy3þ phosphors	OM Ntwaeaborwa and HC Swart
L	Rare Earth Doped Zinc Oxide Nanophosphor Powder: A Future Material for Solid State Lighting and Solar Cells	OM Ntwaeaborwa and HC Swart
M	Surface and spectral studies of Sm3þ doped Li4Ca (BO3)2 phosphors for white light emitting diodes	HC Swart
N	Phosphor Polymer Nanocomposite: ZnO: Tb3+ Embedded Polystyrene Nanocomposite Thin Films for Solid-State Lighting Applications	HC Swart
O	Recent advances in rare earth doped alkali-alkaline earth borates for solid state lighting applications	HC Swart
P	Blue photons excited highly chromatic red light emitting K3La (PO4)2: Pr3+ phosphors for white light emitting diodes	HC Swart
Q	Red emitting non-rare earth doped LiMgBO3 phosphor for light emitting diodes	HC Swart
R	Structural and spectral studies of highly pure red-emitting Ca3B2O6:Eu3+ phosphors for white light emitting diodes	HC Swart
S	RESIDENTIAL ELECTRICITY CONSUMPTION IN SOUTH AFRICA	Alison Hughes, Richard Larmour
T	Residential lighting load profile modelling	O. Popoola, J. Munda
U	Comparative analysis and assessment of ANFIS-based domestic lighting profile modelling	O. Popoola, J. Munda
V	Modeling of residential lighting load profile using adaptive neuro fuzzy inference system (ANFIS)	O. Popoola
W	Residential lighting load profile modelling: ANFIS approach using weighted and non-weighted data	O. Popoola
X	NMISA and the new LED national measurement facility – Lighting design & application (Vector) 2017	Edwin Mofokeng, Pieter du Toit

	Article	Authors
Y	LED Street Lighting for Eskom Properties	André Blignaut
Z	An overview of colour LED & CFL lighting interference on the low voltage PLC network	Allan Emleh, Arnold S. de Beer, Ling Cheng, Hendrik Ferreira
AA	Considerations for lighting in manufacturing – EE Publishers	Brandon Topham, Turck Banner
AB	Extending the efficiency and lifetime of LEDs - EE Publishers	Edwin Brown, Vepac Electronics
AC	How electrochemical compounds protect LEDs from environmental conditions - EE Publishers	Edwin Brown, Vepac Electronics
AD	Lighting emergency gear – what waveform should we use? - EE Publishers	Stirling Marais, Cosine Developments
AE	Surge protection concept for LED streetlights - EE Publishers	Hano Oelofse, DEHN Africa

