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Energy Access Review

End of the Electricity Grid?

On April 30th 2015, Elon Musk the eccentric founder and CEO of Tesla unveiled the Powerwall - a revolutionary 10kWh wall mounted rechargeable lithium ion battery with a 10 year warranty retailing at US$ 3,500. Others including Ecoult, Balqon, Iron Edison and Aquion have unveiled similar products. The 10kWh capacity can sufficiently power a typical urban middle class home with a set of electrical devices including a small fridge and a microwave. Many had predicted that such a day would come. The day that massive energy storage would turn the corner and progress down the road of affordability and scalability. Whether April 30th is really that day is debatable because starts and stops on mass energy storage have been witnessed for decades now. This may remain debateable, and understandably so, as it compares to asking when telephony turned the corner. Was it in 1667 when Robert Hooke created an acoustic string telephone or when Alexander Graham Bell made the first telephone call on record in 1876?

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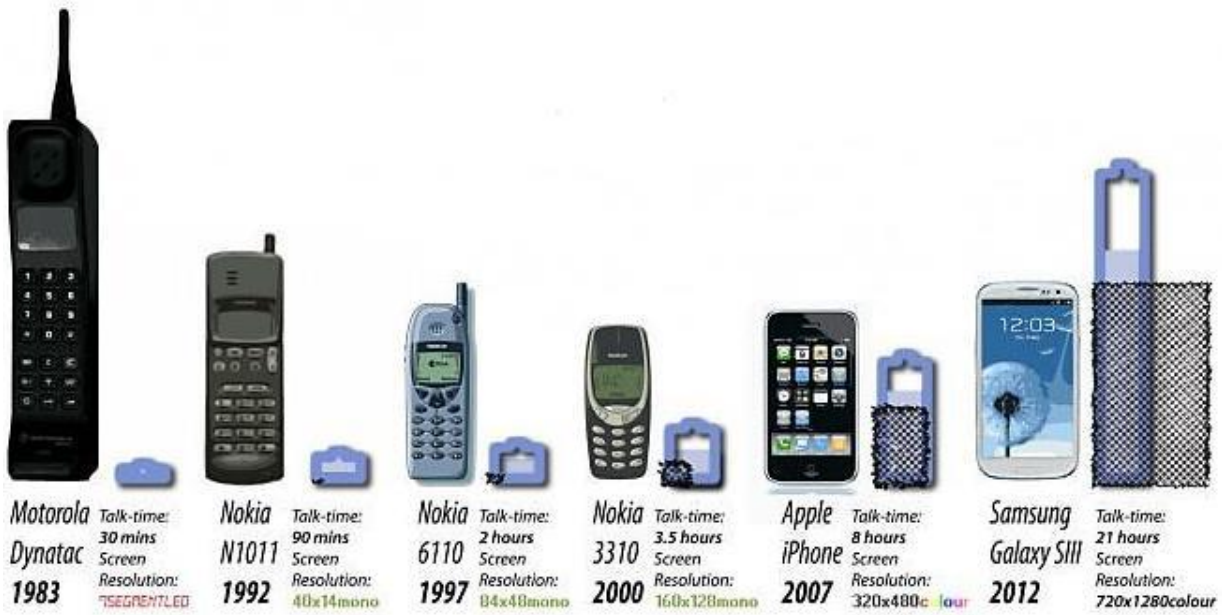
Picture: Elon Musk introducing the Powerwall home energy unit in Hawthorne, California.

Picture Credits: Tesla Motors

"This is going to be a great solution for people in remote parts of the world where there is no electricity or where the electricity is extremely intermittent or expensive." *(Elon Musk, April 30th 2015)*

Figure 1: Evolution of the mobile phone (Picture Credits: www.hzo.com)



