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Dear Reader

With the South African winter in full swing, I bring you this issue of **watt**now, which features Nature, where we focus on renewables, the universe, lightning, and much more.

Our feature article, Burden of Proof (pg 20), gives you a comprehensive review of the feasibility of 100% renewable-electricity systems.

Page 38 shares with you one of the winning papers of the 2017 IEC Young Professional Competition. Bashkaran Vandeyar and Darin Cornish will represent South African in Russia later this year.

We look at Surge Protection for smoke and heat extraction systems on page 42. To leave a building safely due to fire, escape routes need to be kept free of smoke. We look at how you implement the best solution.

Construction has commenced on the largest optical telescope that the world has ever seen. Read the story on page 46.

Our opinion piece this month, written by Michelle Doolan "Letting our Capes Fly" – shares with you why engineers are awesome. Find it on page 56.

Then, something close to my heart is a special project that we have been working on – the SAIEE Sure plan. This is an insurance benefit specifically designed for our SAIEE Members in mind. Read the article and more information on page 14. You, as an SAIEE member, have absolutely NOTHING to lose in giving this a try and see how much you will save on your monthly insurance policy. All you need to do is email your current policy, with your SAIEE membership number in the subject line, to insure@saiee.org.za and decide if you would like to start saving money.

Herewith the July issue, enjoy the read!

Minx

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JACOB MACHINJIKE
2017 SAIEE PRESIDENT

The July 2017 **watt**now edition draws our attention to nature, and some of the phenomena which presents renewables and untapped potential energy benefits to us. At the same time we should be mindful of the challenges we face relating to climate change and other risks.

We are committed to the sustainable development of the economy, poverty reduction, addressing inequality, training and development of our people.

The planet faces climate change due to the amount of greenhouse gases emitted in the past and currently being emitted. Greenhouse gases do not respect boundaries, and subsequently have a global impact, no matter where they are emitted. Climate Change, therefore, is governed at a global level.

Over a decade ago, countries negotiated the United Nations Framework Convention on Climate Change (UNFCCC) at the Rio Earth Summit in 1992. This was negotiated in order to formulate an international response to the challenge of climate change. The UNFCCC is a government-to-government negotiation process. These government negotiation meetings are called the Conference of the Parties (COP). Each of the 196 countries in the UNFCCC process has a veto right. The Paris agreement, which falls under the UNFCCC as its legal instrument, is now the "constitution" of the international climate change negotiations. Thus far, 113 countries representing more than 77% of global emissions sources, have ratified the Paris Agreement, making it one of the fastest ratification processes in the history of international relations.

The Agreement is based on three main objectives;

- limit the increase in global average temperature to well below two degrees Celsius till 2100,
- increase the ability to adapt to the adverse impacts of climate change and
- provide financial resources to ensure a pathway towards low greenhouse gas emissions, and climate-resilient development.

These are intended to translate into peaking global emissions as soon as possible and making rapid reductions thereafter. Net-zero emissions are expected from the second half of the century.

South Africa has committed to allow for emissions growth leading up to a peak by 2025 and then remain level for a decade and, after that, have absolute emissions decline from 2035. This is reflected in the workings of the Integrated Resource Plan (IRP), including in the base case.

Greenhouse gas emissions must fall; and required limits have been devolved to companies in the form of carbon budgets. By 2050 the electricity industry will not be allowed to contribute more than 90-190 Mt CO_2 based on the commitments made by South Africa. This means that we will need to invest in lower, or zero emitting technologies, as the current coal power plant fleet reaches the end of its life. A concerted effort is required to focus on technologies such as nuclear, renewables, gas and large hydro imports.

Each of these technologies have pros and cons, and the trade-offs must be discussed and rationalized, in order to arrive at an electricity energy mix that will tick all the boxes in this complex decision making. The issues of costs, emissions reduction, job protection and creation, socio-economic development and economic growth all need to be addressed, and trade-offs are inevitable. There are opportunities to be gained from driving a lower carbon future. A robust technology energy mix, which is inclusive, is often more palatable and easier to accept in a country which has abundant natural and mineral resources.

J Machinjike| SAIEE President 2017
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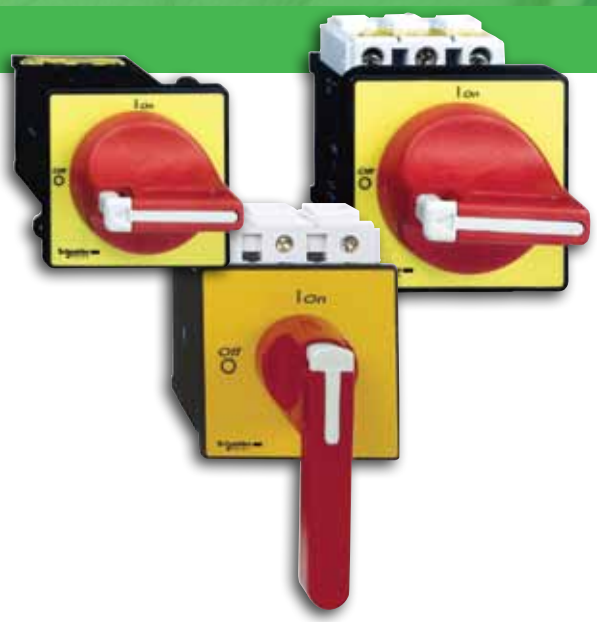

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Efficient Solution For Simple Safety Tasks

Easy configuration of the Leuze RSL Series safety laser scanner via Bluetooth and Ethernet TCP/IP makes this device easy to set up and use.

Easy configuration of the Leuze RSL Series safety laser scanner via Bluetooth and Ethernet TCP/IP makes this device easy to set up and use. Further, despite the large number of possible field pairs – up to 100 – it is simple to create independent configurations with its application oriented one-step configuration.

Available from leading sensing solutions specialist Countapulse Controls, the Leuze RSL safety laser scanner offers 16 device versions with operating ranges of up to 8,25 metres. The large scanning angle of 270 degrees is especially advantageous as this facilitates mounting on corners or edges to allow for front and side guarding. Significantly, depending on the actual application, it is possible to replace a second laser scanner with this single device.

The device features two completely autonomous protective functions, and has two pairs of safety switching outputs making it ideal for safeguarding and access guarding applications with separate machine parts.

Basic functions such as automatic start/restart, start/restart interlock (RES), contactor monitoring (EDM) can be selected. Optimum handling is ensured by means of separate intelligent connection unit and a large, plain-text display with integrated electronic spirit level.

Effectively manage lightning risks for complex applications

"What do airports, mines, power generation plants and power infrastructure, communications/data infrastructure and large industrial plants like oil & gas have in common? They are all particularly exposed and vulnerable to the effects of lightning, and the consequences can be particularly severe." According to Engenamic, with their team's leading specialist professional engineering expertise in the field of lightning safety and lightning protection, there are particular general characteristics of such sites and applications that contribute to this vulnerability and exposure.

In particular, they present complex site and application environments from a variety of aspects (not just technical) - and this complexity impacts directly on the broad-based risks and engineering (and other) management challenges associated with lightning safety and lightning protection. These complexities also mean that a holistic, sound and systematic engineering approach is required, that goes beyond a simplistic application of standards.

Consequently, Engenamic advise that effective management of these risks requires that solutions are comprehensively engineered and managed through an appropriate and systems engineering approach using appropriate professional expertise.

Francois Schindehutte accepting GRT IAS 2017 awards

Growthpoint leads financial reporting and communication at the Investment Analysts Society Awards

Growthpoint Properties is the overall winner of the Investment Analysts Society (IAS) Excellence in Financial Reporting and Communications Awards 2016, and the winner for the property sector for the sixth consecutive year.

Each year, the IAS presents awards to companies that display excellence in transparency, financial disclosure and communication with members of the IAS and the investment community. The IAS awards winners for the 2016 financial year were announced at the JSE yesterday.

An esteemed award for excellence in providing and communicating market intelligence from the IAS is assurance of the quality of information provided to analyse the company. Growthpoint Properties Managing Director, Estienne de Klerk, comments: *"These awards underscore Growthpoint's commitment to excellent financial reporting and communication."*

IEC Young Professional Programme Participants

IEC Young Professionals Winners

The winners of this year's IEC Young Professionals' programme was recently announced at a workshop held by the SABS. The SABS is co-sponsoring this programme with the South African Institute of Electrical Engineers.

Bashkaran Vandeyar of GIBB Engineering, Durban and Darryn Cornish of Sasol are the two candidates chosen as our South African representatives to attend the international IEC Young Professional Programme in Vladivostok, Russia.

The IEC Young Professionals' (YPs) Programme was started by the International Electrotechnical Commission (IEC) in 2010, targeting engineers working in industry in the age group early 20s to mid-30s. The objective is to ensure that the technical work of the IEC would be future-proofed with a growing number of new generation technical experts familiar with standardisation and the role of the IEC.

The first IEC YP Programme took place in 2010, and South African was represented then and every year since, expect for 2011. Since 2013, the South African National Committee (SANC) of the IEC has been organising an annual competition to select two candidates to be proposed to the IEC to attend the international IEC Young Professional Programme, co-located with the IEC General Meeting.

The interest in the competition and in the local South African Chapter of IEC Young Professionals has been growing each year. This year, after reviewing approximately 122 responses to an on-line survey/questionnaire, 26 local YPs were invited to submit essays.

South African Young Professionals in the electrotechnical field are encouraged to join the IEC Chapter of IEC Young Professionals. For more information, contact the Secretary of the South African National Committee, Paul Johnson: paul.johnson@sabs.co.za.

Darryn Cornish with IEC National Committee Secretary, Paul Johnson at SABS.

Bashkaran Vandeyar with SABS GM Denesh Naidu at SABS Durban Offices.

From left: Dr Prathaban Moodley and Jacob Machinjike (2017 SAIEE President).

SAIEE President's Invitational Lecture

The University of Johannesburg's Auckland Park Campus played host to the SAIEE's annual President's Invitational Lecture, presented by Dr Prathaban Moodley.

Dr Prathaban Moodley has been with Eskom for 16 years in various roles. He is currently the Technology Strategy & Planning Manager at Eskom Research, Testing and Development. Dr Moodley's focus areas include: Transmission, Distribution, Asset Management, Network Planning & Operations and Smart Grids. He is active in supervising and examining postgraduates at various academic institutions in South Africa. Dr Moodley is a founding member of the South African Smart Grid Initiative (SASGI).

He also serves on the EXCO of the International Energy Agency's Implementing Agreement for a Co-operative Programme on Smart Grids (ISGAN) as well as the University of Pretoria's Electrical Engineering Advisory Board.

Dr Moodley has studied for various degrees at the University of the Witwatersrand, Johannesburg, which are: BSc (Eng), MEng (Distinction) and PhD degrees in Electrical Engineering.

In his presentation, *"Incremental and Disruptive Technologies and its impact on the Power Utility"* Dr Moodley discussed how technologies will fundamentally change the grid of the future. These technologies include: internet of things, big data, advanced analytics, distributed energy resources, advanced demand side management, and the plug-in electric vehicle. These technologies will inevitably influence the way the wired system is planned, designed and operated. He explored the impact of these technologies and the state of research as well as the barriers and opportunities for leveraging these technologies in the South African and African power system.

Etienne Venter, ACTOM High Voltage Equipment's Design Engineer, and (from left) Andries Modime, Assistant HV Tester; Clarence Tsire, HV Tester; and Silas Risimati, Team Leader, VT Winding Section, with the prototype of the new dual-voltage VT now in production.

ACTOM High Voltage Equipment develops dual-voltage voltage transformers

A move by several major metropolitan municipalities, among others, towards raising the transmission voltage for substations from 88kV to 132kV has prompted ACTOM High Voltage Equipment to develop a dual-voltage voltage transformer (VT) to facilitate the transition at minimal cost to users.

"The conversions due to be implemented by various electrical authorities will involve a process whereby substations that are to be converted need to operate at 88kV for a period until the conversion to the higher voltage level of 132kV has been completed," explained Etienne Venter, the division's Design Engineer.

"Consequently if an 88kV substation is to be converted into a 132kV facility, it requires replacing the existing 88kV VT's with 132kV units. We have overcome this stumbling block by developing the new dual-voltage VT, which provides for a seamless changeover from the lower to the higher voltage without the customer having to incur the extra cost of replacing existing units with higher rated ones."

A number of the new VT's are to be installed in the 88kV/11kV Roosevelt Park substation currently being extended and refurbished in the Johannesburg suburb of that name by Midrand-based substation contractors F&J Electrical. The company placed an order with ACTOM High Voltage Equipment in January this year for six units, along with 21 x 132kV current transformers, for the project.

Design of the new VT commenced late last year. "What enabled us to develop it as speedily as we have is that the bulk of the design was based on the already proven design of the 132kV compact VT we developed and introduced into the market in 2015," said Venter.

"This meant that most of the components had already been tested, so only a limited number of components in the dual-voltage unit needed to put through the full battery of tests normally required on a newly-designed product."

From left: Michelle Naidoo [SHERQ Manager]; Fred Knoetze [MD]; Marthinus van Schalkwyk [Director] unveiling new certificate during staff function.

EHL Consulting Engineers, who have held ISO 9001:2008 certification since 2010, proudly announced on Friday, 9 June 2017 that they have successfully achieved the updated standard ISO 9001:2015 certification. The formal announcement was made during an unveiling of the certificate at their head offices in Marshalltown, Johannesburg.

The staff's commitment and support in attaining this achievement demonstrates the company's resolve to uphold a superior quality management system, consistently providing products and services that meet regulatory requirements, and exceed customer expectations. EHL has now set the industry benchmark with this achievement, being the first consulting engineering firm to obtain the Dekra accreditation for this 2015 version of ISO 9001.

Peter Ndoro, Business and Economics Anchor, SABC2 'Morning Live' being interviewed by Topco Media at the Vision 2030 Summit held 21-22 June 2017

Third Vision 2030 Summit sparks conversations

With the aim of stimulating conversation around a roadmap, for achieving the goals of the National Development Plan (NDP), around 300 decision makers, from both the private and public sector, came together at the 3rd Annual Vision 2030 Summit, to talk about key contributors to alleviating poverty, inequality and joblessness by the year 2030.

This was held at the Birchwood Hotel in Johannesburg, from 21-22 June. The two-day event fielded keynote speakers such as Presidential candidate Dr Mathews Phosa, Stella Ndabeni-Abrahams, Dr Petrus De Kock, Prof. Arthur Mutambara and many more experts.

Both the private and public sectors are prioritising technology and digitisation as an essential driver to accelerate progress on the NDP. This is to be achieved by organising a network of implementers of socioeconomic transformation, thereby empowering ordinary South Africans through connectivity and shared knowledge.

Collaboration, cooperation and communication are key to achieving the NDP.

Delivering a thought-provoking keynote address, Dr Mathews Phosa reflected on the Freedom Charter and honoured the late Oliver Tambo.

He said that South Africa *"deserves a recovery plan, developed and implemented under the watchful eyes and guidance of a trusted and virtuous leadership. A plan reflecting the dreams of those who formulated and penned the Freedom Charter of 1955 ...the National Development Plan must be strongly advanced as the inclusive recovery plan to change South Africa for the better."*

After the intensive discussions of the Vision 2030 Summit, it was time to recognise the outstanding achievements of individuals and organisations that have been furthering or supporting national development in the last year.

The 2017 Vision 2030 Award Winners are: Powering South Africa Award - ArcelorMittal South Africa;

- Agriculture Award - Amadlelo Agri;
- Infrastructure Development Award - Coega Development Corporation;
- Science & Technology Award - Council for Scientific and Industrial Research;
- Healthcare Award - Clicks Group and Hospice Palliative Care Association – Highly Commended;
- Education Award - University of Johannesburg;
- Mineral Award - ArcelorMittal South Africa and Anglo American Platinum – Highly Commended;
- Industrial Policy Action Plan Award - Durban International Convention Centre and Amadlelo Agri - Highly Commended;
- SMME Award - Soweto Outdoor;
- Driver For Change Award - Khalid Abdulla – African Equity Empowerment Investments, and Asher Bohbot – EOH Holdings - Highly Commended.

Solar Powered Variable Speed Drives For Remote Borehole Applications

Farmers are making increasing use of photovoltaic solar panels and variable speed drives (VSDs) to get clean and continuous power to their boreholes in remote locations, cutting out the need for costly infrastructure and cables to link with the main grid.

Zest WEG Group, a subsidiary of leading Brazilian motors and controls manufacturer WEG, supplies these stand-alone electrical solutions so that users in the agricultural sector can immediately benefit from 'free' solar power for pumping water.

As a key element of this arrangement, the VSD protects the motor from the fluctuating energy flow of the solar panel, allowing the motor speed to vary as the strength of the sun's rays changes with weather and times of day. This ensures maximum system operation during the day while protecting the motor and VSD.

In addition to this, the VSD also offers a variety of other motor protection features such as over voltage, under voltage, phase imbalance, phase loss and over current which would normally have had to be done by other external equipment. The appropriate model of VSD is selected from the range of WEG units, to suit the size of motor and pumping capacity required. Typically, the photovoltaic option is chosen for motor sizes up to approximately 5,5 kW, but larger motors can also be catered for by installing more solar power capacity.

The added value in WEG's VSD includes the company's in-house software that allows its highly skilled technicians to optimise the performance of the motor and pump, according to the application.

The solar powered option also eliminates the potential voltage drop over extended lengths of electrical copper cable between the source and the motor, as well as the possible theft of this cable and the resulting disruption and added cost.

Supporting customers is key to Zest WEG Group's operating philosophy, and the Group operates a network of strategically situated branches and distributors across South Africa and the continent.

The WEG VSD protects the motor from the fluctuating energy flow of the solar panel.

Experienced technical staff is available countrywide to advise customers, as well as to set up and commission this innovative, renewables-based solution.

Earnings Have Reached An Upper Turning Point With A Softer Growth Outlook In The Medium Term

The Consulting Engineers South Africa (CESA) Bi-annual Economic and Capacity Survey (BECS) for the period July to December 2016, released in June 2017, indicates that earnings have reached an upper turning point with a softer growth outlook in the medium term.

The South African economy grew by the slowest rate in 2016, since the 2009 recession when economic growth contracted, barely missing another recession. Growth was well below government expectations and therefore has a significant impact on expected revenue collection and expenditure plans. Business confidence remained weak in the 1st quarter of 2017 as political turmoil and instability weigh heavily on the South African economy and business sentiment. At the current rate, investment levels will remain poor, contributing to constraints in South Africa's economic growth as well as investment in construction. All economic indicators currently suggest that investment in relation to GDP is likely to slow over the medium term, due to slower government spending, financial constraints experienced by SOE's and continued weak private sector confidence.

Chris Campbell, CEO of CESA states, *"Considering trends in industry indicators, as reported by our member firms in our latest BECS survey, there are indications that earnings have reached an upper turning point with a softer growth outlook in the medium term for the industry. Business confidence levels first need to be restored to encourage higher levels of investment and kick start the beleaguered South African economy."*

He states that service delivery, especially at municipal level remains a critical burning issue. The consulting engineering industry is threatened by incapacitated local and provincial governments. As major clients to the industry, it is important that these institutions become more effective, more proactive in identifying needs and priorities and more efficient in project implementation and management.

Insurance to benefit our SAIEE Members

Formed in 1909, the South African Institute of Electrical Engineers (SAIEE) has grown to more than 7500 members. The SAIEE Members are professionally engaged in the full range of engineering activities, including academic research, manufacturing, electronics, telecommunications, measurement and control, mining, and power infrastructural services. Our members make meaningful contributions to the quality of life for their respective communities. Their efforts are acknowledged in many countries across the world.

As an SAIEE member, you receive various benefits:

- You receive a discount on ECSA annual membership fees;
- Receive 11 issues of the **watt**now magazine per year;
- Access to the peer-reviewed Africa Research Journal;
- Access to Monthly Lectures;
- Discounts on CPD Training Courses;
- Access to CPD accredited Site Visits;
- Be part of a SAIEE Centre in your area;
- Networking Opportunities;
- Assist in Recruitment;
- A Mentorship Programme;
- Serve on Organising Committees;
- Access to the Electrical Engineering Library at SAIEE House;
- Claim 1 (category 3) CPD credit for being a SAIEE Member.

Now, we have revised the benefits, and decided that our benefits lack something unique. We are introducing, SAIEE Sure – a unique insurance policy that gives the SAIEE Member exclusive benefits.

By belonging to this insurance, the SAIEE Member receives:

- Group rate discount;
- Specialty Cover (R100 000 unspecified all risks);
- Ring-fenced Membership – if a SAIEE Member resigns from the SAIEE, they will automatically default to the public rate;
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- Dedicated back-office support;
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- Tailor-made solutions for each individual;
- Lifestyle Program – discounted hotel stays, etc.; and
- 24-hour emergency assist - plumber, electrician, locksmith, etc.

To join the SAIEE Sure scheme today, email your current policy to insure@saiee.org.za and receive a no-obligation quote, based on your current policy – so you can compare apples with apples!

What are you waiting for – start saving!

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- Specialty Cover (R100 000 unspecified all risks)
- Ring-fenced Membership
- Exclusivity
- Dedicated back-office support
- Fast and Effective Claims Procedure
- Tailor-made solutions for each individual
- Lifestyle Program
- 24-hour emergency assist

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- Start saving

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ELPA Launch

As a country, South Africa experiences 24 million lightning strikes annually, with a related death toll of more than 500 officially recorded every year.