4.3 Analysis of publications

4.3.1 Analysis per sector

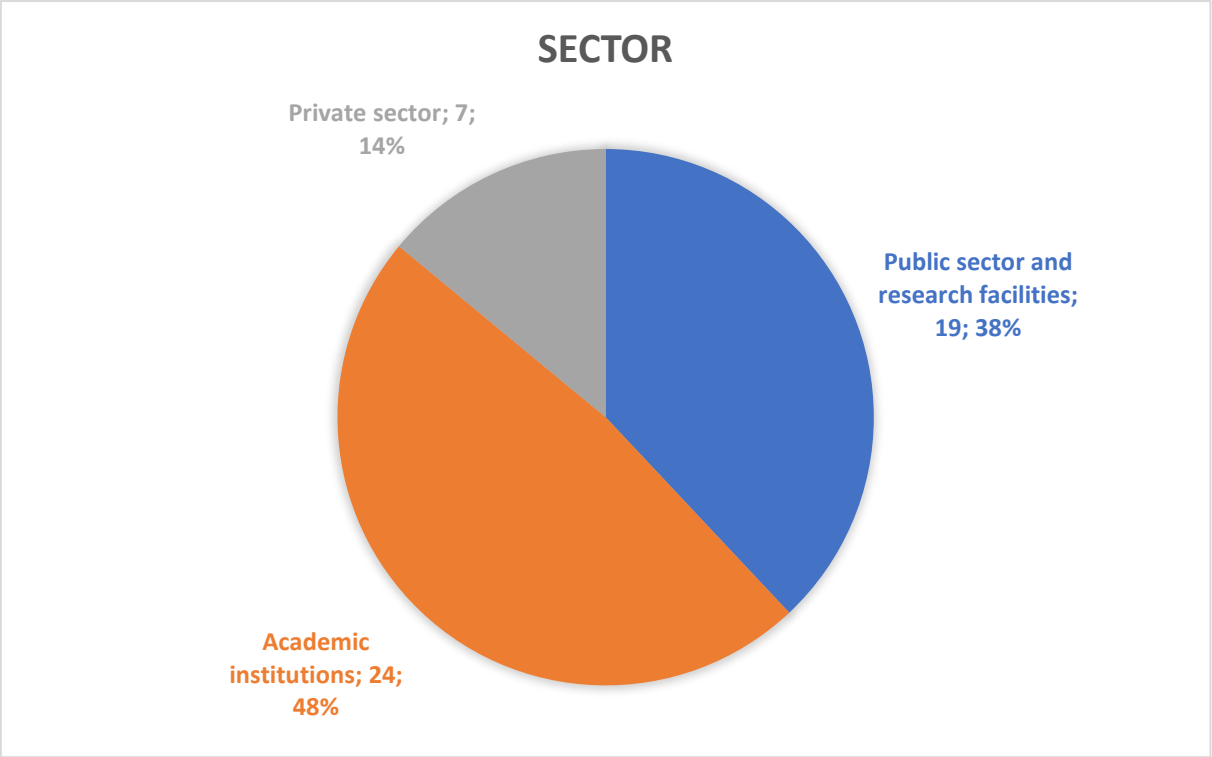


Figure 4-4: Graphical representation of articles quantified based on research sector

Of all the relevant articles reviewed, approximately half are from research conducted at academic institutions (38%). This is followed by the public sector and research facilities, contributing to 38% of research conducted.

