CHAPTER 2

ENERGY FOR ALL

How Innovation Is Democratizing Electricity

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In Rwanda, an estimated 600,000 households in remote areas are accessing the Internet, charging mobile phones, and lighting their homes for the first time thanks to off-grid solar energy.[1] With support from local government, private companies are installing solar systems on residential roofs and using a 'pay as you go' business model to sell energy as a service. Consumers gain partial use of solar systems they could not afford to purchase outright and use their mobile phones, frequently supported by Wi-Fi routers installed by the solar companies, to make weekly or monthly payments.

Opportunities such as this abound in today's fast-evolving power industry. This is particularly true in the developing world, where demand for electricity is high but centralized power grids are scarce, inefficient, and unreliable. Many of these countries face a huge population expansion in the decades ahead, with limited infrastructure to meet existing and future demand. Currently, an estimated 1.2 billion people worldwide lack electricity,[2] and 2.8 billion people live without clean and safe cooking facilities.[3]

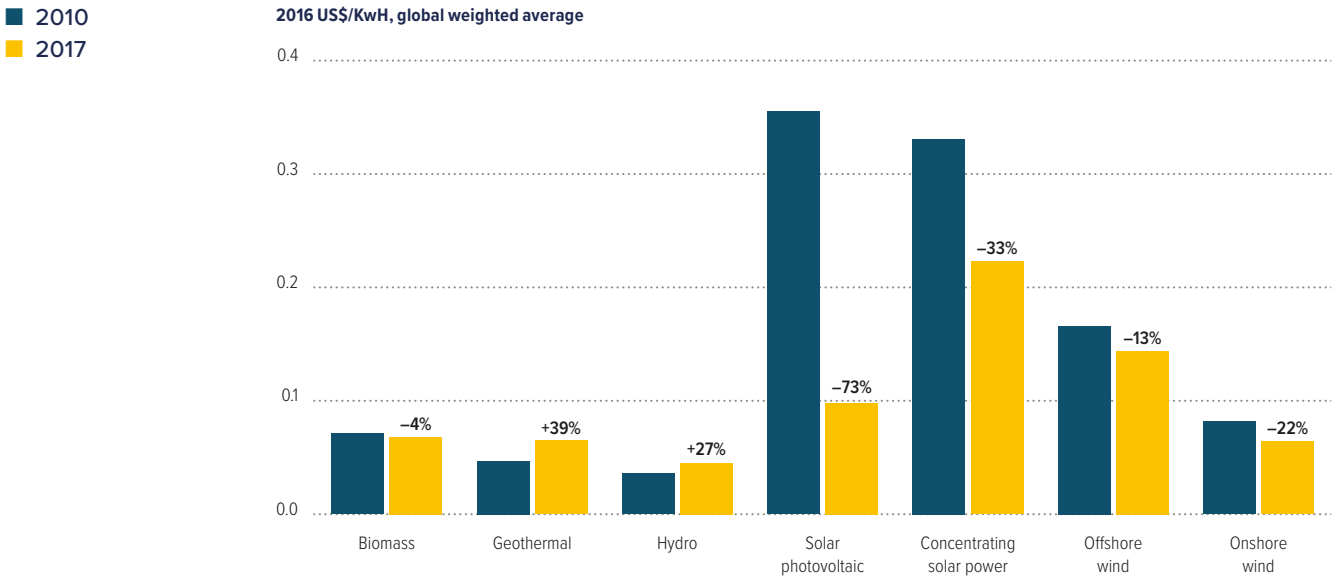
Various international initiatives are underway to address the issue of 'affordable, reliable, sustainable, and modern energy for all,' [4] as set out in the UN's Sustainable Development Goal 7 (see also Box 2 in Chapter 1). In Africa, where programmes are active in Côte d'Ivoire, Ghana, Rwanda, and Tanzania, to name just a few, off-grid renewable energy technology makes it possible to build distributed energy systems from the ground up. In Asia, innovative models are emerging that can transmit stored geothermal energy across national boundaries. In Central America, governments are democratizing energy by mandating the construction of micro-grids to serve remote communities.