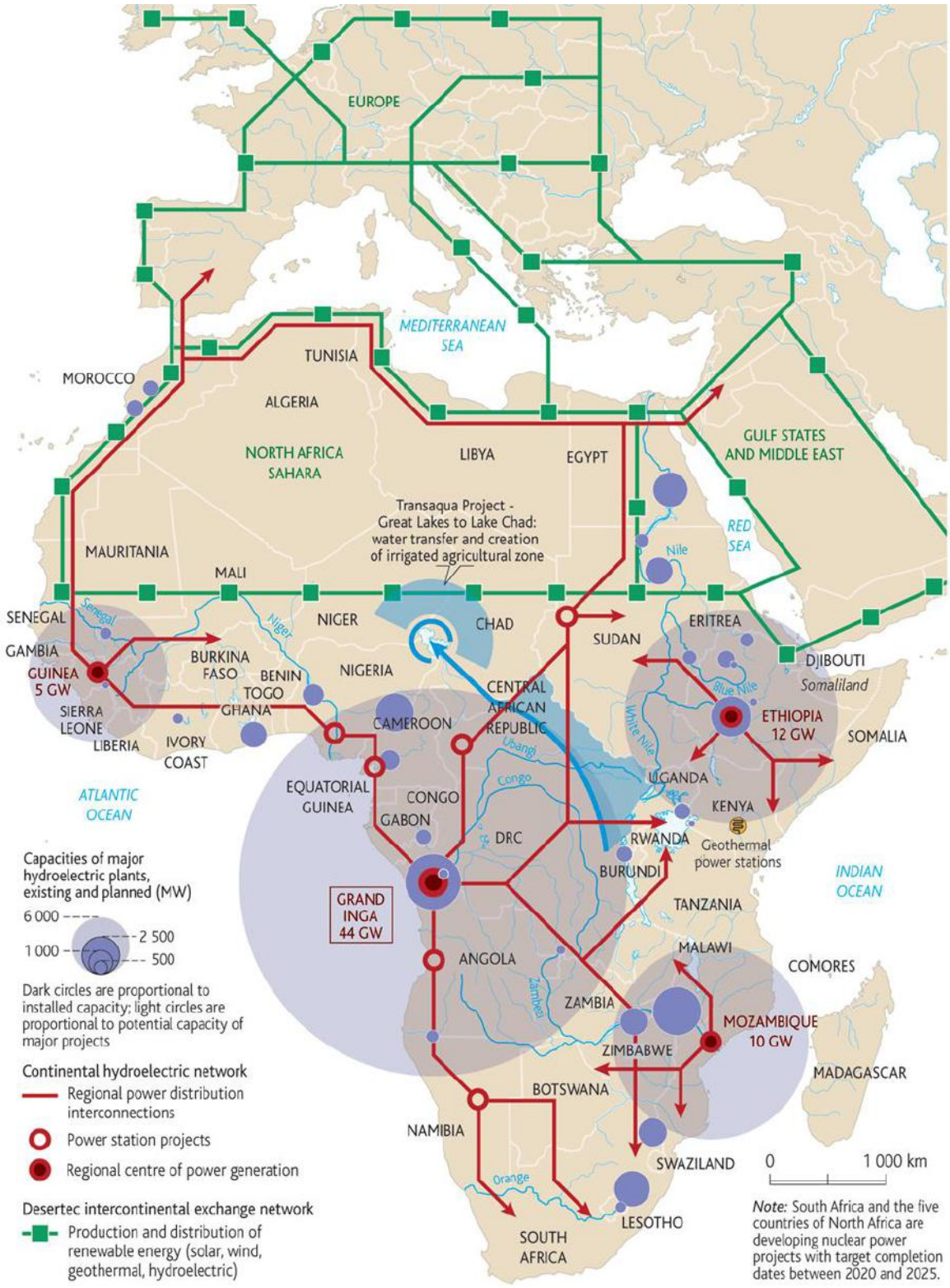
And the story of telephony is different but also similar to the story of electricity. Different because radio waves, which transport digitized voice and data, can be transmitted over the air while transporting a flow of electrons, which create electric energy, is best done using conductors. Similar because both have traditionally depended on a web of wires that constitute an interconnected grid based infrastructure.

