Chapter Two

Electrification, Collaboration, and Cooperation: Managing the Future of Energy and Transportation Systems in the Atlantic Basin

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The countries that comprise the Atlantic Basin[2] are facing major challenges regarding energy and transportation. There are many factors affecting the Atlantic Basin's future, such as mass migration from rural to urban areas and the resultant impact on transportation, water, food, and energy security; reconsideration of central station electric generation as the only reliable means of energy production; environmental impact of fossil fuels; accelerated adoption of renewable energy technologies; emergence of electric vehicles as a plausible alternative for multiple transportation modes; evolving expectations of consumers for greater control of their lives; and income disparity and its impact on the quality of life of low-to-moderate income people.

Concerns are also emerging about the need for greater resiliency in transportation, water, food, and energy systems in the face of both increasing demand and severe weather events. As characterized by UN-Water, "The water-food-energy nexus is central to sustainable development. Demand for all three is increasing, driven by a rising global population, rapid urbanization, changing diets and economic growth."[3]

In addition, the discovery of significant amounts of recoverable terrestrial and offshore reserves of oil and natural gas is setting the stage for the Atlantic

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[2] This paper follows the Atlantic Basin framework as described by Paul Isbell: "In this projection, the Atlantic Basin includes Africa, Latin America and the Caribbean, North America, and Europe, incorporating these four Atlantic continents in their entirety, along with their ocean and islands." Paul Isbell, "An Introduction to the Future of the Atlantic Basin," *The Future of Energy in the Atlantic Basin* (Washington, D.C., Center for Transatlantic Relations, Johns Hopkins University SAIS, 2015), p.10, http://transatlanticrelations.org/wp-content/uploads/2017/03/Doc-43-text-Future-of-Energy-in-the-Atlantic-Basin-text-final-pdf.pdf (accessed August 25, 2017).

[3] "Water, Food and Energy," UN-Water, http://www.unwater.org/water-facts/water-food-and-energy/ (accessed August 25, 2017).

Basin to become largely energy self-sufficient, with trans-Atlantic trade flows and investments increasing the opportunity for greater synergies. In the electric power sector, increasing natural gas supplies offer an opportunity to reduce emissions in the short- to mid-term by replacing higher-emitting coal generation with gas generators that also make possible greater flexibility in managing intermittent renewable resources on the grid, especially when combined with improved storage technologies.

In the words of Daniel Hamilton, Executive Director of the Center for Transatlantic Relations at Johns Hopkins University School of Advanced International Studies (SAIS),

> We are on the cusp of fundamentally changing the way energy is produced, distributed and traded across the entire Atlantic space. Over the next 20 years the Atlantic is likely to become the energy reservoir of the world and a net exporter of many forms of energy to the Indian Ocean and Pacific Ocean basins. The Atlantic is setting the global pace for energy innovation and redrawing global maps for oil, gas, and renewables as new players and technologies emerge, new conventional and unconventional sources come online, energy services boom, and opportunities appear all along the energy supply chain.[4]

Of direct relevance to the future of both energy and transportation in the Atlantic Basin is United Nations Sustainable Development Goal Seven—to ensure access to affordable, reliable, sustainable and modern energy for all by the year 2030.

According to the mid-year 2017 update from the United Nations, there is a significant shortfall in each target area:

> Progress in every area of sustainable energy falls short of what is needed to achieve energy access for all and to meet targets for renewable energy and energy efficiency. Meaningful improvements will require higher levels of financing and bolder policy commitments, together with the willingness of countries to embrace new technologies on a much wider scale.[5]

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[4] Daniel S. Hamilton, Preface to *The Future of Energy in the Atlantic Basin,* op. cit., p. xv.

[5] "Progress towards the Sustainable Development Goals: Report of the Secretary-General,"UN Economic and Social Council, May 11, 2017, http://www.un.org/ga/search/view_doc.asp?symbol=E/2017/66&Lang=E (accessed August 25, 2017).

The update further reports the following statistics:

- Globally, 85.3 percent of the population had access to electricity in 2014, an increase of only 0.3 percentage points since 2012. That means that 1.06 billion people, predominantly rural dwellers, still function without electricity. Half of those people live in sub-Saharan Africa.
- Access to clean fuels and technologies for cooking climbed to 57.4 per cent in 2014, up slightly from 56.5 per cent in 2012. More than 3 billion people, the majority of whom are in Asia and sub-Saharan Africa, are cooking without clean fuels and more efficient technologies.
- The share of renewable energy in final energy consumption grew modestly from 2012 to 2014, from 17.9 per cent to 18.3 per cent. Most of the increase was from renewable electricity from water (hydro), solar and wind power. Solar and wind power still make up a relatively minor share of energy consumption, despite their rapid growth in recent years. The challenge is to increase the share of renewable energy in the heat and transport sectors, which together account for 80 per cent of global energy consumption.
- From 2012 to 2014, three quarters of the world's 20 largest energy-consuming countries reduced their energy intensity—the ratio of energy used per unit of GDP. The reduction was driven mainly by greater efficiencies in the industrial and transport sectors. However, that progress is still not sufficient to meet the target of doubling the global rate of improvement in energy efficiency.

The discussion that follows will explore three concepts that, when taken together, characterize a possible future state of energy and transportation in the Atlantic Basin that would accelerate the effort to meet Sustainable Development Goal Seven by 2030:

- *Democratization of Energy*, fueled by a growing desire for local control of the means of energy production and by the availability of new consumer-centric energy options;
- *The Dynamic Electric Grid*, enabled by communications, measurement, monitoring, and sensor and control devices that facilitate the real-time management of electricity demand; and
- *Environmentally Beneficial Electrification,* driven by the shift of primary end-use in the energy and transportation sectors away from carbon-intensive fuels to efficient electrification that promotes environmental gains, efficient use of water resources, and increased agricultural productivity.

When integrated, these three concepts, local control of energy and transportation management through a dynamic electric grid that increasingly enables electricity-driven economies, present a potential path to meeting the challenges being analyzed and addressed in the energy and transportation sectors of the four interdependent continents of the Atlantic Basin.

The Current State of Electrification in the Atlantic Basin: Access and Decarbonization

The figures below depict the latest available global data to highlight some of the differences and similarities across the four Atlantic Basin continents regarding access to electric service. They illuminate some of the unique opportunities and challenges and establish a baseline for contextualizing trends throughout this chapter.

Figure 1 shows the share of populations in the Atlantic Basin with access to electricity. Access to basic electric service is universal or nearly universal across most of the Americas and Europe. Within Latin America and the Caribbean, however, about 5 percent of the overall population has no access to grid electricity, mainly in rural areas of Central America and the mountainous Andean region of Peru and Bolivia. The most significant outlier is Haiti, where more than 60 percent of the population lacks access to electricity. High levels of access are prevalent across North Africa and in South Africa, but access varies widely across sub-Saharan African nations, where up to three quarters of the population are without electricity. Overall, only 35 percent of the African population had access to electricity in 2012, and rapid population growth makes progress even more challenging.[6]

As Figure 2 shows, sub-Saharan Africa is home to the largest share of people without access to electricity. Access rates are higher in urban areas, but electric grids often do not extend to rural areas where 60 percent of the population resides. Despite urbanization rates second only to Asia, most of the population in the region is still rural and is expected to remain so in the coming decades.[7] Rural electrification is a challenge faced previously in the

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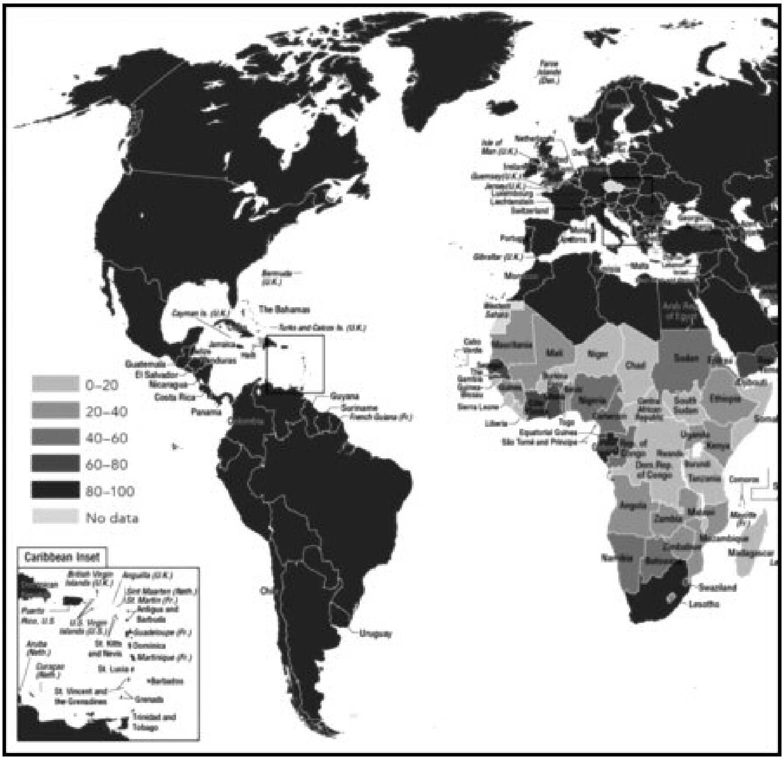
[6] "Making Renewable Energy More Accessible in Sub-Saharan Africa," The World Bank, February 13, 2017, http://www.worldbank.org/en/news/feature/2017/02/13/making-renewable-energy-more-accessible-in-sub-saharan-africa (accessed August 25, 2017).

