NELSON MANDELA UNIVERSITY

PROFESSORIAL INAUGURAL LECTURE

PROFESSOR RUSSELL PHILLIPS

Topic:

THE ROLE OF RENEWABLE ENERGY IN DE-URBANIZING POST COVID AFRICA

Faculty of Engineering, the Built Environment and Technology

28 June 2021

Table of Contents

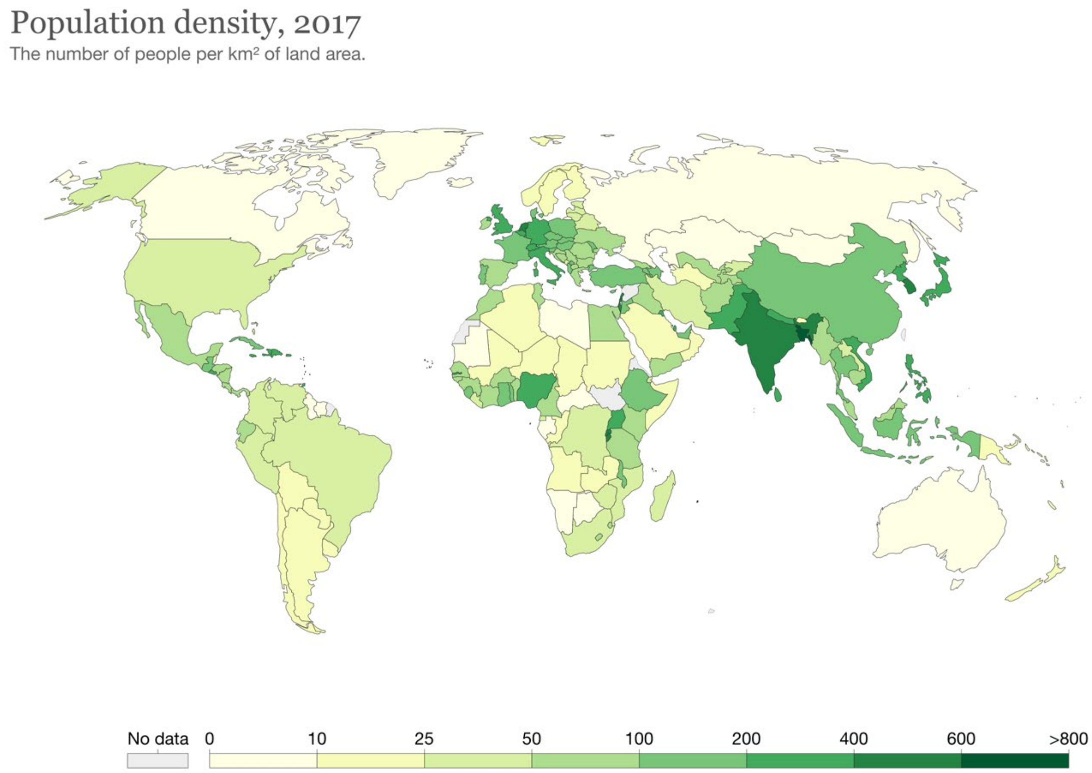
Abstract

The world is becoming increasingly urbanized with more than half of the world population living in cities. In many instances urbanization is seen as a positive phenomenon, however in Africa, urbanization is shown to result in a large proportion of the urban population living in slum conditions. The recent COVID pandemic has necessitated that many persons work remotely and has shown that this arrangement can be both cost effective and efficient. The notion of promoting a remote work concept beyond the pandemic with a view to encouraging de-urbanization is proposed in this research. To achieve meaningful levels of de-urbanization in Africa, particularly in remote, rural areas two major challenges need to be overcome, namely internet connectivity and energy supply. The imminent rollout of Low Earth Orbit Satellites (LEO) for affordable remote connectivity coupled with the maturity of the current solar photovoltaic offerings present seemingly perfect solutions to the identified challenges. Additionally, the record low prices recently reached by Photovoltaic modules and Lithium-ion batteries seem to present fortuitous timing for a mass de-urbanization drive which may have the potential to improve the lives of many people in Africa.

Keywords: De-urbanization, Renewable Energy, Solar Energy, Connectivity.

1. Population density and urbanization

The current world population continues to increase with an almost linear trend with a current total of 7.7 billion people. These 7.7 billion people occupy the planet with a density per country ranging from 10 to 800 people per km^2.



(World Bank 2017)

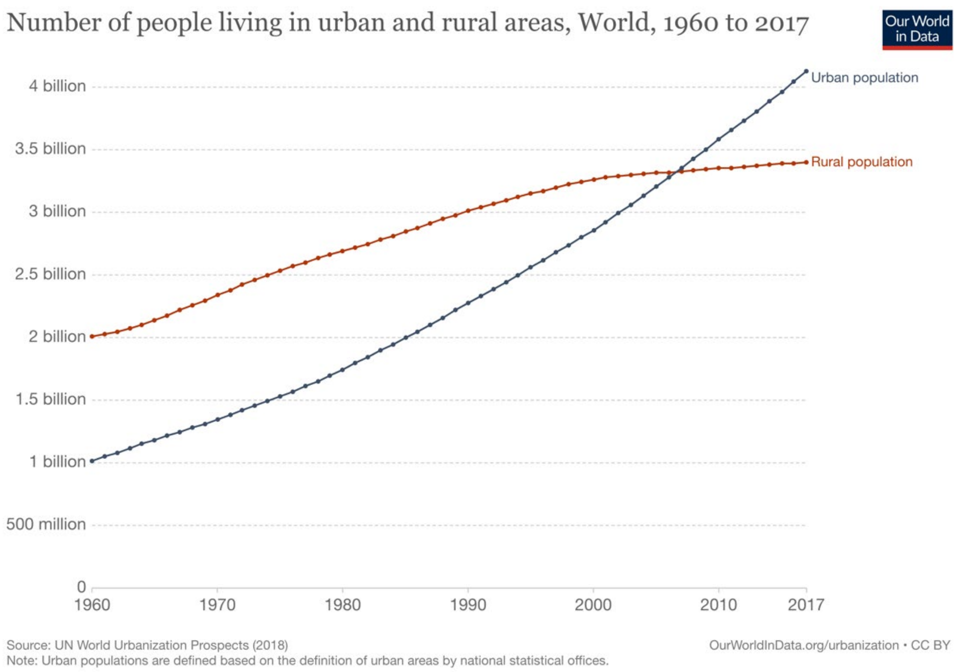
<u>Population densities in cities are as high as 44000/km^2 (Dhaka).</u>