The sun which is the primary source of energy on the earth is, however, already decentralized and it is on this basis that Tesla aspires to change the world. Although the April 30th announcement was made in California it is in developing world, especially Africa where only 600 million people do not have access to grid-based electricity[1], that such a revolution would create a perfect storm. The launch of the Powerwall has striking similarities with the unveiling of the Motorola DynaTac in 1983. At the time, the DynaTac was met with expected skepticism as telephony was synonymous with distribution wires and lines. Skepticism was compounded by the high upfront cost, novelty and short talk time cycles, limited geographic area of operation and wanting sound clarity. When it was first brought to market (although initial design work started in 1947), the Motorola DynaTac which was 9 inches tall, took 10 hours to charge and offered just 35 minutes of talk time. The phone weighed one kilogram and retailed at a handsome US$ 3,995 (comparable to about US$ 10,000 when adjusted to 2015 prices). Since then the mobile phone has evolved drastically. Is Tesla's Powerwall the Motorola DynaTac of electricity access that will mark the beginning of the end to the expansion of, and dependence on grid based distribution in Africa?

In this review we explore the history of energy storage and speculate on a potential future beyond the grid.

[1] AfDB (2014), Tracking Africa's Progress in Figures, African Development Bank, Tunis

Figure 2: The Grid Utopia - Impressions of a possible interconnected future (Source: Philippe Rekavewicz, 2011)



Batteries are the most common form of energy storage devices and range in size from the button cells used in watches to megawatt load levelling applications.

The first battery was invented by Allessandro Volta in 1800 and it was not until 1859 that the first rechargeable battery was invented by Gasto Plante. This battery was known as the Lead-Acid Battery[2]. At present, whole spectrum of battery options exist with different technical and performance characteristics (see figure 3 below). These include: lead based, sodium based, lithium based, nickel based and flow batteries. The choice of batteries is informed by, among other aspects: the depth of discharge (DoD) [3], operating temperature, calendar life [4], cycle life [5], cost, energy content and power density safety.

Battery storage finds application in several areas including homes, industries, vehicles, and the power sector. In the power sector, batteries can be used in grid and off-grid applications. Batteries have had to contend with barriers such as high upfront costs, varied performance, cost competitiveness, and environmental safety concerns. The general trend is a steady shift from the use of sodium sulphur batteries towards lithium ion batteries. Lithium ion batteries have become the preferred choice because of their higher energy and power densities, longer cycle and calendar life, deep discharge cycles, and lower cost. On the other hand, flow batteries are promising long term battery storage solutions due to their ability to handle large energy capacities.

Figure 3: Summary of typical performance characteristics of various batteries

	Lead Based	Lithium based	Sodium based	Nickel based
Capacity	1Ah-16,000 Ah		0.5Ah-2000Ah	380v 40Ah
Nominal energy density	25-50 Wh/Kg	140Wh/Kg	20-80 Wh/Kg	120Wh/Kg
Efficiency	>85%	Almost 100%	>90%	92%
Calendar life	20 years	>20 years	25 years	+ 10 years
Cycle life	>2000 cycles @80% DoD	>5000 cycles @80% DoD	>3000 cycles of nominal capacity	>4500 cycles @80% DoD
Operating temperature	-30^0 C to +50		-40^0 C to + 60^0 C	-40^0 C to + 60^0 C
Recycling	95%	>50%	100%	100%

[2] See history of batteries in figure 5 page 7

[3] Refers to the amount of battery capacity that should ideally be utilized and is expressed as a percentage of the batteries full capacity.

[4] The calendar life of a battery is the number of years the battery can operate before losing considerable performance capabilities.