4.3.2 Analysis per research category

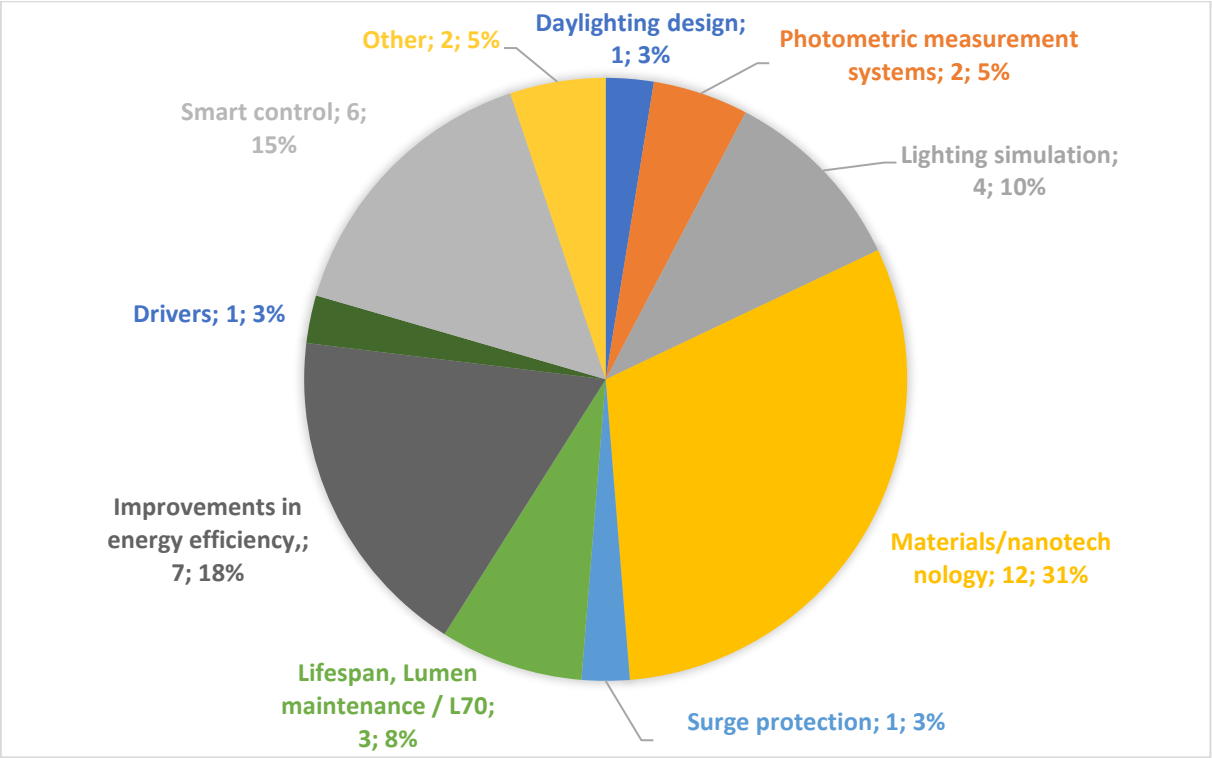


Figure 4-5: Graphical representation of articles quantified based on research category

Most articles reviewed were focused on *materials/nanotechnology* (31%).

Of the reviewed articles, none were focused on *standardised techniques for lifespan testing / warranties / standards, colour shifts with ageing, LED chip, emission spectrum, heatsink,* or *lens/diffuser improvements.*

4.3.3 Analysis per lighting application

From an analysis of the articles in terms of which lighting application they focus on, most research was focused on residential lighting (domestic – 44%). Another significant percentage of research was on public lighting (19%), where street lighting applications were the main contributor.

Included in the 19% of the other category, research was mostly applicable to school and other public building lighting.

There were no articles reviewed that focused on stadium/sports lighting.