In developed countries, the shift towards new energy sources and distribution models is happening at a relatively slower pace, in part because centralized power generation via long-distance power grids is well established and to a large extent runs on marginal cost. The considerable cost of building these grids has already been covered in the past. Hence in these areas, the transition towards renewable energy is primarily a function of political will and burgeoning environmental awareness movements, often alongside strong incentive schemes, technology breakthroughs, and decreasing costs. Indeed, despite the legacy impediments, it is no longer rare for energy consumers in developed countries to take on the mantle of so-called prosumers—for example, by producing their own energy through a rooftop solar panel, using what they need, and sending the excess out to the grid for a fee. This bottom-up nature of energy transformation is a paradigm shift for utilities, which previously generated energy and cascaded it down to the consumers through their transmission and distribution grids.

Viewed broadly, across the globe, the traditional energy frameworks are no longer viable. Energy companies will have to adapt quickly to these changes or risk being rendered irrelevant. Indeed, how well companies innovate using new types of energy and distribution technologies will determine their ability to survive the transformation—and,

Figure 1.

Global levelized cost of electricity from utility-scale renewable power-generation technologies, 2010–17



Source: IRENA, 2018.

importantly, to compete against the many start-ups and entrepreneurial firms eyeing the energy market. Energy executives are well aware of the shifting ground they face. In PwC's most recent Global Power and Utilities survey,[5] 47% of power company executives said that there is a medium-to-high probability that new models of distributed generation could shrink the role of some utilities to providers of back-up power.

A study by the International Renewable Energy Agency (IRENA) revealed that the costs of renewable power generation are already 'very competitive' for meeting the needs of new generation capacity.[6] In fact, in 2017 auctions of offshore wind power in Europe required no government subsidies because bidders could rely on falling technology costs and rising power prices to anticipate profits. And an analysis by the global financial services firm UBS predicts that shrinking battery and solar costs will make the combination of electric vehicles, solar panels, and stationary batteries for excess power in the home or businesses a practicable option in many markets within the next 10 years.[7]

The renewables environment

Of all renewables, solar photovoltaics (PVs) have arguably benefited the most in the past couple of years from scale and technology breakthroughs. Many of the recent improvements in this arena have emerged from advances in cadmium telluride (CdTe), the semiconductor material with the smallest carbon footprint and shortest energy payback time of all solar technologies. Other so-called thin film silicon technologies, primarily copper indium gallium selenide (CIGS), as well as non-silicon approaches (chiefly perovskite) are also beginning to impact the direction that PVs will take in the future. Annual research budgets for the top 12 solar panel manufacturers increased by nearly 500% between 2006 and 2016.[8]

As this R&D blitz has played out, the cost of solar PV electricity has fallen some 73% since 2010, according to IRENA,[9] down to an average of roughly US$0.10 per kilowatt-hour (KwH) compared to a range of $0.05 to $0.17 per KwH for fossil fuels (Figure 1). (Swanson's Law observes that that the price of solar photovoltaic modules tends to drop 20% for every doubling of cumulative shipped volume.[10])

In developed countries, consumers are being courted with plenty of attractive options to make the shift to solar energy. For example, solar PV wafer and cell manufacturers—such as China's JA Solar and Minnesota-based start-up SolarPod[11]—have designed modular assembly systems that simplify the installation of solar panels and reduce maintenance costs, critical improvements needed to overcome consumer reluctance to jump off of the relatively reliable existing utility grid. And some renewables companies, such as Tesla's SolarCity and Utah-based Vivint Solar (in partnership with Mercedes Benz),[12] have stoked latent residential demand through leasing programmes for home PV systems, thereby addressing potential customer concerns about financing these systems.