In Sub-Saharan Africa:

16700/km^2	Kinshasa
14700/km^2	Abidjan
13800/km^2	Lagos
8400/km^2	Nairobi
6900/km^2	Dar es Salaam
6300/km^2	Luanda
3100/km^2	Johannesburg

(UN Habitat Global Urban Observatory. 2014)

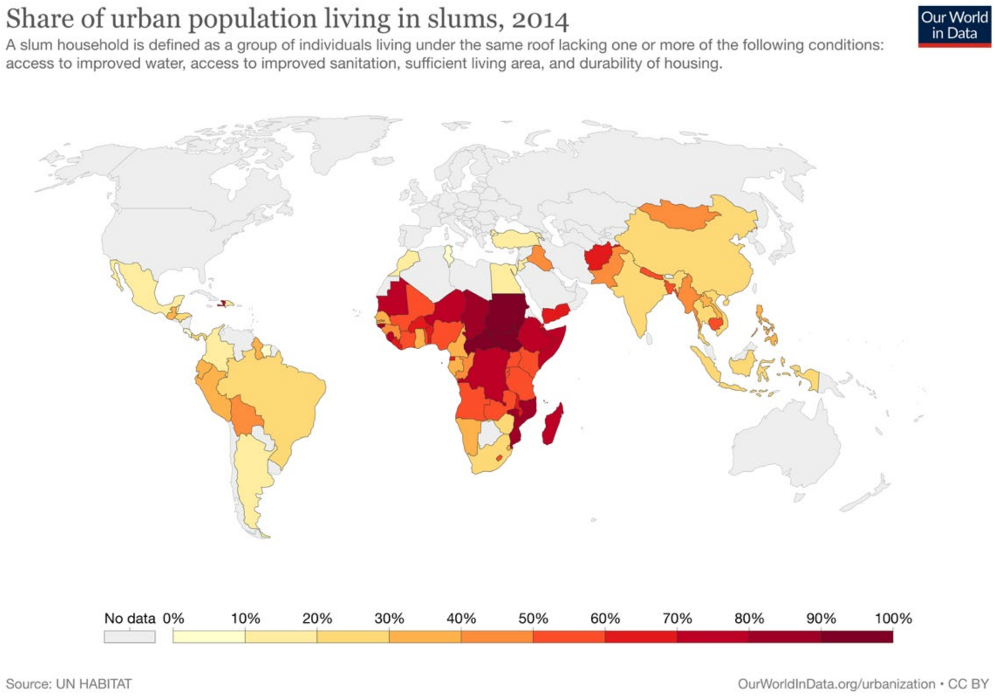
Figures from the United Nations (UN) estimate that more than half (55%) of the world population live in urban areas. The European Commission on the other hand sets this figure as high as 85%. According to Angel et al (2018) the discrepancy is due in part to differences in the statistical definition of urban versus rural.



Ritchie & Roser (2018) present the following summary relating to urbanization:

- *More than 4 billion people live in urban areas globally.*
- *The UN estimates 2007 was the year when, for the first time, more people in the world lived in urban than in rural areas.*
- *Estimates on urban populations vary – mainly as a result of disagreements on the exact definition of an 'urban area' and what this includes.*
- *Just under 1-in-3 people in urban areas globally live in a slum household.*
- *For most of human history, populations lived in very low-density rural settings. Urbanization is a trend unique to the past few centuries.*
- *By 2050 it is projected that more than two-thirds of the world population will live in urban areas.*
- *It's projected that close to 7 billion people will live in urban areas in 2050.*
- *People tend to migrate from rural to urban areas as they become richer.*
- *Living standards tend to be higher in urban areas.*

The final point in the summary suggests that urbanization generally results in improved living standards. Whilst this may be true globally, the African situation paints an entirely different picture as presented below (World Bank 2014). It can be reasonably concluded that urbanization in Africa generally results in large parts of the population living in slum conditions. It therefore stands to reason that if de-urbanization can be implemented the quality of life of people in Africa could improve.