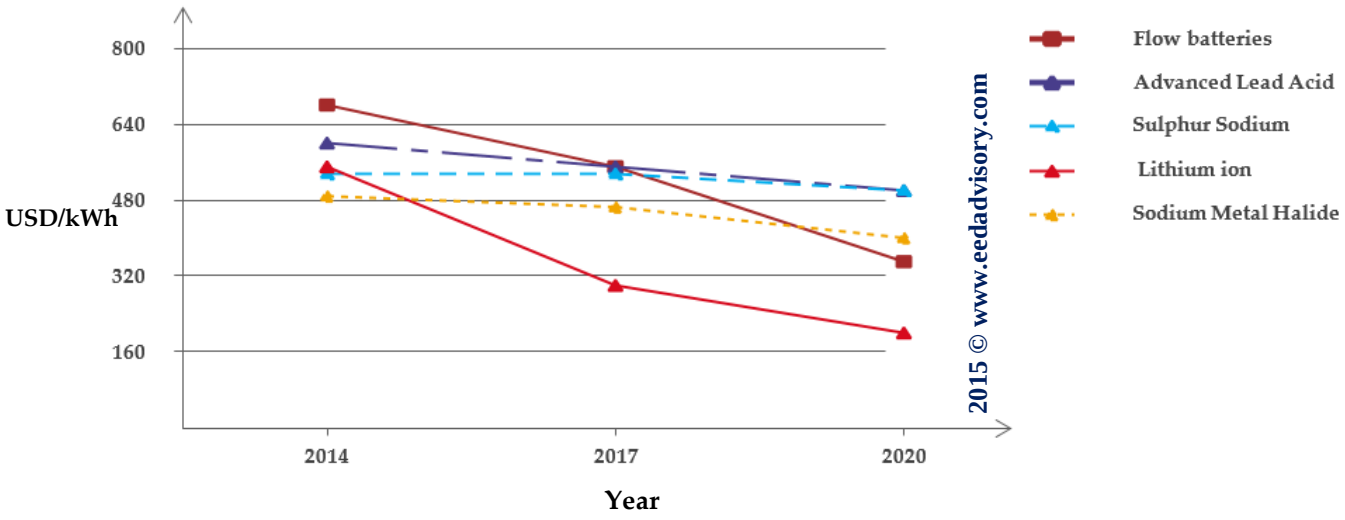
[5] Cycle life is the number of discharge-charge cycles the battery can experience before it fails to meet specific performance criteria.

Over time, battery storage prices have been declining steadily and are expected to drop by approximately 75% over the next decade[6]. This drop is attributed to economies of scale, increased manufacturing capacity, and the development of Electric Vehicles (EV). Lithium ion batteries have experienced the greatest price reduction as a result of policy drives to deploy technology in the electricity sector and EV market. Further, there is on-going research on battery cathode material that would result in increased battery energy density. It is estimated that a lithium ion battery will cost about 200 USD/kWh in 2020[7](see figure 4 below).

It is anticipated that solar power with battery will revolutionize the electricity sector and that solar power may eventually attain grid parity. This is heightened by the observed drop in the price of solar panels by close to 85% over the past seven years[8]. UBS[9] speculates that the model of EVs + Solar + Batteries with no subsidies, will make solar a fully competitive renewable energy technology, with a payback period of between 6-8 years by 2020[10]. A lot of focus has been placed on the drop of the prices. Other important and complementary shifts that will advance the role of batteries include a gradual switch from AC to DC based appliances, a move to ultra-energy efficient electrical devices and innovative business models. Prominent multi-nationals including Schneider Electric, ABB, Bosch, General Electric, Apple, Google, Tesla are all working on these fronts.