In less-developed regions, government energy departments are developing aggressive programmes to expand the presence of PVs. South Africa's government has rolled out a national solar water heater programme with the goal of 1 million installations in households and commercial buildings by 2019, although the campaign has been slowed a bit by financial constraints.[13] In fact, across Africa,[14] where the population is expected to double by 2050—well beyond the capacity of power utilities to satisfy demand—M-Kopa, the continent's market leader in home PVs, has installed some 400,000 PV systems. At its current rate of growth, the company may add another 200,000 to that number over the next year. During the same period, smaller rivals such as Off Grid Electric, Bboxx, and Azuri Technologies could double their client base.[15] These solar home systems offer cleaner, safer, and cheaper lighting over time than kerosene, the primary alternative for lighting in developing nations.

In South America, Chile has set a target of generating 70% of its power from renewables by 2050 and, consequently, has opened its energy grid to private investment by PV companies (see Chapter 10).[16] One of the most ambitious projects is a constellation of solar fields in the Atacama Desert. Among the big investors is Italy's large global utility Enel.

In India, the government is aiming to install 1 million solar water pumps by 2021—which would have a huge impact on the agriculture sector through improved irrigation. In fact, Bloomberg's recent New Energy Finance report estimates that some 8 million irrigation pumps powered by diesel in India could eventually be converted to solar pumps.[17] In Madhya Pradesh province, the local government is currently operating a large procurement programme for solar pumps and is considering replacing even grid-connected electric pumps with solar pumps based on cost economics.

Technology innovation has also transformed the prospects for wind energy, making it the least expensive renewable energy source. Modern wind turbines are increasingly cost-effective and reliable, and they have scaled up in size to achieve multi-megawatt (MW) power ratings. Because of longer, lighter rotor blades, taller towers, and better drivetrains and performance-optimizing control systems, an average onshore wind turbine with a capacity of 2.5–3 MW can produce more than 6 million kWh in a year—enough to supply 1,500 average European households with electricity.[18] Currently, at least 24 countries around the world are meeting 5% or more of their annual electricity demand with wind power.[19]

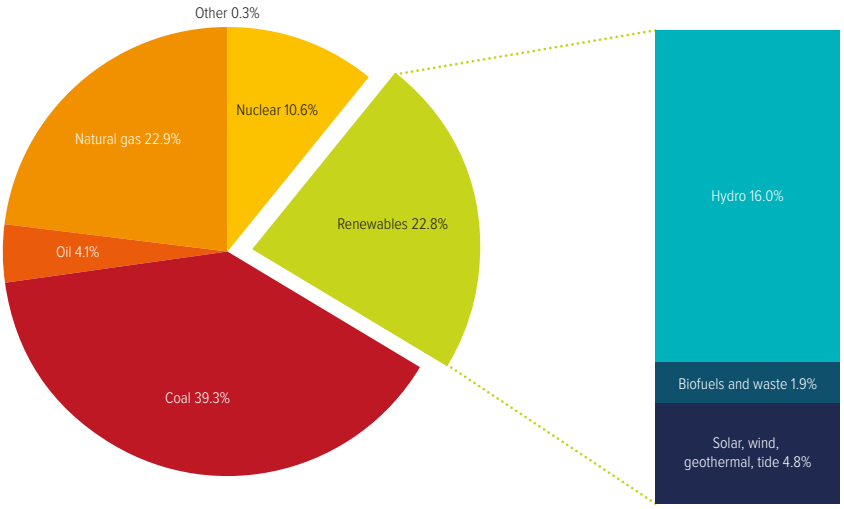
China is the planet's largest wind energy producer, with nearly 100,000 turbines—one-third of the world's volume—that can generate 145 gigawatts (GW) of electricity, nearly double the capacity of wind farms in the United States of America (U.S.).[20] The U.S., Germany, Spain, and India round out the top five producers of wind energy, and all are experiencing steady growth.[21] Exports of wind-powered generating sets from the U.S. rose from US$16 million in 2007 to US$488 million in 2014, but fell back to US$17 million in 2016.[22]