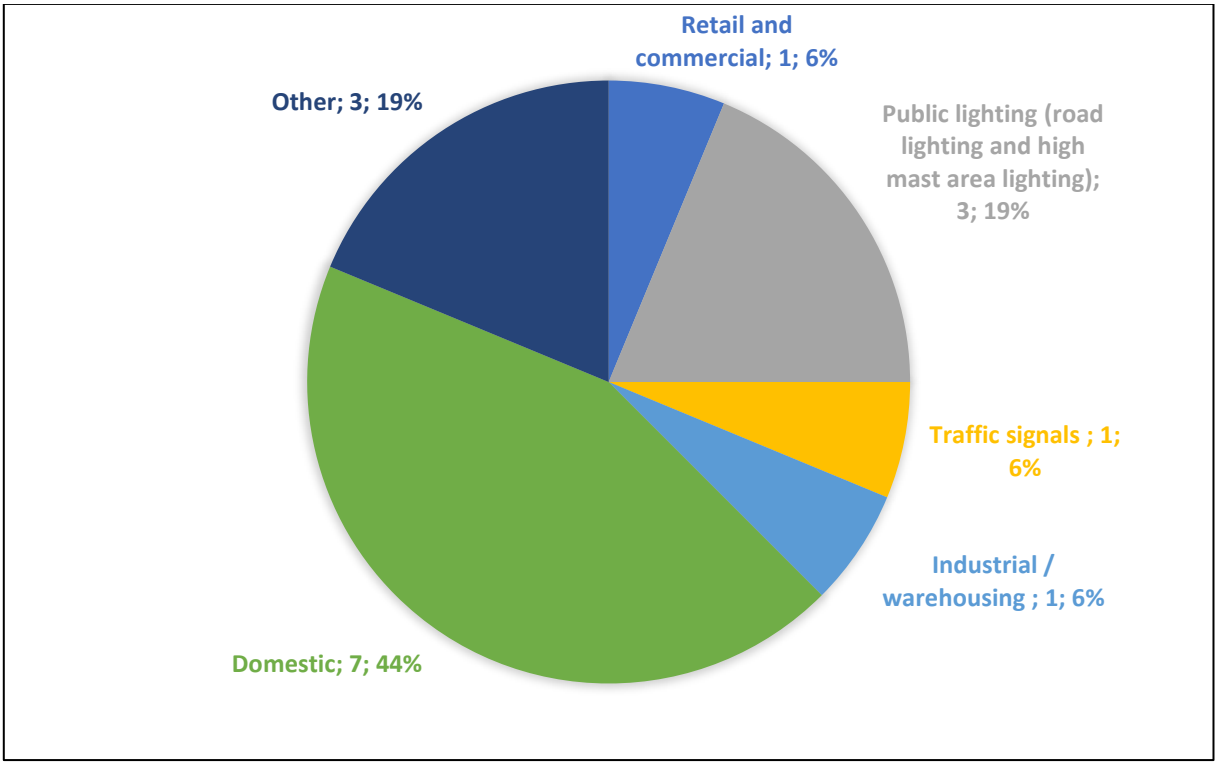


Figure 4-6: Graphical representation of articles quantified based on lighting application

5. Potential gaps in research

5.1 Implementation

Two researchers identified implementation as a gap. It was felt that there should be more implementation of conducted research into practical applications, roll-outs of programmes, etc. rather than just conducting research on the specific topics.

5.2 Efficiency benchmarks

Another two researchers identified the need for standard methodologies to determine "efficiency" as a gap, with the development of a standard methodology to compute savings and mathematical models to predict the techno-economic potential of EEL technologies. This also forms part of *NMISA*'s research focus, which is developing national measurement standards.

5.3 Awareness creation

South Africa has a very diverse profile of recipients of energy services, including access to affordable and efficient lighting. The appropriate motivation of efficient lighting technologies and systems at work and at home is a key factor for sustaining initiatives in this field.

One researcher at IESSA included in his response that he believes research should rather be conducted into how awareness of differences in energy efficiency can be created, and into what the roadblocks are for implementing the research conducted, as well as how to overcome them.

5.4 Electronic drivers

3% of questionnaires received were focusing on researching *drivers.* In Dr Arnold de Beer's recommendation for EEL research, he explained that the efficiency and characteristics of the power electronics drivers for lamps was a topic which should be thoroughly investigated.

This is an aspect that *OrbitX* also addressed in its response, when listing what distinguishes its products from those of other manufacturers. *"No wi-fi or radio interference, which is a common, but relatively unknown weak point of traditional LED drivers."*

5.5 Perception of no gaps

Approximately 15% of researchers (3/20) held that there were no gaps in research. It was expressed that there was not a lack of research into the different aspects of lighting.

5.6 Electrical network interference

Two researchers shared concerns of EEL causing electromagnetic interference (EMI). Basically, it is possible that EEL can "pollute" the electricity grid. Research in South Africa is necessary in this area.

6. Conclusion

SMEC has provided an overview of current EEL research being carried out at South African universities, universities of technology, Eskom, and public and private research institutions.

Research has been analysed and categorised according to sector, research category and application. Common research themes were determined.

A library of 23 profiles of EEL researchers actively working in the field has been created, which will assist in determining future focal areas for EEL research in South Africa.