2. De-urbanization opportunities stemming from the pandemic

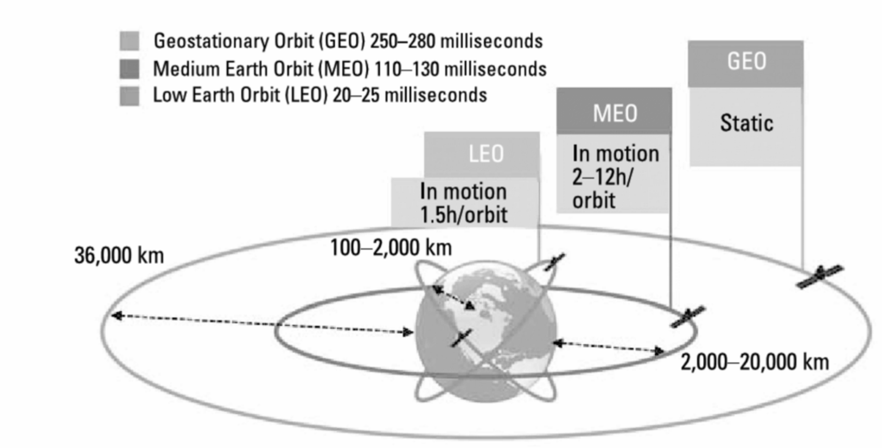
A study conducted before the Covid-19 pandemic by Bloom (2014) compared employees working remotely to employees working from a traditional office setting and concluded that "*the at-home workers were not only happier and less likely to quit but also more productive*".
Bartik et al (2020) drew further conclusions as to which professions were best suited to remote work. These mostly included better educated and higher paid industries and professions.
Certain professions that were previously only possible to conduct in a city could now plausibly be conducted from a rural location. Examples of such professions being Accountant, Attorney, Lecturer, Artist, Designer, Architect, Computer Scientist, Media professional and numerous others. Kapur (2019) suggests that de-urbanization of "white collar" workers will lead to stimulus of employment in rural areas outside of just the traditional agricultural employment sector.

3. Current Connectivity challenges

To be able to effectively conduct any of the professions suggested above from a remote location a reliable internet connection is required. O'Halloran (2020) surveyed 1000 people working from home and found that nine out of ten wasted more than 30 minutes a day due to unreliable internet connections. In a rural setting where wired or fibre connections may not be available the situation is likely to be exasperated leaving cellular connectivity as the only option. Large parts of Africa however lack cellular coverage thereby rendering these areas unsuitable.

4. Low earth orbit satellite constellations (LEO)

Varral (2018, p7) lists the NEWLEO operators as OneWeb, Space X and LeoSat. The author further states that the first two operators have implementation plans for launching hundreds and ultimately thousands of satellites into LEO. In so doing their aim is to service small ground based, solar powered cellular stations which in turn provide low cost, low latency, high speed internet connectivity to users. Because the constellation of LEO's is not geo stationary intersatellite switching is proposed for seamless data transfer. LEO's will orbit with altitudes as low as 100km putting them just above the Karman line. (McDowell 2018).



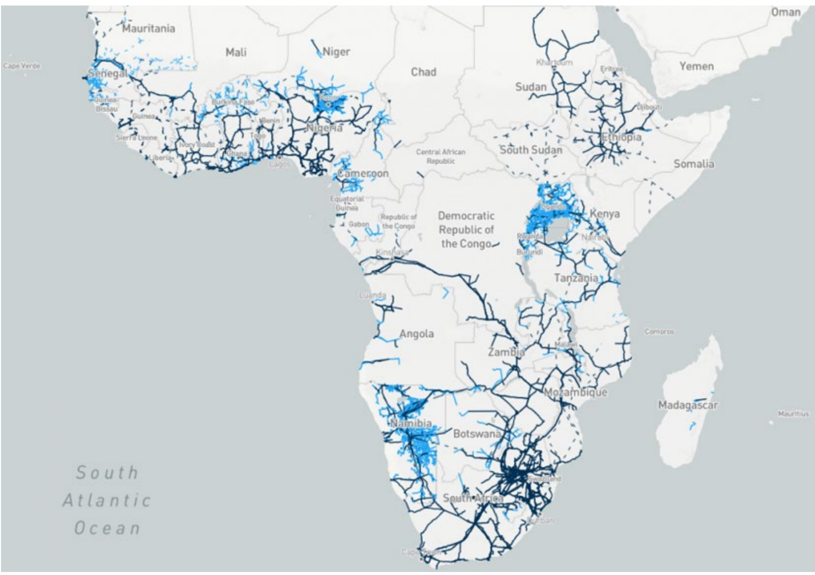
Varral (2018, p10)

5. Holographics to enhance the remote working experience

Xing et al (2015, p71) concludes that "digital holography offers appealing features for 3D imaging applications" and "has the potential to become the ultimate 3D experience". The authors do add though that "digital holography requires a very high data rate".
The constraint of exceptionally high data rate requirements appear to preclude this technology from being implemented immediately. It does show promise however for improving the remote working experience as presented in this display.
https://www.youtube.com/watch?v=DkOKrVV3SS0