This fatality rate, from lightning, is one of the highest in the world; and could, in fact, be even higher when we take into account possible unrecorded lightning deaths in rural areas and, similarly, the homeless people. To date, the South African lightning protection industry has arguably been somewhat disconnected. There is a need for more coherent knowledge dissemination, communication around the potentially deadly dangers presented by lightning, and over-arching legislation to advise and guide all concerned parties. Despite this, the research and development around lightning protection in South Africa has been leading the world in particular areas.

This is according to Alexis Barwise, Chairman of the newly-launched Earthing and Lightning Protection Association (ELPA). This has been formed to protect consumers, establish a uniform interpretation of the codes of practice, and help to regulate and advise the lightning protection industry. ELPA was established as a non-profit organisation of voluntary membership.

Speaking at the ELPA launch on 19 June 2017 at Wits University in Johannesburg, Barwise said, *"When we compare the annual statistics for lightning deaths in South Africa to the numbers of deaths from shark attacks, we could expect a maximum of ten or fewer recorded deaths from unprovoked shark attacks in our waters every year. Shark nets in the waters off our beaches, as well as people on shore who are acting as shark spotters, are quite common around our world-famous coastline and yet statistically, far fewer people are killed by sharks annually than by lightning.*

"I believe that the same vigilance, attention and resources should be applied to protecting people from lightning, and this is the primary reason for ELPA's formation. We acknowledge the need to protect life as well as property. This requires certainty, which we achieve through certification and compliance, all united under one umbrella body which brings together experts and interested parties from various areas of the lightning protection arena."

Echoing the seriousness of the threat posed by lightning, particularly in South Africa, Professor Ian Jandrell, Dean of the Faculty of Engineering and the Built Environment at the University of the Witwatersrand, said in his keynote address, *"Understanding this spectacular natural phenomenon assists with protection against its deadly force. Throughout the ages, human beings have always tried to make sense of lightning through myths and legend. Today we approach the understanding of lightning through science, drawing on decades of research which has taken place across the world and in South Africa - and is still ongoing today. Currently, the barrier to entry in the lightning protection industry is very low, but the barriers to competence are very high. In addition, our data shows that the risk of lightning strikes in this country is increasing.*

"These facts showcase the obvious need for an industry body such as ELPA, which needs to assist with education and awareness in general, including among consumers and the general public, and

should also play a role in improving the technical competency within the industry, in particular that of installers and contractors. There is a need to upskill those who carry out lightning protection installations, so that they understand the science behind what they are doing. In the lightning protection industry overall, we need to move away from a view which looks at price as the most important factor – we need to consider the cost and benefit over the life of the installation, and should never discount the human safety aspect of lightning awareness and protection. Recognising this emphasises the important of proper protection and what the cost implications would be if we cut corners and price."

Barwise explained that the formal establishment of ELPA is an important addition to the standard of safety in the South African lightning and protection industry. The association will offer certification of qualified designers, installers and inspectors, with the support of the Department of Labour, Wits University, the Electrical Contractors Association of South Africa (ECA) and the South African Institute of Electrical Engineers (SAIEE) amongst others.

This will have positive repercussions for the building of both residential and corporate structures and there is an intention to further assist regulation and claims in the insurance industry.

From left: Alexis Barwise, Chairman ELPA and Prof Ian Jandrell, Keynote Speaker.

Barwise clarified, *"Together, ELPA's NEC members already have over 100 years of industry experience. It's our intention that ELPA will prescribe guidelines around good practices, such as the issue of what a good risk management plan looks like. We propose being able to work with the insurance companies and so provide a certain peace of mind, distinguishing between possible residential versus corporate claims. An ELPA guarantee on the work will assist the insurance industry, in that we will commit to fixing sub-standard work at our cost if an installation that was guaranteed by ELPA is later found to be non-compliant. This ties in further with our plans to carry out random quality inspections. In this way, we can see how using an ELPA-certified installer would provide peace of mind. Similarly, we would provide guarantees on the design, even before installation."*

In terms of the structure of ELPA, Barwise said, *"We don't have to create everything – we can work together and use what already exists through collaboration. This is reflected in our Board, which incorporates such role players within the lightning protection industry including manufacturing members, a technical committee, a certification and inspection area, as well divisions according to different regions of the country. In this way, we've noted the need to have expertise in different areas, as well as a need to be able to report in to ELPA within your geographical location in South Africa.*

"Further, we have purposefully structured a business model inside ELPA's executive committee to sustain the organisation and keep it growing into the future. We plan to keep changing the office bearers and so keep bringing new blood into the organisation. Collaborating associations include Wits University, the South African Institute of Electrical Engineers (SAIEE), the Electrical Contractors' Association of South Africa (ECA), Eskom, the Lightning and Electromagnetics Network (ACLENet), the Association of Municipal Electricity Undertakings of South Africa (AMEU), Safe House and the Lightning Interest Group for Health Technology and Sciences (LIGHTS)."

Barwise concluded, *"In short, it is our goal to ensure accountability, and this will be a shared responsibility that will also be driven by other bodies. The entire concept around ELPA's formation hinges around uplifting and uniting the lightning protection industry, and upskilling all those who are involved in it. In all of this, ELPA will be the glue."* wn

Renewables Continue to Break Records, but Room for Improvement Remains

BY | SOFIA SAUVAGEOT | WIND SEGMENT LEADER | GE'S POWER CONVERSION

Ten years ago, the landscape was very different. Driverless cars were just something you saw in sci-fi films. We didn't have film streaming services (can you even imagine a life without them now?), and smart phones just made their debut in the market.

Great strides have been made in the last decade not only in the way we interact with technology, but also in how we consume energy. In 2007, global renewable electricity generation capacity was at an estimated 240 gigawatts, which at the time was a significant amount. Fast-forward to a decade later, and the reality is strikingly different.

Today, countries across the globe are relying less and less on fossil fuels and are continuing to focus on powering the world through clean energy. The latest report from the International Energy Agency claims that a record 153 gigawatts of green electricity was installed last year alone, which was more than the total power capacity of Canada.

It's now time to build on this momentum and commit to a bright future for the next generation. In this blog, we will look at some of the biggest trends that are shaping the renewable energy landscape over the coming years.

FAST INNOVATION CYCLE

Today, innovation is moving at break-neck speed. It took fossil fuels decades to take over the world, yet it took only 20 years for renewables when they overtook coal as the world's largest energy source last year. In order to become a viable and competitive energy source, renewables have, in turn, catalyzed vast technological advances, which have had a profound impact on the business models and mindset that companies must adopt to stay ahead in an increasingly competitive market environment.

In the solar industry, new innovations are focused to increase equipment efficiency to extract more power out of the sun. One of these latest innovations comes from the new material Silicon Carbide (SiC). For example, a Silicon Carbide inverter allows an additional 1 percent in power conversion efficiency compared to today's standards. This may not seem like a big amount at first glance, but if a 100-megawatt solar plant was just 1 percent more efficient, it could result in more than $2.5 million worth of additional energy being produced over the plant's lifetime.

Similar transformations are happening in the wind industry, where equipment availability is of paramount importance. The premium high availability requires high reliability of each single piece of equipment as well as the entire system. At GE, we provide generators, converters, pitch motors and even the turbine itself. We know each piece of equipment inside and out, and therefore are able to provide an integrated solution with each equipment configured for optimized energy output.

GROWTH IN SCALE

Scale is also gaining momentum as the popularity of renewables continues to soar. Today, national governments as well as regional authorities are eyeing to support and leverage large-scale renewable farms to provide more affordable clean energy, as these super-sizing farms can unlock economies of scale and bring in significant infrastructure cost reductions.

As plants grow in size, new opportunities rise to improve efficiency at the farm level through system optimization. Energy organizations should also look at solutions that allow a truly integrated approach.Meanwhile, we have also seen the procurement processes move to an auction model—the government issues a call for tenders to procure a certain capacity or generation of renewables-based electricity. This new approach is providing privilege to large renewable farms that can then enjoy economy of scale out of larger installations. Driven by a more well-planned and transparent process as well as more cost-effective renewable electricity production, the model is expanding worldwide. Emerging countries, such as Brazil, are among the first to launch this auction system.

WHERE THE FUTURE LIES

However, as the demand for power continues to increase globally, relying on a sole source of renewable energy does (unnecessarily) limit options. That's why the current focus should be on using technology to combine multiple energy sources and tackling the overarching challenge of unpredictable energy output. Hybrid power generation really is the key to unlocking the power required for future generations, but this is not the only option. Through utilizing digital technologies, operators can also manage multiple farms from a central location, helping to monitor performance concurrently and make data-driven decisions to optimize energy output while maximizing revenues based on changing grid pricing conditions.

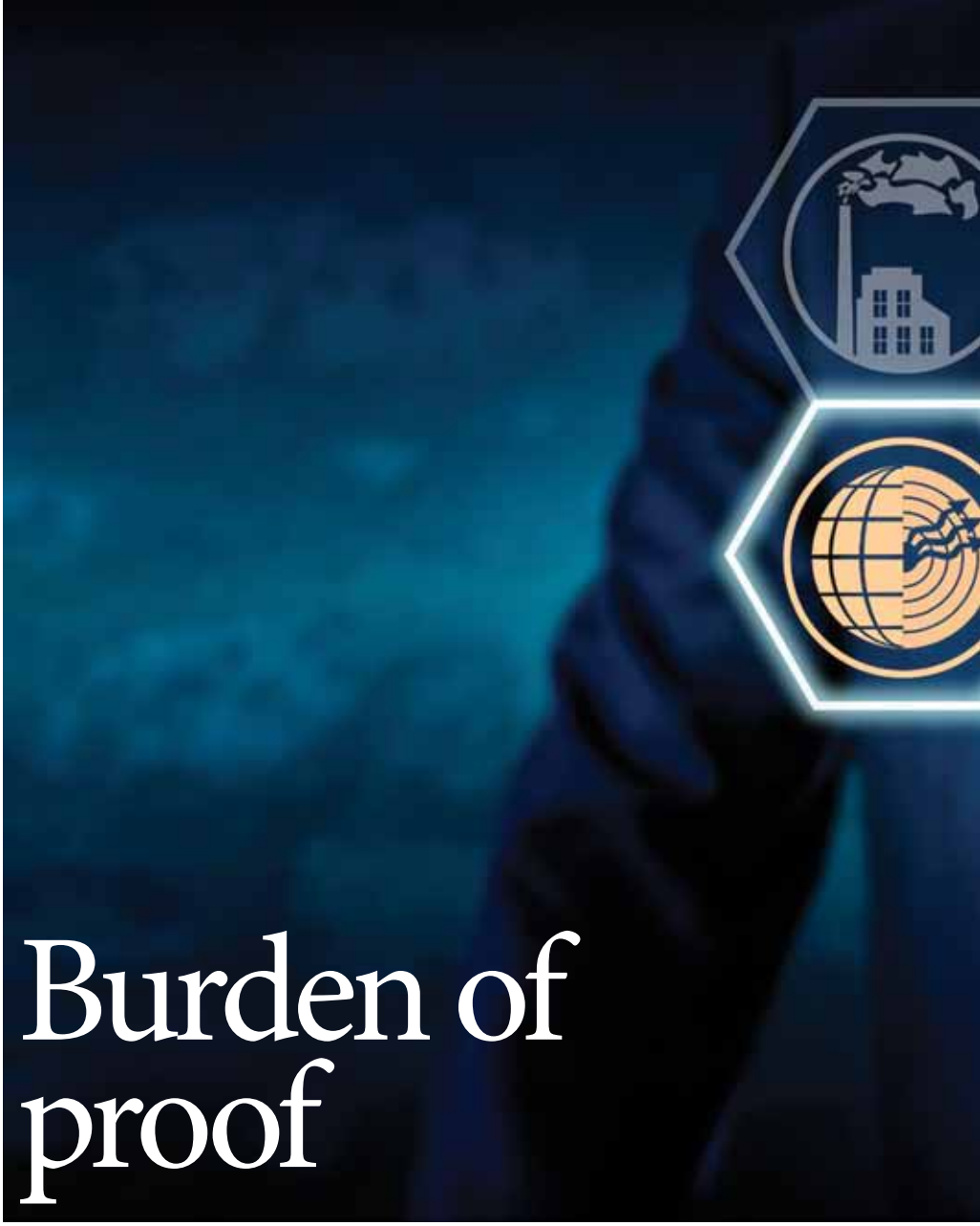
The use of the "digital twin"—a powerful digital replica of physical assets—can allow operators to move to a predictive model of maintenance. This allows for the reduction of unplanned downtime and excessive maintenance costs. By comparing the digital twin to the asset at real time, it can warn of off-standard behavior up to weeks in advance and prevent potential failures before they strike. This data-driven approach can thus increase efficiency and productivity, as well as reduce risks of plant shutdown.

In fact, the digital promise stretches farther and wider. From Henry Ford's moving assembly line to Taiichi Ohno's Toyota production system, now known as lean production, manufacturers globally have constantly strived to make their operations better. Today, the key to this is digital technology. GE has built "Brilliant Factories" where factory equipment and software can talk to each other over the internet in real time, share information and help operators make more informed decisions that will help ensure product quality and avoid unplanned plant shutdowns.

Renewables are expected to cover more than 60 percent of the increase in world electricity generation over the medium term, rapidly closing the gap with coal. While 2016 was an excellent year, there is still room for more work. Incremental gains can be achieved through asset optimization, but as the future of renewables is inevitably marching towards a more sustainable hybrid and digital future, companies should make themselves ready to embrace the leap to ensure its continued vitality and long-term viability. wn

Earn CPD Credits

An effective response to climate change demands rapid replacement of fossil carbon energy sources. This must occur concurrently with an ongoing rise in total global energy consumption. While many modelled scenarios have been published claiming to show that a 100% renewable electricity system is achievable, there is no empirical or historical evidence that demonstrates that such systems are in fact feasible.



Burden of proof

A comprehensive review of the

Of the studies published to date, 24 have forecast regional, national or global energy requirements in sufficient detail to be considered potentially credible. We critically review these studies, using four novel feasibility criteria, for reliable electricity systems needed to meet electricity demand this century. These criteria are: consistency with mainstream energy-demand forecasts; simulating supply to meet demand reliably at hourly, half-hourly, and five-minute timescales, with resilience to extreme climate events; identifying necessary transmission and distribution requirements; and maintaining the provision of essential ancillary services. Evaluated against these objective criteria, none of the 24 studies provides convincing evidence that these basic feasibility criteria can be met. Of a maximum possible unweighted feasibility score of seven, the highest score for any one study was four. Eight of 24 scenarios (33%) provided no form of system simulation. Twelve (50%) relied on unrealistic forecasts of energy demand. While four studies (17%; all regional) articulated transmission requirements, only two

BY | B.P. HEARDA | B.W. BROOK | T.M.L. WIGLEYA | C.J.A. BRADSHAW

feasibility of 100% renewable-electricity systems

scenarios—drawn from the same study—addressed ancillary-service requirements. In addition to feasibility issues, the heavy reliance on exploitation of hydroelectricity and biomass raises concerns regarding environ- mental sustainability and social justice. Strong empirical evidence of feasibility must be demonstrated for any study that attempts to construct or model a low-carbon energy future based on any combination of low-carbon technology. On the basis of this review, efforts to date seem to have substantially underestimated the challenge and delayed the identification and implementation of effective and comprehensive decarbonization pathways.

The recent warming of the Earth's climate is unequivocal. Over the 20 years to 2015, atmospheric concentration of carbon dioxide has risen from around 360ppm (ppm) to over 400ppm; emissions of carbon dioxide from fossil fuels have grown from approximately 6.4 Gigatonne of Carbon (GtC) year^{-1} in 1995 to around 9.8 GtC year^{-1} in 2013. Global average temperature rise has continued, with 2016 confirmed as the warmest year on record. Thermal coal production increased for 14 consecutive years to 2013 before recording a slight decline, with a net increase of approximately 3 billion tonnes of production per year since 1999.

Inexpensive and abundant energy remains crucial for economic development; the relationship between per-capita energy consumption and the United Nations Human Development Index is "undeniable". But there seems little prospect of decreasing energy consumption globally this century, especially with > 10% of the global

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population in extreme poverty. With the fate of modern society and global environments at stake, effective action on climate change demands credible, evidence-based plans for energy systems that: (i) almost wholly avoid the exploitation of fossil carbon sources, and (ii) are scalable to the growing energy demands of approximately nine to ten billion people by mid-century, and perhaps over 12 billion by the end of the century. This process logically begins with displacing coal, gas and oil in electricity generation. This must eventually expand to eliminate nearly all fossil hydrocarbon used in industrial and residential heat, personal and commercial transportation, and most other energy-related services.

Much academic, governmental and non-governmental effort has focused on developing energy scenarios devoted exclusively to energy technologies classed as 'renewable' (mainly hydroelectricity, biomass, wind, solar, wave and geothermal), often with the explicit exclusion of nuclear power and fossil fuels with carbon capture and storage. These imposed choices automatically foreclose potentially essential technologies. In this paper, we argue that the burden of proof for such a consequential decision is high and lies with the proponents of such plans. If certain pathways are excluded a priori, then such exclusions should be fully justified and the alternatives proven. This is rarely the case.

There is a near-total lack of historical evidence for the technical feasibility of 100% renewable-electricity systems operating at regional or larger scales. The only developed-nation today with electricity from 100% renewable sources is Iceland, thanks to a unique endowment of shallow geothermal aquifers, abundant hydropower, and a population of only 0.3 million people. Other European nations lauded for their efforts in renewable energy deployment produce greenhouse emissions from electricity at rates close to the EU-27 average (468, 365 and 442 g CO_2-e kWh^{-1} for Denmark, Germany and EU-27, respectively).

Scenarios for 100% renewable electricity (and energy) have nevertheless proven influential as a platform for advocacy on the development of energy policy. Despite this, there has been only limited structured review of this literature to test for fundamental technical feasibility. A narrative review of 23 studies in 2012 provided a useful diagnosis of common features and gaps in the peer-reviewed literature on 100% renewable systems .

That review identified extensive deficiencies in the evidence, highlighting in particular the lack of attention paid to the necessary transmission/distribution networks, and provisions of ancillary services. In assessing the feasibility of these studies however, feasibility itself was not defined, and no firm conclusions were drawn regarding the most basic questions that responsible policy making requires: (i) can such a system work? and (ii) what evidence is required to describe such a system in sufficient detail such that elements like time, cost, and environmental implications can be estimated accurately?

IPCC Working Group III, in examining the potential contribution of renewable energy to future climate-change mitigation, examined 164 scenarios from 16 different large-scale models. However, the IPCC did not examine explicitly the feasibility of the various renewable-energy systems considered.

Repeated critiques of individual studies by Trainer have highlighted feasibility deficiencies, including the reliance on only single year's of data to determine the necessary generating capacity, and not accounting for worst-known meteorological conditions.

A critique by Gilbraith et al. identified insufficient analysis of the "technical, economic and social feasibility" of a 100% renewables proposal focused on New York State. Another recent assessment has highlighted serious and extensive methodological errors and deficiencies in a 100%-renewable plan for the continental United States. Loftus et al. examined global decarbonization scenarios (encompassing all energy use, not only electricity), including several 100%-renewable analyses. Their review highlighted several deficiencies in the latter, including assumptions of unprecedented rates of decline in energy intensity. However, their review did not consider national- or regional- level studies, nor did it attend closely to issues of electricity reliabilit.

Policy makers are therefore handicapped regarding the credibility of this literature - there is no empirical basis to understand the evidence behind propositions of 100%-renewable electricity (or energy) for global-, regional- or national-scale scenarios. Consequently, there is a risk that policy formation for climate-change mitigation will be based more on considerations of publicity and popular opinion than on evidence of effectiveness, impacts, or feasibility.

Here we provide a first step in remedying this problem. We present the results of a comprehensive review seeking evidence

that the electricity requirements of modern economies can be met through 100% renewable-energy sources. We describe the method we used to identify the relevant scenarios, define the concept of feasibility, and describe and justify our choice of assessment criteria.

We discuss the results of the assessment in terms of the strength of the evidence for technical feasibility of 100% renewable-electricity systems, and outline some of the major environmental and human development implications of these proposed pathways. Our intention is to provide policy makers and researchers with a framework to make balanced and logical decisions on low-carbon electricity production.

METHODS

We identified published scenarios that have attempted to address the challenge of providing electricity supply entirely from renewable sources.

We applied the following screening criteria for this literature search: (i) Scenarios had to be published after 2006: we applied this cut-off date to weight selections towards literature that was representative of the current state of knowledge; (ii) Scenarios must propose electricity supply to be from at least 95% renewable sources (through some combination of hydroelectricity, biomass, wind, solar, geothermal or wave energy); (iii) For spatial scale, scenarios must consider large-scale demand areas such as the whole globe, whole nations, or covering extensive regions within large nations (so excluding scenarios for single towns, small islands, counties, cantons and the like); (iv) Scenarios were required to forecast to the year 2050 or earlier. If scenarios extended beyond 2050, but still allowed scores to be determined based on 2050 milestones, we included the scenario and scored it against the 2050 outcome.