[7] Mariama Sow, "Foresight Africa 2016: Urbanization in the African context," Brookings, December, 30, 2015, https://www.brookings.edu/blog/africa-in-focus/2015/12/30/foresight-africa-2016-urbanization-in-the-african-context/ (accessed August 25, 2017).

Figure 1: Share of Population with Access to Electricity (2014)



Source: "SDG 7: Affordable and Clean Energy," *Atlas of Sustainable Development Goals,* The World Bank, 2017, http://datatopics.worldbank.org/sdgatlas/SDG-07-affordable-and-clean-energy.html (accessed August 25, 2017).

other continents of the Atlantic Basin, and the lessons learned there may be able to be applied here.

As shown in Figure 3, even where there is universal or near-universal access to electricity, per capita consumption in developing countries across the Atlantic Basin is significantly lower than in the developed countries of the region. Economic growth and electric usage tend to grow in tandem. This is especially true in rapidly developing countries where growth leads to new demands for electricity from homes and businesses.[8]

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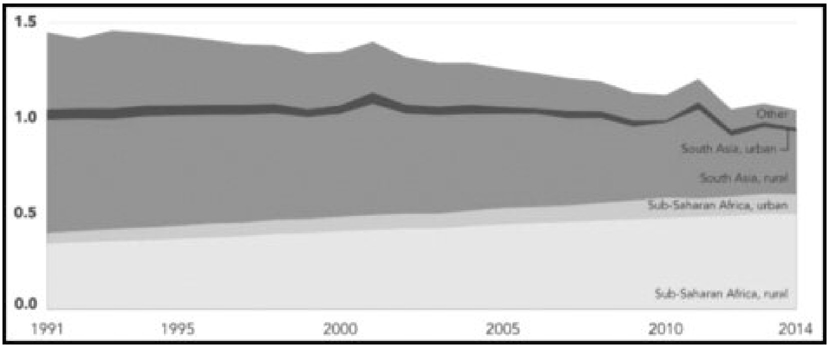
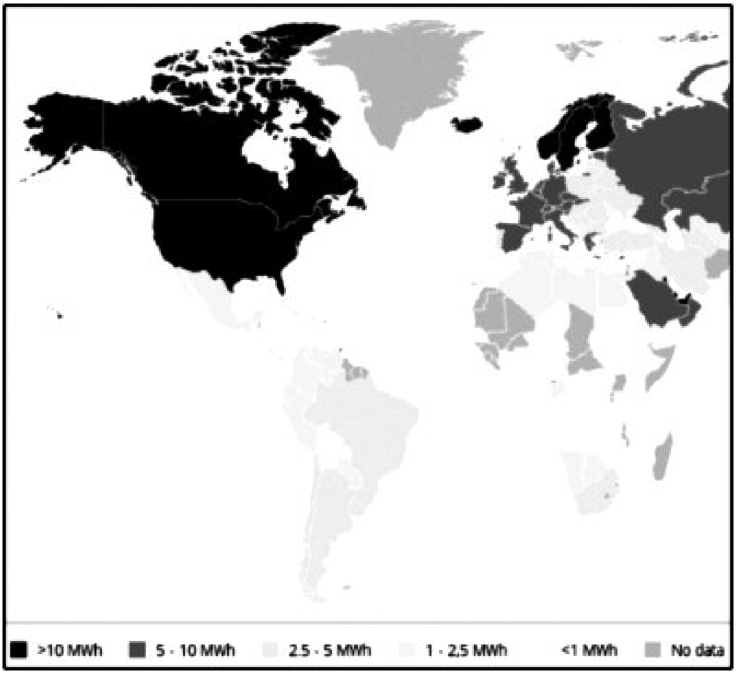
[8] Bosco Astarloa, Julian Critchlow, and Lyubomyr Pelykh, "The Future of Electricity in Fast-Growing Economies," World Economic Forum, January 2016,http://www3.weforum.org/docs/WEF_Future_of_Electricity_2016.pdf (accessed August 25, 2017).

Figure 2: Number of People without Access to Electricity (billions)



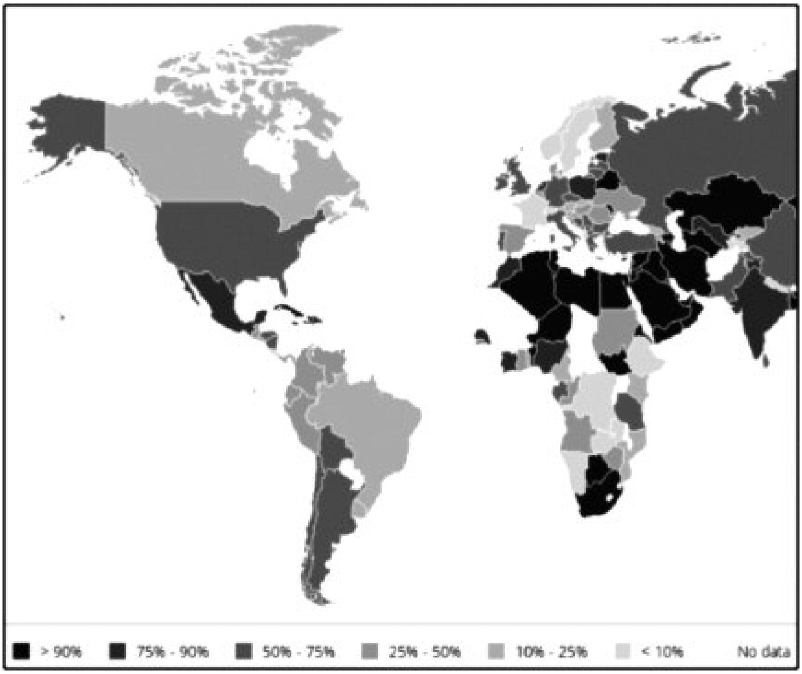
Source: "SDG 7: Affordable and Clean Energy," Atlas of Sustainable Development Goals World Bank, 2017. http://datatopics.worldbank.org/sdgatlas/SDG-07-affordable-and-clean-energy.html.

Figure 3: Electricity Consumption per Capita (2015)



Source: "Electricity: Consumption per Capita (MWh/capita), 2015," Atlas of Energy, International Energy Agency, 2017, http://energyatlas.iea.org/#!/tellmap/-1118783123/1 (accessed September 19, 2017).

Figure 4: Share of Fossil Fuels in Electricity Production (2015)



Source: "Share of Fossil Fuels in Electricity Production (%), 2015," Atlas of Energy, International Energy Agency, 2017, http://energyatlas.iea.org/#!/tellmap/-1118783123/2 (accessed September 19, 2017).

As a proxy for the current carbon intensity of electric grids across the Atlantic Basin, Figure 4 shows the share of electric production in each country that comes from fossil fuels. This subtractive look is useful because other sources of electricity are generally non-emitting (hydroelectric, non-hydroelectric renewable, nuclear) or carbon neutral (biomass, waste-to-energy). This map does not distinguish between fossil fuel types, however; and significant shifts from higher emitting coal to lower emitting natural gas have taken place in the United States and, to a lesser extent, in Europe. In the United States, coal has fallen from about half of all electric generation in the late 1990s to 30 percent in 2016 and was surpassed by natural gas generation on an annual basis for the first time in that year. In the EU countries, coal-based generation declined from about 30 percent of all generation to just over 21 percent over the same period, falling behind electricity generated from renewables and nuclear energy.[9]

Taken together, some interesting points can be gleaned from the figures above. First, the developed countries of the Atlantic Basin have made and continue to make significant progress towards decarbonizing their electric grids. Second, many developing countries in Latin America and several in Africa already have low-carbon electric grids. However, as they develop they will need to invest in low-and non-emitting technologies if they are to meet the demands of increasing energy consumption to power their economies without significantly increasing the carbon intensity of their electric sectors.[10] This is especially important as developing economies invest in expanding electric access for homes, businesses, and transportation that will be further discussed in this chapter. Third, similar to the landline-cell tower infrastructure leap, developing countries may decarbonize their grids by leapfrogging over previously sequential waves of adaptation and development.

Democratization of Energy

Throughout the Atlantic Basin there is a deepening interest in local control of energy resources. In fact, the beginnings of an energy cooperative network are being driven by two common interests: local control of energy production and renewable energy availability. European renewable energy cooperatives have emerged in the past ten years, many of which are participating in the European Federation of Renewable Energy Cooperatives (REScoop), a federation with 1,240 members and 650,000 consumers. Among its members are the cooperative association of Germany, DGRV, with 850 co-ops serving

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[9] "Coal power continues market share retreat in U.S. and Europe," *The Economist*, March 7, 2017,http://www.eiu.com/industry/article/455191829/coal-power-continues-market-share-retreat-in-us-and-europe/2017-03-07 (accessed September 5, 2017).