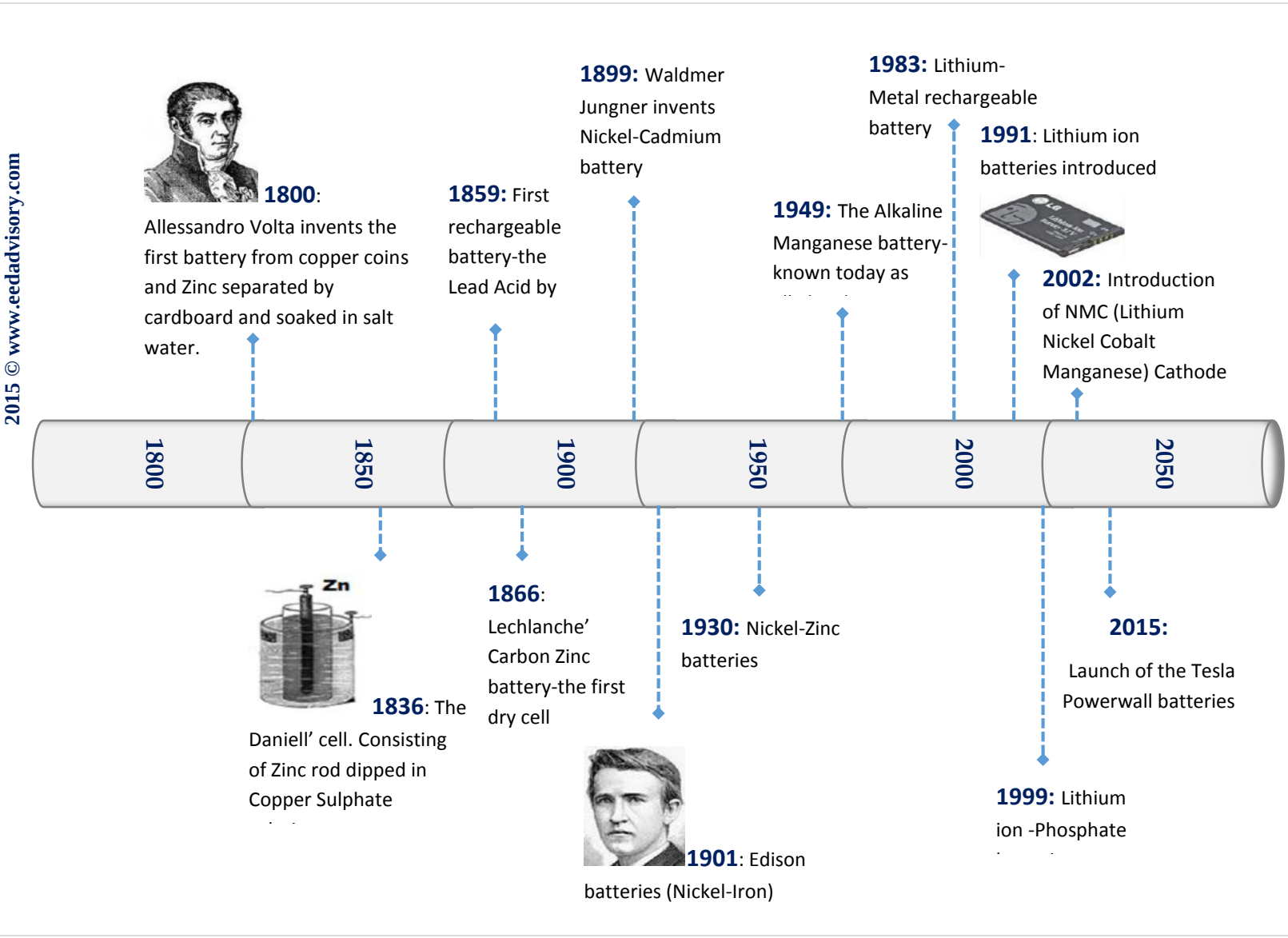
At the current price of US$ 3,500 and design specifications it still does not make sense to go entirely off-grid but we cannot help but wonder whether this will be marked in history as the beginning of the end of the electricity grid.

Figure 4: Current and projected battery prices (USD/kWh) by type for utility-scale applications



[6] UBS 2014, Will solar, batteries and electric cars re-shape the electricity system,20th August,2014
[7] Ibid
[8] IRENA 2015, Battery storage for renewables: Market status and technology outlook, International Renewable Energy Agency
[9] Swiss global financial services company with its headquarters in Basel and Zürich, Switzerland
[10] UBS 2014,

Figure 5: History of batteries



Graphene and the potential impact on the energy markets

The isolation of graphene from a lump of graphene in 2004 at Manchester University by Andre Geim, a physics professor at the University and Konstantin Novoselov a PhD student then[11], has stirred mixed reactions on the possibility of the material creating a revolution in the scientific world. Graphene is a two-dimensional, one-atom-thick allotrope [12] of carbon with a planar honeycomb lattice. Considered to be both the thinnest element in the world as well as the first two-dimensional element, graphene has a bond to bond length of 0.142 nanometers and a weight of about 0.77 mg/m^2.

Graphene presents great potential for the development of future technologies and improvement of existing products due to its unique electronic, optical, and mechanical properties. Its transparency, excellent electrical conductivity, and flexibility renders it an advantage over existing materials such as indium tin oxide(ITO)[13] used in coating plasma TVs and phones. It can also be used in making wearable and bendable electronics and electrodes for photovoltaics. With a high electron mobility of about 200 times faster than silicon, it allows for the creation of very small and faster transistors that consume less energy and dissipate heat faster than silicon based device transistors. Its flexibility and high stress resistance makes it suitable for light, high resistance carbon