We were principally concerned with evidence for the strict technical feasibility of proposed 100%-renewable electricity systems. We were not seeking to establish the viability of the proposed systems. These terms are frequently used interchangeably. We use viability as a subordinate concept to feasibility. We define feasible as "possible within the constraints of the physical universe", so a demonstration of feasibility requires that evidence is presented that a proposed system will work with current or near-current technology at a specified reliability.

Note that our use of feasible refers to the whole electricity system, not merely the individual items of technology, such as a solar panel or a wind turbine. Viable means that the system is not only feasible, but also realistic within the socio-economic constraints of society. Thus, unless something is first established as feasible, there is no point in assessing its viability.

Our definitions are not unique; feasibility has been used elsewhere to refer to technical characteristics of the energy system under assessment, and Dalton et al. explicitly distinguished between solutions that are "technically feasible" but not considered "economically viable". This distinction is not applied universally. Several other studies confound these terms or have used them semi-interchangeably. For example, while Loftus et al. acknowledged the physical barriers of feasibility, their use of the term extended beyond what they called "hard physical constraints". Our study is based on the lower hurdle only. We require only evidence for feasibility, i.e., that the system will work.

Even so, our use of feasible requires four subsidiary criteria so that it can be workable when applied to a whole electricity network. Our goal is to distil many of the issues raised by previous critical examinations into a well-defined set of criteria. Below we describe our four subsidiary feasibility criteria.

Criterion 1: The electricity demand to which supply will be matched must be projected realistically over the future time interval of interest

Total global energy consumption, consisting of both electrical and non-electrical energy end-use, is projected to grow to at least 2100. Population growth is expected to continue at least to the end of the century. Nearly all of the expected population growth - around 2.4 billion people relative to today (range 1.4–3.5 billion) - will occur in Africa, Asia and the Middle East. These growth trends contain such momentum that the range of possible mid-century outcomes is insensitive even to major interventions in fertility policy, or widespread catastrophe. This population growth will occur at the same time as growth in per-capita income, which is strongly correlated with per-capita energy consumption in the early stages of modern development.

Growth is also anticipated specifically for electricity consumption. The International Energy Agency estimates that in 2016, > 1.2 billion people had no access to electricity. Electricity supplies an increasing share of the world's total energy demand and is the world's fastest growing form of

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delivered energy. Projected "electrification" of energy use in countries outside the Organisation for Economic Co-operation and Development (OECD) is higher (3.6% year^{-1}) than in OECD countries (1.1% year^{-1}), but different models make a wide range of forecasts.

An effective climate change response requires provision of electricity to avoid the exploitation of fossil fuels. Substitutes will also be required for non-electric energy services traditionally met by fossil fuels. Today, fossil-fuel sources account for about 80% of primary energy and two thirds of final energy. This reflects not only the availability, but also the great utility of hydrocarbon fuels in a variety of services including transportation and industrial process heat. To achieve deep climate-mitigation outcomes, these energy services must be provided in ways that minimize the use of fossil carbon sources. Electrification of energy services via non-carbon-based electricity generation offers one pathway towards that outcome. However, other energy-intensive pathways, such as the production of synthetic hydrocarbons or ammonia, are also likely to be required to achieve the required stabilization of atmospheric carbon dioxide while meeting demand for versatile energy services.

Given these issues, any future global scenario that presents static or reduced demand in either primary energy or electricity is unrealistic, and is inconsistent with almost all other future energy projections. Such an outcome would be at odds with the increase in global population, ongoing economic development for the non-OECD majority, and the firmly established link between industrialization and increased energy consumption. The inevitability of increased primary energy consumption holds, even after accounting for projected rates of decline in energy intensity (primary energy GDP^{-1}) - rates that are expected to be more than the average rate of change for the last 40 years (−0.8% year^{-1}). For example, the most extreme (Level 1) mitigation scenarios in the US Climate Change Science Program Report show primary energy increases of 0.26%, 0.62% and 0.85% yr^{-1} over 2010–2050 for the IGSM, MERGE and MiniCAM models, respectively, compared with (and much less than) the corresponding rates of gross domestic product change (2.80%, 2.35% and 2.28% yr^{-1}, respectively).

While the implied reductions in energy intensity are large, primary energy consumption will still increase. Electrification results (electric primary energy/total primary energy) show how complex this parameter is. For the IGSM from 2010 to 2050, electrification is predicted to decrease (from 0.43 to 0.37), while electrification increases in the other two models, from 0.38 to 0.54 in MERGE, and from 0.41 to 0.52 in MiniCAM. Scenarios that project electricity demand under the assumption of extreme increases in electrification might imply unrealistic energy transition pathways that are inconsistent with the mainstream literature.

So for scenarios to be feasible, they must be consistent with: (i) the range of primary energy projections in the mainstream literature for that region, and (ii) complementary projections in total electricity consumption. Electricity-demand scenarios that are inconsistent with the above represent low-probability outcomes. Effective climate-change mitigation under scenarios that diverge from the above would call for total reinvention of both supply and demand of energy. Proposed supply systems for such scenarios therefore represent policy pathways with a high potential for failure.

Criterion 2: The proposed supply of electricity must be simulated/calculated to be capable of meeting the real-time demand for electricity for any given year, together with an additional back-up margin, to within regulated reliability limits, in all plausible climatic conditions

An electrical power system must provide reliable electricity to its customers as economically as possible. Cepin stated that power-system reliability depends on both adequacy and security. Adequacy refers to the existence of sufficient generation for the electric power system to satisfy consumer demand at any time. Security describes the ability of the system to respond to multiple types of disturbance in the quality of power supply. These concepts together define a reliability standard, which prescribes the required service as a percentage of customer demand that must be served over a given period of time (e.g., 1 year).

High reliability (>99.9%) is a common requirement of modern electricity supply (e.g., 99.98% service of customer demand every year for the Pennsylvania, New Jersey, Maryland (PJM) network in the United States, and 99.998% for the Australian National Electricity Market). Electricity supply must vary dynamically to ensure instantaneous matching with demand. For this reason, generation that is constant (i.e., available at all times [baseload]) and/or fully dispatchable (able to be called-up or with- drawn at any time in response to demand changes) is deemed essential for system reliability.

The increasing penetration of variable, climate-dependent sources of generation that are largely uncorrelated with demand, such as wind and solar generation, provides additional challenges for managing system reliability. Such generators can have high reliability in terms of being in working order, yet they have low and intermittent availability of the resource itself.

Furthermore, system-wide reliability cannot be determined based on 'typical' weather conditions, but must instead account for present and predicted variability in the resource over foreseeable time scales, from < 1 minute to decadal. Atypical conditions that are extreme, yet credible (e.g., based on historical precedent or realistic future projections), must be identified, both for each generation type in isolation and in combination (e.g. severely drought-impacted hydro-electric output in winter combined with coincident low solar and wind output).

Any proposed supply system must therefore demonstrate that the proposed supply will meet any foreseeable demand in real time at a defined reliability standard, and with a sufficient reserve margin for unscheduled outages like breakdowns. It must do so in a way that fully accounts for the limited and intermittent availability of most renewable resources and the potential for extreme climate conditions that are outside the historical record. As per Criterion 1, this reliability must be demonstrated as achievable for the full range of plausible future energy demand.

Criterion 3: Any transmission requirements for newly installed capacity and/or growth in supply must be described and mapped to demonstrate delivery of generated electricity to the user network such that supply meets both projected demand and reliability standards

Transmission networks transport electricity from generators to distribution networks, which in turn transport electricity to customers. To achieve high penetration of renewable energy, augmented transmission networks are vital. Credible characterization of the necessary enhanced transmission network is essential for establishing the feasibility of any high-penetration renewable electricity system.

Criterion 4: The proposed system must show how critical ancillary services will be provided to ensure power quality and the reliable operation of the network, including distribution requirements

Ancillary services are a physical requirement of any electrical system and have been necessary since the development of reticulated power. The availability of ancillary services can be compromised by high penetration of renewable energy sources. For example in Germany, the determined implementation of the *Energiewende Strategy* has triggered an examination of how ancillary services will be retained.

Unresolved challenges, particularly in system-restart requirements, have been identified to 2033, even in a scenario that maintains 72 GW (28% of total installed capacity) of fossil-fuel-powered, synchronous generators, in a network that is connected to greater Europe.

Such challenges at 100% penetration of renewables remain largely unexamined and unresolved.

We discuss two examples of ancillary service requirements:

1. FREQUENCY CONTROL ANCILLARY SERVICES

At any point in time, the frequency of the alternating-current electrical system must be maintained close to the prescribed standard (typically 50 or 60 cycles per second [Hz] within a normal operating band of ± 0.1 Hz). In practice, the frequency varies due to changes in electrical load on the system. Changes in frequency arise from the small, instantaneous and ongoing variation in load that occurs due to consumer behaviour (e.g., turning lights on and off), to larger changes in demand occurring in the normal course of a day. Instantaneous frequency control is typically provided by the inertia of 'synchronous' generators, where electricity is generated through turbines spinning in unison at close to the regulated standard. However, increased wind and solar penetration, with asynchronous generation of electricity, displaces traditional synchronous generators from the market.

For example, in the Australian National Electricity Market, the provision of all frequency-control ancillary services comes from bids to the market by 116 connected generating units (a mixture of coal, gas and hydro-electric power stations). No wind or solar generators are registered bidders for these services. The increase of intermittent renewable generation is already leading to a scarcity of support services in the network and an increasing risk of breaching reliability standards. Modeling the potential withdrawal of coal-fired generation to meet Australia's COP-21 commitments suggests this situation could be exacerbated in the future. In

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September 2016, the loss of transmission lines in South Australia during a major storm caused disturbances triggering the departure of 445 MW of wind generation. Without adequate synchronous generation, the rate of change of frequency exceeded prescribed limits, resulting in total power loss to all 1.7 million residents, all business and all industry in the state. The estimated economic impact of this event was AU$367 million.

2. NETWORK CONTROL ANCILLARY SERVICES: VOLTAGE CONTROL

Voltage must be managed to within specified tolerances for insulation and safety equipment. Voltage management is affected by the expansion of generation that is connected to an electrical-distribution network, known as 'embedded generation'. The impact of embedded generation has been transformed by the rapid uptake of small-scale solar photovoltaic systems. As a consequence, voltage control at distribution level has become a concern in markets with high penetration of solar photovoltaics.

Projected 100%-renewable electricity systems are incomplete in the absence of evidence that essential, regulated ancillary services will be maintained. This is particularly relevant for 100% renewable-supply systems that propose high reliance on asynchronous wind generation and embedded, asynchronous solar photovoltaic generation.

3. SCORING

With our four feasibility criteria we can assign scores for each individual study. We assigned each of Criteria 1, 3 and 4 a maximum score of one. Studies fully meeting an individual criterion scored one and we combined scores for each of these three criteria without weighting. We gave studies not meeting a criterion a score of zero. If efforts to address a criterion stood out among studies, yet still did not address the criterion fully, we gave the study a score of 0.5.

We subdivided Criterion 2 into four parts because different scenarios simulate system reliability over different time scales. We gave a score of one to scenarios simulating supply to the hour; an additional score of one to those simulating to the half-hour, and another score of one to scenarios simulating to the five-minute interval. Finally, we gave another score of one to scenarios that specifically attempted to account for, and adequately addressed, the impact of extreme climate events. Our emphasis on Criterion 2 (higher relative weighting, with a maximum score =4) is justified based on the following: (i) demand-supply matching is one of the most challenging aspects of electricity provision; (ii) the cost of meeting higher reliabilities is non-linear (i.e. increasing reliability toward 100% imparts exponentially rising costs, with diminishing returns on loss-of-load probability reductions); and (iii) maintaining reliability under extreme climate conditions that have no historical precedent further exacerbates the challenge. Thus, the maximum possible score for any scenario was seven.

RESULTS

Based on our criteria, none of the 100% renewable-electricity studies we examined provided a convincing demonstration of feasibility. Of the 24 studies we assessed, the maximum score accrued was four out of a possible seven for Mason et al. Four scenarios scored zero (i.e. they did not meet a single feasibility criterion). Eight of the 24 scenarios did not do any form of integrated simulation to verify the reliability of the proposed renewable electricity system. Twelve of the 24 relied on unrealistic energy-demand scenarios, either by assuming unrealistic reductions in total primary energy and/or by making assumptions of extreme increases in electrification. Only four of the studies articulated the necessary transmission requirements for the system to operate, and only two scenarios, from the same author, partially addressed how ancillary services might be maintained in modified electricity-supply systems. No studies addressed the distribution-level infrastructure that would be required to accommodate increased embedded generation, leaving a gap in the evidence relating to ancillary services and overall system reliability.

1. ENERGY DEMAND

Our review revealed that among the 100% renewable-energy studies examined, many assumed reductions in primary energy. This is conceptually unrealistic, and at odds with most of the literature. To show how widely each proposed global renewable energy scenario diverges from 'mainstream projections', we compared energy demand in the scenarios that considered the whole globe to the primary energy data from the following sources: the IPCC Special Report on Emission Scenarios, the US Climate Change Science Program (an inter-agency effort from the U.S. Government), and the World Energy Technology Outlook of the European Commission. We plotted 28 demand scenarios from these three organizations in 10-year steps from 2000 (where available) to 2050 (Fig. 2). This set of 28 included scenarios with strong mitigation of greenhouse-gas emissions in response to climate change. We also

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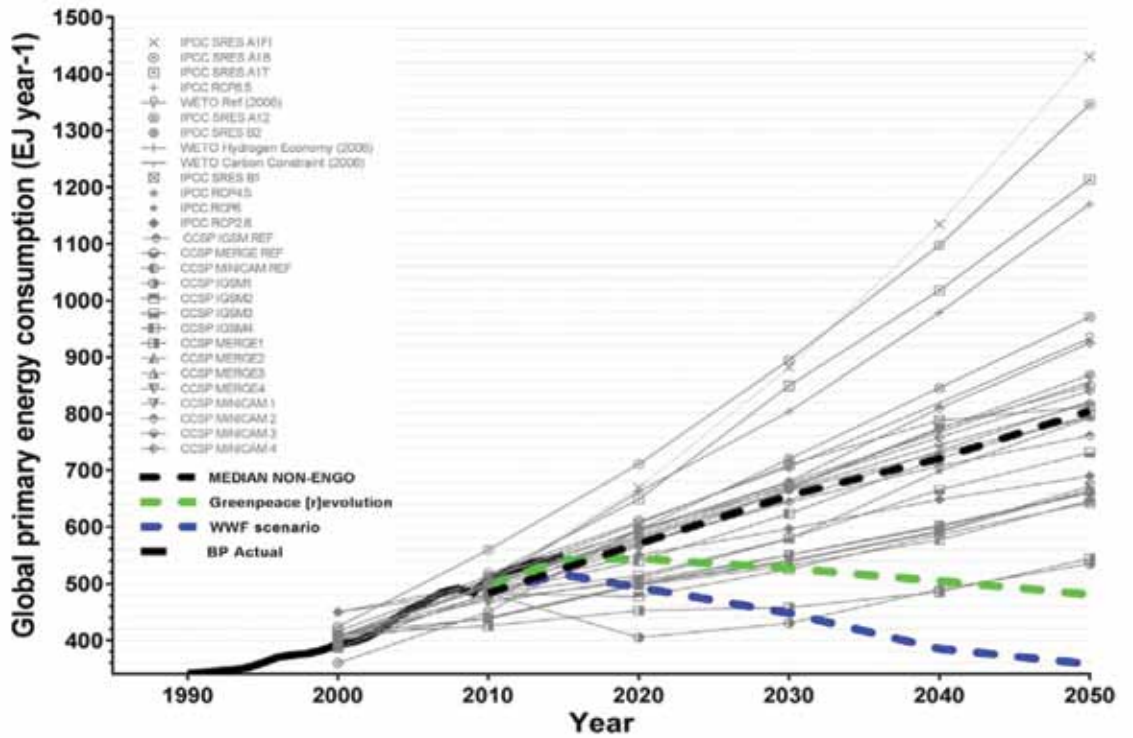

Fig. 1. Comparison of scenarios for global primary energy from the Intergovernmental Panel on Climate Change (IPCC), the Climate Change Science Program (CCSP), the World Energy Technology Organisation (WETO), the BP Statistical Review, Greenpeace and the World Wildlife Fund (WWF). All WETO values are converted from million tonnes oil-equivalent. All EIA values are converted from quadrillion British Thermal Units. Greenpeace values are converted from petajoules. All WWF values were published as final energy only and are converted from final energy to primary energy based on the ratio of primary to final energy provided in the Greenpeace scenario.

plotted actual (observed) annual global primary energy data from 1990 from the BP Statistical Review of World Energy. We calculated the median of all 28 scenarios in ten-year steps from 2000.

Primary energy consumption in 2050 for the scenarios ranges from 535 EJ for the US Climate Change Science Program IGSM Level 1 scenario (1.2% below the actual primary energy consumption figure for 2014) to 1431 EJ (165% above 2014 actual primary energy). The median is 805 EJ (+49% above 2014). Twenty-three of the 28 scenarios projected global primary energy to between 600 and 1000 EJ in the year 2050.

These 28 scenarios provide a reasonable spectrum of credible possibilities within which realistic 100%-renewable scenarios should lie (Fig. 1).

The two global scenarios from environmental non-governmental organizations (WWF and Greenpeace) assumed that total (global) primary energy consumption in 2050 would be less than primary energy consumption in their respective baseline years (481 EJ, or only 97% of the 2009 baseline for the Greenpeace scenario; and 358 EJ, or only 74% of the 2010 baseline for the WWF scenario) (Fig. 2).

These assumptions are clearly unrealistic. Human population will grow by about 3 billion compared with the baseline years.

Even in the baseline years, approximately 2.4 billion people live in energy poverty. To rely on contraction in total primary energy in 2050 compared to today, by as much as 30% in the case of the WWF scenario, is therefore implausible. Several other national and regional scenarios were based on similarly unrealistic assumptions relating to steep reductions in primary energy (Fig. 2). Additional analysis from Lund et al. contends that the magnitude of energy demand must be adjusted to the realistic amount of supply from renewable

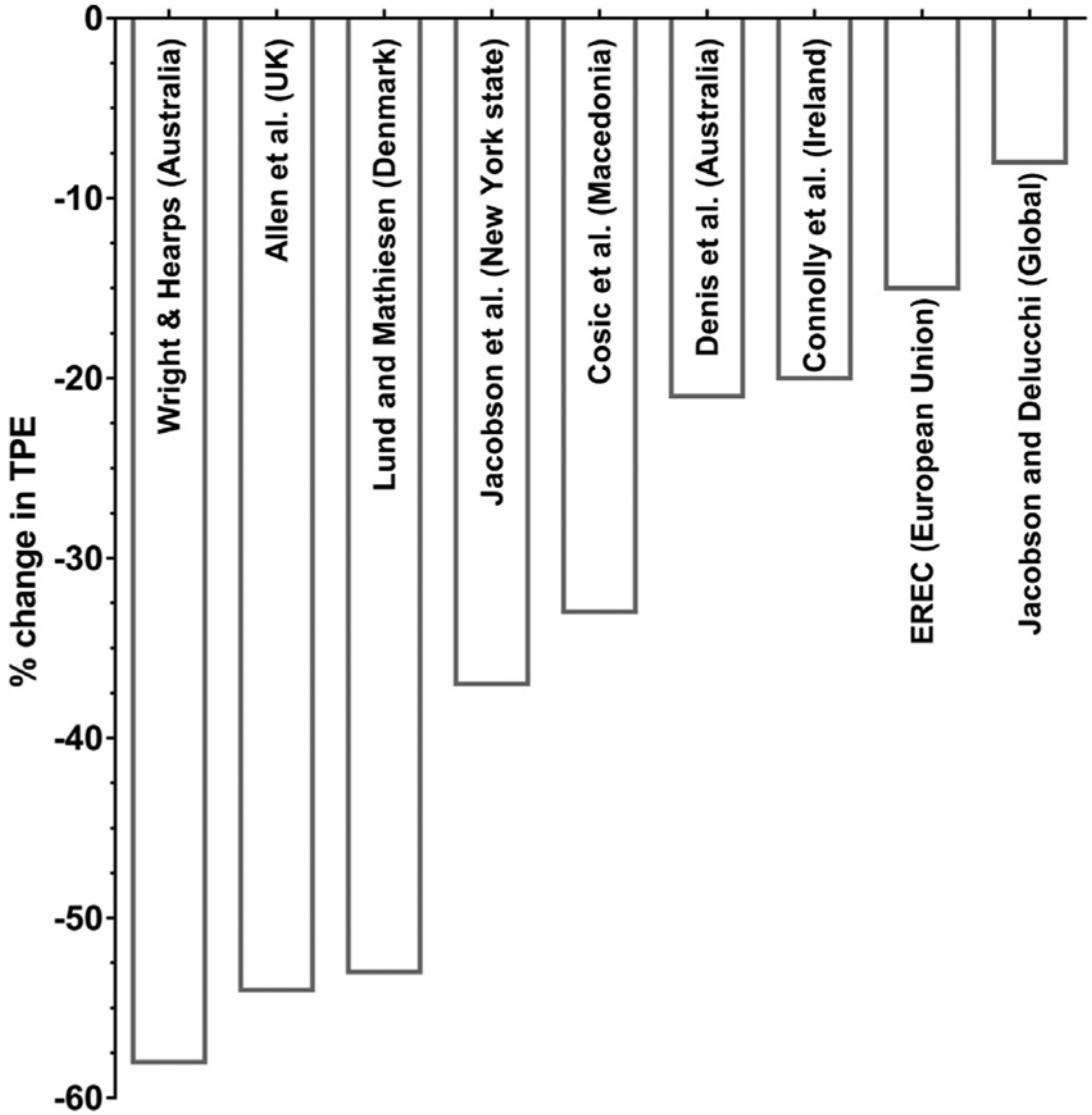

Fig. 2. Summary of percentage changes in Total Primary Energy (TPE) from baseline years across nine scenarios of 100% renewable energy. Baseline years vary among scenarios.

sources. We contend the opposite is true; supply solutions must be scalable to realistic projections of future demand.