[10] There remains the possibility of successfully capturing CO_2 output from coal plants and finding productive uses that could be marketed globally. Electric cooperatives in the United States, partnering with the state of Wyoming and others in the U.S. and Canada, have invested in an Integrated Test Center located at Basin Electric Cooperative's Dry Forks generating station in Wyoming to explore uses and markets for CO_2 output. The X-Prize Foundation has, in turn, offered a U.S.$20 million NRG Cosia Carbon XPRIZE for the successful demonstration of such an outcome. Twenty-three teams from six countries, including Canada, U.S., UK, and Switzerland, represent an incredible diversity of approaches to turn waste (CO_2 emissions) into valuable products such as fish food, fertilizer, carbon nanotubes, and building material. Wyoming Integrated Test Center, http://www.wyomingitc.org/ (accessed September 18, 2017), and NRG Cosia Carbon XPRIZE, https://carbon.xprize.org/teams (accessed September 18, 2017).

150,000 consumers; Enercoop of France, with 10 co-ops serving 23,000 consumers; and Cooperative Energy of Great Britain, serving 250,000 consumers. The Alliance for Rural Electrification, headquartered in Brussels, Belgium, has members across the Atlantic Basin, including electric and energy cooperative representatives.[11]

In the United States 834 electric distribution cooperatives deliver electric service to 19 million meters and 42 million people in 47 states. These cooperatives cover more than half of the nation's landmass.[12] As cooperatives, they are not-for-profit energy service providers, owned and democratically governed by the consumers they serve. Many distribution cooperatives have joined together to form generation and transmission cooperatives (G&Ts) that provide power to distribution co-ops through their own generation facilities or by aggregating wholesale electricity purchases on behalf of their distribution members. The cooperatives, each independently governed and managed, are supported by an extensive, sophisticated cooperative network for capital financing, insurance, research and development, power marketing, information technology, materials supply, and back office support.

In terms of renewable energy development, the most advanced cooperative project globally is located on Kauai, an island of 66,000 people in the state of Hawaii. Like many islands, Kauai historically has been reliant on expensive imported diesel for its electricity. To reduce costs, Kauai Island Utility Cooperative (KIUC) has set a goal of using renewable resources to generate 70 percent of its power by 2030. KIUC has made significant progress towards this goal, with more than 40 percent of its electricity now coming from renewable generation, including solar, hydropower, and biomass. On the sunniest days, solar generation can provide in excess of 90 percent of the island's energy needs. KIUC's newest projects are two large solar arrays with battery storage systems that allow their output to be dispatched more flexibly, even after the sun goes down.[13]

Many electric cooperatives have developed or are in the process of developing electric vehicle recharging policies and, in some cases, have installed charging stations. According to Advanced Energy, a U.S. energy consulting firm, "Electric cooperatives throughout the United States are well underway with implementing strategies to increase electric vehicle (EV) adoption and take advantage of its benefits. Public charging stations are going up, member

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[11] Alliance for Rural Electrification, http://www.ruralelec.org (accessed September 8, 2017).

[12] America's Electric Cooperatives, https://www.electric.coop (accessed September 8, 2017).

[13] Kaua'I Island Utility Cooperative, http://website.kiuc.coop/ (accessed September 8, 2017).

education events and workshops are being hosted, and incentives are available."[14] As an example, New Hampshire Electric Cooperative in the U.S. offers incentives for the installation of electric vehicle charging stations to its commercial and municipal members. Members can install fast-charging stations and qualify for an incentive of 50 percent of the cost.[15] Much of the longer-distance need for electric vehicle charging in the U.S. will be located in rural areas served by cooperatives.

In addition to electric service, U.S. electric co-ops are deeply involved in their communities, promoting development and revitalization projects, small businesses, job creation, improvement of water and sewer systems, broadband deployment, and assistance in delivery of health care and educational services.

Electric cooperatives throughout Latin American and the Caribbean have renewable energy projects underway. The largest electric cooperative in the world is Cooperativa Rural Electrificación (CRE),[16] headquartered in Santa Cruz, Bolivia. CRE serves 600,000 consumers and is deploying large solar arrays. Costa Rica has four electric cooperatives that rely entirely on electricity generated from hydropower, wind, and solar power. Argentina has more than 500 electric cooperatives, many of which have invested in grid-connected renewable projects. In the Caribbean, Cuba is developing biofuels for use in electricity generation and is pursuing the development of cooperatives as a matter of government policy. In sub-Saharan Africa there are fewer examples of electric cooperative start-ups, but the concept is applicable to the goal of electricity access for all.

Futurist and EU advisor Jeremy Rifkin predicts that an "Energy Commons" will develop as an alternative to the current control of the electricity delivery system by large, investor-owned utilities: "A new Commons model is just beginning to take form, and interestingly enough, it is an outgrowth of an older Commons model for managing electricity that arose in the 1930s to bring electricity to the rural areas of the United States."[17]

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[14] Jonathan Susser, "Electric Vehicle Strategies for Electric Cooperatives," Advanced Energy, February 21, 2017, https://www.advancedenergy.org/2017/02/21/electric-vehicle-strategies-for-electric-cooperatives (accessed September 18, 2017).

[15] "Electric Vehicle (EV) Charging Stations are good for business," New Hampshire Electric Cooperative, https://www.nhec.com/ev-commercial-charging/ (accessed September 18, 2017)

[16] Cooperativa Rural de Electrificación, http://www.cre.com.bo (accessed August 28, 2018).

[17] Jeremy Rifkin, *The Zero Marginal Cost Society* (New York, 2014), p. 206.

Rifkin believes that the cooperative business model is ideally suited for an Internet-based economy:

> The Internet of Things gives the advantage of the lateral power made possible by the new distributed and collaborative communications and energy configuration. The prospect of a new economic infrastructure and paradigm that can reduce marginal costs to near zero makes the private firm, whose very existence depends on sufficient margins to make a profit, less viable. Cooperatives are the only business model that will work in a near zero marginal cost society. Thousands of green energy and electricity cooperatives are springing up in communities around the world, establishing a bottom-up Commons foundation for peer-to-peer sharing of electricity across regional and continental transmission grids. In the European Union, where more people invest in cooperatives than in the stock market—a striking fact—cooperative banks are taking the lead in financing green electricity cooperatives.[18]

Rifkin's observation about European cooperative banking interests and renewable energy is being replicated in the United States. The National Cooperative Bank, in collaboration with the Cooperative Finance Corporation, now offers lending to consumers of electric cooperatives who wish to install rooftop solar systems or to participate in community solar programs that are discussed below.[19] Also, a start-up credit union, Clean Energy Federal Credit Union, has been chartered by the National Credit Union Administration and will offer consumer financing to the 4,300 members of the American Solar Energy Society for the purchase of solar panels and electric or hybrid vehicles and high-efficiency home energy improvements.[20]

Cooperatives operate with a consistent set of principles adopted globally through the International Cooperative Alliance: voluntary and open membership; democratic member control; member economic participation; autonomy and independence; education, training and information; cooperation among cooperatives and concern for community. In addition, cooperatives

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[18] Ibid. pp. 214-215

[19] "National Cooperative Bank and CFC Launch Retail Financing Program to Expand Renewable Energy Options for Electric Cooperative Members," National Cooperative Bank, June 12, 2017, https://ncb.coop/media/press-releases/2017/national-cooperative-bank-and-cfc-launch-retail-financing-program-to-expand-renewable-energy-options-for-electric-cooperative-members (accessed September 18, 2017).

[20] Clean Energy Credit Union,https://www.cleanenergyfcu.org/ (accessed September 18, 2017).

are based on the values of self-help, self-responsibility, democracy, equality, equity, and solidarity.[21]

The Canadian historian Ian MacPherson saw cooperatives as a critical contributor to the global economy:

> Most co-operatives are effective businesses. That is attested to by the age of many co-operatives around the world and by the rapid growth of new cooperatives. There is some evidence that cooperatives have a better survival rate than capital-driven enterprise. The capacity of the cooperative model to be applied in many different contexts and in pursuit of many kinds of business is remarkable; its ability to strengthen local economies is a much-needed asset in a globalizing world. At the same time, the potential of the international co-operative movement to create an alternative, people-based economic system represents one of its most promising and important opportunities.[22]

A recent report by the International Labor Organization suggests that cooperatives represent a proven model of sustainable development:

> Cooperatives are sustainable enterprises that work for the sustainable development of their local communities through policies approved by their members. Cooperatives and the cooperative movement have been addressing these issues for over 150 years—since the first formal co-operative was established. Similarly, but driven by a global concern of the environmental limits of the planet, the World Commission on Environment and Development (the Brundtland Commission) famously defined the term sustainable development as "meeting the needs of the present generation without compromising the ability of future generations to meet their own needs."
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> Despite the fact that sustainable development and the cooperative movement were born out of different motivations, they address—although to different degrees and at different levels—a common ground: to reconcile economic, social and environmental needs, be it the needs of a local community or the needs of the whole world. Accordingly, cooperatives are ideally placed to promote sustainable development

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[21] "What is a Cooperative?" International Co-operative Alliance, https://ica.coop/en/what-co-operative (accessed September 2, 2017).

[22] Ian MacPherson, "The Centrality of Values for Co-operative Success in the Market Place," *The Cooperative Business Movement, 1950 to the Present*, (Cambridge, 2012), http://www.academia.edu/4377149/Co_op_values (accessed September 18, 2017).