6. Energy

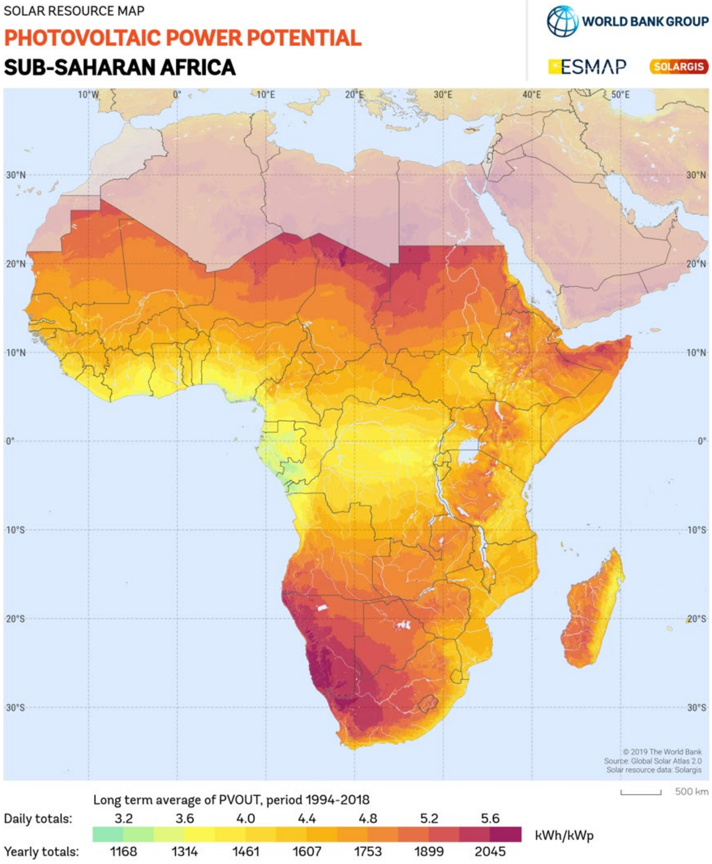
Assuming that basic human needs and connectivity are available at a rural and/or remote site there remains one major need without which remote habitation and working cannot be contemplated. This need is energy. Ardene et al (2017) state that in the African context the electricity grid provides electricity access to only 38% of the people in Africa. Mingaleva and Balkova (2015) highlighted the de-urbanization constraint at that time as follows: "problems are factors such as limited energy resources, the high cost of energy, including alternative energy".



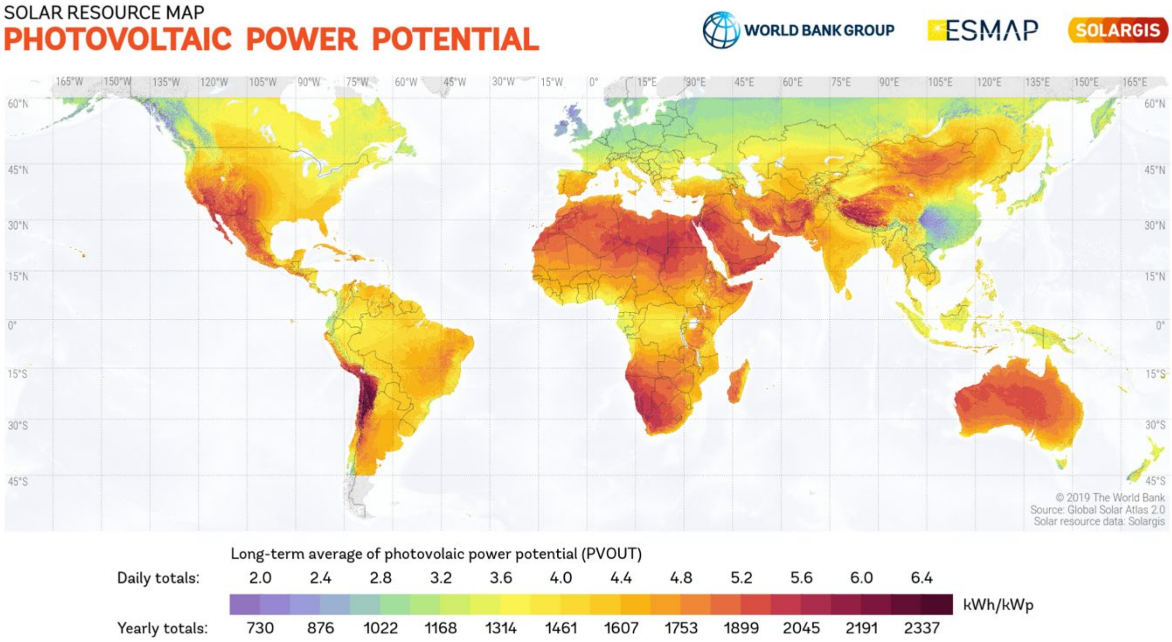
Africa's energy grid: World Bank (2017)

7. Solar Energy

The Global Solar Atlas map presents the potential of Photovoltaic (PV) installations in Sub Saharan Africa in a convenient format of kWh of energy produced daily and annually in relation to the installed capacity of PV. The high potential in Africa, particularly in areas with little or no energy grid coverage presents a favourable case for the use of PV as an energy source.

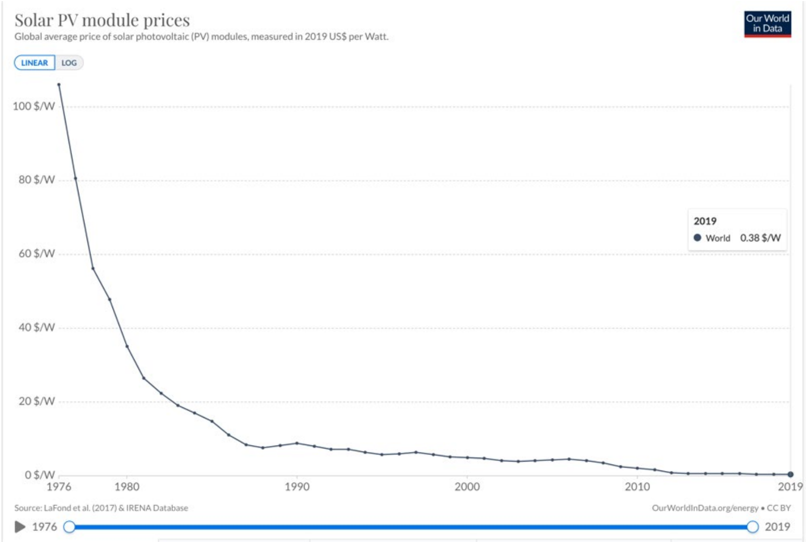


Global Solar Atlas (2019)