A few scenarios attempted to maintain final energy demand at values consistent with the mainstream literature. These scenarios assumed up to 100% transition of whole-of-economy energy to either direct electrification or electrolytic hydrogen production, with reliance on flexibility of demand and/or widespread storage of energy using a range of technologies (most of which—beyond pumped hydro—are unproven at large scales, either technologically and/or economically). The speculative storage assumptions used in these scenarios, as for the earlier primary energy assumptions, are inconsistent with the literature on future energy, so these scenarios represent low-probability outcomes. They also prematurely foreclose on the application of several potential technology pathways, such as synthetic fuels or second-generation biofuels for transportation energy, and high-temperature nuclear reactors for industrial heat applications (or electricity generation).

2. SYSTEM SIMULATIONS

The absence of whole-system simulations from nine of the reviewed studies suggests that many authors and organizations have

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either not grasped or not tackled explicitly the challenge of ensuring reliable supply from variable sources. For example, WWF assumes that by 2050 the share of energy from variable renewable sources could increase to 60% via all of the following: (i) grid-capacity improvements, (ii) demand-side management, (iii) storage, and (iv) conversion of energy excesses into storable hydrogen. This suite of assumptions for managing a system dominated by supply-driven sources is largely repeated in the Greenpeace scenario (Teske et al.). In neither case is evidence from system simulation provided for how this might occur. Jacobson et al. also proposed supply systems without doing simulations, instead referencing other studies to assert that system reliability is possible. Jacobson et al. did not apply simulation processes to their own, different proposed systems, nor did they address the uncertainties, challenges and limitations articulated in their supporting references or related critiques. A recent critique highlights these and other errors in the methodologies of Jacobson and co-authors.

Of the 16 scenarios that provided simulations, only two simulated to intervals of <1 hour and only two tested against historically low renewable-energy conditions. Historical testing is useful in general, but such tests do not address the high variability of output from renewable resources, let alone the attendant uncertainties associated with future climatic changes. Because of these issues, the system-simulation approaches applied so far mostly cannot demonstrate the feasibility and reliability of 100% renewable energy systems. Additionally, several of the simulations assumed reliance on electricity-generation technologies, such as wave, tidal or enhanced dry rock geothermal, that are yet to be established on any comparable scale anywhere in the world, yet they are assumed to provide dispatchable and baseload roles in the simulations. Our framework applies no penalty against these technology assumptions; however, it further highlights the challenges that must be overcome to ensure reliability. The only study we reviewed that simulated below half-hourly reliability (i.e. 30min)offers a system simulation for the continental United States.

The results show a perfect match between supply and demand based on a renewable-energy scenario that assumed (i) expansion in the use of thermal stored energy (ii) total electrification of the United States' whole-of-economy energy needs, (iii) nation-wide dependence on underground thermal-energy storage for space and water heating based on a system that has not yet been commissioned, and (iv) flexibility in demand ranging from 50% to 95% across different energy sectors, including some industrial applications. As such, the scenario is unrealistic, violating the first criterion. Such work calls into question whether energy system simulations are valid when the system under simulation bears little resemblance to that in operation today, or one likely to be achieved in the foreseeable future.

3. LARGE, DISPATCHABLE SUPPLY

Most of the studies that did system simulations included high proportions of dispatchable-generation sources for the provision of a reliable electricity system. Those scenarios exploited two intrinsically 'stored' resources in particular: hydro-electricity and biomass. Mason et al. simulated 75–78% of generated electricity coming from dispatchable sources of expanded, unconstrained hydro-electricity and geothermal. For New Zealand, with large endowments of hydro and geothermal resources and a small population (4.5 million people), a 100%-renewable electricity system might be possible at reasonable cost, provided the consequences of unconstrained hydro ramping (i.e., the change in power flow from one time unit to the next) are deemed acceptable for the operations of the plant and the hydrology of the waterways.

The Mason and colleagues' studies reinforce the notion that integration of variable renewable energy sources into existing grids can be cost-effective up to penetrations of around 20%, after which integration costs escalate rapidly. An upper threshold to economically rational amounts of wind generation capacity is also found in simulations for the United Kingdom. Any further installed wind-generating capacity makes little difference in meeting electricity demand in times of low wind supply. While the cost-effective threshold for integration of variable renewable electricity will vary among grids, 100%-renewable studies such as these reinforce that penetration thresholds exist and that alternative dispatchable generation supplies are required to meet the balance of supply.

In other scenarios where high penetration of hydro power was not possible, biomass typically filled the need for fully dispatchable supply. Jacobson and Delucchi excluded the use of biomass globally, citing irreconcilable concerns relating to air pollution, land use and water use. However, other studies have found biomass to be essential to ensure system reliability, providing between 2% and 70% of the

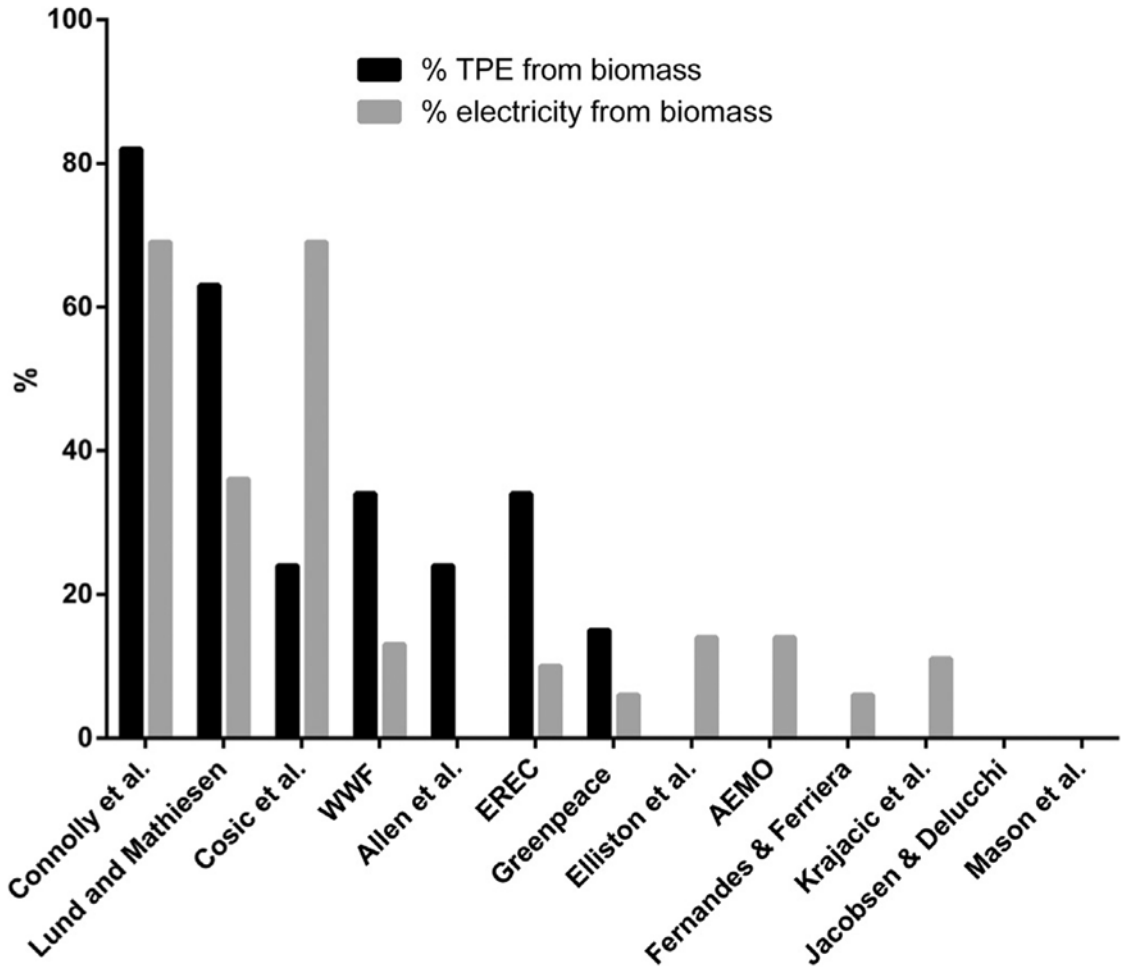

Fig. 3. Percentage contribution of biomass to total primary energy (TPE) (for scenarios covering all energy) and to electricity production other selected scenarios

electricity supplied under 100%-renewable scenarios (Fig. 3).

4. SOLAR SHOWS PROMISE IN AUSTRALIA, BUT WITH LIMITATIONS

Scenarios for Australia drew heavily on solar-thermal technologies with energy storage, and solar photovoltaics. Elliston et al. claimed to meet the high reliability standard of Australia's National Electricity Market of 99.998% on a cost-optimized basis, with 46% of generation from onshore wind and 20% from solar photovoltaic (with no storage). The scenario simulated hourly supply for a single year based on demand for the year 2010. That study did not consider demand variation on < 1-hr time scales and in terms of representativeness, is limited by using a single simulation year (both common problems; see Table 1). There is ample evidence for conditions with sustained, coincident low output from both wind and solar resources in Australia. Such conditions might converge with drought-constrained hydroelectric output in the future. Solar photovoltaic output varies on timescales of minutes, with large changes in output occurring on sub-hourly timescales. Simulation to the one-hour timescale only will therefore not account for these rapid fluctuations. Finally, an assessment based on a single year's current demand and meteorological record underestimates the system-wide reliability requirements in all years in a nation where electricity demand is forecast to grow by 30% to 2050. The subsequent attempted costing of this system is therefore unrepresentative of the future range of possibilities.

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Study	Coverage	I (Demand)	II (Reliability)	III (Transmission)	IV (Ancillary)	Total
Mason et al.	New Zealand	1	2	1	0	4
Australian Energy Market Operator (1)	Australia (NEM–only)	1	1	1	0.5	3.5
Australian Energy Market Operator (2)	Australia (NEM–only)	1	1	1	0.5	3.5
Jacobson et al.	Contiguous USA	0	3	0	0	3
Wright and Hearps	Australia (total)	0	2	1	0	3
Fthenakis et al.	USA	0	2	0	0	2
Allen et al.	Britain	0	2	0	0	2
Connolly et al.	Ireland	1	1	0	0	2
Fernandes and Ferreira	Portugal	1	1	0	0	2
Krajacic et al.	Portugal	1	1	0	0	2
Esteban et al.	Japan	1	1	0	0	2
Budischak et al.	PJM Interconnection	1	1	0	0	2
Elliston et al.	Australia (NEM–only)	0	1	0	0.5	1.5
Lund and Mathiesen	Denmark	0	1	0	0	1
Cosic et al.	Macedonia	0	1	0	0	1
Elliston et al.	Australia (NEM–only)	0	1	0	0	1
Jacobsen et al.	New York State	1	0	0	0	1
Price Waterhouse Coopers	Europe and North Africa	1	0	0	0	1
European Renewable Energy Council	European Union 27	1	0	0	0	1
ClimateWorks	Australia	1	0	0	0	1
World Wildlife Fund	Global	0	0	0	0	0
Jacobsen and Delucchi	Global	0	0	0	0	0
Jacobson et al.	California	0	0	0	0	0
Greenpeace (Teske et al.)	Global	0	0	0	0	0

Table 1

Summary of scoring against feasibility criteria for twenty-four 100% renewable energy scenarios. 'Coverage' refers to the spatial/geographic area of each scenario. Total' means the aggregated score for the scenario across all criteria with a maximum possible score of 7. Criteria are defined in Methods. For concision, the 'Reliability' column aggregates all four potential scores for reliability into a single score.

The Australian Energy Market Operator Ltd. generated 2050-based supply-systems with conventional baseload profiles using biomass and geothermal energy as continually available sources of generation. Low-cost, inflexible solar photovoltaics were deployed to reach between 22% and 37% of installed capacity. We generously awarded these scenarios a mark as realistic in demand and a mark for simulation to the hourly timescale.

To achieve reliability of supply, Australian Energy Market Operator Ltd. assumed that between 5% and 10% of demand in any hour is "flexible". Unfortunately "flexible" was not defined, how the demand was to be controlled was not discussed, and achieving this flexibility was not costed. In the absence of this assumed "flexible" demand, and based on values shown in the cited report, the simulation would likely have unmet demand on every single day. The system would not, therefore, be feasible according to our minimum criteria.

5. ANCILLARY SERVICES LARGELY IGNORED

The report from Australian Energy Market Operator Ltd. is the only study in the published large-scale scenario literature to acknowledge the importance of maintaining ancillary services through the wholesale system redesign demanded by 100% renewable electricity.

The other 22 studies make no reference to these challenges. The review from Australian Energy Market Operator found that the operational issues should be manageable. However, they also cautioned that such a system is at or beyond globally known capabilities and this demands further assessment. Furthermore, none of the studies we reviewed considered any of the challenges that will be faced in redesigning distribution networks to accommodate greater embedded generation, offering no robust way of assessing the associated costs.

DISCUSSION

Our review of the 100%-renewable-scenario literature raises substantial concerns. The widespread assumptions of deep cuts in primary energy consumption defy historical experience, are generally inconsistent with realistic projections, and would likely raise problems for developing countries in meeting goals of poverty alleviation. Loftus et al. found that scenarios with a decline in total primary energy consumption from 2009 to 2050 required annual declines in energy intensity

(primary energy consumption GDP^{-1}) of 3.4–3.7% yr^{-1}, which is approximately twice the most rapid rates observed at the global scale over the last four decades.

The US Climate Change Science Program scenarios shed further light on energy-intensity requirements. If primary energy were not to increase, the energy intensities would have to decrease by 2.72%, 2.29% and 2.06% yr^{-1}, respectively, with even larger rates of increase if primary energy were to decrease from 2010 to 2050 (as in the WWF and Greenpeace scenarios).

Whether these estimated required rates of decline in energy intensity are possible is a complex question. Our view is that they are not. The large decline in the IGSM Level 1 case is atypical and depends on other assumptions made in that model. But this misses the essential point that economic growth and poverty reduction in developing countries is crucially dependent on energy availability. A reduction in primary energy is an unlikely pathway to achieve these humanitarian goals.

To move beyond subsistence economies, developing nations must accumulate the necessary infrastructure materially concentrated around cement and steel. That energy-intensive process likely brings with it a minimum threshold of energy intensity for development. Across a collation of 20 separately modelled scenarios of primary energy for both India and China, Blanford et al. found a range of energy-growth pathways from approximately +50 to +200% from 2005 to 2030. None of those scenarios analyzed for these two countries — with a combined population of almost 2.5 billion people — suggested static or reduced primary energy consumption.

Many, or possibly all, of the changes assumed to decrease the energy intensity of economies in the scenarios that assumed falling primary energy demand might have individual elements of realism.

However, in applying so many assumptions to deliver changes far beyond historical precedents, the failure in any or several of these assumptions regarding energy efficiency, electrification or flexible load would nullify the proposed supply system. As such, these systems present a fragile pathway, being conceived to power scenarios that do not exist and likely never will. The evidence from these studies for the proposition of 100% renewable electricity must therefore be heavily discounted, modified or discarded.

Our review also found that reliability is usually only simulated to the hour or half-hour in modelled scenarios. A common assumption is that advances in storage technologies will resolve issues of reliability both at sub-hourly timescales and in situations of low availability of renewable resources that can occur seasonally. Yet in the 24 scenarios we examined, 23 either already relied directly on expanded storage technology, or they described an implicit reliance on such technologies without simulation support. Despite these storage assumptions, only five of the 24 studies demonstrated sub-hourly reliability. A high-penetration renewable scenario for California developed by Hart and Jacobson suggested that moving to 100% generation from renewables would require a lower bound storage capacity of 65% of the peak demand to decouple most real-time generation from real-time demand. The authors describe this as a "significant paradigm shift in the electric power sector".

Achieving such a paradigm shift is an unresolved challenge, one that Hart and Jacobson claim will require a willingness to transform not only a region's generating fleet, but also the controls, regulations and markets that dictate how that fleet is operated. It behooves policy makers to interrogate such pathways carefully and critically, and to ask the question of whether more mature, dispatchable clean energy technologies should be rejected *a priori* at the cost of uncertainty and upheaval required by 100%-renewable systems.

It is reasonable to assume a greater range of cost-effective options in energy storage will be available in the future. Such solutions will undoubtedly assist in achieving reliability standards in systems with greater penetration of variable renewable generation. However, whether such breakthroughs will enable the (as yet unknown) scale of storage and associated paradigm shift required for 100% renewable remains unknown and is largely unaddressed in the literature (see additional discussion in Supplementary Material). To bet the future on such breakthroughs is arguably risky and it is pertinent for policy makers to recall that dependence on storage is entirely an artefact of deliberately constraining the options for dispatchable low-carbon generation. In optimal systems for reliable, decarbonized electricity systems that have included generic, dispatchable zero-carbon generation as well as variable renewable generation, the supply provided by storage is just 2–10%.

Not accounting for the full range of variability of renewable energy resources is another area of vulnerability. The year-to-year variability of inflows that ultimately

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determine hydro-electric output is well-known - the minimum annual US output over 1990–2010 was 23% lower than mean output for the same period. The range of capacity factors for Hydro Portugal varied from 11.8% to 43.2% over 13 years to 2009. Recent drought has reduced California's hydro-electric output by more than half. Record-low dam levels in Tasmania coincided with the failure of network interconnection and triggered an energy crisis for that state in 2015–2016.

Extreme droughts are also projected to impact hydroelectric output negatively in the Zambezi River Basin. Yet there has been limited or no effort, with the exception of studies by Mason et al. and Fthenakis et al., to identify and resolve renewable-energy conditions that are not 'typical', but are ultimately inevitable in a system that is relied on every year.

Ensuring stable supply and reliability against all plausible outcomes in renewable energy availability, not only for hydro-electricity, but also for wind, solar and commercial biomass, will raise costs and complexity through the need for additional capacity that will be redundant in most years. Such costs are obscured unless the impacts of worst-case conditions are expressly identified and quantified.

Resource variability is not the only concern regarding hydro-electricity. The widespread potential disruption to rivers and associated habitats from hydro-electric dams are well documented, particularly for the rivers and forests of the Amazon. Proposed hydro-electric developments in the Amazon will be major drivers of disruption to connectivity of habitat and deforestation. Proposed developments will also lead to displacement of indigenous populations.

Perhaps our most concerning finding relates to the dependence of 100% renewable scenarios on biomass (see Fig. 3). The British scenario is a typical example; even with the assumption of a 54% reduction in primary energy consumption, biomass requires 4.1 million hectare of land to be committed to the growing of grasses, short-rotation forestry and coppice crops (17% of UK land area). Lund and Mathiesen described how Denmark would need to reorganize farming from wheat to corn to produce the requisite biomass, in a scenario of 53% reduction in primary energy consumption from the baseline year. For Ireland, Connolly et al. calculated a biomass requirement that was 60% of the total potential biomass resource in Ireland. Crawford et al. suggested that short-rotation and coppice crops, coupled to an extensive and logistically challenging fuel-distribution infrastructure, would be required to meet energy requirements. Turner et al. proposed trucking and burning Australia's agricultural residue, and then trucking the residual ash back to avoid long-term nutrient depletion.

The WWF scenario demanded up to 250 million ha for biomass production for energy, along with another 4.5 billion m^3 of biomass from existing production forests to meet a scenario of an absolute reduction in primary energy from today.

The demand-reduction assumptions in most of the scenarios considered here, when combined with their dependence on hydro-electricity and biomass, suggest that 100% renewable electricity is likely to be achievable only in a low-energy, high-environmental-impact future; where an increasing area of land is recruited into the service of providing energy from diffuse sources. The realization of 100% renewable electricity (and energy more broadly) appears diametrically opposed to other critical sustainability issues such as eradication of poverty, land conservation and reduced ecological footprints, reduction in air pollution, preservation of biodiversity, and social justice for indigenous people.

The remaining feasibility gaps lie in the largely ignored, yet essential requirements for expanded transmission and enhanced distribution systems, both to transport electricity from more sources over greater distances, and to maintain stable system operations. Fürsch et al. suggested that a cost-optimized transmission network to meet a target of 80% renewables in Europe by 2050 would demand an additional 228,000 km of transmission grid extensions, a 76% addition compared to the base network. However, this is an underestimate because they applied a "typical day" approach to assess the availability of the renewable-energy resources instead of using full year or multi- year hourly or half-hourly data. Rodríguez et al. concluded that to obtain 98% of the potential benefit of grid integration for renewables would require long-distance interconnector capacities that are 5.7 times larger than current capacities. Becker et al. found that an optimal four-fold increase in today's transmission capacity would need to be installed in the thirty years from 2020 to 2050. An expansion of that scale is no mere detail to be ignored, as it has been in Elliston et al., all work led by Jacobson, the global proposals from major environmental NGOs and many more of the studies we reviewed. Transmission lines

are acknowledged as slow projects, taking 5–10 years on average to construct, projects that are vulnerable to social objection that may force even more delay. In one case, a transnational interconnection took more than 30 years from planning to completion. Recent work demonstrates the importance of power-flow modeling done at the necessary scales. In that study, where the necessary transmission network was identified and the power flows were modelled, the system in question required 100 GWe of nuclear generation (delivering 16% of supply) and 461 GWe of gas (delivering 21% of supply). In the absence of such baseload and dispatchable contributions, the expanded transmission requirements will evidently present technical, economic and social challenges that are largely unexamined in the 100% renewables literature. Policy makers must be aware of this gap.

