Local materials and know-how key to sub-Saharan Africa's energy shift

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The energy landscape in sub-Saharan Africa is bleak. Half the energy supply comes from biomass, mostly wood and charcoal, burned in inefficient cook stoves. The resulting smoke and particulate matter pollution is linked to around 600,000 premature deaths.

Grid power comes mostly from fossil fuels. But with the exception of South Africa, where 85% of the population has electricity access, most nations have weak grid infrastructure. As a whole, only one out of three sub-Saharan Africans has access to electricity, and the number without access—some 620 million people—is rising. The World Bank estimates that electricity shortages hold back economic growth in the region by as much as four percent a year. It also forces millions to turn to diesel and gasoline-fueled generators for electricity, which are typically more expensive than grid electricity.

But the region is now poised for an energy revolution. It has some of the richest solar, wind, biomass, hydro, and geothermal energy resources in the world, all of which remain largely untapped. There has been massive economic growth since 2000. Young inventors and entrepreneurs are creating a booming innovation scene in South Africa, Nigeria, Kenya, and Uganda. Foreign governments are prompting energy investments. Domestic initiatives and international collaborations are spurring research in solar photovoltaic (PV), biomass, and waste combustion.

The International Renewable Energy Agency's "Africa 2030" report released in October 2015 states that modern renewable energy technologies could meet 22% of Africa's total energy demand by 2030, more than quadruple the 5% share in 2013. "There's a tremendous opportunity to have millions of people bypass fossil fuels and go directly to renewables," said Veronica Augustyn, a materials science professor at North Carolina State University.

Much of the energy revolution is happening at the grassroots. And materials technologies play an important role. Optimizing technologies for local conditions using local expertise is crucial, said Adrian Hightower, manager at the Metropolitan Water District of Southern California and a board member of the Uganda-focused NGO Aid Africa. Several researchers are now working on local solutions using low-cost, easily available materials and tools, which will be vital for sustainable development.

The most dynamic energy growth in sub-Saharan Africa has been in small-scale localized power systems. Here renewables have a huge advantage over fossil fuels. Solar PV technology lends itself especially well. Gleaming silicon panels indicate the presence of mini-grids, power kiosks, phone-charging stations, and water pumping stations that are spreading across Africa.

Many researchers believe organic and dye-sensitized solar cells could have an even bigger impact. These cells, made from conductive organic polymers and organic dyes, respectively, can be easily made in large quantities at a low cost. Unlike the clean rooms and vacuum processing that crystalline silicon needs, they are produced with solution-based processes and modest instruments, said Teketel Anshebo, a professor of materials science at Addis Ababa University. This makes it easier to set up labs and conduct research in Africa.

Especially exciting in the case of dye-sensitized cells is the potential to use natural dyes extracted from local berries and flowers. Anshebo and others are trying to improve the efficiency of these solar cells.

Novel applications of solar PVs are attractive in low-resource settings. Gregory Beaucage, a professor of chemical and materials engineering at the University of Cincinnati, is working with colleagues at Ethiopia's Dire Dawa University to establish startups that manufacture solar PV technologies for local markets. In 2015, the team manufactured 50 prototypes of solar-powered streetlights with locally purchased parts and installed them in a neighboring village. The Ethiopian students have since installed advanced prototypes. They now plan to start a manufacturing company with support from the government, which has offered 70% of startup funds for recent graduates of their new universities to encourage entrepreneurship, said Beaucage.

The researchers have also developed a prototype solar-powered adsorption icemaker that they hope to manufacture in Dire Dawa in December. The idea is based on evaporative cooling, which uses two chambers: one where a liquid evaporates for cooling, and another where the vapors are adsorbed onto an adsorbent material that is then heated to release the vapors and repeat the cycle.

Traditional evaporative cooling refrigerators use ammonia and water as the working liquid and adsorbent, respectively. But the US-Ethiopian research team uses methanol, which is safer than ammonia, and activated carbon as the adsorbent since it can be easily produced locally by burning coconut shells. The device uses sunlight in a solar collector to desorb the methanol. "We are attempting to address development needs, poverty, and employment, as well as the retention of technical know-how in Ethiopia," said Beaucage.