> and foster a Green Economy—which was adopted by Rio+20 as a practical concept and vehicle for achieving sustainability.[23]

A notable example of the impact of local control of energy resources and the power of aggregation is the emergence of community solar programs pioneered by U.S. electric cooperatives. In this approach a large solar array is installed in the cooperative's service area, and individual members are offered the opportunity to purchase or lease one or more solar panels in the array. In return, the individual member receives a rebate on the monthly bill calculated on a rate-of-return basis. The advantage is that consumers receive access to a renewable resource while the cooperative is able to take advantage of its economies of scale to provide that resource at a lower cost. Community solar also makes solar available to all members who want it, including renters or members who cannot (or choose not to) add solar to their rooftops.

There is a great deal of debate across all four Atlantic Basin continents about the best way for consumers to take greater control of their energy services. Some believe that the best way to facilitate this energy future is for utilities to step aside and simply provide a platform for consumers and third-parties to interact with new applications for energy management. One version of this argument is the idea of redefining utilities as distribution system operators (DSOs)[24] that provide only grid management services, allowing the consumer to choose among multiple wholesale power and energy service suppliers. Alternatively, the utility could become a consumer-centric utility,[25] offering or facilitating the same innovative energy services that would otherwise be available through a third-party provider. This model allows the utility to continue to integrate and optimize resources on the system for the benefit of all consumers.

The energy cooperative as a business model functions as both a DSO and an energy management service provider in the form of a consumer-centric

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[23] "Providing clean energy and energy access through cooperatives," International Labour Office Cooperatives Unit, (Geneva, 2013), p. xvii-xviii, http://www.ilo.org/wcmsp5/groups/public/—-ed_emp/—-emp_ent/documents/publication/wcms_233199.pdf (accessed September 18, 2017).

[24] For a discussion of DSOs in a European context, see "The Role of Distribution System Operators (DSOs) as Information Hubs," EURELECTRIC, June, 2010,http://www.eurelectric.org (accessed September 5, 2017).

[25] Definitions and details of the concept of the "consumer-centric utility" can be found in "The Consumer-Centric Utility Future," National Rural Electric Cooperative Association (NRECA), March 23, 2016,https://www.cooperative.com/public/51st-state/Documents/51st-State-report_FINAL.pdf (accessed September 5, 2017).

utility. The ability to aggregate the benefits and minimize the risks of new products and energy management services is a defining characteristic of the consumer-centric utility. The community solar product mentioned above is an excellent example of a cooperative solution that is both consumer-centric and optimized for the benefit of the entire membership.

Cooperatives can play a central role as consumer-centric utilities that maintain the core infrastructure of the electric system by providing safe and reliable service, system planning and grid operations, long range planning, capital investment, and consumer services. The cooperative business structure can and does also provide an essential safety net for low-income consumers through policies that ensure that all members benefit from an affordable level of service.

The Dynamic Electric Grid

The cooperative model directly addresses the desire of consumers to have a greater say in their energy future through local control and ownership. However, the innovative applications needed to fully achieve this outcome will require advances in how the electric grid is operated with dynamic two-way flows of energy and data. That, in turn, will require advances in communications, measurement, monitoring, and sensor and control technologies.

Related to this evolution is the concept of economic-based grid control. According to *Renewable Energy World*,

> Every day, the number of new power generators from renewable resources joining the world's collective electricity grid goes up. Growing at an equal pace are the people working to keep the balance between supply and demand on that collective grid. More and more, they are turning to an intelligent and interactive networked system based on economics and market mechanisms where transactions are used to manage the grid and ensure reliability and efficiency.[26]

The key point about the evolution of the electric grid is that, beyond the ability to track and analyze energy demand, demand can now be managed

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[26] Jennifer Delony, "A Transactive Energy Future: The Inevitable Rise of Economic-based Grid Control," Renewable Energy World, September 11, 2017, http://www.renewableenergyworld.com/articles/print/volume-20/issue-5/features/solar-wind-storage-finance/a-transactive-energy-future-the-inevitable-rise-of-economic-based-grid-control.html (accessed September 18, 2017).

from the user's side of the system, as for example the ability to remotely adjust a thermostat level using a smart phone. In the future the ability to account for peer-to-peer energy transactions among homeowners and businesses likely will become widespread, representing an interesting application of platform economics.[27]

The evolution of the grid will also enable greater resiliency—i.e. the ability to maintain a reliable operational state or to return to a reliable operation state as quickly as possible during or after a disruptive event, a need that is becoming acutely clear in the face of increasingly severe weather events in the Atlantic Basin.

Cooperatives are innovative developers and implementers of emerging grid technologies. Local control enables the cooperative utility to move nimbly and often without the traditional regulatory oversight required of larger for-profit and crown corporation utilities. Tools and planning models perfected in one geographic area can support accelerated deployment in other geographic areas through networks that fulfill the foundational principle of cooperation among cooperatives.[28]

As an example, tools built by U.S. cooperatives that provide for the integration of utility-operated software systems at the distribution level are now deployed across the Atlantic Basin through MultiSpeak©,[29] an internationally recognized interoperability standard. MultiSpeak©, in turn, is being harmonized with comparable tools developed at the wholesale supply level in Europe through the International Electrotechnical Commission in Brussels.

A second example is in the arena of microgrid development. In the state of North Carolina, North Carolina Electric Membership Cooperative has developed the state's first grid-interconnected microgrid on an island that it serves and has another mainland microgrid in development at an animal confinement facility for waste management and odor control. The island microgrid is an exercise in community resilience, protecting a community that is often in the path of offshore storms and can be used for demand

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[27] Ibid.

[28] "Co-op 101: Understanding the Seven Cooperative Principles," NRECA, https://www.electric.coop/seven-cooperative-principles%E2%80%8B/ (accessed September 18, 2017).

[29] MultiSpeak© is a utility standard that allows the exchange of data with any system or application commonly used in a distribution utility such as outage detection, accounting, meter reading, or engineering analysis. "What is MultiSpeak?" http://www.multispeak.org/what-is-multispeak/ (accessed September 5, 2017).

response, energy arbitrage, and ancillary services in the regional power market. The resources in the microgrid include a 3-megawatt diesel generator, a Tesla 500-kilowatt / 1 megawatt-hour battery, 15 kilowatts of solar, and 225 internet-connected, consumer-controlled thermostats and water heaters. These resources also can reduce reliance on the main power grid during times of high demand when the island reaches its peak population in the summer, and provide backup power in case mainland power is interrupted.[30] At times of low consumption in the winter, these same resources can be deployed into the regional wholesale market for financial return.

In addition, cooperative organizations are using geographic information system tools for electrification planning in sub-Saharan Africa. These tools require the collection of base data that include transportation infrastructure, electric infrastructure, and demographics, among other items. Such efforts are being integrated with dynamic modeling tools developed by U.S. cooperatives to make cost-effective and reliable grid investments and, in particular, to conduct microgrid analyses that employ more sophisticated modeling and analytic capabilities.

Such analytical tools enable robust grid expansion as well as providing a platform for consumer participation and local control of energy production. They further complement analyses of existing transportation, water, food, and energy systems from a resiliency and sustainability perspective.

Grid modernization and the integration of low-carbon technologies go hand-in-hand. The intensity and approach of such efforts varies substantially between and among the four continents of the Atlantic Basin, and yet there is a common direction driven by two concurrent trends. The first is the rapidly declining cost and increasing efficiency of renewable energy, especially wind and photovoltaic solar. The second is the massive increase in recoverable reserves of natural gas at historically low prices. A third trend, increased research, development, and deployment of energy storage resources, is at an earlier stage but shows potential to contribute to decarbonization, especially when deployed in conjunction with intermittent renewable generation.

Each of these trends—growth of renewables, natural gas supply, and storage technologies will now be expanded upon within the Atlantic Basin con-

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[30] Robert Walton, "How Ocracoke Island's microgrid kept (most of) the lights on during last month's outage," Utility Dive, August 29, 2017, http://www.utilitydive.com/news/how-ocracoke-islands-microgrid-kept-most-of-the-lights-on-during-last-mo/503806/ (accessed September 19, 2017).

text leading to a discussion of the modernization of the electric grid and the evolution of microgrids necessary to optimize the value of each trend to both the energy and transportation sectors.

Growth of Renewables

Deployment of wind and solar power has received significant and ongoing policy support from the U.S. government and the EU governments via incentives and mandates. This has resulted in achieving significant scale and very significant cost reductions, as shown in Figure 5. In the EU, the 2020 Package adopted in 2009 mandates that renewables supply 20 percent of total energy by 2020,[31] and the emissions trading program helps support renewable deployment. In the U.S., federal tax subsidies and state renewable mandates[32] have resulted in significant growth in renewable generation. Between 2005 and 2015, the share of electric generation in the United States from renewable sources shot up dramatically from under 9 percent to over 13 percent, and exceeded 15 percent in 2016.[33] In the EU, renewable generation rose from just under 15 percent in 2005 to nearly 29 percent in 2015.[34] In 2016, wind and solar made up the majority of new capacity additions in both the U.S. and the EU, accounting for about 63 percent[35] and 86 percent,[36] respectively.

Expansion has driven technological improvements, with resulting increased output and cost reductions, in more mature markets like the U.S.

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[31] This target is not just for electric generation.

[32] While efforts to pass a national Renewable Portfolio Standard (RPS) have not passed the U.S. Congress, such standards been adopted by 29 states and the District of Columbia (DC), with several others adopting voluntary standards. Recently, some states have extended their standards or increased their goals. In 2016 alone, DC, Oregon, and New York extended and expanded their RPS standards with many other states in ongoing conversations about altering their renewable standards.

