

Decentralizing Energy for a High-Demand, Low-Carbon World

Decentralization can play a role in achieving an affordable, clean, and resilient power system. Yet, transitioning away from traditional centralized energy networks requires large-scale changes across sectors. This *Voices* asks: what are the challenges and potential solutions associated with realizing the rapid and effective decentralization of global energy?

Going Solar, Together



Anya Schoolman
Solar United Neighbors

The best way to decentralize our energy system is by empowering individuals to take control of where their energy comes from. I came to this realization after a simple question: “Mom, can we go solar?”

My son had just seen *An Inconvenient Truth* and wanted to act. This was more than a decade ago. Going solar was complicated and expensive. I realized for the work it would take for my family to go solar, we might as well take the neighborhood solar. So we did. We worked with our neighbors to form a “solar co-op.”

Since then, more than 200 groups across the country have used the solar co-op model we developed. The solar co-op process educates members about the technology and details of installing solar panels. Members select an installer through a competitive process, which ensures that co-op members receive a quality bid at a good value. Members decide individually whether going solar is right for them.

When homeowners go solar, they become energy producers. They think about how they use electricity and what more they can do. This might mean buying an electric car or adding battery storage.

The solar co-op enables members to think beyond their own home as well. Because they’ve gone solar with a group of people, co-op members are a part of a community of fellow solar supporters.

This community is eager to help more people benefit from solar power. It creates a feedback loop. People go solar. They build a community and fight for policies that enable more people to go solar. This is how individually owned rooftop solar power is building a market for a decentralized energy system from the ground up.

PICs Can Leapfrog to a Sustainable Future



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Decentralized energy systems are gaining attention globally as a viable option for sustainable energy systems, but in island settings, power systems distributing clean energy are the only option for universal electrification.

With a widely dispersed population, almost 70% of which is without electricity, and an extremely high dependence on imported fuels, Pacific Island countries (PICs) are searching for a sustainable, low-carbon pathway to achieve Sustainable Development Goal 7 (SDG7: affordable and clean energy). They grapple with two energy challenges—energy access and energy security—while also striving to meet their commitments to climate-change mitigation.

Papua New Guinea has an electrification rate of less than 15%. With a population density of fewer than 20 people per square kilometer and difficult terrain, access to centralized grid electricity is prohibitively uneconomical, even on the main island. However, distributed renewable energy systems (solar, micro-hydro, etc.) can be economically deployed to supply electricity to people who currently spend a significant amount of money on kerosene and batteries for their basic lighting needs. In Fiji, solar-powered freezers are helping remote island communities to store their catch safely and improve their livelihoods. The co-benefits of this energy access are many and range from health and education to job security.

Addressing SDG7 will provide a platform for helping to achieve other sustainability targets in these remote communities and will increase much-needed climate and disaster resilience in a time of increasingly frequent extreme events.

An Unstoppable Tipping Point



Bill Nussey
The Freeing Energy Project

Decentralized electricity production is quickly and quietly reaching a tipping point that will upend the business model of our century-old grid. Simply put, electricity from onsite solar panels and batteries is becoming cheaper than buying it from utilities. Hawaii and California have already reached this point, and as the price continues to decline, the rest of the world will follow. The reason we are reaching this tipping point is as uncomplicated as it is powerful—solar power is a technology and not a fuel (the same is true for batteries). This has profound implications.

Electricity from fuel-based power plants (such as natural gas, coal, and nuclear power) benefit from economies of scale—larger plants mean cheaper kilowatt hours. Although solar power benefits from scale as well, the phone in your pocket is a reminder that technology can be decentralized and small but also affordable. Why is that? Technologies also benefit from economies of volume—the more you manufacture, the cheaper each unit becomes. Twenty billion solar cells were made in 2018, and experts predict that prices will continue to decline for decades as more factories are built.

Today’s regulatory system was designed for a time when economies of scale were the only path to affordable and reliable electricity. Now that we have options that are smaller, cleaner, and cheaper, it’s time for some policy upgrades. First, stop the artificial fees foisted on owners of solar rooftops. Second, shift utilities from a return-on-assets business model to a performance-based model. Third, and most exciting, allow distribution feeders to become transactive marketplaces.