Less well-known innovations in power generation will also have a substantial impact on the energy upheaval underway. For instance, geothermal power,[23] which is generated from steam produced from reservoirs of hot water found a couple of miles or more below the Earth's surface, is an attractive alternative in areas where drilling into the Earth is relatively easy and inexpensive. In California's dried up Salton Sea, the independent power company CalEnergy Generation is managing 10 massive geothermal plants that generate 327 MW, enough to power half a dozen small cities.[24]

Lao People's Democratic Republic, Malaysia, and Thailand recently signed an historic multi-lateral geothermal power trade deal.[25] This comes on the heels of 16 cross-border energy projects targeted by countries in the Association of Southeast Asian Nations (ASEAN) with the goal of transferring up to 23,200 MW of power across the region. Government leaders view regional renewable energy power trading agreements as an effective way for countries with excess installed capacity to export power to neighbours facing blackout issues as well as for those who

Figure 2.

Fuel shares in global electricity production, 2015



Source: OECD/IEA, 2017b.

Note: 'Other' includes electricity from non-renewable wastes and other sources not included elsewhere, such as fuel cells, chemical heat, and so on. Because of rounding, totals in the figure may not add up exactly.

need more energy to speed up economic, industrial, and infrastructure development.

Another renewable advance with some promise is converting waste to energy (WtE), which involves primarily incinerating biomass to produce clean electricity, heat, or fuel. Methane is perhaps the most familiar WtE application, but more sophisticated and environmentally safer approaches are under design. Most of the WtE activity is taking place in developing countries, providing vital sources of energy for cooking, lighting, and agricultural uses. For instance, biogas has especially high potential in Kenya,[26] where in 2017 the Gorge Farm Plant debuted to power the cultivation of vegetables and flowers, heat greenhouses, and provide surplus energy to up to 6,000 rural homes. In India, cities produce some 62 million tons of waste annually, of which only 82% is collected—and of that only 28% is treated.[27] But WtE projects are now on the rise. It was reported in 2016 that some 24 waste-to-energy projects that would produce 233 MW of electricity were in various stages of construction,[28] and research by PwC estimates that 20 jobs will be created for every MW produced from WtE in India.

Transmission turmoil

Even as the renewables movement evolves (Figure 2), there will still be a place for fossil fuel power. But the latter's influence will wane as it morphs into a supplemental energy source, satisfying demand when sufficient electricity is not available from renewables. Facing this instability in their main power source, utilities are struggling to find growth opportunities in their primary business lines: distribution and transmission grids. Moreover, although utilities offer customers numerous plans for offloading excess generated renewable energy either at a residential site or a larger power facility to the grid, so it can be delivered as needed, many private non-utilities are interceding and creating their own local off-grid transmission solutions. For instance, GE Energy Connections is installing renewable energy distribution hubs in France, Canada, and Singapore,[29] while ABB has a large operation in Australia.[30]

Fuelling off-grid activities are significant breakthroughs in energy storage devices. Such devices primarily include batteries that can warehouse renewable power in people's homes

or in local facilities, providing a steady stream of energy regardless of the solar or wind conditions in the area. Battery storage technology has gotten a big boost from the automotive industry, where battery innovation for electric vehicles has been a priority and has led to a sharp drop in the cost of energy storage solutions.

Indeed, since 2012, the price of lithium-ion batteries has dropped some 70%;[31] analysts forecast that lithium-ion storage could fall below US$200/kWh by 2019 and perhaps hit US$100 by 2025, from about US$250/kWh now.[32] At US$200/kWh, previously uneconomical applications, such as the colocation of battery storage and solar PV systems, suddenly become extremely attractive. Solar industry experts at IHS Markit believe that, by 2025, the world's base of cumulative installed battery storage capacity will reach 52 GW, up from around 4 GW today. And revenue from this sector is forecast to grow at a 16% compound annual growth rate (CAGR), reaching $7 billion.[33]

Befitting its role in electric vehicle development, Tesla has pushed battery storage across all applications. Already, in South Australia, Tesla has built and installed a 100 MW lithium-ion battery to dispense power into an electricity grid that was crippled during a mass blackout in 2016. But, beyond Tesla's innovations, a lot of other activity will change the face of energy storage and decouple renewable energy from the grid even more. For example, the global power company AES is building a 300 MW battery storage facility that will function as a power plant in the middle of Long Beach, California.[34]