Nonetheless, of the four criteria we propose, transmission networks could arguably be regarded as more a matter of viability than feasibility; the individual requirement of long-distance interconnection is well-known and understood. Rescoring all the studies excluding this criterion (effectively granting all the assumptions of a copperplate network), feasibility is still not met completely by any study.

The same grace cannot be granted for maintaining sufficient synchronous generation, voltage requirements and ensuring robust system-restart capabilities in 100% renewable systems with high production from variable and asynchronous sources. The state of research into how variable renewable sources such as wind can contribute actively to providing frequency control services is nascent. There is a much research examining the role of batteries in frequency control, indicating growing understanding of the potential applications, prototype large grid-connected projects, and aggregation of distributed-storage systems via novel technology platforms.

However, we found nothing approaching a clear understanding of the scale of intervention that might be required for maintaining these services in 100% renewable electricity systems in large markets . As well as the direct use of batteries or modified wind turbines, maintaining stability could require interventions that include payments for minimum synchronous generation to remain online, development of new markets in ancillary services, network augmentation, and even the mandated curtailing of supply from wind and photovoltaics in some supply situations. Others have suggested that changes in market operations will be required to accommodate energy sources that are euphemistically described as "flexible".

A practical portfolio of solutions to these challenge lies beyond current operational knowledge. In Germany where penetration of solar photovoltaic systems is the highest in the world, voltage overloading is leading to grid-reinforcement requirements expected to cost €21–27 billion. Potential partial solutions include intelligent operation of distributed energy storage (i.e. batteries), grid reinforcement, active power curtailment (i.e. preventing export from photovoltaics to the feeder, representing a loss of income to the owner of the photovoltaics), and active and reactive power control from the photovoltaic unit itself, demanding more advanced inverters.

It is axiomatic that these requirements add to the uncertainty surrounding 100% renewable pathways as we depart from well-known and understood electricity systems into novel approaches that rely on reinvented networks with greater complexity. It seems likely that current research and applications will boost the potential role for variable renewable energy sources. However, compelling evidence for the feasibility of 100% renewable electricity systems in relation to this criterion is absent.

LIMITATIONS OF OUR FRAMEWORK

The scoring system we developed and applied emphasizes the importance of simulating supply to meet demand. In turn, this underscores the issue of achieving reliability with electricity-generation systems that vary over time. With our simple scoring system, some specific item scores might be unjustified when assessed more holistically - specifically if there are major deficiencies in other areas.

For example, some studies have done system simulations (earning a score between 1-4 depending on the time-scale of the simulation), but have made unrealistic assumptions in setting up the simulation. We did not penalize these cases. The work of Jacobson et al. is an example of this because it depends strongly on extraordinary assumptions relating to electrification, energy storage and flexibility in demand. Although this work scored 3 for a fine-grained timescale simulation, the results of such a simulation are likely to be meaningless because the underlying assumptions are unrealistic. There is potential for a more useful framework to be developed that reflects these interdependencies.

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Under our framework, a study can achieve relatively low scores, which might suggest it lacks breadth of coverage of the feasibility criteria. Yet the study itself can be meritorious for its quality in areas it has specifically chosen to address. We highlight the work of Elliston et al. as one such example, because it provides valuable insights in several areas and explores useful assessment methods. Finally, the criteria of ancillary services will be of varying importance depending on the proposed mix of technologies. For example, approximately 80% of the proposed renewable generation for New Zealand comes from dispatchable, synchronous hydro and geothermal, with <20% of supply from wind and no embedded solar generation. Such a mix provides some certainty at the outset in terms of system reliability and power quality.

CONCLUSIONS

Our assessment of studies proposing 100% renewable-electricity systems reveals that in all individual cases and across the aggregated evidence, the case for feasibility is inadequate for the formation of responsible policy directed at responding to climate change. Addressing the identified gaps will likely yield improved technologies and market structures that facilitate greater uptake of renewable energy, but they might also show even more strongly that a broader mix of non-fossil energy technologies is necessary. To date, efforts to assess the viability of 100% renewable systems, taking into account aspects such as financial cost, social acceptance, pace of roll-out, land use, and materials consumption, have substantially underestimated the challenge of excising fossil fuels from our energy supplies. This desire to push the 100%-renewable ideal without critical evaluation has ironically delayed the identification and implementation of effective and comprehensive decarbonization pathways. We argue that the early exclusion of other forms of technology from plans to decarbonize the global electricity supply is unsupportable, and arguably reckless.

For the developing world, important progress in human development would be threatened under scenarios applying unrealistic assumptions regarding the scale of energy demand, assumptions that lack historical precedent and fall outside all mainstream forecasts. Other outcomes in sustainability, social justice and social cohesion will also be threatened by pursuing maximal exploitation of high-impact sources like hydro-electricity and biomass, plus expanded transmission networks. The unsubstantiated premise that renewable energy systems alone can solve challenge of climate change risks a repeat of the failure of decades past. The climate change problem is so severe that we cannot afford to eliminate a priori any carbon-free technologies.

Our sobering results show that a 100% renewable electricity supply would, at the very least, demand a reinvention of the entire electricity supply-and-demand system to enable renewable supplies to approach the reliability of current systems. This would move humanity away from known, understood and operationally successful systems into uncertain futures with many dependencies for success and unanswered challenges in basic feasibility. Uniting the alleviation of poverty with a successful climate-change response in our energy and electricity systems should be an international goal. This is likely to require revolutionary changes in the way we grow food, manage land, occupy homes and buildings, demand electricity, and otherwise live our lives. Such changes will require more, not less energy. It would be irresponsible to restrict our options to renewable energy technologies alone. The reality is that 100% renewable electricity systems do not satisfy many of the characteristics of an urgent response to climate change: highest certainty and lowest risk-of-failure pathways, safeguarding human development outcomes, having the potential for high consensus and low resistance, and giving the most benefit at the lowest cost. A change in approach by both researchers and policy makers is therefore required. It behooves all governments and institutions to seek optimized blends of all available low-carbon technologies, with each technology rationally exploited for its respective strengths to pursue clean, low-carbon electricity-generation systems that are scalable to the demands of 10 billion people or more. Only by doing so can we hope to break the energy paradox of the last twenty years and permit human development to continue apace while rapidly reducing greenhouse gas emissions from electricity generation and other demands for energy. Anything less is an abrogation of our responsibilities to both the present and the future.

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SABS APPROVED

An engineering graduate, although aware and exposed to the significance of technical standards, does not fully appreciate the multiple engineering paradigms through which these standards interface with industry.

BY | BASHKARAN VANDEYAR | WINNER 2017 IEC YP ESSAY COMPETITION

The influence the IEC has on my industry

BASHKARAN VANDEYAR
WINNER 2017 IEC YP
ESSAY COMPETITION

It is in the working environment that the importance of this is brought to the fore, as was the case with my own experience. There is a necessary evolution in perspective, when approaching engineering deliverables, when the context transitions from an academic environment to a working and industrial one. The challenges that emerge from this transition are substantially aided by the existence of technical standards and the International Electrotechnical Commission (IEC). In South Africa, the South African Bureau of Standards (SABS) develop and control national standards, seeking to document engineering best practices developed from years of experience, of which many are direct adoptions or adaptations of IEC standards, to align with international best practices. Having worked in the railway and power generation industries in different roles, whilst engaging in further study, I have been exposed to various aspects related to IEC and/or South African National Standards (SANS) and the indispensable role they play in industry (globally).

Starting off my career as an electrical engineering graduate, my mind was both eager and conditioned to understand and solve problems, often from a first principles basis. Although the philosophy of avoiding "re-inventing the wheel", general engineering principles, safety and standards did feature in my studies, time did not permit for technical standards receiving its due recognition. Without discounting the value in the engineering curriculum, this structured learning, when combined with a theoretically biased mind, creates a thinking framework which is not always efficient in creating the most practical solutions. There are subtle practicalities, embodied in a technical standard which, from my experience might have otherwise been overlooked. IEC Standards serve as a rich source of information to the reader investigating a specific subject. Often the principals presented in one standard can be applied to subject matter outside the scope of a standard. Similarly, IEC Standards provide a safe, internationally accepted standard, where national standards are not available, such as one would find in other areas of Africa.

Transnet Freight Rail, a state-owned enterprise responsible for the railways, was where I was first employed as an engineer-in-training. I was deployed to the Infrastructure Engineering Department, where infrastructure projects made intensive use of specifications when scoping projects. The types of projects included systems on which I had never worked with before, such as 3 kV DC, 25 kV AC Traction substations, Over Head Track Equipment (OHTE), and some 11 kV distribution systems. These specifications often referred to other technical standards, of which my first impression was that they were bespoke documents updated, through the experience of several years, in the development of this rather specialized industry. At that point, I did not recognise the connection to IEC/SANS standards, but I was impressed with the detail and confidence the presence of these documents provided. It reduced the effort an engineer had to apply toward design, performing risk analyses, co-ordinate compatibility, determination of best practices and allowed for focus on the high-level specifications, based on the desired output performance of the system.

The influence of the IEC

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It was when I moved from the asset owner (Infrastructure Engineering) to the technology owner (Technology Management), that I had an opportunity of truly understanding specifications and the development thereof, as well as its influence of standards. Part of my responsibility was to develop and update these specifications, some of which dated back to the 1980's. These would often refer to IEC standards. I had to interrogate the validity of these specifications, as well as the relevance of references to standards, determine the changes to the standards, and any impact thereof. In this rather unique role in the organisation, I was fortunate to have my attention drawn to the changes to IEC standards (and adoptions by SANS), as well as how they permeate and offer relevance, even in the most niche systems. An example of this is a specification for a change-over system for locomotives transitioning between AC and DC voltage systems, where SANS standards (based on IEC) such as that for surge arrestors and transformers were referenced.

My other subset of responsibilities at Technology Management was on the R&D side, where I was afforded the opportunity to develop and/or evaluate solutions for the railway industry. Often standards would serve as a starting point, offering some key guidance concerning the expectations of the system components I am designing, and thus provided a set of design criteria to reverse-engineer the design within. It also provides some assumptions for typical devices or systems with which a design may interface. Basic information such as interpretation of IP ratings, colour coding, or standard voltages are found in IEC standards, and can be accepted with confidence. The other activity with which I was fortunate to be involved, is the evaluation of different technologies. One such example is when I leaned on IEC/SANS standards to develop a set of tests for evaluating the performance of silicone rubber coatings on porcelain insulators. The use of standards such as SANS 61109 or SANS 62073 (both adopted from IEC), guided my methodology and provided some key reference parameters, like that of the hydrophobicity or wettability classes of which I was initially unaware.

I was also exposed to the quality of (electrical) supply measurements, where the standards served as a framework for defining and measuring performance, such as that expressed in NRS048, which explicitly acknowledges the IEC and its influences. The standards also served as a reference when compiling specifications for procurement, as the standards provided criteria which I used to specify power quality measurement equipment. Even though Transnet has relatively unique infrastructure and documentation systems, such as high level specifications, detailed specifications and engineering instructions, there was, and still is a strong influence of IEC standards. In my opinion this influence should only grow and support the industry by providing an accessible platform of standardization, thereby improving inter-operability with global systems, and promoting world trade.
When I began my studies toward a Government Certificate of Competency in Plant Engineering, the Occupational Health and Safety Act and Regulations became my study material. Here the focus of technical standards shifted from being guidelines, best practices and conformity assessment tools, to being formally incorporated into law. This emphasised a new dimension to the way standards are applied, the impact on safety, and vice versa. Standards such as SANS 10400 (Building Regulations) which by the title itself, is something that anyone could appreciate, to standards for the "determination of lead in the workplace air by atomic absorption spectrophotometry" (SANS 6164). In taking steps to obtaining a wireman's license, I had to write the installation rules exams, which focused on SANS 10142-1 (LV wiring of premises). This has proven to be indispensable throughout my career. It also serves as a fundamental reference source which I will use in a private career as an electrical contractor.

My next career step led me to Eskom Generation, where I was deployed to a coal-fired power station. There the standards moved from a study of the importance on safety, to a live application of it. At a power station, a national key point, working with critical equipment handling high power near people, safety is paramount, and compliance with standards is essential. Hazards such as arc-flash around the various distribution boards become a serious risk in this environment; and the engineer is heavily reliant on SANS984 and 724 in determining the exposure, and Personal Protective Equipment (PPE) requirements to address such risk. SANS/IEC standards govern so many aspects across disciplines at a power station. A few typical examples are mechanical engineers with pressure equipment (SANS347); C&I engineers with SCADA and communications (IEC61850); chemists with water treatment (SANS241) and electrical engineers with wiring codes for LV and MV systems (SANS 10142).

The engineering consulting industry, my current environment took me back to the railways, where I moved from being the client of such services to the provider.

In this role, I was involved in a multi-disciplinary project based environment where new technologies merge with old. SANS standards often assisted in ensuring that the client receives adequate solutions from the contractor, as these standards close the gap on where the tender scope was silent or unclear. This provides a solid reference ensuring performance which could be specified with confidence, that a safe and environmentally friendly system is in line with best practice. In the railway environment, technical standards such as IEC 62313 and SANS3000, presents a systemic view on safety within the railway environment, used by the Railway Safety Regulator (RSR) to assess compliance. This demonstrates the influence of specifications on industry regulation. In the consulting environment, as an electrical engineer reviewing designs and commissioning installations, SANS10142 is critical, whether it be volt drop calculations, cable containment, or providing a check list for inspections and tests. In my studies and experience relating to standards, which I have briefly outlined, I have discovered that technical standards, published and influenced by the IEC provide an internationally accessible platform to indispensable multi-dimensional resources. For me, it has played an instrumental role in my development to perform better in my industry. These technical standards, harmonised by the IEC, play a role in all engineering functions, whether it be in design, testing, construction, maintenance, regulation and commissioning, amongst others. The IEC thus plays a vital role in capturing and codifying the continual improvement, and learnings employed to develop engineering best practices.

Thus it supports quality, safety, technology, efficiency, world trade and sustainable socio-economic development. IEC standards can also be used to mitigate uncertainty, technology dumping, repetition of poor practices and harm to the environment. As a young professional, the IEC and related standards play a pivotal role in my career, field of interests, companies in which I have worked, and the industries within which they operate. wn

To be able to safely leave a structure in case of fire, escape routes must be kept free of smoke which causes orientation and breathing problems.

Smoke and heat extraction systems are both equipped with manual call points and automatic detectors which detect the smoke or heat produced and extract it from the escape route via electromechanically or pneumatically driven windows or domelights.

In addition to this main function, the windows or domelights are also used for ventilation. For this purpose, additional switching devices are available which are capable of issuing switching commands of lower importance. Since the availability of smoke and heat extraction systems must be ensured even in the event of power failure, the fire control panels are equipped with accumulators which supply the smoke and heat extraction systems. Therefore, the actuators of the windows and domelights are dimensioned for d.c. operation.

The surge protective devices in the examples described in figure 1 are dimensioned

Surge protection for smoke and heat extraction systems

based on a voltage of 24 V D.C. which is commonly used in this industry. Moreover, electromechanically driven domelights with a maximum nominal current of less than 1.8 A or 4 A D.C. are used.

STRUCTURE WITH NON-METAL ROOF AND EXTERNAL LIGHTNING PROTECTION SYSTEM

Embedded or protruding roof-mounted structures on structures with external lightning protection system must be located in the protected volume of air-termination systems as per IEC 62305-3 (EN 62305-3) under consideration of the separation distance s if the following limit values are exceeded:

Embedded or protruding metal roof-mounted structures:

- Height above the roof level: 0.3 m
- Total area of the roof-mounted structure: 1.0 m^2
- Length of the roof-mounted structure: 2.0 m
- Embedded or protruding non-metal roof-mounted structures:
- Height above the air-termination system: 0.5 m

Due to the above requirements, domelights of a certain size must be protected against lightning strikes.

If air-termination rods are installed, the domelights are located in LPZ 0_B which means that no lightning current is injected

Surge Protection

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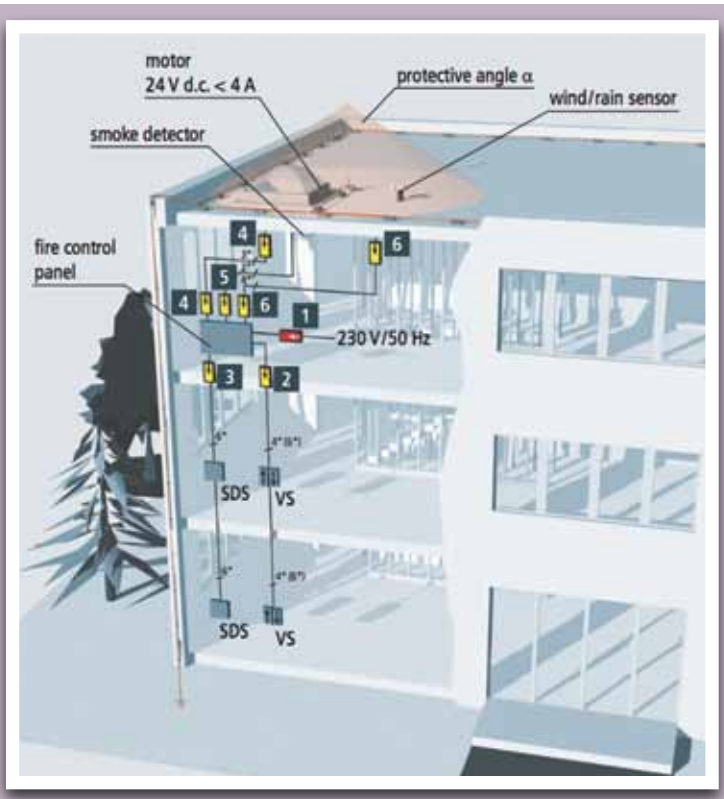


Figure 1: Domelight located in the protected volume of an air-termination rod on a non-metal roof of a structure with external lightning protection system.

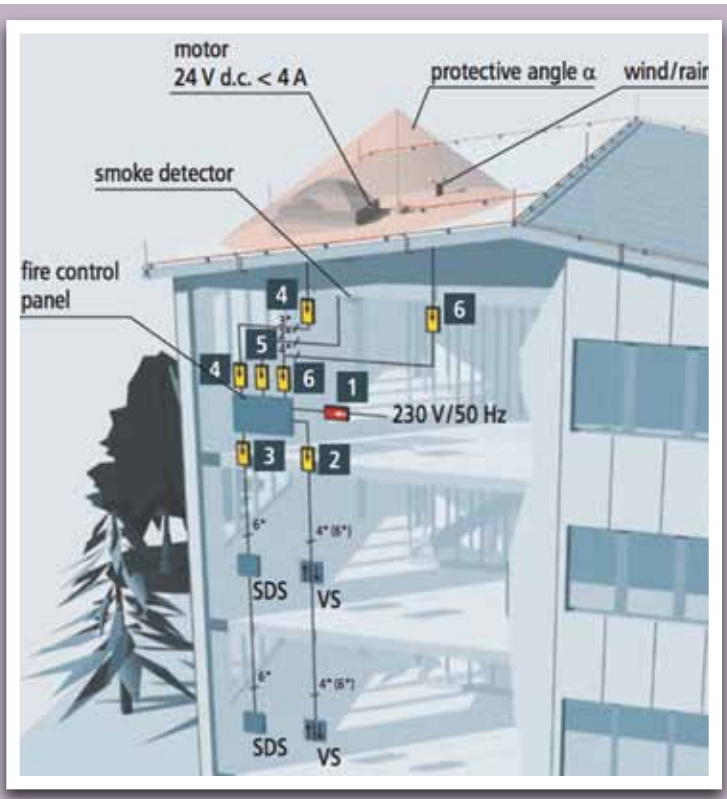


Figure 2: Domelight located in the protected volume of an air-termination rod on a metal roof of a structure with metal down conductor.

into the equipment installed in this zone (Figure 1). A surge arrester prevents inductive coupling in this zone.

STRUCTURE WITH METAL ROOF AND EXTERNAL LIGHTNING PROTECTION SYSTEM

In contrast to structures with non-metal roofs and external lightning protection system, different normative requirements are placed on the lightning current carrying capability of metal roofs which are used as air-termination system:

- The metal roof can be used as natural air-termination system if the manufacturer cofirms that it suited for this purpose.
- The metal roof does not have the required thickness t' (IEC 62305-3 (EN 62305-3), and must be protected against direct lightning strikes by means of air-termination systems since perforation can cause fire due to the highly flammable materials (such as wooden boards) underneath the tin roof and the ingress of water can no longer be prevented.
- The air-termination systems must be interconnected by means of lightning current carrying conductors if there is no other lightning current carrying connection (e.g. by means of tested terminals, brazing, welding, squeezing, seaming, screwing or riveting).
- The metal roof has the required thickness

There are two types of down conductors for the metal roofs described before:

- The walls consist of an interconnected lightning current - carrying steel reinforcement or a steel frame construction. In both cases, the separation distance does not have to be considered since either the current is very low due to the high number of current paths (reinforcements) or the low inductance (steel beams) does not cause puncture to other metal systems. Metal façades which are connected to the earth-termination system at intervals of 15 m at the lowest point (ground) also meet the requirements described above.
- The walls consist of non-conductive material (bricks, wood, etc.) and the down conductors are connected to the earth-termination system.