Unlocking Africa's Utilities of the Future



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Despite not traditionally being central to conversations on the “future grid” or the “energy transition,” utilities in sub-Saharan Africa arguably have much to gain by embracing the global decentralization and digitization trends that are revolutionizing energy-service provision. Our utilities generally operate in vertical, non-competitive environments challenged by system inefficiencies, limited and congested networks, capital constraints, and low-consumption customer bases. Integrating decentralized generation technologies, along with advances in storage, sensor, and metering technology, represents an opportunity to defer generation capital investments to improve the extent and performance of transmission and distribution infrastructure and to develop new pricing, incentivization, and billing mechanisms, all of which potentially drive down costs for providers and consumers while improving reliability and service quality. The challenge is for utilities to interpret these disruptions as an opportunity to evolve and grow their base rather than as a threat of displacement. The African utility of the future must grapple with how to harness demand-side forces, how to align their incentives with those of the consumer, how to incorporate and partner with new technology providers, and how to upskill the workforce. Regulators must strengthen the sector’s governance, provide enabling policy that encourages innovations to service delivery, reform institutional structures, and redesign rules regarding electricity tariffs. In fact, failure to do so could render our utility models outdated for the future—stifling economy and impeding universal energy access for the growing continent.

Decentralized Clean Energy Solutions to Achieve SDG7



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In 2015, the United Nations adopted 17 SDGs to address humanity’s grand challenges. SDG7 aims to “ensure access to affordable, reliable, sustainable, and modern energy for all.” This includes universal access to electricity and increasing renewable energy penetration.

Decentralized solutions—mini-grids (MGs) and solar home systems (SHSs)—are essential to achieving SDG7. MGs are isolated electricity networks that serve a few dozen to a few thousand people. SHSs consist of a small rooftop solar panel connected to lights and a battery box with electrical outlets. Approximately 1.2–1.4 billion people—almost all in low-income countries—will require electricity access by 2030 to achieve SDG7, and MGs and SHSs are the least-cost way to serve 700–800 million of them. Meanwhile, the dominant MG generation technology over the next decade will be solar photovoltaics (PV), so expanding electricity access through MGs and SHSs will help increase renewable energy penetration.

However, deploying MGs and SHSs at scale brings numerous challenges. Low-income countries will need to develop detailed national electrification plans that identify areas best served by the main grid, MGs, and SHSs. A suite of activities is needed to decrease the costs of MGs and SHSs alongside initiatives to increase household income in rural areas. Significant investment is needed to upgrade infrastructure to support efficient supply chains. Climate change, economic shocks, and policies that favor centralized power systems are examples of additional challenges.

Academics have a duty to engage with humanity’s grand challenges, and SDG7 is a worthy and fertile research agenda.

SchoonSchip: Toward a Cellular Grid Architecture



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Spectral

Decentralization is an essential driver of the renewable energy transition. If done wisely, it will help increase the efficiency, flexibility, and resilience of our energy system. The unstoppable sales growth of solar PV, electric vehicles, heat pumps, and residential batteries creates a strong case for creating local energy communities or microgrids. To help speed up the energy transition, facilitating decentralized developments should be a top priority for policymakers.

A good example can be found in the Netherlands, where an energy cooperative of 30 houseboats called SchoonSchip (“Clean Ship”) has gained a special exemption from the Dutch energy law. This exemption allows them to manage their own energy flows, engage in peer-to-peer energy trading, and gain direct access to electricity wholesale markets. In doing so, they can broker cheaper wholesale electricity prices while simultaneously helping to balance the grid both locally and nationally.

I like to think of such an energy community as a cell: a highly resilient and semi-autonomously functioning unit. Just like a cell is part of an organ, this community will be integrated into a larger body. The next planned step is to connect SchoonSchip to several other microgrid projects in Amsterdam-North, thereby creating a multi-microgrid platform that will more effectively manage its energy flows and aggregate its flexibility. Developments like this herald a clear change toward a highly decentralized, integrated, and cellular grid architecture that will literally empower citizens to take the energy transition into their own hands.

Decentralized Energy Solutions Crucial to Achieving SDG Objectives



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1.2 billion people in the world lack access to electricity. 3 billion lack access to clean cooking energy. 900 million people will remain without access to clean cooking energy, and 600 million Africans will remain without access to electricity by 2030 despite all the current efforts to bring modern energy to the people.

To achieve sustainable energy for all and the SDGs by 2030, decentralized off-grid solutions are expected to deliver more than 70% of all new electricity connections in rural areas to serve over 400 million people.