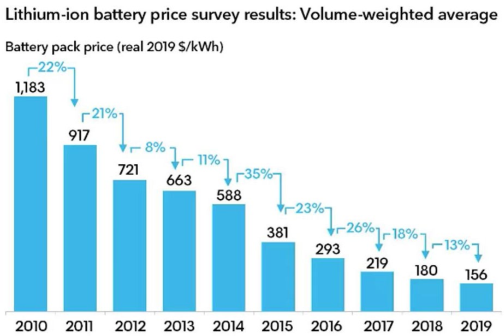
Global Solar Atlas (2019)

8. The cost of PV



Irena Database (2019)

9. The cost of lithium-ion batteries



Bloomberg (2019)

10. Essential components of a modern domestic solar energy system with storage

10.1 Photovoltaic modules

Photovoltaic modules output electrical energy as Direct Current (DC) during daylight hours. Expected daily and annual yields can be obtained from the PV power potential maps above.

10.2 Battery Storage

For uninterrupted electricity supply during the day and for supply during the night a battery storage system is necessary. Until recently Lead-acid batteries were commonly used, however their relatively short lifespan before replacement in comparison to Lithium-ion batteries, coupled with the reduction in Lithium-ion prices has rendered the latter the current batteries of choice in most new installations.

10.3 Inverter

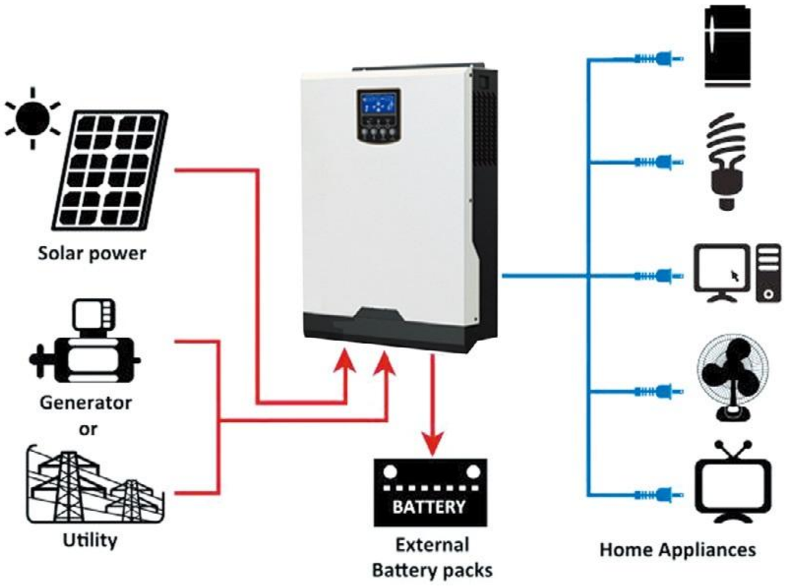
Household or office needs are typically for Alternating Current (AC). The inverter converts the DC current from the PV modules and/or batteries to AC at the required voltage and frequency. (Typically 240V, 50Hz).

10.4 Maximum Power Point Tracker (MPPT)

To extract the full energy potential from the PV modules with varying solar irradiation a MPPT is required. Conveniently this is now typically integral with the modern hybrid type inverter.

10.5 Diesel/Petrol generator (optional)

In extreme cases of persistent cloudy weather and high energy usage even a properly sized solar system will deplete its battery storage. In instances where power outages cannot be tolerated a generator is required. This can be seamlessly integrated into the system and automated.



Hybrid inverter system - Electrogadgets.co.za (2021)

11. Sizing and costs of a modern domestic solar energy system with storage

Actual usage for the author's home office, household lighting and refrigeration is presented below:

Month	Solar energy produced (kW.h)	Grid energy used (kW.h)	Battery storage utilised (kW.h)
June 2020	145.06	Not connected	112.11
July 2020	148.57	Not connected	116.92
August 2020	127.68	Not connected	64.16
September 2020	160.29	11.7	128.51
October 2020	184.5	5.06	141.42
November 2020	198.12	13.5	127.39
December 2020	151.61	3.25	114.73
January 2021	179.84	7.37	123.22
February 2021	220.74	0.91	134.32
March 2021	179.07	5.47	127.05

Author (2021)

The system has an installed peak capacity of 2.4kW(p) and is located in Gqeberha with a daily expected average PV yield of 4.2 kW.h/kW(p). Total lithium-ion battery storage capacity is 10.5kW.h. During the period tabulated above the author worked from home due to the COVID-19 pandemic hence the data is representative of the needs of a typical remote office. The system also provided for other household needs such as lighting and refrigeration. Water