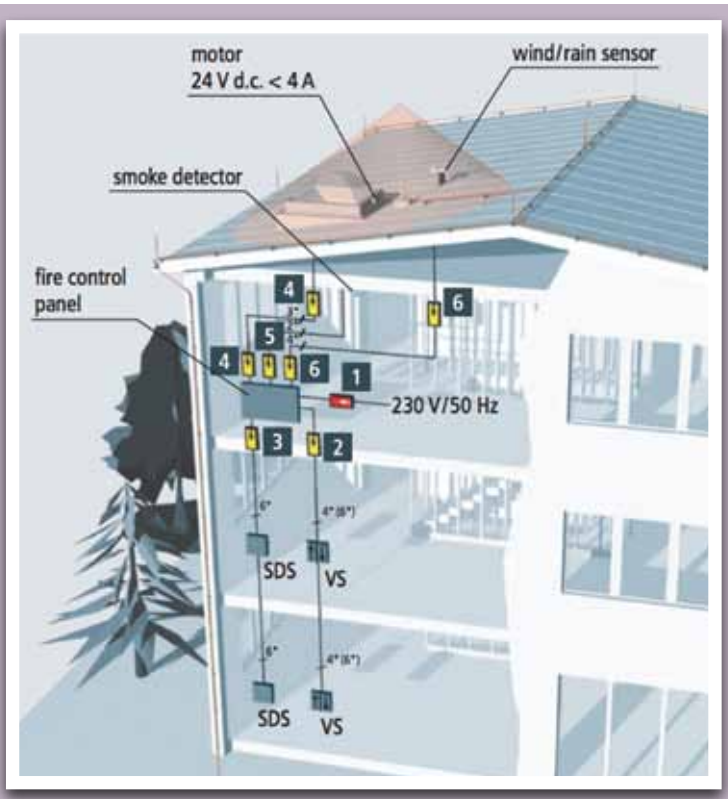


Figure 3: Domelight located in the protected volume of an air-termination rod on a metal roof of a structure equipped with conventional arresters.

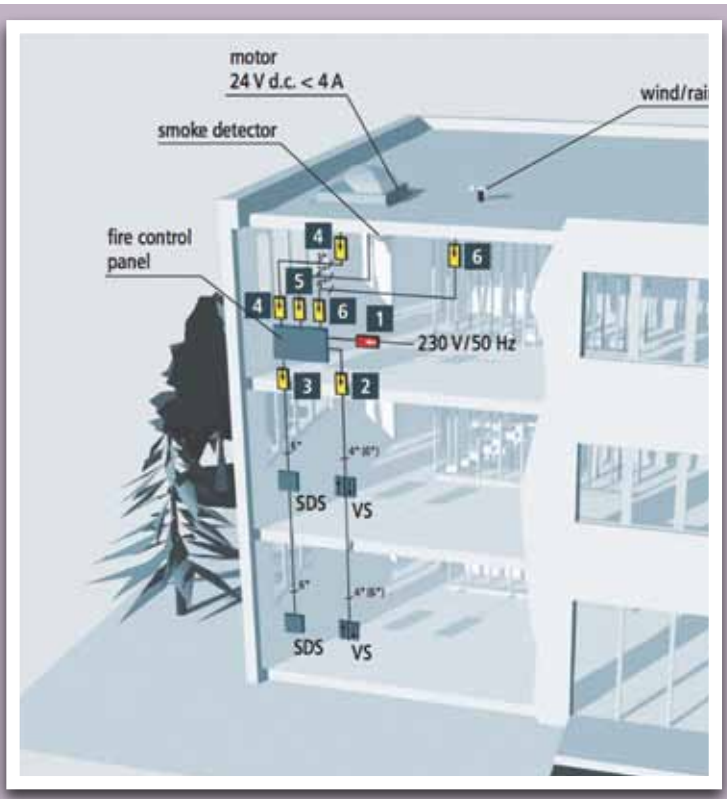


Figure 4: Domelight located on a non-metal roof of a structure without external lightning protection system.

Different combinations of air-termination systems and down conductors can be used. Ignitable sparkover does not occur in structures with air-termination systems and down conductors in certain combinations. Air-termination systems must be installed to prevent lightning strikes to the domelights. Thus, the domelights are protected against direct lightning strikes, however, they are not located in LPZ 0_B since the air-termination systems directly conduct the lightning current to the metal roof, thus spreading the lightning current over a large area.

In view of the fact that lightning may also strike in the vicinity of the domelights, it is recommended to install a lightning current arrester (Figure 2).

A structure with a metal roof and conventional down conductors is considered to be critical (Figure 3).

In case of a lightning strike, the lightning current will be evenly distributed between the down conductors. Nevertheless, the structure is still at risk and the relevant separation distance must be maintained. Air-termination systems must also be installed to prevent direct lightning strikes to this type of structure, however, the domelight is not located in LPZ 0_B.

Since partial lightning currents may flow into the structure via the cable for the drive of the smoke and heat extraction system, a lightning current arrester must be installed. Due to their size, structures with domelights typically have several down conductors which prevent overload of the lightning current arrester.

STRUCTURE WITHOUT EXTERNAL LIGHTNING PROTECTION SYSTEM

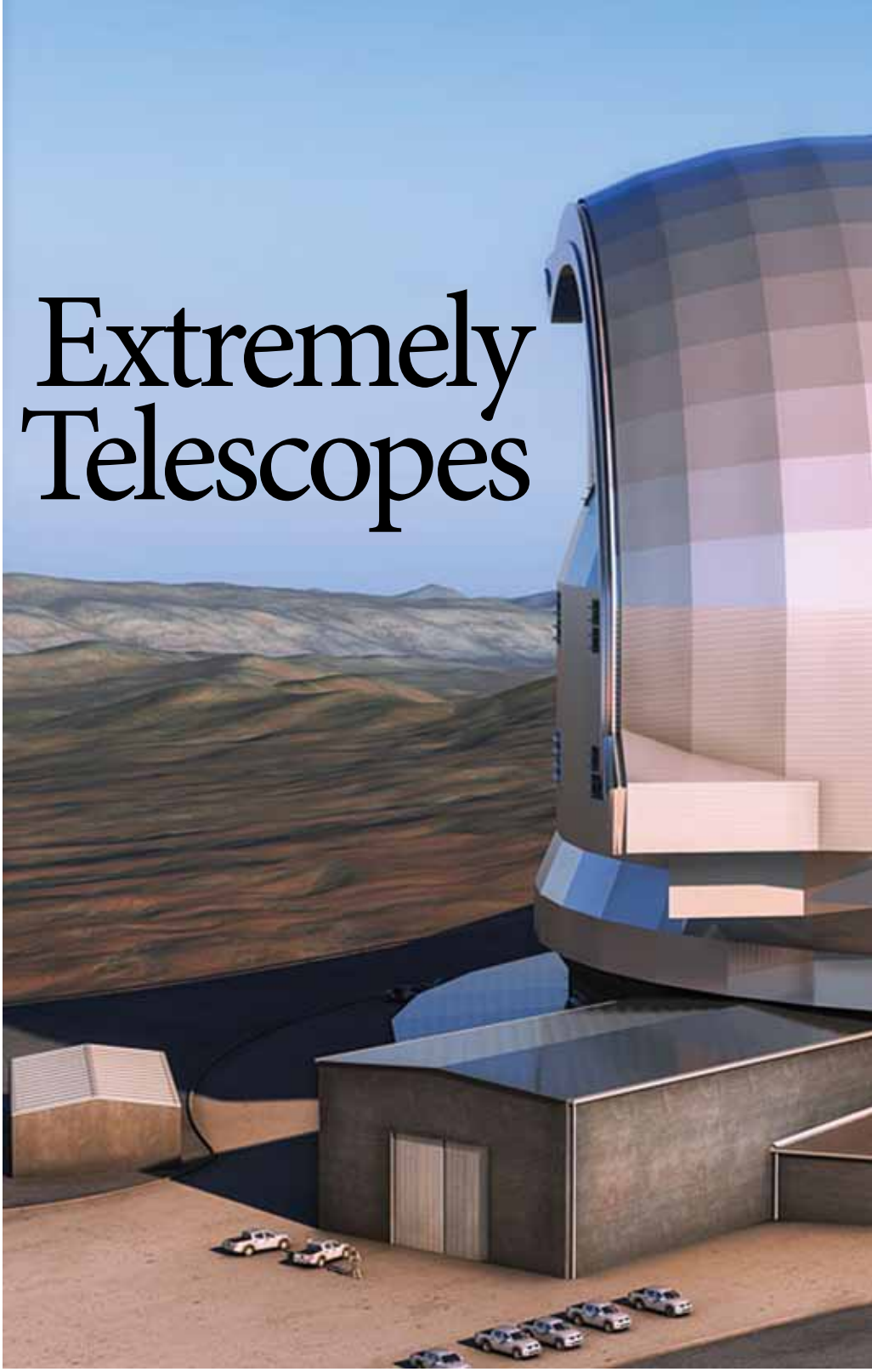
No distinction has to be made between metal or non-metal roofs since every direct lightning strike to the structure presents a fire hazard.

Lightning current arresters are not capable of coping with direct lightning strikes to the domelights.

Therefore, surge arresters must be installed to protect the structure from inductive coupling (Figure 4). wn

Earn CPD Credits

The Extremely Large Telescopes

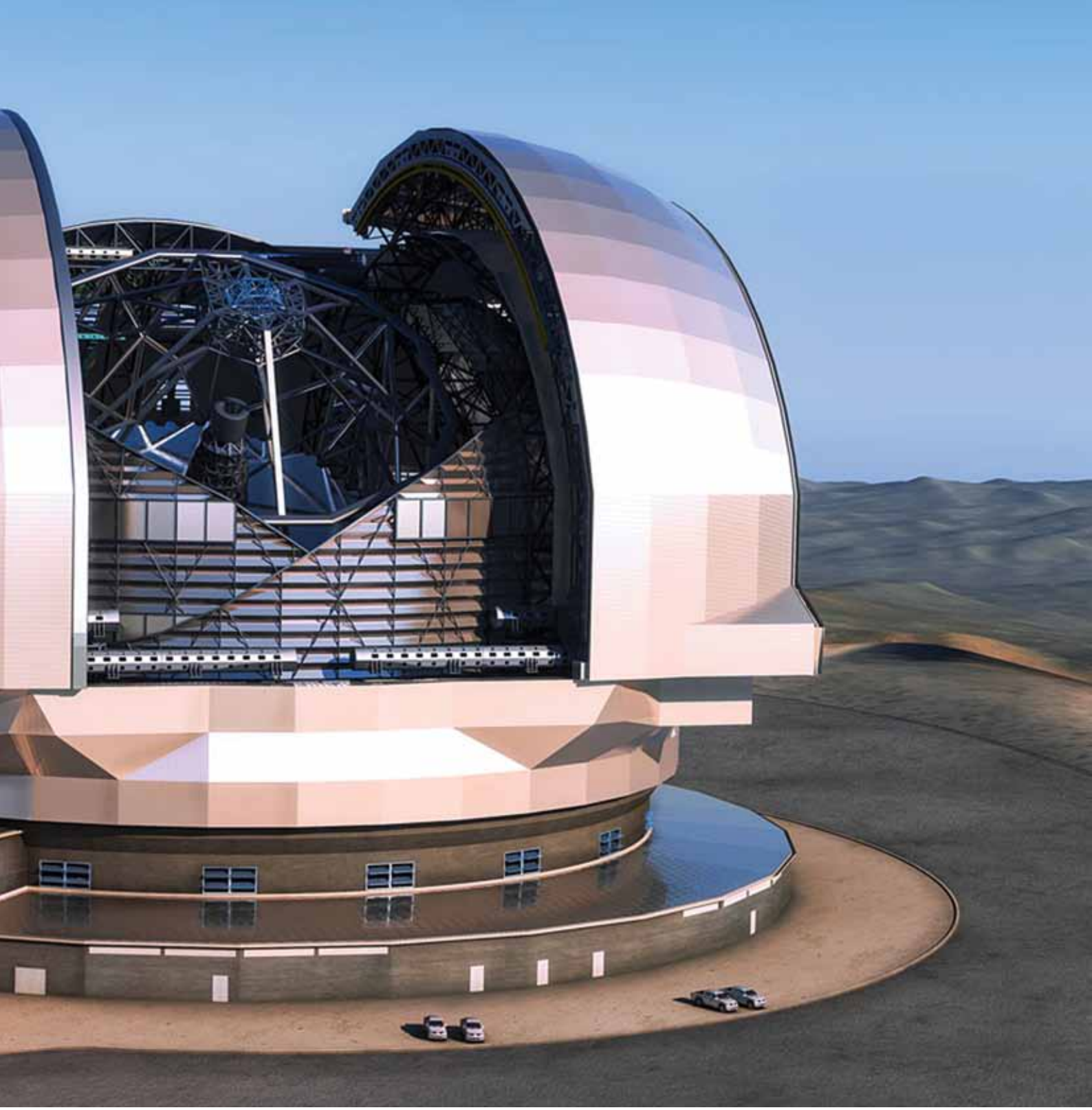


Construction has started on the largest optical telescope that the world has ever seen. ESO's Extremely Large Telescope is a revolutionary scientific project for a 40 metre class telescope that will address many of the most pressing unsolved questions about our universe.

COMPILED BY | DUDLEY BASSON

The original conceptual design by the ESO (European Southern Observatory) organisation was for a gigantic 100 metre telescope known as the OWL (Overwhelmingly Large Telescope). Due to the prohibive cost and complexity, the project was downscaled to a 39 metre telescope known as the ELT (Extremely Large Telescope).

In June 2012 the ESO Council fully approved the E-ELT program which will start operations as an integrated part of the Paranal Observatory, Chile, early in the next decade. At a ceremony on 18 January 2017 at ESO's Headquarters in Garching, Germany, four contracts were signed for major components of the ELT.



Artist's impression of the European Extremely Large Telescope (E-ELT) in its enclosure on Cerro Armazones, a 3060-metre mountaintop in Chile's Atacama Desert. The 39-metre E-ELT will be the largest optical/infrared telescope in the world — the world's biggest eye on the sky. Operations are planned to start early in the next decade, and the E-ELT will tackle some of the biggest scientific challenges of our time. The design for the E-ELT shown here is preliminary. Credit: ESO/L. Calçada

Large Telescopes

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These were for: the casting of the telescope's giant secondary and tertiary mirrors, awarded to SCHOTT; the supply of mirror cells to support these two mirrors, awarded to the SENER Group; and the supply of the edge sensors that form a vital part of the ELT's huge segmented primary mirror control system, awarded to the FAMES consortium. The secondary mirror will be largest ever employed on a telescope and the largest convex mirror ever produced.

The construction of the 39-metre ELT, the largest optical/near-infrared telescope in the world, is moving forward. The giant telescope employs a complex five-mirror optical system that has never been used before and requires optical and mechanical elements that stretch modern technology to its limits.

Contracts for the manufacture of several of these challenging telescope components have just been signed by ESO's Director General, Tim de Zeeuw, and representatives of three industrial contractors in the ESO Member States.

Introducing the ceremony, Tim de Zeeuw said: *"It gives me great pleasure to sign these four contracts today, each for advanced components at the heart of the ELT's revolutionary optical system. They underline how the construction of this giant telescope is moving ahead at full speed - on target for first light in 2024. We at ESO look forward to working with SCHOTT, SENER and FAMES - three leading industrial partners from our Member States."*

Site preparation started in June 2014 with the levelling of the top of Cerro Armazones of the Atacama Desert in northern Chile.

This is some 20 km from the Cerro Paranal Observatory of four VLTs (Very Large Telescopes). ESO's Paranal VLTs have 8,2 metre mirrors of 20 tons each and also have 1,8 m movable auxiliary telescopes.

The telescopes have active optics, adaptive optics and can also work together as an interferometer. The interferometric light paths in underground tunnels must be kept accurate to within a micron per 100 m permitting image resolution to within milliarcseconds – 25 times finer than with the individual telescopes. The individual telescopes are able to resolve objects as faint as magnitude 30 with a one hour exposure. As is commonly used with large telescopes, the optical design is Ritchey-Chrétien reflector. There are also several other Paranal telescopes. The flagship Paranal complex is regarded at present as the most advanced optical observatory on Earth. First light for the VLTs occurred as follows: UT1-Antu 25 May 1998, UT2-Kueyen 1 March 1999, UT3- Melipal 26 Jan 2000, UT4-Yepun 4 September 2000. The 8,2 m mirrors are at the practical limit for monolithic mirrors – larger mirrors will need to be of segmented design.

The first stone of the ELT telescope structure was ceremoniously laid on 26 May 2017. First light is hoped for by 2024. The complex five-mirror optical system will be provided with two large Nasmyth platforms for the suite of advanced detection instruments. Using Nasmyth focal points greatly facilitates the changing of detection instruments, as this can be done without changing the elevation of the telescope.

The following scientific instruments are envisaged for the ELT:

- CODEX:-
  Narrow-field optical spectrograph - (COsmic Dynamics and EXo-earth experiment);
- EAGLE:-
  Wide-field, multi-channel integral-field near-infrared spectrograph, with multi-object adaptive optics;
- EPICS:-
  Optical/near-infrared planet imager and spectrograph with extreme adaptive optics - (ExoPlanet Imaging Camera and Spectrograph);
- HARMONI:-
  Single field, wide-band integral field spectrograph - (High Angular Resolution Monolithic Optical and Near-infrared Integral field spectrograph);
- METIS:-
  Mid-infrared imager and spectrograph - (Mid-infrared ELT Imager and Spectrograph);
- MICADO:-
  Diffraction-limited near-infrared camera - (Multi-adaptive optics Imaging Camera for Deep Observations);
- OPTIMOS:-
  Wide-field imager and Low-Medium Resolution Slit spectrograph;
- SIMPLE:-
  High-spectral-resolution near-infrared spectrograph;

The two post-focal adaptive optics modules currently being studied are:

- ATLAS:-
  Laser tomography adaptive optics module;
- MAORY:-
  Multi-conjugate adaptive optics module.

Oxford University scientists are playing a key role in the project, and are responsible for the design and construction of its

spectrograph 'HARMONI', an instrument designed to simultaneously take 4000 images, each in a slightly different colour. The visible and near-infrared instrument will harness the telescope's adaptive optics to provide extremely sharp images. HARMONI will be used to explore galaxies in the early Universe, study the constituents of the local Universe and characterise exoplanets in great detail. In many ways, it will be complementary to ALMA and the James Webb Space Telescope.

For a full-screen rendering of the five-mirror optics as well as a super slideshow comparing the various large telescopes visit the following website:
www.en.wikipedia.org/wiki/European_Extremely_Large_Telescope#
The primary mirror, elliptical concave segmented, will consist of 798 hexagonal segments, each 1,4 m wide and 50 mm thick with a 4 mm gap between segments.

The mirror is in six identical sectors of 133 segments each, giving 133 segment families, each with a different optical shape. The assembled mirror will have a focal ratio of f/0,93. The outer diameter of the assembled mirror will be about 39 m with a central obstruction of 11,1 m. A total of 931 segments will be held to provide for maintenance. Re-coating will be done at a rate of two segments per day to keep the primary in perfect condition. The segments have coating life of 18 months. The hexagonal shape of the segments permits a common support structure for all the segments. The segments can be moved in piston and tip-tilt mode to compensate for deflections due to temperature and gravity. The mirror segments are axially supported on 27-point whiffletrees. Three position actuators are provided for each segment. Inductive edge sensors, working with nanometre precision, provide direct feedback to the position actuators and also for global reconstruction of the mirror shape. The geometrical shape of the mirror is to be kept accurate to within nanometres. (A sheet of copier paper has a thickness of 100 000 nanometres).

The mirrors are to be made of costly Zerodur glass ceramic by Schott AG of Mainz, Germany. Zerodur is a lithium-aluminosilicate glass-ceramic with a very low coefficient of thermal expansion. This has been used in the manufacture of many prominent telescope mirrors. French company Safran Reosc will polish one mirror per day to meet the 7-year deadline. The surfaces will be polished to within a surface irregularity of 7,5 nanometres RMS. Safran Reosc will mount the mirrors and complete all optical testing before delivery. This is the second largest contract for the ELT construction.

The secondary mirror is a thin meniscus aspheric convex Zerodur mirror of 4,2 m diameter and a mass of 3,5 tons. The unused part at the centre is of 1,09 m diameter. Complex support cells are required to ensure the flexible secondary and tertiary mirrors retain their correct shape and position. The mirror will be polished to a precision of 15 nanometres.

The tertiary mirror will be a thin meniscus concave active mirror of 3,8 m diameter. This will also be manufactured from Zerodur glass ceramic. A third mirror is an unusual feature for a large telescope. It is expected that the tertiary mirror will give a better final image quality over a larger field of view than would be possible with two mirror optics.