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Biomass forms the core of the energy mix in sub-Saharan Africa. One in four Africans uses traditional biomass such as wood and charcoal for cooking. Given the pollution hazards and inefficiency of traditional open-fire stoves, several projects are promoting the use of efficient cook stoves that use less fuel and vent smoke outside. Aid Africa, for instance, has worked with researchers at Makerere University in Kampala, Uganda, to develop cook stoves made from local clay. "The same clay that's used for building construction is modified by adding biomaterials like rice husks and leaves," said Hightower. The resulting porous material is much more insulating than the natural clay.

A big development opportunity lies in replacing wood and charcoal with recycled waste biomass. Briquettes and pellets made from farming waste are denser and carbonized and hence burn longer and with lower emissions, said Ange Irankunda, who founded the startup Earth's Swagg in Burundi to produce such briquettes. "Using waste instead of cutting trees also has a carbon-reduction impact," she said.

Kenyan startup Bright Green Renewable Energy is already selling similar charcoal briquettes in Nairobi. The company makes its briquettes from urban waste it collects in the city, said founder Chebet Lesan. In addition to being more efficient and environmentally friendly than traditional charcoal, it is also cheaper.

Biogas is another vastly untapped clean energy source. The methane-rich gas produced from the anaerobic digestion of organic matter such as animal dung and food waste can be used for lighting, heating, and even power generation, said Thubelihle Moyo, a renewable energy systems consultant based in Zimbabwe. Digesters range in size, with large ones for garbage dumps and smaller ones for homes. The nonprofit SNV Netherlands has installed over 51,000 residential biogas digesters in Kenya, Ethiopia, Tanzania, Uganda, and Burkina Faso and plans to reach another 100,000 households by 2017.

The biggest challenge to more widespread biogas use is "lack of government commitment in the form of policy formulation and incentives that will promote uptake," said Moyo. Another issue is cost.

Students at Makerere University in Kampala, Uganda, test dye-sensitized solar cells that are assembled using an experiment kit from the SciBridge project. Credit: Veronica Augustyn.

Digester systems provided by NGOs are still unaffordable for most communities at about USD$500–1200. "A good approach would be to encourage local businesses to be the ones that design, install, and retail the biogas systems," he added.

The will for innovation and development in sub-Saharan Africa is clear. But exploiting the region's vast energy resources will take more. Better patent laws and clear policy frameworks need to be put in place to foster innovation and growth. There is a need for general governance reforms, easier investment climate, and more regional collaborations. Bureaucratic and political hurdles have slowed President Obama's ambitious USD$7 billion Power Africa initiative with the goal of doubling electricity access across sub-Saharan Africa.

Education will also play a key role. "There's a significant knowledge gap in addition to an income gap in the developing world," said Augustyn.

The Joint Undertaking for an African Materials Institute (JUAMI) hopes to fill such gaps. JUAMI was launched in 2012 with the goal of building research collaborations by young materials scientists in the United States and Africa. Augustyn was one of 50 researchers from the United States and East Africa selected to attend a two-week JUAMI program consisting of lectures, hands-on activities, and resource sharing at Addis Ababa University.

Together with another JUAMI fellow John Paul Eneku, a physics lecturer at Makerere University, Augustyn launched the SciBridge project in 2013. With an MRS Foundation grant, SciBridge prepares high-tech energy technology experiment kits made from low-cost, nontoxic materials and sends them to Ugandan universities for student research and training. They have so far sent 25 kits focused on dye-sensitized solar cells and metal-air batteries and are now developing a solid-state cooling device kit that uses thermoelectric materials.

Programs such as these could help lay the knowledge foundation needed to jump-start a locally driven clean energy industry. The SciBridge founders believe that educating young scientists and engineers in African countries is key for them to work and pursue innovation locally, including the huge task of bringing electricity to sub-Saharan Africa.

The silver lining to sub-Saharan Africa's grim energy landscape is that much of the development is starting from scratch, said Augustyn, so acquiring and implementing new technologies could be faster and easier. "The question is will they have the resources and technical training to do so?" □

The JUAMI school is endorsed by MRS, and the competition at JUAMI received a Materials Research Society Foundation Grant.