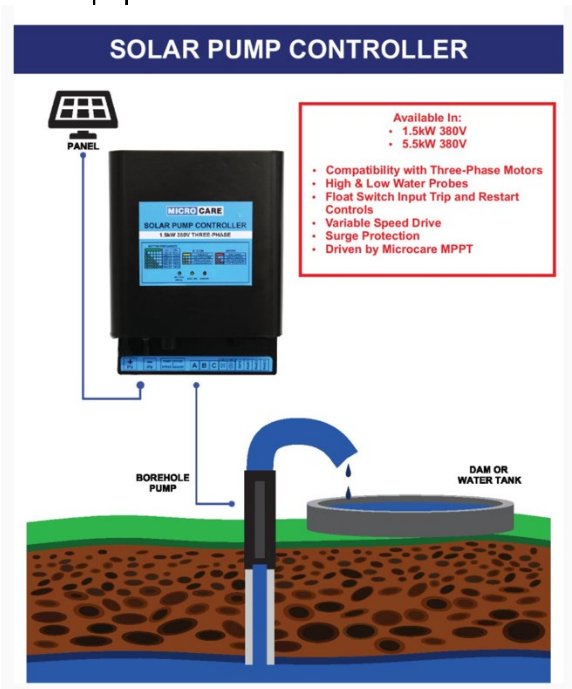
heating was not provided by the system but instead by solar water geysers. The latter would also be available for the proposed remote office proposed in this research.
The energy deficit in the final 7 months averaged approximately 4%. It is reasonable to assume that an additional 10% of PV capacity and an additional 10% of battery storage capacity should provide a conservative solution to address this deficit.

The final proposed solution is presented below and should offer a reliable remote office/ household solution (without water heating) for any area in Africa with a PV yield potential greater than or equal to 4.2kWh/kW(p).

Component	**Capacity**	**Qty**	**Cost (ZAR incl VAT)**
PV	2.6kW(p)	8 [330W modules]	14950
Inverter/MPPT	5kW	1	14375
Lithium-ion batteries	14kW.hrs	4 [3.5kW.h packs]	75900
Installation			12000
TOTAL			**117225**

12. Water pumping

The proposed remote working location may be located in a small town or village with reticulated water supply or it may be located in a more rural setting such as on agricultural land. If the latter is the case it is likely that water for domestic use will need to be pumped from a water source. The Eastern Cape and Gqeberha in particular has played a leading role in research and development of 3 phase variable speed drive (VSD) solar pumping technology. It is understood that the unique needs for water pumping in large parts of South Africa not serviced by the electrical grid lead to this pioneering work. The result is a recently developed high efficiency, cost effective solution that links directly between the solar modules and a standard readily available 3 phase AC water pump. There are no batteries and the system delivers water throughout the day with an output proportional to the solar irradiance. The timing of this offering together with the current record low PV price is seen as fortuitous to the remote work concept presented in this paper.



microcare.co.za/solar-pump-controllers

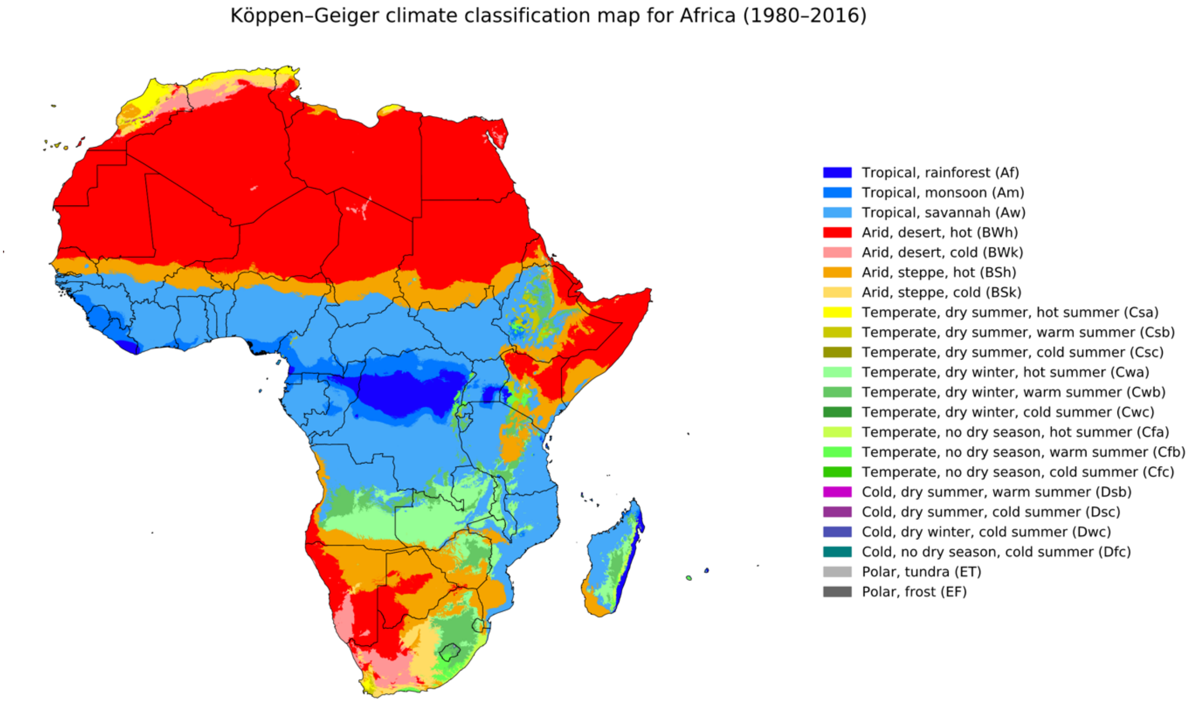
Author (2020)

The image above shows a test installation completed in September 2020 by the Nelson Mandela University (NMU) Renewable Energy Research Group (RERG) on a community site in the Northern Cape. The 11.88kW_p PV array consists of thirty six 330 W multi-crystalline solar modules. The modules power a 5.5 kW submersible pump through a 5.5 kW three-phase VSD solar pump controller with Maximum Power Point Tracking (MPPT). The pump delivers 350 l/min at a 43m head and will be adequate for the domestic and subsistence farming needs of the small community. The PV array is sized to ensure that full pumping capacity is attained for at least 6 hours per day in winter and significantly more in summer. The installation pictured would be adequate for the domestic needs of a remote located family and provide water needs for small scale subsistence farming if desired. If the latter were not required smaller systems with four modules and a 1.5kW controller and pump would suffice. Such a system is shown below.