The fourth mirror will have a size of 2,38 x 2,40 m. This will be a flat adaptive 2 mm thick mirror with up to 8000 actuators providing high speed adaptive optics. This mirror will correct in real time for high order wave front errors (e.g. atmosphere, wind shake, low spatial frequency telescope errors) and small amplitude residual tip-tilt corrections.

The deformable mirror will be the largest adaptive mirror ever made and consists of six component petals, control systems and voice coil actuators. Information of wind turbulence in the upper atmosphere will be obtained by means of 'reference stars' created in the upper atmosphere by laser beams which will excite sodium atoms conveniently left by passing meteors.

Each laser consists of a source that generates a powerful laser beam (589nm, 20-25W) with suitable properties for sodium excitation and a relay that projects it onto the sky to create the artificial star. Four laser beacons are required by the telescope while six may be required for specific instruments.

The fifth mirror in the train belongs to the tip-tilt/field-stabilization unit. This mirror is a fast steering, ultra-lightweight mirror whose main purpose is to compensate for image motion at frequencies of up to a few Hz and to stabilize field. It is flat and elliptical in contour. The mirror dimensions are approximately 2,7 m by 2,1 m. This mirror will direct the light through the vertical movement trunnions to the Nasmyth mounted instruments.

James Nasmyth was a Scottish engineer/inventor/astronomer who supplied the nineteenth century Industrial Revolution

Large Telescopes

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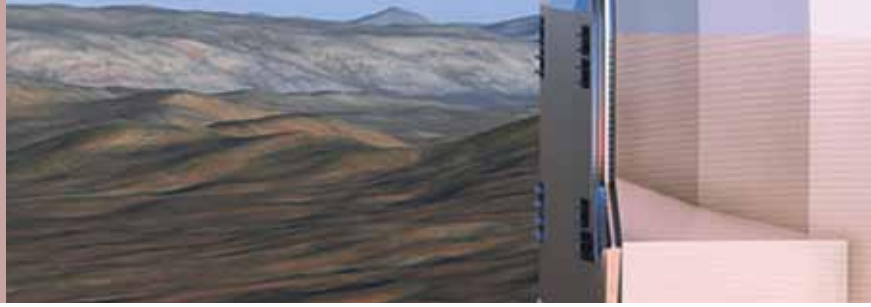

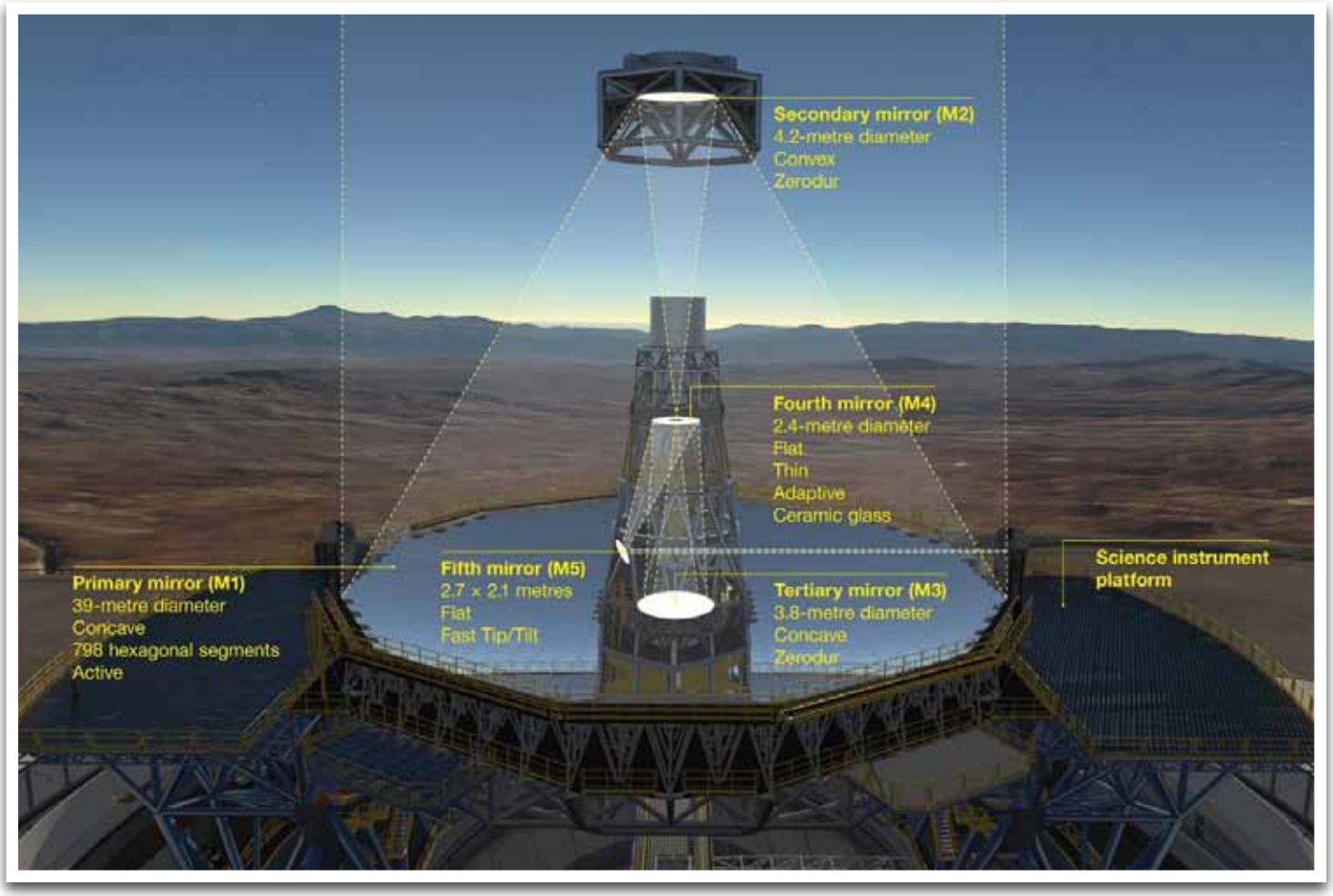

The E-ELT's novel five mirror optics and Nasmyth platforms

with powerful but precisely controlled steam hammers. In his retirement he became the astronomer who devised the Nasmyth focal points at the sides of a reflector telescope.

The ground breaking E-ELT enterprise promises to be a modern marvel of engineering, optics and computer science, which will make major contributions to our understanding of the universe.

The TMT (Thirty Metre Telescope) is another giant that will dwarf all currently operating optical telescopes. The TMT Project has been developed as collaboration among:

- California Institute of Technology (Caltech);
- University of California (UC);
- Association of Canadian Universities for Research in Astronomy (ACURA);
- National Astronomical Observatory of Japan;
- Department of Science and Technology of India;
- National Astronomical Observatory of China.

The TMT International Observatory LLC (TIO), a non-profit organization, was established in May 2014 to carry out the construction and operation phases of the TMT Project.

The TMT project has completed its $77 million design development phase with primary financial support of $50 million from the Gordon and Betty Moore Foundation and $22 million from Canada.

The project has now entered the early construction phase thanks to an additional $200 million pledge from the Gordon and Betty Moore Foundation. Caltech and the

An artist's rendering of the TMT in its modern looking calotte dome

University of California have agreed to raise matching funds of $50 million to bring the construction total to $300 million, and the Canadian partners propose to supply the enclosure, the telescope structure, and the first light adaptive optics.

TMT has received support for design and development from the following: Gordon and Betty Moore Foundation, Canada Foundation for Innovation, Ontario Ministry of Research and Innovation, National Research Council of Canada, Natural Sciences and Engineering Research Council of Canada, British Columbia Knowledge Development Fund, Association of Universities for Research in Astronomy, and the National Science Foundation (USA).

The preferred site for the TMT is on Mauna Kea, Hawaii. There are several other large telescopes at this high altitude (4050 m) site. A northern hemisphere site is preferred as it would have sky viewing inaccessible to the E-ELT in the Atacama Desert.

Progress has been delayed by large scale opposition to the project on religious and environmental grounds. On 29 March 2017 an agreement was signed with the Instituto de Astrofisica de Canarias (IAC) to host the telescope at the Observatorio del Roque de los Muchachos (ORM) on La Palma (Canary Islands) in case the Mauna Kea site does not become available. This is also the site of the Gran Telescopio Canarias and the proposed Giant Magellan Telescope.

IAC Director Rafael Rebolo declared: *"We are excited about the possibility of welcoming TMT to the Observatorio del Roque de los Muchachos on La Palma. The capacity for outstanding astronomical discoveries is beyond thrilling. This hosting agreement serves TIO, Spain and the worldwide astronomy community well."*

TMT Executive Director Ed Stone commented: *"This is an important step for TMT. We want to ensure we have by April 2018 a site suitable to start construction should Mauna Kea not be feasible. We now have a signed agreement and are moving ahead with the appropriate government approvals so that everything will be in place if needed."*

Large Telescopes

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Caltech Professor and TIO board member Tom Soifer added: *"The true spirit of collaboration between TIO and Spain has been really uplifting. We thank the IAC and Spain for their tremendous support and for the warm welcome to ORM."*

On 24 April 2017 the TMT project accepted 72 mirror blanks produced by OHARA, a Japanese optical glass manufacturer in Sagamihara near Tokyo, and polished by CANON Inc., under the direction of the National Astronomical Observatory of Japan (NAOJ).

This official acceptance confirms the excellent quality of the blanks and is based on stringent verification of the technical specifications set for all 492 TMT primary segment blanks (plus an additional 82 spare units) that will ultimately make TMT's 30-meter diameter primary mirror. A special glass ceramic 'CLEARCERAM' with a nearly zero coefficient of thermal expansion is used.

The telescope will be designed for a wide range of wavelengths (310 nm to 2800 nm) from near ultraviolet to mid infrared and will also have adaptive optics.

The primary mirror will be segmented using 1,44 m hexagonal mirrors. The Active Optics System will adjust the shape of each of the 492 segments using the 21-actuator warping harnesses that is built into the support assembly for each segment. Ten segments will be exchanged every two weeks for re-coating.

The optics will be Ritchey-Chrétien with the addition of a flat tertiary mirror for directing the light to the Nasmyth mounted instruments. The 3,6 m secondary mirror will produce an unobstructed field-of-view of 20 arcminutes.

The MCAO (Multi-conjugate Adaptive Optics) system will measure atmospheric turbulence using a combination of natural stars and laser produced artificial stars to adjust a pair of deformable mirrors, many times per second, to compensate for wave-front distortions.

Three first light instruments are envisaged: The Wide Field Optical Spectrometer (WFOS) will provide near-ultraviolet and optical (300 nm – 1000 nm) imaging and spectroscopy over a more than 40 square arcminute field-of-view.

Using precision cut focal plane masks, WFOS will enable long-slit observations of single objects as well as short-slit observations of hundreds of objects simultaneously. WFOS will use natural (uncorrected) seeing images.

The Infrared Imaging Spectrometer (IRIS) will be mounted on the observatory MCAO system and be capable of diffraction-limited imaging and integral-field spectroscopy at near-infrared wavelengths (800 nm - 2500 nm).

The Infrared Multi-object Spectrometer (IRMS) will allow close to diffraction-limited imaging and slit spectroscopy over a 2 arcminute diameter field-of-view at near-infrared wavelengths (800 nm - 2500 nm).

Diffraction-limited imaging is achieved when the only limit to resolution is due to the size of the primary mirror and the wavelength of light being used.

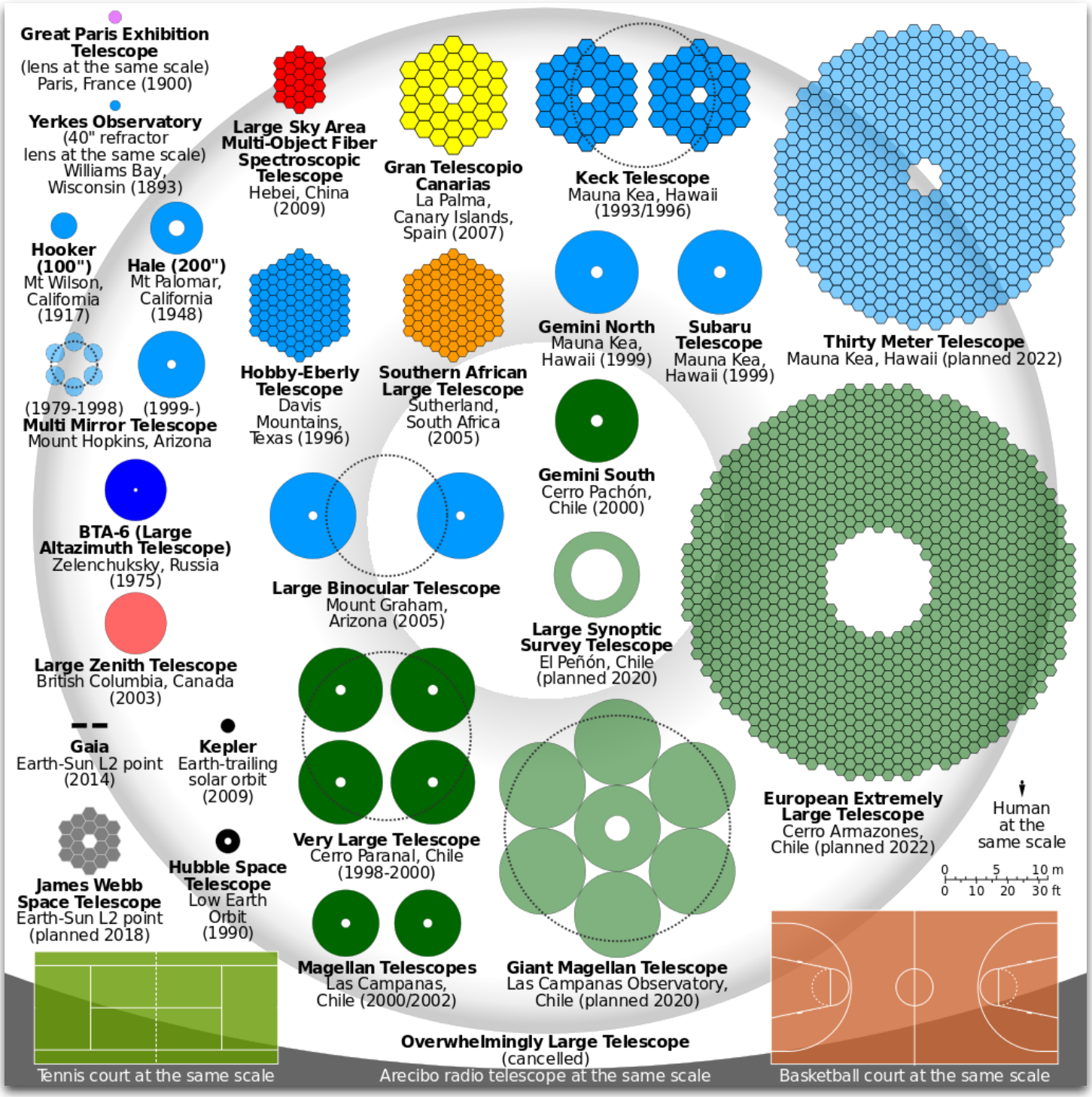
For a technical Comparison of the E-ELT and the TMT (dated 2010) see: www.casca.ca

Whether the TMT is installed on Mauna Kea or the Roque de los Muchachos, it is firmly on course to make major contributions to the astronomy of the next decade.

Click the following URL for fascinating 'must-see' videos of the ELT and its optics: https://www.eso.org/public/videos/

For more information on ESO's active optics see: https://www.eso.org/public/teles-instr/technology/active_optics/

For information on the mirrors see: https://www.eso.org/sci/facilities/eelt/telescope/mirrors/ wn



A comparison of the primary mirrors of the world's largest telescopes.

WHY YOU SHOULD JOIN THE EARTHING AND LIGHTNING PROTECTION ASSOCIATION

The establishment of the Earthing and Lightning Protection Association (ELPA) is a significant milestone for the sector. Following more than two years of hard work, ELPA has been set up with the intention of becoming the industry benchmark, and source of information for both businesses and individuals seeking to protect their buildings or homes.

Numerous meetings and discussions have since taken place, resulting in what will be an important addition to the standards of safety in South Africa, in terms of the training and certification of qualified designers, installers, and inspectors with recognition by the Department of Labour, SAQA, the University of the Witwatersrand, SAIEE and others.

The founding committee held its first 'annual general meeting' which attracted a significant portion of the industry and where almost all the major companies were represented by their owners. Here, a unanimous vote was taken to go ahead and create an association under the principles presented.

Since ELPA represents a trade directly involved in the provision of the first, second and third lines of defence against one of nature's most mysterious phenomena, a pass mark for its qualifying examination has been set at a minimum of 80% to ensure the competence of its members. It is upon this rigorous standard that ELPA plans to take the industry into the future, securely providing South Africa with genuinely certified, competent lightning protection installers.

The provision of a central database, of suitably qualified and skilled Lightning Protection Service Providers, will help people and organizations source specialists skilled in the art, science, and practises of conformant lightning protection designs, installations, inspection, testing, and certification. The modular nature of the skills training program equips ELPA certified specialists in many of the higher aspects of contracting, such as quality control programs, risk identification, analysis, and management, amongst others.

Committee members include: chairman, Alexis Barwise (DEHN Africa), Mike Visser and Jan Jordaan (Power Quality), Pieter Human (Tesla Power and Lightning Protection), Nelson Pillay (Vodacom), Doug Kay (Electrotech), Andrew Economou and Kevin Rahn (Pontins), Gary Thoresson (Thor Earthing), Trevor Manas (LPConcepts), Paul van As (Surgetek), Seath Scowby (Lightning Protection Services), Bertie van Zyl (Advanced Lightning Protection), Ron Fourie (Pro-lightning), Jacques Hannekom (EHL) and Nico van der Berg (Independent Inspectors).

ELPA officially launched at its second Annual General Meeting at the University of the Witwatersrand on June 19, where Professor Ian Jandrell, Dean of the Faculty of Engineering and the Built Environment, gave the keynote address.

The board is committed to an open, fair, and just association dedicated to the continual improvement of our members concerns in an environment of equality, where the voice and vote of every member counts. wn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EARTHING AND LIGHTNING PROTECTION ASSOCIATION
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IN MY OPINION - MICHELLE DOOLAN

Letting Our Capes Fly:

Why Engineers Are Awesome

BY | MICHELLE DOOLAN

You don't have to sit a 5-year old down and teach her the physical and psychological benefits of building forts. Chances are she has wrecked your lounge many times before. Written into the defaults of our DNA is the impulse to create - to bring something that never was into being.

Take away the plastic weapons of mass destruction from your toy box, and watch your toddler turn his peanut butter sandwich into a gun. Beach sand becomes castles; snow days invite igloos; the world is a wonderful palette that kids just intuitively want to paint on. Essentially, the engineer is hidden inside all of us.

The question for us engineers who still hold the title is, are we still living like one?

Because we may need to be reminded from time to time, the job of an engineer is a great one. By comparison to some of the other professions, engineering is often not seen as the "cool" one. TV shows like LA Law and Boston Legal glamorise legal eagles battling it out in high profile court cases.

ER, House and Scrubs bring the world of medicine into our living rooms. Even Grand Designs puts architecture on a pedestal. Isn't it about time that TV producers got in touch with the profession that is shaping the future world we live in like no other?

As a discipline, it lies at the very fabric of our society, shouldering the systems and spaces that give our world its meaning. Too often the profession is associated with hard hats and tool belts, viewed as difficult and esoteric. But in reality, engineering is a far cry from 'restrictive' and 'routine'. It is alive and multi-dimensional, unleashing the power of connected societies to unlock the impossible.

Engineering invades every domain and asks the question, 'how can we make this space into something fantastic?' To be an engineer is to be nothing less than the shapers and problem solvers of our collective future.

WE GET TO DO THIS

Confucius said, "Choose a job you love, and you will never have to work a day in your life." In spite of the many challenges and demands, the job of a passionate engineer should often feel like play. Edges are invitations; and we, of all people, should welcome the thrill of stepping off the ledges of previous paradigms, to see what new support systems open up beneath us.

Every day, we get to blend new technologies into the world around us. Big data helps us gain new insight into people's needs, which in turn fuels new design, that facilitates healthy and sustainable workflows and social interactions.

All the more, we are called to create new virtual reality visions of the future, which anticipate the 'what if's' and puts the unknowns at ease. We get to re-imagine energy as we know it, and tinker with a thousand unimaginable ways to address some of the single-most important issues of our day.

If we are going to remain agile and imaginative in our approach to urban co-creation and problem solving, then engineering needs to stay fun, and occasionally open to failure. If we subscribe to methodologies that resist change and reward bottom line only, we will dangerously stay too neatly within the lines.

WE PEN THE STORY

Whether it be a mass transit system, a power system, a water network or a building, engineers are asking the question, 'how will this infrastructure be relevant in the future?' We have the privilege to keep reshaping life into systems and spaces that

breed more life. Every day we are faced with the opportunity to look at issues through new lenses and improve upon historic archetypes.