A list of 31 relevant recent research publications was also created. The following key gaps in research have been identified:

- Implementation of conducted research into practical applications
- Efficiency benchmarks
- Awareness creation
- Electronic drivers
- Electrical network interference
- Perception of no gaps (15%)

Appendix A: Questionnaire template

1	Are you currently involved with any research projects pertaining to EEL? If yes, please continue to fill out the full questionnaire. If no, please respond to item 2 only.	
2	Do you see any gaps where research should be conducted on EEL?	
3	Which sector does your research fall under? (a) Public sector and research facilities (b) Academic institutions (c) Private sector (d) If other, please specify	
4	Which category does your research fall under? (a) Daylighting design (b) Photometric measurement systems (c) Lighting simulation (d) Materials/Nanotechnology (e) Surge protection (f) Lifespan, lumen maintenance/L70 (g) Standardised techniques for lifespan testing/warranties/ standards (h) Colour shifts with ageing (i) Improvements in energy efficiency (j) LED chips (k) Emission spectrum (l) Drivers (m) Heatsink (n) Lens/Diffuser improvements (o) Smart control (p) If other, please specify	
5	What type of lighting would you classify your research as being most relevant to? (a) Retail and commercial (b) Stadium/Sports lighting (c) Public lighting (road lighting and high-mast area lighting) (d) Traffic signals (e) Industrial/Warehousing	

	(f) Domestic (g) If other, please specify	
6	Please provide your details. Are you a rated researcher? If so, please provide your NRF rating.	Name: Position: Organisation: Cell number: Email: NRF rating:
7	Please provide a short biography (3-6 lines).	
8	Please provide a short description of the focus of your research. 8.1 Summarise the topic. 8.2 What aspect of lighting are you focused on? 8.3 What are the potential impacts of your research?	
9	Please provide a list of all recent (from 2015) published papers or articles of which you are an author.	
10	Please provide references to any other researchers/organisations in South Africa in the EEL research field. Are you collaborating with any international institutions/universities?	Name: Email address:
11	(Optional) Please include/share any other information you think would be valuable for this project.	
12	(Optional) What, in your opinion, are the research gaps concerning EEL research in South Africa which is not already mentioned above?	
13	(Optional) What are your recommendations for EEL research?	

Appendix B: List of individuals/organisations contacted

The following individuals/organisations have been contacted.

Appendix B1: Academic institutions

Table 2: Table of contacted academic institutions

Organisation name	Title	Initials	Name	Surname
CPUT	Dr	M	Marco	Adonis
CUT	Prof.	H	Herman	Vermaak
DUT	Dr	I	Ian	Lazarus
MUT	Dr	BP	Bubele	Numbi
Nelson Mandela	Prof.	E	Ernest	van Dyk
NWU	Prof.	A	Albert	Helberg
NWU	Prof.	J	Jan	de Kock
SU	Dr	AJ	Arnold	Rix
UCT	Dr	A	Amos	Madhlopa
UCT	Dr	J	Jiska	de Groot
UFS	Prof.	HC	Hendrik	Swart
UJ	Prof.	H	Hartmut	Winkler
UKZN	Dr	F	Freddie	Inambao
UNISA	Prof.	M	Mokhotjwa	Dhlamini
UNIVEN	Prof.	V	Vaith	Sankaran
UP	Dr	M	Mmantsae	Diale
UWC	Dr	S	Sylvain	Halindintwali
WITS	Prof.	N	Neil	Coville
WITS	Prof.	D	Dave	Billing
NWU	Electrical engineering department			
SU		JA	Jason	Samuels
SU	Prof.	MJ	Thinus	Booysen
UFS	Dr	J	Johan	Venter
UJ	Prof.	M	Martin	Ntwaeaborwa
UKZN	Prof.	GT	Genene	Mola
UP	Prof.	JW		Odendaal
WITS	Dr	D	Daniel	Wamwangi
WITS	Prof.	A	Alex	Quandt
WITS	Dr	M	Manoko	Maubane
WITS	Dr	R	Rudolph	Erasmus
WSU	Prof.	S	Sam	Chikwembani
CUT	Dr	K		Kusakana
TUT	Prof.	OD		Dintchev
UCT	Prof.	P	Pieter	Levecque
UP	Electrical engineering department			