Figure 6 : Properties of Graphene

1	Atom	Thick, two-dimensional element
2.3	%	White light absorbed by Graphene
10	X	Better heat conductivity than Copper
20	%	Flexibility without damage
97	%	Transparency
200	X	Stronger than structural steel
1,000	X	Lighter than paper
1,000	X	The electoral capacity of copper
15,000	$Cm^2.V^{-1}.S^{-1}$	Electron mobility
1,000,000	X	Thinner than human hair
130,000,000	KPa	Tensile strength of Graphene

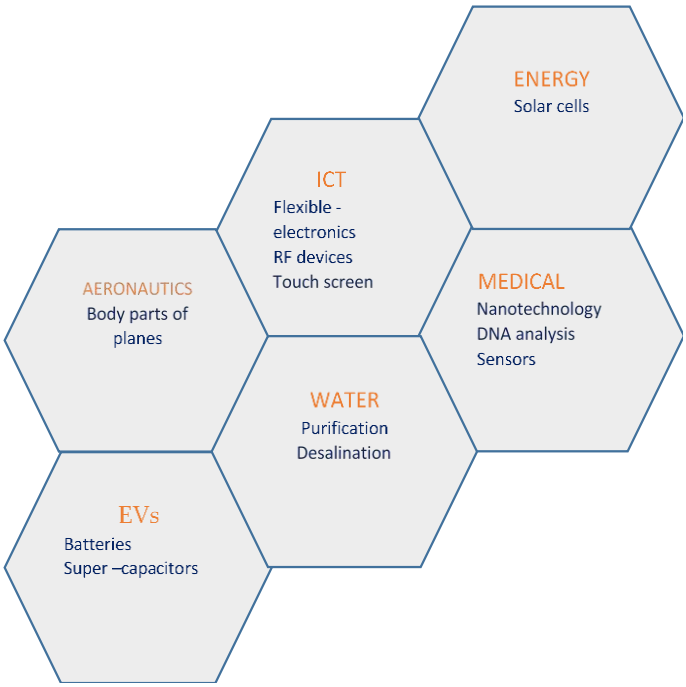
[11]University of Manchester, the story of graphene retrieved from: http://www.graphene.manchester.ac.uk/explore/the-story-of-graphene/. Geim and Novoslov were awarded the Nobel Prize in Physics in 2010.

[12] An allotrope is any of two or more different physical forms in which an element can exist. Graphite, charcoal, and diamond are the other allotropes of carbon

[13] Indium tin oxide is a transparent coating material made from indium, tin and oxygen in varying proportions? It is mostly used in liquid crystal displays, plasma displays and touch panels.

composites to be used in aeronautics and cars. Graphene membranes can be used in water sector for purification as well as desalination. Mono-

Figure 7: Possible applications of Graphene



molecular membranes of graphene with nanometric holes could be used for DNA separation.

Graphene is becoming of great interest to the clean energy sector due to its abundance, environmental safety, and excellent optical and electrical properties. This sector so harassed by high prices of storage batteries may soon find a breakthrough by using graphene in the manufacturing of batteries, super capacitors and solar cells. There is on-going research on the use of graphene as the cathode material in Lithium ion batteries[14]. It is expected that this will result in high charging and discharging batteries with high energy density and portability. Graphene can be used in the manufacturing of rapidly charging and discharging Super capacitors which are most suited for Electric Vehicles (EV). Recently, Sunvault Energy in collaboration with Edison Power Company built the first 10,000 Farad graphene Super capacitor. This capacitor is estimated to cost US$ 100/kwh at the moment and the price anticipated to drop to half by end of the year[15]. Graphene is proving to be a better material in the manufacturing of solar PVs than silicon that has been used in the past. High electron transfer of graphene minimizes the current loss and improves the efficiency of the panels. Since it is quite flexible, graphene would replace the brittle ITO and allow for PVs to bend and take the structure of the rooftops.

Success in these technologies would result in low cost of energy storage devices, drop in the price of solar panels and an increase in the uptake of Electric Vehicles. These will see a growth in the clean energy market and increase in energy access through off-grid solutions and solar home based systems. An increase in the number of Eclectic Vehicles will as well decrease the carbon dioxide emissions from the combustion of fossil fuels from the transport sector resulting in a low carbon pathway.