Author (2017)

Additionally, solar pumping systems such as these can be used to provide the required water flow and pressure for de-salination plants and filtration systems.

13. Cooling – future research possibilities

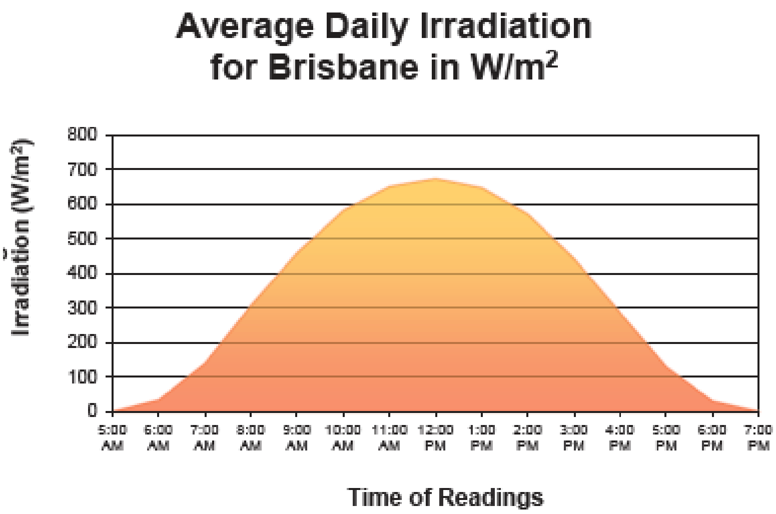


Beck et al (2018)

Certain potential remote working locations in Africa fall within areas classified as hot. Particularly in summer the high temperatures may require cooling of office and other working spaces. Cooling via conventional air-conditioning is feasible however the solar system proposed in (11) would require significant up-scaling. If the air-conditioning system is required to run through the night further upscaling of the battery storage system in particular would drive costs up further.

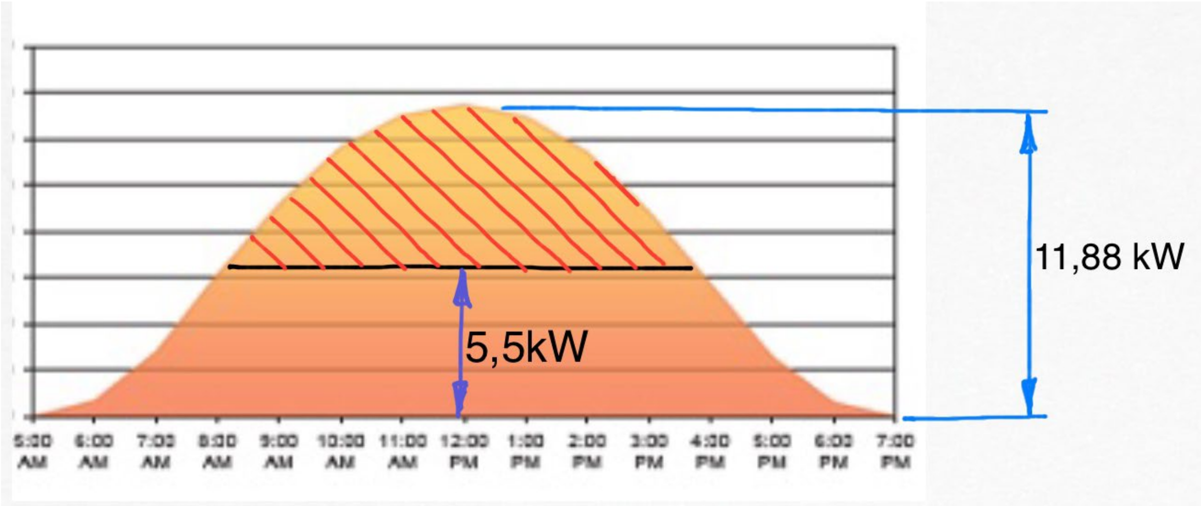
A possibility is currently being researched by the RERG to create a cooling system that uses surplus energy from a solar pumping array to cool a phase change material during daylight hours.

Solar pumping arrays are normally deliberately oversized to increase the amount of water pumped in a day. The solar resource varies during a day according to a curve as presented below by Thorogood pg22 (2012).



Thorogood (2012)

For example in the case of the solar pumping system described in (12) above the following oversizing was applied:



The reason for the oversizing being that the full pumping power of 5.5kW is attained early in the day and maintained until late afternoon. Whilst effective and not overly costly due to the current low cost of PV it does however render the shaded portion of the energy curve wasted. The proposed concept is to utilise this significant and previously wasted energy to run a refrigeration unit capable of operating effectively on this varying available power.
A suitable substance will be cooled during the period of available excess power. The substance will be held within an insulated vessel. When cooling is required for living spaces, or food/produce refrigeration a suitable heat exchange process will take place between the space to be cooled and the cold substance. The proposed system holds two principal cost advantages over a conventional battery storage system running an air-conditioner, namely: a) It uses existing solar modules b) It does not require battery storage. Research has commenced on the refrigeration system, selection of substance and the design of the heat exchange and storage process. If the concept proves to be successful it would offer additional viability to the concept of remote work and living.