Meanwhile, in China, where transmission limitations are impeding the expansion of power from renewable energy, the government is promoting a 15-year Energy Technology Innovation Action Plan. This plan calls for accelerated research into advanced energy storage to support renewables integration, micro-grid development, and electric vehicles. An initial project is the construction of a vast energy storage installation in the northeast city of Dalian, led by Chinese battery manufacturer Dalian Rongke. The 200 MW facility will nearly triple China's present grid-connected battery capacity when it is completed in 2018.[35]

The possibilities from battery storage are especially welcome in developing regions. Lithium-ion technology promises to offer emerging economic areas the alternative of quickly installing micro-grids as energy distribution sources, rather than having to wait for fully functioning national grids. In Africa, for example, Fenix International and mobile payment provider MTN Group Ltd are partnering to bring solar panel and battery systems to nearly 1 million consumers for as little as $0.20 a day, so they can charge mobile phones and light their homes.[36]

While battery storage will clearly be a mainstream solution within the next decade, the volume of energy innovation research currently underway means that unexpected developments will likely play a role as well, even if they seem far-fetched now. One of these, power to gas (PtG), avoids battery storage altogether while creating a virtuous circle for renewable energy programmes. Under this concept, excess power produced by wind or solar can be converted into methane gas, stored in traditional gas pipelines, and used to fuel cars and heat buildings on a sustainable basis at zero marginal cost. In a pilot project, automaker Audi has two e-gas plants that produce synthetic methane from wind-generated electricity.[37]

Does this mean that traditional transmission lines will be obsolete in future? It is unlikely. But because building long-distance grids is costly and can present environmental challenges, the case for new grids is increasingly difficult to justify—especially as offsite and storage solutions become viable. In Germany, these obstacles are even affecting a renewable resource project: little progress has been seen to date in a planned few thousand kilometres of new transmission lines to transport wind energy north to south because of environmental and political concerns.

Cash flow

A compelling sign that an energy revolution is underway is the amount of money from public and private sectors pouring into activities related to developing and distributing power from renewable sources. It is relatively commonplace for virtually every major private equity firm to have a lending arm devoted solely to developing renewable energy projects. Large investors such as Blackrock and Aon Hewitt are pouring money into the sector.[38] They are attracted by strong demand for new projects, which is increasing valuations and rates of return rapidly. Long-term investors that provide capital upfront can receive a stable bond-like cash flow for decades from an individual project. Moreover, as coal and nuclear plants are retired globally, renewable project assets will only become more attractive to investors.

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Private-sector investment will be a centrepiece of the new energy ecosystem.

Another significant source of money for renewable energy efforts is pension funds, some of which are flush with cash. One of the biggest pension funds in the world, the California State Teachers' Retirement System, announced plans a few years ago to double its clean energy and technology investments to US$3.7 billion through the end of the decade. This group has already put US$1.9 billion into these projects in the past.[39]

More creative, non-traditional investment vehicles are also emerging. Typical of these are the new renewables' crowdsourcing opportunities. One of the more successful took place in 2013, when Mosaic offered online investors 4.5% returns for loans as small as US$24. Within 24 hours the project was sold out.[40] Since then, there have been dozens of similar investment programmes provided by an array of businesses.

In a likewise novel approach, solar power companies have begun to sell bundled securities backed by pools of residential and commercial solar energy projects. The assets included in these tranches are loans and leases on renewable energy facilities and transmission lines as well as power purchase agreements (PPAs), which organizations use to buy off-grid renewable energy. PPAs are becoming a significant revenue stream in the renewables ecosystem because many of the world's largest companies—such as Google, Heineken,[41] and AB InBev[42]—are investing in PPA-based projects to supply themselves with renewable energy and add capacity and distribution to local grids. Recently General Electric formed its own PPA unit to accelerate renewables project development around the world.[43]

Renewable energy credits (RECs) are providing yet another channel for cash flow in the new power paradigm. Led by firms such as Sterling Planet and Green Mountain Energy, REC companies offer residential and commercial solar and wind farm customers chits for excess energy sold back to large and small grids. These credits can then be resold in various local energy markets.