However, in order for decentralized off-grid solutions to achieve the above, over US\$52 billion (the majority of which would be channeled to sub-Saharan Africa) needs to be invested per annum. Currently, investment stands at US\$32 billion.

Policies and regulatory frameworks are important aspects to facilitate the scale of the required decentralized off-grid solutions. To date, over 30 African countries have no or a lack of appropriate regulatory frameworks. Policies and regulations need to be created and/or improved in most of the African countries if decentralized renewable energy and off-grid solutions are to be developed and installed at the required scale.

Flexible and Digital Roadmap



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The ongoing power-sector transformation, which is at the core of the energy revolution over the world, is being accelerated by the combination of electrification, decentralization, and digitalization.

Distributed energy resources (DERs), which turn the consumer into an active participant in the power market, are growing at an accelerated rate. However, decentralization is not driven by landmark-efficiency, convenience innovations as we have seen in the past but rather is characterized by a gradual shift toward renewables and sustainable growth. To accelerate the process further, we need to address three challenges.

First, we need to formulate a reasonable roadmap of DERs globally and nationally by considering natural endowment, demand growth, geopolitics, and pre-existing energy-system persistence in each country.

Second, we need to solve technical problems in power-system flexibility. Given that most DER output is used or delivered in the form of electricity, a more flexible and reliable distributed system should be built as the fundamental platform for managing intermittency issues from solar or wind resources.

Third, we need to establish policies, regulations, and a market environment to foster the development of DERs. Today, solar PV and wind-power technologies are benefiting greatly from early policy and financial support, resulting in large-scale deployment.

Digital technologies, such as smart distribution systems based on efficient communication, self-healing technology, and advanced remote automation, could be the key solution to these challenges. Wide availability of high-powered internet to business and customers alike is essential to enabling the application of such technologies.

Super-Smart Energy Systems



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To reach sustainability targets, current energy systems require substantial restructuring. Through the coupling of sectors (e.g., electric vehicles, electric heat pumps, power-to-fuels, and power-to-chemicals) and decentralizing energy, we could significantly increase energy efficiency and electrification, phase out fossil fuels, adopt 100% renewable energy, and reduce societal costs. Although centralized system elements will remain valuable for balancing energy flows across larger geographic rims, modern energy technology allows us to combine the benefits of centralized and decentralized systems through super-smart energy-system design. All major world regions, such as Europe, North America, Northeast Asia, and others, can reduce their energy-system costs by realizing super grids, whereas the majority of power flows still remain within the range of just a few hundred kilometers. Solar PV, batteries, heat pumps, and electric vehicles offer a broad range of decentralized options for electricity supply, storage, and usage and help realize sector coupling on an end-user basis in addition to centralized utility-scale units. Market development in various parts of the world indicates additional benefits of such a system: prosumers of solar PV (those who both consume and produce energy surplus to their needs) can contribute substantially to the overall demand coverage by feeding surplus electricity back into the grid and thus becoming a source and increasing energy-system resilience. Decentralization removes the pressure and dependency away from a few large energy providers. This increases resilience and enables energy provision at a peer-to-peer level. Such a system can be further improved by information technologies such as artificial intelligence.

Decentralization: Technology Challenges and Outlook



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Decentralized systems feature prominently in transition scenarios toward a clean and secure energy future. They facilitate the generation of renewable energy, which is diffuse and driven to a large extent by small, private installations featuring small-scale technologies. Of importance in this context, however, are the reduced performance and increased costs of smaller-scale technologies for decentralized energy generation, transmission, storage, and utilization in relation to the conventional, larger-scale counterparts, especially when these comprise components that involve thermal or mechanical processes. In such cases, the economics are unfavorable at small scales, whereas performance variations with scale are significant. Although this is generally acknowledged, these features are not typically accounted for in high-level whole-system or integrated assessment models aimed at identifying optimal pathways toward high-efficiency, low-carbon energy systems.

Development of small-scale technology specifically for implementation within decentralized systems is not trivial. For example, component selection can be very different at different scales, making the identification of high-performance yet affordable designs challenging. In general, although significant research has been done, progress toward commercialization and deployment has lagged. Nevertheless, decentralized systems are slowly emerging as a *de facto* solution to the energy challenge. Even in the absence of more widespread implementation at present and given the differences between decentralized systems and their centralized counterparts, it is important to promote innovation and the development of suitable technologies.