WITS	Electrical engineering department			
DUT	Electrical engineering department			
TUT	Dr	O	Olawale	Popoola
CPUT	Prof.	MT	Mohamed	Kahn
MUT	Dr	A		Mienie
Nelson Mandela	Electrical engineering department			
UFS	Electrical engineering department			
UCT	Electrical engineering department			
NWU	Ms	T	Tanya	Fouche
UFS	Prof.	K	Koos	Terblans
UJ			Roana	Tanzwani
Nelson Mandela	Dr	H	Herve	Fritz
UCT	Ms.	M	Mascha	Moorlach
NWU			Johan	Rens
UNIVEN				
UWC	Prof.	E	Emmanual	Iwuoha
WSU	Electrical engineering department			
UFH	Electrical engineering department			
UP	Prof.		Sunil	Maharaj
UP	Prof.		Wilhelm	Leuschner
TUT			Giscard	Binini
UJ	Dr	AS	Arnoldus	De Beer
UFH	Prof.	EL		Meyer
UP			Alice	Ikuzwe

Appendix B2: Research institutions

Table 3: Table of contacted research institutions

Organisation name	Initials	Name	Surname
ESKOM	A	André	Blignaut
ASSAf	R	Roseanne	Diab
SAEE Confederation	T	Thieda	Ferreira
CSIR	J	Jeremy	Gibberd
SANi	E	Edward	Nxumalo
NMISA	N	Natasha	van Der Walt
ESKOM			
CSIR			
CEF			
ASSAf			
DMRE			
NRF			
SAIEE			
DSI			
UCT - Energy Research Centre			
SANi	V	Vincent	Nyamori
SANi	L	Laila	Smith
IESSA	D	Daniel	Kasper

Appendix B3: Private sector

Table 4: Table of contacted private sector

Company	Initials	Name	Surname
OrbitX	F	Frans	Rossouw
Beka Schreder	G	Gordon	Arons
Regent Lighting	E	Ewald	Germishuys
LighTec	M	Mario	Roos
Genlux	S	Sello	
Bergstrom	G	Graham	
Phillips	C	Craig	Wilson
Regent Lighting			
SEM Solutions	T	Tiaan	Hendriks
Regent Lighting	A	Allistair	
SABIC			
Regent Lighting	R	Ricardo	
Matleng Energy			
LED light consultant	P	Paul	Nel
Azoteq			
Vepac electronics	E	Edwin	Brown
Cosine Developments	S	Stirling	Marais
DEHN Africa	H	Hano	Oelofse

Appendix C: Data analysis

Appendix C1: Questionnaire

Table 5: Current research per sector

	Eskom	NMISA	SU	UFS	CUT	UKZN	WITS	UCT	TUT	UNISA	UJ	Green X	OrbitX	Genlux	Bergstrom	LED Light Consult
Public sector and research facilities		X	X		X	X			X							X
Academic institutions			X	X	X	X	X		X	X	X					
Private sector		X			X				X			X	X		X	X
Other								X	X					X		

Table 6: Current research per category

	Eskom	NMISA	SU	UFS	CUT	UKZN	WITS	UCT	TUT	UNISA	UJ	Green X	OrbitX	Genlux	Bergstrom	LED Light Consult
Daylighting design	X					X									X	X
Photometric measurement systems	X	X				X										
Lighting simulation	X				X	X	X		X			X	X	X	X	
Materials/Nano-technology	X			X					X	X			X			
Surge protection					X						X			X		X
Lifespan, lumen maintenance/L70	X	X			X								X			X
Standardised techniques for lifespan	X	X			X								X			X

	Eskom	NMISA	SU	UFS	CUT	UKZN	WITS	UCT	TUT	UNISA	UJ	Green X	OrbitX	Genlux	Bergstrom	LED Light Consult
testing/warranties/ standards																
Colour shifts with ageing	X	X														X
Improvements in energy efficiency	X		X	X	X	X	X	X	X			X	X		X	
LED chips		X		X												
Emission spectrum	X	X		X						X	X		X			
Drivers													X			X
Heatsink													X	X	X	X
Lens/Diffuser improvements														X		
Smart control			X		X				X				X	X	X	
Other		X	X					X		X				X		