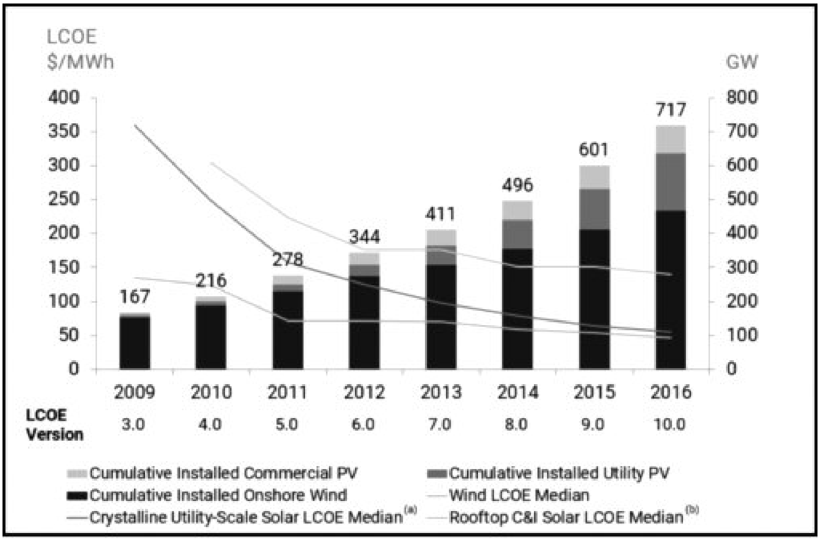
[33] This is in part due to rapid growth in non-hydro renewables and the end of drought conditions in the western United States that had depressed hydroelectric generation output.

[34] "Renewable Energy Statistics," *Eurostat*, June 2017, http://ec.europa.eu/eurostat/statistics-explained/index.php/Renewable_energy_statistics#Electricity (accessed August 25, 2017).

[35] "Renewable generation capacity expected to account for most 2016 capacity additions," EIA, January 10, 2017,https://www.eia.gov/todayinenergy/detail.php?id=29492 (accessed August 25, 2017).

[36] "Almost 90 percent of new power in Europe from renewable sources in 2016," *The Guardian*, February 9, 2017,https://www.theguardian.com/environment/2017/feb/09/new-energy-europe-renewable-sources-2016 (accessed August 25, 2017).

Figure 5: U.S. Unsubsidized Levelized Cost of Energy—Wind/Solar PV (Historical)



Source: Levelized Cost of Energy Analysis 10.0," Lazard, December, 15 2016, https://www.lazard.com/perspective/levelized-cost-of-energy-analysis-100/ (accessed August 25, 2017).

and Europe that help to drive down the costs of these resources across the entire Atlantic Basin.

Hydropower has been the primary source of power generation in Latin America for several decades and will continue to be developed, although much of the potential has already been tapped and new projects are in more difficult to access areas and often face significant popular opposition. Moreover, concerns have increased regarding cyclical droughts.[37]

Non-hydro renewables provide about 2 percent of generation in Latin America, but these technologies are expected to be the fastest growing source of electricity over the next five years, as the declining costs and increasing efficiency of wind and solar generation have made these resources more economically attractive, compared to fossil generation.[38] In fact, in

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[37] Ramón Espinasa and Carlos G. Sucre, "What Powers Latin America? Patterns and Challenges," *ReVista: Harvard Review of Latin America*, 2015, https://revista.drclas.harvard.edu/book/what-powers-latin-america (accessed August 25, 2017).

[38] Mae Louise Flato, "Is Latin America the New Global Leader in Renewable Energy?" *Atlantic Council*, February 7, 2017,http://www.atlanticcouncil.org/blogs/new-atlanticist/is-latin-america-the-new-global-leader-in-renewable-energy (accessed August 25, 2017).

2016 the region set records for both wind and solar installations, and Latin America's share of global demand for solar PV is expected to more than double in 2017, reaching 10 percent by 2020.

In Africa, hydropower historically has played a major role in development in the region, especially along the Nile, Niger, and Congo River basins. Excluding South Africa, hydropower accounts for more than half of the installed electric capacity in the sub-Saharan region.[39]

Since 2000 several new hydropower projects totaling more than 3 gigawatts have been added in this region, many involving Chinese financing and construction.[40] There have also been several high profile solar projects. Notably, in Morocco the first phase of the Noor Ouarzazate Power Station came online in 2016. Once the whole facility comes online it will be the world's largest solar facility totaling 580 megawatts. This facility uses concentrated solar thermal panels that are coupled to steam turbines to generate power. Concentrated solar technology is not yet as cost competitive as fossil generation. The Noor Ouarzazate plant includes 80 megawatts of solar PV in combination with 500 megawatts of solar thermal generation. The goal is to add additional solar and wind resources to reduce Morocco's dependence on imported fuel.

Morocco's stable government, extensive electric grid, and robust economy have attracted foreign investment; and the majority of the project funding is from EU development banks, the World Bank, and the African Development Bank, with significant additional contributions from the Moroccan government. Similar but smaller projects also have come online previously in Egypt and South Africa, and there are significant solar PV projects in Ethiopia, Kenya, Uganda, Tanzania, Ghana, and Nigeria.[41]

Wind presents a similar picture, with multiple large projects installed. South Africa leads the continent with more than one gigawatt of installed

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[39] South Africa accounts for more than half of the installed electric generating capacity in sub-Saharan Africa.Nkiruka Avila, Juan Pablo Carvallo, Brittany Shaw, and Daniel M. Kammen, "The energy challenge in sub-Saharan Africa: A guide for advocates and policy makers (Part 1)," Oxfam, 2017, https://www.oxfamamerica.org/static/media/files/oxfam-RAEL-energySSA-pt1.pdf (accessed August 25, 2017).

[40] SzabolcsMagyari, "The up-and-coming African solar: Top 50 announced African solar PV projects," *Solarplaza*, April 11, 2017, https://www.solarplaza.com/channels/top-10s/11689/-and-coming-african-solar-top-50-announced-african-solar-pv-projects/ (accessed September 5, 2017).

[41] "Morocco starts construction on 70 MW Noor Ouarzazate IV PV plant," *PV* Magazine, April 3, 2017, https://www.pv-magazine.com/2017/04/03/morocco-starts-construction-on-70-mw-noor-ouarzazate-iv-pv-plant/ (accessed August 25, 2017).

capacity and plans to exceed two gigawatts. Morocco and Egypt each have close to one gigawatt of installed wind. These countries all have fairly advanced electric grids and high access to electricity; but there is also significant wind capacity online in less-developed Ethiopia and planned in Kenya.[42]

In general, sub-Saharan Africa presents a unique challenge, with 650 million people without access to electricity and frequent outages and high prices for those who do have access. Sub-Saharan Africa is the most electricity poor area of the world.

Less capital intensive off-grid solutions using solar PV and batteries offer the most immediate opportunity to provide basic electric service in rural sub-Saharan Africa[43] and underserved portions of Latin America and the Caribbean. In these areas, the falling cost of solar PV and batteries makes this an attractive resource for off-grid electric power. Solar power can charge batteries to power lights at night, charge phones, and power schools in these areas. As electric technologies have become more efficient, more can be done with less. Off-grid solar can provide safer and cleaner lighting and cooking, help students read and study, and save people money since it is cheaper than buying candles and kerosene for illumination or paying for phone charging.[44]

As noted above, the latest update on UN Sustainable Development Goal Seven indicates that progress in affordable and clean energy is far short of what is needed and urges more financing and adoption of successful technologies like off-grid solar on a vastly wider scale. Thus, while other parts of the Atlantic Basin focus on reducing their energy and carbon intensity, for sub-Saharan Africa and other underserved areas of the Atlantic Basin, the focus is on increasing access to basic electricity for productive agriculture, manufacturing, and cleaner cooking and lighting.[45]

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42. Tony Tiyou, "The five biggest wind energy markets in Africa," *Renewable Energy Focus*, October 19, 2016, http://www.renewableenergyfocus.com/view/44926/the-five-biggest-wind-energy-markets-in-africa/ (accessed August 25, 2017).

43. Alister Doyle, "Vast Moroccan solar power plant is hard act for Africa to follow," *Reuters*, November 5, 2016, http://www.reuters.com/article/us-climatechange-accord-solar-idU.S.KBN1300JI (accessed August 25, 2017).

44. Adam Critchley, "Latin America's Bright Future for Off-Grid Solutions," *Solarplaza*, March 16, 2017, https://latam.unlockingsolarcapital.com/news-english/2017/3/16/latin-americas-bright-future-for-off-grid-solutions (accessed August 25, 2017).

45. Nathalie Risse, "UN Secretary-General Issues Second SDG Progress Report," *SDG Knowledge Hub*, June 8, 2017, http://sdg.iisd.org/news/un-secretary-general-issues-second-sdg-progress-report/ (accessed August 25, 2017).

New Natural Gas Supply

Another factor driving decarbonization of electricity in the Atlantic Basin is the significant expansion of natural gas supply. Natural gas supply is important for energy production as well as for its significant ramping capability essential to integrate increasing amounts of intermittent renewable resources. The trend toward a vastly increased supply and lower and less volatile pricing due to the shale gas revolution in the United States and Canada has captured the most attention, with the potential for increased liquefied natural gas (LNG) export throughout the Atlantic Basin.