[14] Renjie Chen et al, (2014), Graphene-wrapped sulfur/metal organic framework-derived microporous carbon composite for lithium sulfur batteries.

[15] Market Watch, Press release: *Sunvault Energy and Edison Power Company Create Massive 10,000 Farad Graphene Super capacitor,* published May 6,2015 retrieved at http://www.marketwatch.com/story/sunvault-energy-and-edison-power-company-create-massive-10000-farad-graphene-supercapacitor-2015-05-06

Second Quarter 2015 Energy Access News Highlights

- **AfDB approves a loan of US $ 70.5 million to finance energy reforms** - The African Development Bank (AfDB) approved a loan of US$ 70.5 million in May to finance reforms in the energy sector. The reforms known as Tanzania Power Sector Reform and Governance Support Programme (PSRGSP) will cover economic and financial governance. The objective of the operation is to promote inclusive growth and enhanced economic competitiveness in the power sector.
- **Gas resources estimated at 55 trillion cubic feet** - Tanzania's Energy and Minerals Minister revealed that as a result of ongoing exploration activity, natural gas resources discovered in the country rose from 46.5 tcf in June 2014 to 55.08 tcf in April 2015, equivalent to an increase of 18 per cent. The government lifted the natural gas resources estimate following new discoveries by Statoil, Exxon Mobil, BG Group and Ophir Energy. The commercial operational date of gas processing plants and a 532 km pipeline from the gas sites to Dar es Salaam has now been set at September 2015
- **Rural Electrification Authority (REA) sets to connect 1.2 million rural residents by 2020 –** REA envisages supplying 1,250,000 rural dwellers with electricity in the next five years, thanks to about US$ 400 million that the government has set aside to support the grand project. The project involves construction of six sub-stations in Kigoma, Kasulu, Kibondo, Ngara, Mbiga and Tunduru and a 13,600km 11/33 KV distribution line.

- **Government launches Last Mile Connectivity Project and cuts cost of power connections –** The project financed by the Government of Kenya and AfDB at a cost of US$ 138 million will involve extension of the low voltage network to reach households located within 600 meters of a transformer. In addition, the government through the Rural Electrification Authority cut the cost of connecting houses to the electric grid by 57 percent. Households which are near transformers serving public utilities will now pay US$ 154 for connection, down from US$ 359, with those who cannot afford the new rate having the option of paying by instalments through their monthly bills.
- **Kenya Electricity Generating Company (KenGen) wins Africa energy awards–** Electricity generator KenGen won the Africa Power Utility Company award for 2014/15 during the African Utility Week and Clean Power Africa Conference, an event for the power and water utilities professionals in Africa, held between the 17th and 20th May in Cape Town, South Africa. KenGen beat Umeme of Uganda, Electricity Company of Ghana Limited, Nigeria's Niger Delta Power Holding Company Ltd and Uganda Electricity Transmission Company Limited to clinch the award. The company's Olkaria geothermal steam generation project was also ranked Africa's clean energy project of the year.

- **Plans of a 50 MW solar plant in Garissa -** The Chinese government is set to construct a solar plant in Garissa following an agreement with the Kenyan government. The Chinese Ambassador to Kenya Liu Xianfa also revealed that the power station will be funded by a concessional loan from the Chinese Export-Import Bank.

- **US$95 million sought to fund power plant -** Information Minister Jim Muhwezi said in a statement the finance ministry would borrow US$ 50 million from the French Agency for Development and US$ 45 million from Germany's state controlled development bank KFW to fund the Muzizi hydro power dam meant to generate 44.7 MW of electricity.
- **Umeme to invest up to US$ 100 million upgrading Uganda network –** The Managing Director, Selestino Babungi, revealed Umeme Ltd., the Ugandan power distributor owned by Investec Asset Management Ltd. and Actis LLP, may invest as much as US$ 100 million in upgrading its network this year. This is part of US$ 440 million the company is spending between 2013 and 2018 overhauling old equipment, buying new technology and adding distribution points.
- **Government seeks ways to refinance Bujagali power dam** - Uganda is looking for a way to refinance the private debt built up by developers of the Bujagali hydropower dam in a bid to cut the cost of electricity, particularly for industry. The 250 MW Bujagali dam on the River Nile, developed by U.S. Blackstone Group and the Aga Khan Development Network, was financed by the World Bank, and several European development finance agencies. Commissioned in 2012, it cost approximately US$ 900 million. President Yoweri Museveni said that power generated by Bujagali, which costs US¢ 10.1 per kilowatt hour, was too high and was partly responsible for the high cost of electricity in the country.