Table 7: Current research based on lighting application

	Eskom	NMISA	SU	UFS	CUT	UKZN	WITS	UCT	TUT	UNISA	UJ	Green X	OrbitX	Genlux	Bergstrom	LED Light Consult
Retail and commercial	X				X	X	X		X		X		X		X	
Stadium/Sports lighting	X					X					X		X	X		
Public lighting (road lighting and high-mast area lighting)	X				X	X	X		X		X		X	X		
Traffic signals					X	X	X				X					
Industrial/ warehousing	X				X	X	X				X		X	X	X	X
Domestic	X			X	X	X	X	X	X	X	X					
Other		X	X	X		X	X		X		X	X				

Appendix C2: Published papers

Table 8: Publications/articles per sector

Article reference	Public sector and research	Academic institutions	Private sector
A		X	
B	X	X	
C	X	X	X
D		X	
E		X	
F		X	
G	X	X	X
H	X	X	
I	X	X	
J	X	X	
K	X	X	
L	X	X	
M	X	X	
N	X	X	
O	X	X	
P	X	X	
Q	X	X	
R	X	X	
S	X	X	
T	X	X	
U	X	X	
V		X	
W		X	
X	X		
Y	X		
Z		X	
AA			X
AB			X
AC			X
AD			X
AE			X
Total	19	24	7
% split of results	38%	48%	14%

Table 9: Publications/articles per category of conducted research

Ref. no.	Daylighting design	Photometric measurement systems	Lighting simulation	Materials/ nanotechnology	Surge protection	Lifespan, lumen maintenance/L70	Techniques for lifespan testing/warranties/ standards	Colour shifts with ageing	Improvements in energy efficiency	LED chips	Emission spectrum	Drivers	Heatsink	Lens/Diffuser improvements	Smart control	Other
A	X	X							X							
B						X			X							
C																
D															X	
E						X										
F																X
G									X						X	
H				X												
I				X												
J				X												
K				X												
L				X												
M				X												
N				X												
O				X												
P				X												
Q				X												
R				X												
S									X							
T			X												X	
U			X												X	
V			X												X	
W			X												X	
X		X														
Y									X							
Z																X
AA									X							
AB						X			X							

Ref. no.	Daylighting design	Photometric measurement systems	Lighting simulation	Materials/ nanotechnology	Surge protection	Lifespan, lumen maintenance/L70	Techniques for lifespan testing/warranties/ standards	Colour shifts with ageing	Improvements in energy efficiency	LED chips	Emission spectrum	Drivers	Heatsink	Lens/Diffuser improvements	Smart control	Other
AC				X												
AD												X				
AE					X											
Total	1	2	4	12	1	3	0	0	7	0	0	1	0	0	6	2
% split	3%	5%	10%	31%	3%	8%	0%	0%	18%	0%	0%	3%	0%	0%	15%	5%

Table 10: Publications/articles per lighting application

Article names	Retail and commercial	Stadium/Sports lighting	Public lighting (road lighting and high-mast area lighting)	Traffic signals	Industrial/ Warehousing	Domestic	Other
A						X	
B							
C							X
D			X				
E				X			
F							
G							X
H							
I							
J							
K							
L							
M							
N							
O							
P							
Q							

Article names	Retail and commercial	Stadium/Sports lighting	Public lighting (road lighting and high-mast area lighting)	Traffic signals	Industrial/ Warehousing	Domestic	Other
R							
S						X	
T						X	
U	X					X	
V						X	
W						X	
X							
Y			X				
Z						X	
AA					X		
AB							
AC							
AD							X
AE			X				
Total	1	0	3	1	1	7	3
% split of results	6%	0%	19%	6%	6%	44%	19%

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