14. Autonomous agricultural robot

Unlike in the city the remote working and living professional may have access to some agricultural land and may wish to partake in part time small scale farming. A recent RERG doctoral student (Sewell J. 2020) investigated the possibility of low cost solar powered agricultural robots capable of performing repetitive menial farming tasks autonomously. A prototype was developed and is currently being refined. The robot uses a real-time deep learning database to identify crop and weeds. A low-input user interface ensures ease of operation. The robot can be quickly retro-fitted with various end effectors (tools) for different tasks such as weeding, spraying, watering and even harvesting. The robot senses the type of end effector automatically thereby further simplifying setup and operation. The low-input user interface requires the operator to simply manoeuvre the robot to be over a representative example of the crop. It then learns what is crop using a vision system and deep learning. Once ready it proceeds with the assigned task using a combination of GPS and intra-row vision based navigation to execute the autonomous operation. Onboard batteries are charged by the solar module and when depleted or when the solar irradiance is too low the robot stops and waits until the batteries are adequately recharged. The low cost and ease of use are seen as key benefits of the robot, particularly for the small scale, time constrained farmer.

(Sewell J 2020) – solar powered autonomous farming robot

(Sewell J 2020) – vision based crop detection

(Sewell J 2020) – end effector

15. Conclusion

The notion of leaving the city and relocating to a rural location and practicing one's profession from that location via remote connectivity may seem to be a bizarre prospect however it appears that it will soon be technically feasible and hence worthy of further consideration.

References

World Bank. 2017. *Population density.* [Online]. (Updated April 26, 2021) Available at: http://data.worldbank.org/data-catalog/world-development-indicators [accessed 11 May 2021]

UN Habitat Global Urban Observatory. 2014. *Population density by city.* Available at: https://ourworldindata.org/grapher/population-density-by-city [accessed 12 May 2021]

World Bank. 2017.*Urban population.* [Online]. (Updated April 26, 2021) Available at : http://data.worldbank.org/data-catalog/world-development-indicators[accessed 11 May 2021]

Angel et al. (2018). *Our Not-So-Urban World*. The Marron Institute of Urban Management, New York University. Available at: https://marroninstitute.nyu.edu/uploads/content/Angel_et_al_Our_Not-So-Urban_World,_revised_on_22_Aug_2018_v2.pdf [accessed 11 May 2021]

Ritchie H and Roser M (2018) - "*Urbanization*". Published online at OurWorldInData.org. Retrieved from: https://ourworldindata.org/urbanization [Online Resource]

World Bank. 2014. http://data.worldbank.org/data-catalog/world-development-indicators

Bloom N. (2014). *To raise Productivity, Let More Employees Work from Home.* Harvard Business Review. January-February 2014.

Bartik A. Cullen Z. Glaeser. E Luca M. Stanton C. *What jobs are being done from home during the COVID-19 crisis? Evidence from firm level surveys.* Working Paper 27422 http://www.nber.org/papers/w27422 National bureau of economic research 1050 Massachusetts Avenue Cambridge, MA 02138 June 2020

O'Halloran J. 2020. *Poor connectivity sees home workers lose over half an hour of work a day. Computer Weekly*. [online] https://www.computerweekly.com/news/252487354/Poor-connectivity-sees-home-workers-lose-over-half-an-hour-of-work-a-day

Varrall, G. 2018. *5G and Satellite Spectrum, Standards and Scale*. Boston. Artech House.

Xing Y. Kaaniche M. Pesquet-Popescu B. Dufaux F. *Digital Holographic Data Representation and Compression*. Elsevier.

Imperial College Business School. *World's first lecture delivered via hologram* https://www.youtube.com/watch?v=DkOKrVV3SS0 Nov 29 2018

Ardene C. Zhao N. Tanvez Y. *Mapping Africa's energy infrastructure: open data lights the way.* https://blogs.worldbank.org/opendata/mapping-africa-s-energy-infrastructure-open-data-lights-way 18/5/2017

Beck. 2018. Present and future Koppen-Geiger climate classification maps at 1-km resolution. Available at: https://www.researchgate.net/figure/Koeppen-Geiger-climate-type-map-of-Africa_fig1_26640584. Accessed 13 May 2021.

Thorogood C. Thorogood A. *Understanding Renewable Energy Systems.* 2nd edition 2012.Pg 22

Mingaleva Z. Balkova K. *The process of de-urbanizaqtion: problems of power supply of rural area and agricultural production.* Food and Agricultural Organization of the United Nations. Available at: https://agris.fao.org/agris-search/search.do?recordID=RU2015308863. Accessed 18/5/2021

Kapur R. 2019. *Employment Opportunities in Rural Areas.* University of Delhi. Available at: https://www.researchgate.net/publication/331892664_Employment_Opportunities_in_Rural_Areas [Accessed] 18/5/2021

McDowell J. *The edge of space: Revisiting the Karman Line*, Acta Astronautica,Volume 151,2018,Pages 668-677,ISSN 0094-5765, https://doi.org/10.1016/j.actaastro.2018.07.003. (https://www.sciencedirect.com/science/article/pii/S0094576518308221)

Sewell J. 2020. *Sensor-based Deep Learning System for Application in Small-Scale South African Farms.* Nelson Mandela University. Doctoral Thesis.

Sewell J, Van Niekerk T, Phillips R. *Correction of Converging Verticals Distortion to Camera Pose and Position,* MAURICON 2020, 2020 International Conference on Intelligent and Innovative Computing Applications (ICONIC)