Since the early 2000s, with the emergence of hydraulic fracturing, or fracking, the potential recoverable reserves have increased significantly because of the ability of this new technology to drill into areas that were otherwise previously unattainable or not economically feasible.

The U.S. Energy Information Administration (EIA) estimates that at the beginning of 2015, there were 2,355 trillion cubic feet of recoverable dry natural gas reserves in the United States. On the basis of current natural gas consumption levels, this amount of reserves would supply the U.S. for over 80 years with no new unproved reserves found.[46] Natural gas from unconventional sources has already become the largest source of natural gas production in the United States. At current production levels, the EIA forecasts in its 2017 Annual Energy Outlook (AEO) that shale gas and tight oil will account for nearly two-thirds of U.S. natural gas production by 2040, as shown in Figure 6.[47]

Increased supply has led to historically low U.S. spot market prices for natural gas, in the range of U.S.$2 to U.S.$5 per MMBTU since 2009. Analysts project that the price of natural gas will stay below U.S.$4 MMBtu through 2018, a direct result of the increased supply.[48] Over the longer term, prices are projected to stay below U.S.$5/MMBtu through at least 2030.

Elsewhere in the Atlantic Basin, in addition to increased availability of LNG from North America, there have been significant discoveries of large new offshore natural gas fields in the Eastern Mediterranean, much of whose capacity is expected to be marketed in Europe, assuming pipeline infrastruc-

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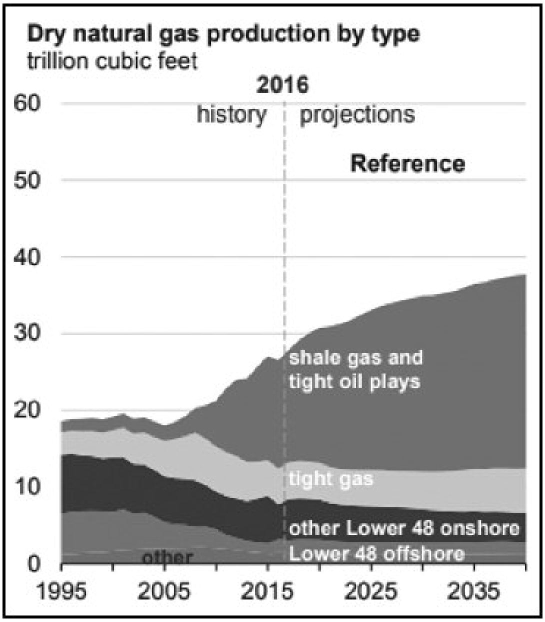
[46] "Natural Gas Consumption by End Use," EIA, July 31 2017, https://www.eia.gov/dnav/ng/ng_cons_sum_dcu_nus_a.htm (accessed August 25, 2017).

[47] *AEO 2017*, EIA, January 2017, https://www.eia.gov/outlooks/aeo/ (accessed August 25, 2017).

[48] "Natural Gas Futures Prices (NYMEX)," EIA, August 23, 2017, https://www.eia.gov/dnav/ng/hist/rngwhhda.htm (accessed August 28, 2017).

Figure 6: U.S. Natural Gas Production, Historic and Projected



Source: AEO 2017, EIA, January 2017, https://www.eia.gov/outlooks/aeo/ (accessed August 25, 2017).

ture can be built out. European countries are reliant on natural gas imports to meet two-thirds of their demand. At full output, these resources could supply most of the EU's import needs. Accordingly the EU has designated the construction of an Eastern Mediterranean pipeline to allow imports via Greece, a "project of common interest" with the region, streamlining processes and making the project a diplomatic priority, while exploring LNG options. Competition from other sources and challenges to regional cooperation likely will result in failing to reach these levels. Nonetheless, these new sources of gas offer European countries the opportunity to diversify suppliers and lower costs, making natural gas a more competitive source of electricity generation in Europe as well.[49]

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[49] TareqBaconi, "Pipelines and Pipedreams: How the EU can support a regional gas hub in the Eastern Mediterranean," European Council on Foreign Relations, April 21, 2017, http://www.ecfr.eu/publications/summary/pipelines_and_pipedreams_how_the_eu_can_support_a_regional_gas_hub_in_7276 (accessed September 19, 2017).

By offering an economically competitive alternative to coal, natural gas could reduce the emissions impact of the planned retirement of Germany's nuclear plants and help the country meet its energy transition (*Energiewende*) goals. In Germany, natural gas produces more than 12 percent of the country's electricity, just slightly less than the 13 percent produced by those nuclear plants set to retire. Higher-emitting coal, however, produces more than 40 percent of electricity, offering significant opportunities for emissions reduction by switching to lower-emitting natural gas.[50]

Natural gas is already the primary fossil fuel for electric generation in Latin America, supplying about a quarter of the region's generation. The shale gas supply boom most directly affects Mexico, which is the largest export market for the United States, through pipelines rather than LNG. The Latin America and Caribbean region also has significant sources of supply from gas fields in the Andean region of Peru and Bolivia, and from Trinidad and Tobago, a long-time exporter of LNG. The Vaca Muerta shale formation in Argentinian Patagonia, according to Energy Information Agency (EIA) estimates, holds the world's second largest shale gas reserves and the world's fourth largest shale oil reserves.[51]

There are significant opportunities to reduce costs while achieving greater efficiency and emissions reductions by converting existing oil and diesel generation to run on natural gas, especially in the Caribbean. These resources ensure that, along with renewables, natural gas generation will play an important role in meeting increased demand in the region.[52]

While there is great potential for renewables in expanding electric generation in Africa, fossil generation will still be necessary to meet burgeoning demand, expand access, and increase reliability. Increased natural gas supply and lower prices will also offer an opportunity for African countries seeking to expand their generation to do so at lower cost and with lower emissions. Some of the new production in the Eastern Mediterranean will be used to

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[50] Dagmar Dehmer, "Natural gas is key to German Energiewende, says association chief," Euractiv/Der Tagesspiegel, August 24, 2017, https://www.euractiv.com/section/energy/news/natural-gas-is-key-to-german-energiewende-says-association-chief/ (accessed August 25, 2017).

[51] Santiago Miret, "Vaca Muerta, Vaca Viva—Argentina's Shale Story," Berkeley Energy & Resources Collaborative, November 19, 2014, http://berc.berkeley.edu/vaca-muerta-vaca-viva-argentinas-shale-story/ (accessed September 18, 2017).

[52] Ramón Espinasa and Carlos G. Sucre, "What Powers Latin America? Patterns and Challenges," *ReVista: Harvard Review of Latin America*, 2015, https://revista.drclas.harvard.edu/book/what-powers-latin-america (accessed August 25, 2017).

supply North Africa and Egypt in particular. There are also significant natural gas supplies across Africa and potential for large new discoveries, all of which could help reduce energy costs and boost local investment if they can be developed and delivered.[53]

Storage Technologies

Much of the recent excitement around storage technology has been driven by the increasing production and declining costs of battery technologies. Battery storage has the potential to help increase the flexibility and reliability of intermittent renewable technologies, especially solar PV. While there is not yet wide deployment and experience with combined utility-scale solar PV-battery storage systems, a recent report by the U.S. National Renewable Energy Laboratory (NREL) found that these systems become increasingly financially viable the higher the level of PV penetration. It concluded that while grid-connected solar PV without storage is generally more financially attractive today, by 2020 PV-battery storage systems will be more economic at penetration levels over 15 percent with current solar tax subsidies and at levels of 24 percent or higher even without subsidies. While this study focused on the United States, its conclusions should be broadly applicable in other grid-connected areas in the Atlantic Basin.

Batteries are not the only storage option. There are already dozens of pumped hydro projects deployed around the world. This nearly century-old technology uses inexpensive power overnight, when demand and prices are low, to pump water to an elevated reservoir and then release the energy as needed to spin a turbine and generate during the peak of the day, when demand and prices are high. Less common are compressed air storage systems, which use off-peak power to compress air into a cavern or vessel that is then released to generate electricity. Pumped storage has always had some carbon reduction benefit since it offsets peaking generation from resources such as combustion turbines that tend to have higher emissions. When coupled with renewable generation, such storage systems can act to absorb excess non-emitting energy when it is not needed and shift to it when it is needed. This is especially attractive with wind generation, where output tends to be higher at night when demand is low but can also be used in areas of high solar penetration.

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[53] Antonio Castellano, Adam Kendall, Mikhail Nikomarov, and TarrynSwemmer, "Powering Africa," McKinsey, February 2015, http://www.mckinsey.com/industries/electric-power-and-natural-gas/our-insights/powering-africa (accessed August 25, 2017).