- **Nigeria's Akinwumi Adesina elected African Development Bank President-** Nigerian Agriculture Minister Akinwumi Adesina was elected president of the African Development Bank, beating other candidates from across the continent. Adesina secured 58 percent of the votes in the final round at a meeting in Abidjan, Ivory Coast, and will succeed Donald Kaberuka as head of the bank on September 1. He faced off against Chadian Finance Minister Kordje Bedoumra, who secured 32 percent support, and his counterpart from Cape Verde, Cristina Duarte, at 10 percent. Kaberuka is accredited for raising the portfolio of the bank from US$ 5 billion to US$ 12 billion. He also increased the capital of the bank by 200 per cent, and mobilized the US$ 25-billion African Development Fund for poor countries. He gave a big push to infrastructure — US$ 28 billion — of which US$ 11 billion is for energy.

- **EU unveils private equity fund to invest in African energy-** The EU has unveiled plans to partner up with a Paris-based private equity firm to invest in energy

companies across Sub-Saharan Africa. The EU-backed Electricity Access Fund, which will be directed by Astor Capital Partners, a Paris-based private equity firm, plans to invest up to € 55 million in around 20 businesses over five years, with investments ranging between € 500,000 and € 3 million. Energy Access Ventures Fund will make equity investments in SMEs involved in providing electricity and related services in particular through power generation systems (e.g. solar home devices and micro-generation infrastructures) generally off-grid, energy distribution and ancillary activities. Low-income populations and small businesses starting in Kenya, Uganda and Rwanda, and eventually West Africa, will be the main targets for investment.

- **Italian utility Enel targets Africa as growth market -** Italian utility Enel plans investments in renewable energy and grids in Africa. It has won the right to sign power purchase agreements (PPA) for 280 MW of additional wind power capacity in South Africa. The 142-MW Soetwater and 138-MW Garob wind farms in Northern Cape will be up and running by 2018. The company has won over 1,200 MW of wind and solar projects in South Africa's public tenders under the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP). It also plans to spend heavily on wind, solar, geothermal and hydro energy in Kenya, Tanzania, Uganda, Mozambique and Ethiopia, while participating in a wind tender in Morocco.

- **India nominates Kundapur Vaman Kamath to lead BRICS Bank –** India's Ministry of Finance in May tapped Mr. KV Kamath, the non-executive chairman of ICICI Bank (India's largest non-state bank) and Infosys (India's second-biggest software services exporter), to be chief of the New Development Bank, a development bank created by the emerging BRICS economies, namely Brazil, Russia, India, China and South Africa. The establishment of the bank was agreed at a BRICS summit in Fortaleza, Brazil, in July 2014, at which the heads of state from BRICS signed the BRICS bank charter agreement. The US$100 billion development bank will offer loans to mainly fund infrastructure projects to other middle- and low-income countries. The bank will have an authorized lending of up to US$34 billion annually, and an initial subscribed capital of US$50 billion, which will be equally shared by the five BRICS members.

- **BioTherm Energy sells controlling interest to SunEdison -** BioTherm Energy, an Independent Power Producer, backed by private equity firm Denham Capital, has agreed to sell a 60% interest in a portfolio of solar and wind power plants in South Africa to global solar company, SunEdison. Terms of the deal were not disclosed. The portfolio consists of three operating plants, two solar and one wind, generating a combined capacity of 48.5MW, and have a 20-year fixed price purchase power agreements with Eskom, the country's largest public utility. SunEdison will take over managing the 27-megawatt Dassiesklip wind farm and the Konkoonsies and Aries solar farms, each of which generate about 10.8 MW a year, after the deal closes.

In the Next Issues of Energy Access Review

- Calculating the real cost of electrification in East Africa
- The case of floating solar PVs
- Comparison of power outage frequency across Africa
- Plus the regular roundup of news on energy and environment from the region

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