Take the example of Elon Musk, whose invention of the Tesla Electric Car presents itself like a lifeline to the sinking ship we call today's fossil fuel-dependent automotive industry. His passion to reduce global warming has pushed open major doors in solar energy, and cracked the ceiling of our paradigms - even to include outer space. Thanks to Musk's SpaceX Program, some of us are now googling how to grow vegetables on Mars.

Good engineers steward safe boundaries. Great engineers push them wider to the benefit of society. Game changers such as Mark Zuckerberg have altered the stakes of social engagement worldwide, through Facebook's far-reaching and immediate ability to connect people around the world.

IDEO is pioneering concepts around people at the centre of design and economies of circular value. And because they have a sobering understanding of the responsibility which goes hand-in-hand with crafting community, they don't easily back down.

Zuckerberg has used his unique position to pledge 99% of his lifetime Facebook shares (worth about $45 billion) to "advance human potential and promote equality in areas such as health, education, scientific research and energy".

As "impatient optimists working to reduce inequity", the Gates Foundation has so far given away $35 billion to 'take on the really tough problems' of hunger, disease and poverty. At their core, engineers are pioneers who create platforms to propel humanity upward and onward.

WE CAN CREATE IT!

Engineering is a constant exercise in diagnosis and treatment. We identify the pain points of society; we prescribe the remedies; and then we even get to deliver the solutions ourselves.

Every day the hand of the engineer provides enormous benefit to communities - whether that be in the form of a surgeon performing groundbreaking fibre optic treatment, or something as commonplace these days as an overseas Skype call using broadband or fibre network.

Biomedical engineers are developing artificial hearts and giving amputees a new spring in their step. And leaders of science, technology and innovation are carrying the keys to unlocking poverty alleviation and meeting the basic human needs of adequate food, clean drinking water, sanitation, good health provision, shelter and education.

Through tight collaboration with government, business leaders, academic institutions and the public at large, we can lead true change by painting wide-stroke solutions over societal problems. We carry cutting edge solutions and skills that embed the systems and smart technologies carving out our future urban ecosystems. It's to everyone's detriment when we fail to step up and lead.

We encourage engineers to be proud to leave their mark… to shake off their 'behind the scenes' identities and become ambassadors that talk proudly about the full range of work and sectors they are involved in.

This is not a time for false humility; it's a time to let our capes fly. Engineering is far more than a job. It's a way of seeing the world and believing we can improve upon it. The degree to which we own our superhero status in the collective story is the degree to which we all win. wn

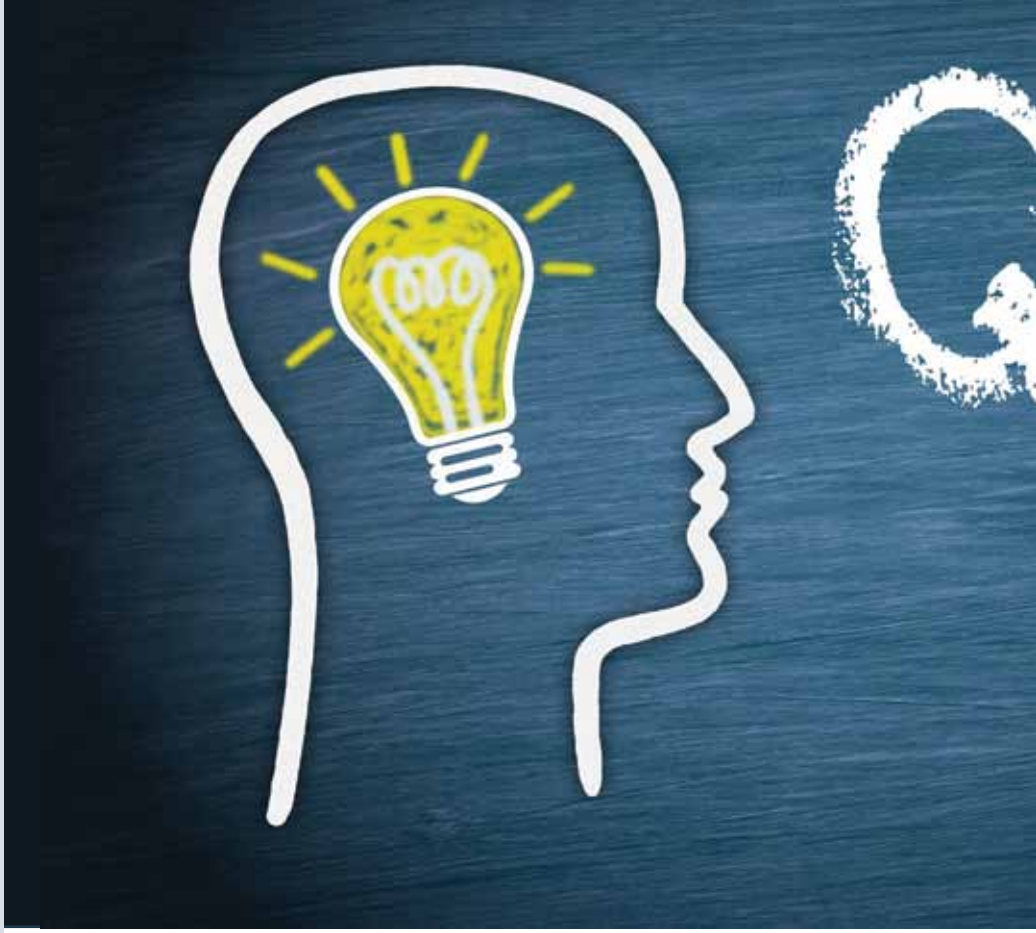
WATT? is a forum related specifically to the industrial and commercial electrical sector.

Do you have any burning questions, topical issues or points of interest about the electrical industry, from the perspective of a contractor, supplier or professional service provider? Submit your comments, thoughts, ideas, suggestions or questions for the attention of our industry experts, and these will be addressed in a future issue of the magazine. This is your forum, and we would like to hear from you!

WATT? is an opportunity for people on the ground to engage with each other and related professionals in an informative and friendly manner. This is a platform for you to discuss anything related to your particular sector, to highlight anything new, or to ask a specific question related to a technical topic or to engage in general industry issues. . Please note that we will not be considering anything related to the domestic sector, such as residential wiring.

We hope that this section of the magazine not only becomes a regular feature, but that it is widely read and distributed among your peers. Remember, it can only become a success with the full participation of our readers! Send your burning questions to minx@saiee.org.za - subject 'WATT?'.

We look forward to hearing from you.
- Ed



QUESTION ONE

What remedial measures should be taken when an electric motor is not immediately put into operation?

ANSWER ONE

When a motor is not immediately put into operation, it should be protected against moisture, high temperatures and impurities to avoid damage to the insulation. The winding insulation resistance must be measured before operating the motor.

If the ambient contains high humidity, a periodical inspection is recommended during storage. It is difficult to determine rules for the actual insulation resistance value of a motor as the resistance varies according to type, size, rated voltage, condition of the insulating material used and method of construction of the motor.

When motors are not immediately unpacked, boxes should be stored in their normal upright position at a dry location free of dust, dirt, gases and a corrosive environment. Other objects should not be stacked over or against the boxes, and motors must be stored in places free from vibrations to avoid damage to the bearings.

In the event of outdoor storage, the motors should be placed at a location to guarantee the protection of the motors from potential flooding and ground dampness which could lead to the equipment sinking into the ground. Placing the motors on pallets, wooden beams or a raised foundation can potentially protect the motors from these conditions.

Covers or tarpaulins can be used to protect the equipment against weather conditions but direct contact should not be made with the surfaces of the equipment. In addition, adequate air circulation must be ensured by positioning wooden spacer blocks between the equipment and the covers.

When a motor is kept in stock for a period of six months or less, it is not necessary to introduce additional lubricant on the bearings before running it. It is, however, required that the motor shaft be rotated manually on a monthly basis.

QUESTION TWO

Why is the alignment and levelling of an electric motor important, and what actions are required to guarantee sufficient alignment and levelling of the motor?

ANSWER TWO

To ensure the adequate operation the electric motor must be accurately aligned and sufficiently balanced with the coupled equipment and the components mounted on the shaft end. Incorrect alignment can cause bearing defects, vibrations and even shaft breaking.

The best way to ensure correct alignment is to use dial indicators placed on each coupling half; one reading radially and the other axially. In this way, simultaneous readings can be informed and one can check any parallel or concentricity deviations by rotating the shaft.

When it comes to the alignment and the levelling, it is important to consider the effect of the temperature over the motor and driven machine. The different expansion levels of the coupled machines can modify the alignment and levelling during motor operation. There are instruments which use a visible laser in conjunction with a computer programme to ensure precision alignment.

The type of motor base is crucial for high precision alignment and depends predominantly on the nature of the soil at the installation site or on the floor dimensions. When designing the motor foundation, it must be taken into account that the motor might occasionally be subjected to higher than the rated torque values. With an incorrect design, vibration problems can occur that will affect the motor and the driven machinery. It is, therefore, important that all the structure equipment is designed in such a way that they can transmit any force or torque which may occur during the operation.

Motors are most commonly fixed onto concrete bases. The type and size of the foundation, as well as other fixing devices, will depend on the type and size of the motor. When pulleys are used for the drive system, the motor should be mounted on slide rails and the lower part of the belt must perform be pulling action. The motor is bolted to the rails and set on the base and the drive pulley is then aligned so that its centre is level with the drive pulley centre. Motor and driven machine shafts must be in a parallel position and the belt should not be excessively stretched.

On metallic bases, a flat surface under the motor feet is required to avoid frame deformation. The bearing housing surface of the motor should be configured so that shim plates, approximately 2 mm thick, could be placed under the feet of the motor. Motors should not be removed from their common metallic bases for alignment purposes but the metallic bases should rather be levelled on the actual foundation.

When a metallic base is used to adjust the height of the motor shaft end with the machine shaft end, it should be levelled on the concrete base. After the base has been levelled, foundation studs tightened and the coupling checked, the metal base and the studs could then be cemented. wn

Information provided by Zest WEG Group

July

Movers, shakers and history-makers

COMPILED BY | JANE BUISSON-STREET
FSAIEE | PMIITPSA | FMIITSPA

1 JULY

1982 Helen Joseph, who had been under a series of banning orders since 1962, was released from such restrictions.

2 JULY

2005 South African tennis player, Wesley Moodie, and Australian, Stephen Huss, won the Wimbledon Men's double title. Huss and Moodie had never played together in a tour level event before this tournament.

3 JULY

1928 John Logie Baird demonstrated the first colour television transmission in London.

4 JULY

1959 Four matches were played to mark the official start of professional soccer in Southern Africa.

5 JULY

1989 African National Congress leader Nelson Mandela met with President P.W. Botha at Tuynhuis to begin discussing how to end apartheid. This meeting is regarded as significant as it brought together two opposing leaders in a surprisingly cordial manner.

6 JULY

1916 The 1st South African Infantry Brigade was recruited at Potchefstroom in August and September for service overseas. It was comprised of four battalions of infantry.

7 JULY

1668 Isaac Newton received his Master of Arts from Trinity College, Cambridge, England.

8 JULY

1895 The Delagoa Bay railway line was officially opened by Paul Kruger. This railway linked the land-locked Transvaal Republic and Delagoa Bay, situated on the southeast coast of Mozambique.

9 JULY

1959 A Royal Air Force Vickers Valiant, under Wing Commander M.J. Beetham, set a new record for the London-Cape Town flight by completing the journey (non-stop) in 11 hours 27 minutes.

10 JULY

1847 The rotary printing press (a printing press in which the images to be printed are curved around a cylinder). was patented by Richard Hoe.

11 JULY

1895 The first ever car race began in Paris, France. The route was from Paris to Bordeaux and back (1,178 km). The winning time was 48 hours, 48 minutes, with an average speed of 24 km/hr. Emile Levassor was the first over the finish line, driving a Panhard et Levassor car with a two-cylinder, 750-rpm, four-horsepower Daimler Phoenix engine.

12 JULY

1998 Nelson Mandela concluded his four-day visit to England by accompanying Queen Elizabeth II on a coach drive through the streets of London. In a BBC documentary afterwards, Mandela repeatedly referred to Queen Elizabeth II as *"my friend, Elizabeth"*.

13 JULY

1836 After receiving and granting 9 957 patents, the US patent started assigning numbers. US patent #1 was for locomotive wheels.

14 JULY

2014 The Church of England voted in favour of allowing women to become bishops.

15 JULY

1916 The S.A. Infantry Brigade, under Major-General H.T. Lukin, was ordered to clear the wood at d'Elville, north-east of the village of Longueal, France, of enemy soldiers, thereby covering the flanks of the British Brigade. The Battle of Delville Wood went down in the history of WWI as an example of supreme sacrifice and heroism and was the most costly action the South African Brigade fought on the Western Front.

16 JULY

2006 Maluleke George, the Deputy Defence Minister, attended the 90th commemoration of the Battle of Delville Wood in France. During the ceremony, a new South African coat of arms was unveiled at the South African memorial on the site.

17 JULY

1959 Mary Leakey, a British Paleoanthropologist, discovered the partial skull of a new species of early human ancestor, Zinjanthropus boisei or 'Zinj' that lived in Africa almost 2 million years ago. She also discovered the earliest (3.6 million years old) human footprints at Laetoli, Tanzania.

18 JULY

1999 South African swimmer Penny Heyns set four world records in just two days in the 100m and 200m breaststroke in South California, USA.

19 JULY

1799 During Napoleon Bonaparte's Egyptian campaign, a French soldier discovered a black basalt slab inscribed with ancient writing near the town of Rosetta, about 56km north of Alexandria, Egypt. The irregularly shaped stone contained fragments of passages written in three different scripts. The artefact held the key to solving the riddle of hieroglyphics, a written language that had been "dead" for nearly 2,000 years.

20 JULY

1969 The Apollo XI Mission, the first manned mission, landed on the Moon. Parts of the Eagle Landing Ship were held together using Pratley Putty, a South African invention. The extremely strong adhesive, was invented by George Pratley, from Krugersdorp in Gauteng, in 1948 while he was trying to develop a glue to hold components in an electrical box.

21 JULY

1884 The first of over 100 test matches was played at Lord's; England defeated Australia by an innings and 5 runs.

22 JULY

1933 American aviator, Wiley Post returned to Floyd Bennett Field in New York, after having flown solo around the world in 7 days, 18 hours, and 49 minutes. He was the first aviator to accomplish the feat.

JULY

continues from page 61

23 JULY

1996 South African swimmer Penny Heyns won gold again in the women's 200m breaststroke final, after setting an Olympic record in her heat and again in the final with a time of 2:25.41.

24 JULY

1943 During World War II in Europe, the Royal Air Force conducted Operation Gomorrah. When raiding Hamburg, aluminium foil strips were thrown out which resulted in the German radar screens seeing a blizzard of false echoes. As a result, only twelve of 791 Allied bombers involved were shot down.

25 JULY

1909 The world's first international overseas airplane flight was achieved by Louis Bleriot in a small monoplane. After asking, *"Where is England?"* he took off from France and landed in England near Dover, where he was greeted by British police.

26 JULY

1745 The first recorded women's cricket match takes place near Guildford, England.

27 JULY

1944 The first British jet fighter was used in combat for the first time namely the Gloster Meteor. It was the first British jet fighter and the Allies' only operational jet aircraft during the Second World War. The Meteor's ground-breaking turbojet engines were pioneered by Sir Frank Whittle and his company, Power Jets Ltd.

28 JULY

2004 Around 2003/2004, a counterfeit R5 coin was circulated in South Africa. Although not an exact match of the original, the coin was convincing enough to fool many people. This prompted the Reserve Bank to redesign the coin in order to outsmart counterfeiters.

29 JULY

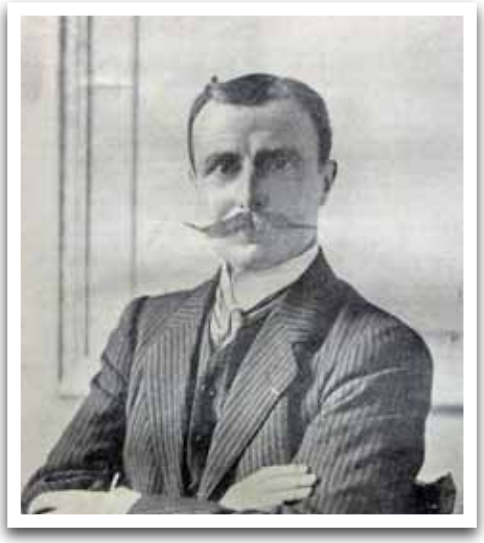
1954 John Ronald Reuel Tolkien's "Fellowship of the Ring", the first volume of "Lord of the Rings" was published by George Allen and Unwin of London, England.

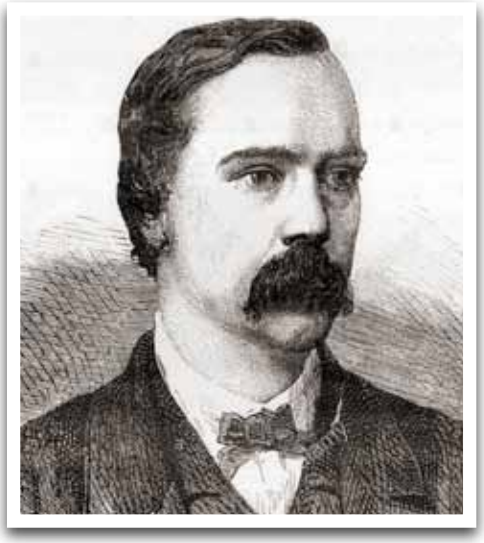
30 JULY

1872 Mahlon Loomis received U.S. Patent 129,971 for a wireless telegraph. His one-page patent made a vague claim about using atmospheric electricity to eliminate the overhead wire used by the existing telegraph systems, but it contained no schematic diagram of how to build it, and no theory of how it might function.

31 JULY

1879 The first telegraph cable connection between SA and Europe, via Aden, was launched. It was laid by the British electrical engineer Charles Tilston Bright as part of his project to link the British Empire with growing telecommunications technologies. WN





calendar

JULY | AUGUST | SEPTEMBER 2017

JULY 2017

4 - 5	Photovoltaic Solar Systems	Johannesburg	roberto@saiee.org.za
12 - 13	HV/MV Circuit Breaker, Operating & Maintenance	Johannesburg	roberto@saiee.org.za
12- 14	Planning Strategic Feasibility Studies	Johannesburg	roberto@saiee.org.za
12 - 14	West Africa Power Summit	Senegal	www.wafpower.com
18 - 20	PowerGen Africa	Johannesburg	www.powergenafrica.com
19 - 20	Network Frequency Control with Increasing Renewable Power Plants	Johannesburg	roberto@saiee.org.za
19 - 21	Smart Meters for Smart Grid Training	Johannesburg	roberto@saiee.org.za
24 - 26	Fundamentals of MV Protection	Johannesburg	roberto@saiee.org.za
26 - 28	Substation Design & Equipment Selection	Johannesburg	roberto@saiee.org.za

AUGUST 2017

2 - 3	Internet of Things (IoT)	Johannesburg	roberto@saiee.org.za
3 - 5	NOCCI Business Expo	Kimberley	www.nocci.co.za
4 - 6	Empire Money Expo	Johannesburg	www.themoneyexpo.co.za
7 - 9	Rapid Underground Mine and Civil Access Conference	Johannesburg	www.saimm.co.za
11	Application of LV Frequency Control to Industrial Drives	Johannesburg	roberto@saiee.org.za
14 - 16	Industrial & Commercial use of Energy Conference	Cape Town	www.energyuse.org.za
15	Smart Buildings & Infrastructure Western Cape Summit	Cape Town	www.smart-summit.com
16	ELPA Examination	Midrand	www.elpa.org.za
16 - 17	Fundamentals of LTE Mobile Communication	Johannesburg	roberto@saiee.org.za
16 - 17	Fundamentals of Power Distribution	Johannesburg	roberto@saiee.org.za
17	ELPA Examination	Midrand	www.elpa.org.za
22	ELPA Examination	Midrand	www.elpa.org.za
23	ELPA Examination	Midrand	www.elpa.org.za
23 - 24	Incident Investigation & Management (Including Root Cause Analysis)	Johannesburg	roberto@saiee.org.za
23 - 24	Fundamentals of Developing Renewable Energy Plants	Johannesburg	roberto@saiee.org.za

SEPTEMBER 2017

6 - 7	Design Of Economical Earthing Systems	Johannesburg	roberto@saiee.org.za
12 - 15	Advanced Microprocessor Based Power System Protection Course	Johannesburg	roberto@saiee.org.za
13 - 14	Microsoft Project Professional	Johannesburg	roberto@saiee.org.za
19 - 21	SAIEE SmartGrid Conference	Midrand	www.saiee-smartgrid.co.za
19 - 22	Managing Projects Effectively	Johannesburg	roberto@saiee.org.za
20 - 21	Photovoltaic Solar Systems	Johannesburg	roberto@saiee.org.za
27 - 29	Measurement And Verification Of Energy Efficiency	Johannesburg	roberto@saiee.org.za
28 - 29	Arc Flash Studies	Johannesburg	roberto@saiee.org.za

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Western Cape Centre

Chairman | Joyce Mtimkulu

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SAIEE

www.robotscience.co.za
www.youtube.com/electronicsafrica

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DATE

22 October 2017
10:00-16:00

PLACE

Zwartkops Raceway, Quagga Road, Centurion, Gauteng

ENQUIRIES

michaele@uj.ac.za

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