Advances in grid architecture are also delivering opportunities to aggregate demand side resources to provide storage. “Community Storage” is an emerging term for programs that aggregate distributed energy storage resources that are located throughout a community, such as water heaters, electric vehicles, and interconnected storage batteries to improve the operational efficiency of electric energy services to consumers. The defining characteristic of a community storage program is the coordinated dispatch and optimization of premises-based energy storage resources, often behind a consumer’s energy meter, to achieve electric system-wide benefit.[54]

As noted by Keith Dennis of the U.S. National Rural Electric Cooperative Association in *Public Utilities Fortnightly*, electric cooperatives are leaders in community storage:

> As a real-world example of community storage in the U.S., Great River Energy (GRE), a wholesale energy cooperative with 28 distribution co-op members in the state of Minnesota, stores a gigawatt-hour each night, every night, in water heaters in homes across its territory. Some of that energy is sourced from wind generation that would otherwise be curtailed. This storage capacity is valuable, so valuable that Steele-Waseca Electric Cooperative, a distribution cooperative member of GRE, will give any member who signs up to participate in the water heater control program an electric storage water heater at no cost. The member can also purchase the output from solar panels from the community solar project at a discount. This small but exciting project empowers members to contribute to shared environmental goals while saving money by eliminating the cost of purchasing a water heater altogether.[55]

Grid Infrastructure Modernization and Microgrid Development

Renewable energy resources often are not geographically co-located within centers of electricity demand because of the nature of the renewable resource and the fact that scalability requires a large footprint. Significant transmission infrastructure throughout the Atlantic Basin would be necessary to deliver renewable energy from rural or off-shore sources to densely populated centers of electricity demand. Examples throughout the Atlantic Basin include:

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[54] Keith Dennis, “Community Storage—Coming to a Home Near You,” Public Utilities Fortnightly, February 2016, https://www.cooperative.com/public/bts/energy-efficiency/Documents/Community-Storage-Public-Utilities-Fortnightly.pdf (accessed August 25, 2017).

[55] Ibid.

- The Clean Renewable Energy Zones project to deliver wind power from the Texas panhandle to the state's major cities in the southeast;[56]
- The Madeira transmission line, the world's longest, delivering hydropower from the Amazon Basin to major electricity demand centers near the southeastern coast of Brazil; and
- A proposal for several new transmission lines to deliver off-shore wind power from northern Germany to industrial centers in the south.[57]

Even though solar resources are more widespread and less concentrated, allowing for more flexible siting closer to electricity demand centers, larger solar PV projects face many of the same transmission challenges as wind projects due to their large footprint. Transmission projects, however, often face significant public opposition, making them difficult to site and build on a timely basis.

One way to overcome the transmission challenge is to put greater reliance on distributed energy resources (DERs), including small scale generation, storage, and demand-side management resources that can be positioned closer to the electric demand centers. Historically, electric grids have supported one-way flow of electricity, i.e. from the generator, through the transmission and distribution systems, and finally into productive end-use. Central-station generation[58] was the primary, and in many cases the only, source of electricity. Today, distributed energy resources are becoming more prevalent, necessitating the ability to effectively, and hopefully optimally, handle two-way flows of electricity and two-way flows of data. A longer and more technical version of this point would focus on the grid becoming an agile fractal grid, with the ability to isolate sections of a distribution system for protection purposes and to provide a continuous flow of power from distributed resources when central-station power is unavailable.[59]

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[56] Terrence Henry, "How New Transmission Lines Are Bringing More Wind Power to Texas Cities," National Public Radio, June 26, 2014, https://stateimpact.npr.org/texas/2014/06/26/how-new-transmission-lines-are-bringing-more-wind-power-to-texas-cities/ (accessed August 25, 2017).

[57] Benjamin Wehrmann, "The Energiewende's booming flagship braces for stormy times," Clean Energy Wire, June 14, 2017, https://www.cleanenergywire.org/dossiers/onshore-wind-power-germany (accessed August 25, 2017).

[58] Large power plants are historically more efficient, and most developed grids have relied on them to provide most generation, which is then delivered by transmission and distribution lines to where it is needed.

[59] Craig Miller, Maurice Martin, David Pinney, and George Walker, "Achieving a Resilient and Agile Grid," NRECA, 2014, http://www.electric.coop/wp-content/uploads/2016/07/Achieving_a_Resilient_and_Agile_Grid.pdf (accessed August 25, 2017).

Former U.S. Secretary of Energy Ernest Moniz described the electric grid as "a continent-spanning machine, of immense complexity, which is at its best when it is invisible."[60] This is certainly true throughout the Atlantic Basin, including northern Africa and the more developed areas of sub-Saharan Africa. At the same time, many analysts envision a grid that is made up of smaller, independent or quasi- independent generating entities, or microgrids:

> The "grid of grids" is not necessarily a better model than an integrated grid everywhere and at all times, but there is no doubt that the integration of locally more autonomous generating units needs to be addressed. There are definite advantages to having access to and control of distributed energy resources. Advanced control technology will be very useful to accommodating and then taking advantage of innovative approaches to distributed generation, storage and load control.[61]

As microgrids become more prevalent, the ability to optimize their performance for grid stability and reliability will require the creation of dynamic distribution networks with control and information technologies that operate in real time. This becomes an engineering education challenge, with the likelihood that it can best be achieved through a collaborative trans-Atlantic process. Such developments will evolve differently depending on the context of each national and regional grid. For example, in developed countries like the United States and Germany, which today rely on significant fossil generation, this means upgrading and modernizing a complex and longstanding electric grid to accommodate a changing energy mix. It will be particularly interesting to compare approaches developed in the Americas to those being developed in Germany as critical to the *Energiewende*.

For developing economies across the Atlantic Basin that already have universal or near universal electricity access, the challenge will be to adapt the existing grid to harness additional low- and non-emitting technologies in such a way that development and increased per capita electricity use does not result in runaway growth in greenhouse gas emissions.

For those developing economies in sub-Saharan Africa where access is still limited and electric grids are not fully deployed, especially in rural areas, this might mean developing grids that look very different from those

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[60] Ernest Moniz, "Keynote speech to the Innovative Smart Grid Technologies Conference," IEEE (Washington, February 19, 2014), https://smartgrid.ieee.org/resources/videos/387-ernest-moniz (accessed September 19, 2017).

[61] Craig Miller et al, "Achieving a Resilient and Agile Grid."

deployed elsewhere. While wider deployment of grid electricity may represent a longer-term goal, the end result might look very different from the central-station-dominated grids deployed across the Americas and Europe. Just as sub-Saharan Africa has leap-frogged landlines through widespread adoption of mobile phones, there is a possibility that non-grid resources will evolve into microgrids that eventually will be joined together to form a much more decentralized model than seen elsewhere, with a far greater reliance on distributed generation.

Out of necessity, microgrids have been developed in rural areas in the state of Alaska in the U.S.. The Alaska Village Electric Cooperative (AVEC) is the power provider for 33,000 people in 58 small communities in the state's interior, western, and southeastern areas. They are not connected to Alaska's Railbelt electric grid that serves the more densely populated areas between Anchorage and Fairbanks. To serve these communities, AVEC has 50 microgrids (a few communities are close enough to share). Given extreme weather and the lack of road connections, these systems are built with extensive redundancy. The primary fuel is diesel, which is generally expensive and has to be brought in by boat, costing AVEC $26 million last year even at a time of low oil prices. AVEC seeks practical and affordable solutions to reduce fuel costs. The co-op has deployed 34 small wind turbines to help offset fuel costs, saving over $1 million in 2016. At peak output, wind generation exceeds demand, so excess power is diverted to passive loads such as boilers at water treatment plants and other public facilities, reducing their need for diesel. AVEC also makes heat from its diesel engines available for water plants and public buildings.[62]

Ongoing rural electrification in areas of sub-Saharan Africa may provide novel insights into the role of microgrid development for resiliency purposes in mature grids. Local governance models, including cooperatives, for managing transportation, energy, water, and food in emerging economies might also provide learning opportunities for more mature economies.

The dynamic grid, the expansion of renewable generation, and the displacement of fossil generation results in every kilowatt of electricity being consumed more cleanly than the previous vintage of supply. These developments of the grid underlie the value of using more electricity, not only for quality of life and economic prosperity, but also for environmental gain.

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[62] Derrill Holly, "Are Microgrids the Wave of the Future?" NRECA, June 29, 2017, https://www.electric.coop/microgrids-potential-for-alaska-power/ (accessed August 28, 2017).

Environmentally Beneficial Electrification[63]

Electrification has always been a means to an end, enabling a better quality of life and supporting greater economic prosperity. The availability of high speed communications enabled by electrification as well as the evolving electrification of the transportation sector further enhances positive economic impacts and improves environmental performance and decarbonization efforts.

Modernizing the electric grid, adding real-time control technologies and building out microgrids are the foundations needed for the full development of the concept of environmentally beneficial electrification through the decarbonization of end-uses of electricity and through the electrification of transportation systems. This also has the benefit of creating more resilient energy systems, less likely to suffer from cascading outages experienced in more centralized systems and of being able to be restored individually and then reconnected to the grid.

End-Use Electrification

Historical data from research by the World Bank demonstrates that access to electricity is one of the most powerful economic development multipliers, enabling people around the world to break free from subsistence and economically prosper.[64] Now, more than a century after the advent of electricity, the electric power industry is undergoing a second revolution as the industry dramatically alters not only the fuel mix but also the electric distribution system itself.

Trends in energy generation and end-use technology are changing the environmental value of using electric appliances to produce heat and hot water in buildings. In fact, many experts now believe we are approaching a tipping point: we simply cannot meet the global CO_2 reduction goals if we continue to promote burning fossil fuel on-site in homes and businesses. The strategy of pursuing environmentally beneficial electrification has been

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[63] The concepts and arguments in this section on environmentally beneficial and end-use electrification are taken from Keith Dennis, "Environmentally Beneficial Electrification: Electricity as the End-Use Option," The Electricity Journal, November, 2015, http://www.sciencedirect.com/science/article/pii/S104061901500202X (accessed August 25, 2017).