The 30,000-foot view

With all of the changes that are already being witnessed in the power generation and distribution landscape, it is obvious that we—and the utilities industry, in particular—are in for a rapid period of continuing transformation. International initiatives such as the Kyoto Protocol and the Paris Climate Change Accord have placed an increased focus on renewable energy, and on integrating it with innovative local distribution and storage solutions: micro-grids, batteries, and smart technologies. This trend reflects both a commitment to decarbonize the economy and the falling costs and innovative attractiveness of the technology.

Private-sector investment will be a centrepiece of the new energy ecosystem. Traditional utilities can still play a big role by leveraging their relationships with consumers to offer new types of power distribution and generation programmes. For their own survival, utilities should not think of this period as purely a disruption against which they need to defend. Instead they should view it as an opportunity to use their breadth and scale to provide renewable resource access for consumers and convenient ways for consumers to manage their power use and store or share excess capacity.

At the same time, start-ups and entrepreneurs in developed and developing regions have clearly determined that, as renewables become more viable, the power industry has the potential of being a bonanza. These innovators will continue to follow new research threads and apply new technologies to the full array of renewable resources, even those barely known to us now. Their activities will ensure that the once-staid energy market will be evolving for decades to come.

Meanwhile, local and state governments have a relatively straightforward job ahead: provide private companies with a safe environment to get a return on their investments. Given the increasing cost competitiveness of renewable energy, there is less need for policy makers to offer consumer rebates and investment tax credits for solar, wind, and other types of non-fossil fuels. Instead, regulators should be incentivizing innovation in all types of energy generation and transmission, allowing the marketplace to sort out winners and losers.

In individual countries, the market shape for power distribution will depend on policy direction as well as on other local factors. These can include the extent of competition and customer choice, access to fuel, the nature of existing infrastructure, the degree of electrification, and degrees of interconnectedness or isolation from neighbouring territories. But regardless of how renewable energy is generated, stored, and distributed, it is already boosting local economies; democratizing energy generation and transmission; and giving customers unprecedented access, control, and choice.

Notes

1 The Economist, 2016.

2 Bloomberg New Energy Finance, 2016.

3 OECD/IEA, 2017a.

4 Information about the Africa Renewable Energy Initiative is available at http://www.arei.org/.

5 PwC, 2015.

6 IRENA, 2018.

7 Vidal, 2014.

8 Osborne, 2017.

9 IRENA, 2018.

10 Crooks, 2016.

11 Lewis, 2013.

12 Ferris, 2017.

13 Energy Department, Republic of South Africa, National Solar Water Heater Programme, no date.

14 The Economist, 2016.

15 The Economist, 2016.

16 Londono, 2017.

17 Bloomberg New Energy Finance, 2017.

18 Further information about WindEurope is available at https://windeurope.org/about-us/new-identity/.

19 REN21, 2017.

20 Hernandez, 2017.

21 GWEC, 2018.

22 U.S. Department of Energy, 2016.

23 Nelson, 2017.

24 Further information about CalEnergy Generation is available at https://www.bherenewables.com/imperialvalley_geothermal.aspx.

25 GE Reports Staff, 2017.

26 Kamadi, 2017.

27 Pradhan, 2018.

28 Prasad, 2016.

29 GE Grid Solutions, 2017.

30 Wood, 2017.

31 Clover, 2017.

32 Curry, 2017.

33 Driscoll, 2017.

34 Saltzgaver, 2017.

35 Vest, 2017.

36 Prinsloo, 2017.

37 Audi MediaCenter, 2016.

38 Shankleman, 2017.

391 Baker, 2015.

40 Hymas, 2013.

41 BPVA, 2015.

42 Frangoul, 2017.

43 Peters, 2016.

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