[64] *The Welfare Impact of Rural Electrification: A Reassessment of the Costs and Benefits*.The World Bank Independent Evaluation Group, (Washington, 2008), http://siteresources.worldbank.org/EXTRURELECT/Resources/full_doc.pdf (accessed September 18, 2017).

suggested by the likes of Energy and Environmental Economics (E3)[65] and Lawrence Berkeley National Lab (LBNL)[66] in their assessments of how the state of California will meet its aggressive climate goal and by Jeffrey Sachs in his solutions to address the issue of climate change on a more global scale.[67] Furthermore, this trend is supportive of end-use consumer desires to be more environmentally sustainable in their energy choices, a trend that is at the core of the democratization of energy concept.

Engineering-based analysis demonstrates that electric end-use is the environmentally superior choice over on-site fossil fuel use for space and water heating, cooking, vehicles, agricultural pumping, and other equipment.[68] These trends include a long-term reduction in greenhouse gas intensity of the electric grid, increased efficiency of electric end-use appliances, and the increased need to manage end-use electric demand to help integrate variable renewable resources. As these trends continue to develop, electricity will only increase in environmental performance while on-site fossil fuel use has reached the virtual limits of its efficiency. A 2013 report by Lawrence Berkeley National Lab asserted that “moving away from oil and natural gas and towards electricity is a key decarbonization strategy.”[69]

The potential of environmentally beneficial electrification is being recognized in Europe as well. The EU power sector is committed to reducing greenhouse gas emissions by 80 to 95 percent by 2050, and there are calls to promote more efficient electric technologies such as heat pumps to replace

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[65] Amber Mahone, Elaine Hart, Ben Haley, Jim Williams, Sam Borgeson, Nancy Ryan, and Snuller Price, “California PATHWAYS: GHG Scenario Results,” E3, April 6, 2017, http://www.ethree.com/wpcontent/uploads/2017/02/E3_PATHWAYS_GHG_Scenarios_Updated_April2015.pdf (accessed September 18, 2017).

[66] Max Wei et al., “Scenarios for Meeting California’s 2050 Climate Goals: California’s Carbon Challenge Phase II: Volume I,” LBNL Energy Research and Development Division, September 2013, http://www.energy.ca.gov/2014publications/CEC-500-2014-108/CEC-500-2014-108.pdf (accessed August 28, 2017).

[67] Jeffrey Sachs, “Five Questions for Jeffrey Sachs on Decarbonizing the Economy,” *Yale Environment360*, July 15, 2014, http://e360.yale.edu/digest/five_questions_for_jeffrey_sachs_on_decarbonizing_the_economy (accessed September 5, 2017).

[68] This argument focuses on end-use space and water heating appliances. There are similar opportunities for electrification of vehicles, diesel agricultural pumps, and small internal combustion engines like lawnmowers and commercial blowers.

[69] James Nelson et al., “Scenarios for Deep Carbon Emission Reductions from Electricity by 2050 in Western North America Using the Switch Electric Power Sector Planning Model: California’s Carbon Challenge Phase II Volume II,” LBNL Energy Research and Development Division, February 2013,http://www.energy.ca.gov/2014publications/CEC-500-2014-109/CEC-500-2014-109.pdf (accessed August 28, 2017).

on-site combustion of oil and natural gas for space and water heating.[70] Indeed, the logic of environmentally beneficial electrification is applicable for grid-connected areas throughout the Atlantic Basin.

For less developed areas in the Atlantic Basin, including Haiti and rural sub-Saharan Africa, environmentally beneficial electrification includes cooking using cleaner fuels as part of a transition from the black carbon produced by coal, charcoal, and fuelwood used in traditional cooking, which is simultaneously creating serious health problems, particularly among women and children.[71]

Electrification of Transportation[72]

Ideally, the effort to decarbonize transportation will proceed in tandem with the movement to decarbonize the electric grid. It is interesting to note that some of the earliest applications of environmentally beneficial electrification were focused on seaports and airports, displacing diesel power equipment with electric power equipment (see Chapter Seven). Today, there are a variety of competing technologies seeking to reduce or eliminate direct emissions from transportation.[73] Despite the greatly increased supply of oil and gas in the Atlantic Basin due to fracking and offshore discoveries, there is a growing momentum to displace the internal combustion engine through the introduction of electric vehicles (see Chapters One and Three). In addition, the growing supply of lower-emitting natural gas and biofuels is likely to play a role in this change. This is complemented by the increase in battery production and decline in battery costs that are driving the growth in battery storage in the electric sector.

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[70] Kristian Ruby, "Electrification: A Key Driver for a Decarbonized and Energy Secure Europe," The Energy Collective, April 6, 2016,http://www.theenergycollective.com/aolaru/2375457/electrification-a-key-driver-for-a-decarbonized-and-energy-secure-europe(accessed August 25, 2017).

[71] For detailed discussions of the environmental and health impacts of black carbon, see Baron, Montgomery and Tuladhar,"An Analysis of Black Carbon Mitigation as a Response to Climate Change," Copenhagen Consensus on Climate, http://www.copenhagenconsensus.com/sites/default/files/ap_black_carbon_baron_montgomery_tuladhar_v.4.0.pdf(accessed August 25, 2017) and Janssen, et.al., "Health effects of black carbon," World Health Organization, 2012,http://www.euro.who.int/__data/assets/pdf_file/0004/162535/e96541.pdf (accessed August 25, 2017).

[72] The discussion of projections regarding electric vehicle penetration are taken from Brian Sloboda https://www.cooperative.com/public/bts/energy-efficiency/Documents/Member-Advisory-Alleviating-Misconceptions-about-Electric-Vehicles.pdf (accessed August 28, 2017).

[73] Direct tailpipe emission from vehicles, rather than life-cycle or source energy.

As this evolution occurs, the same logic underlying end-use environmentally beneficial electrification applies to transportation as well; electricity from a decarbonizing grid will ultimately emit less carbon than direct combustion of fossil fuels. The electrification of the terrestrial transportation sector in the Atlantic Basin will, in many cases, necessitate the development of grid-tied transportation systems. In such a future, decisions will need to be made on the location and ownership of electric vehicle charging stations as well as the role that electric utilities will play.

The year 2017 may be the turning point for the electric vehicle (EV). France and Britain both announced that they would ban sales of petrol and diesel automobiles by 2040.[74] They join Norway, the global leader in electric vehicle adoption, which last year announced a 2025 ban on emitting vehicles. Several other European countries have set goals or targets for EV sales and for the phase out of fossil fueled vehicles.[75] Multiple automobile manufacturers released models that represent true technological innovation. Volvo went so far as to announce that all of its vehicles will either be hybrid or electric by 2019. This announcement was so significant that it took attention away from the much-anticipated assembly line roll-out of the Tesla Model 3.

According to the Center for Automotive Research (CAR), U.S. sales of electrified vehicles in the U.S. were up 16.4 percent in 2017 compared to 2016. The only other vehicle types seeing a sales increase in 2017 were CUV, SUV, and pickup trucks, with increases in the single digits. All other segments experienced negative sales growth. Electrified vehicles (hybrids and electrics) accounted for 3.1 percent of all auto sales, outselling the large car segment and only 2.1 percentage points behind luxury car sales.

Although the EV market is still small, adoption is increasing (see Chapter Three). If current trends continue, significant penetration of electric vehicles is likely over the next 15 years, particularly in suburban areas and bedroom communities for large cities. As shown in Figure 7, electric vehicle sales are projected to surpass internal combustion engine sales by 2038. A Bloomberg New Energy Finance forecast indicates that "adoption of emission-free vehicles will happen more quickly than previously estimated because the cost

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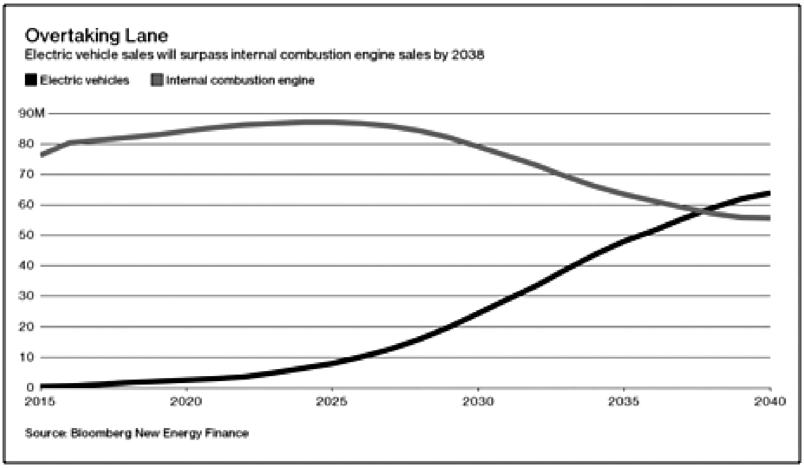
[74] Charlotte Ryan and Jess Shankleman, "U.K. Joins France, Says Goodbye to Fossil-Fuel Cars by 2040," *Bloomberg*, July 25, 2017 https://www.bloomberg.com/news/articles/2017-07-25/u-k-to-ban-diesel-and-petrol-cars-from-2040-daily-telegraph (accessed August 25, 2017).

[75] Outside of the Atlantic Basin, China and India (the world's largest and sixth largest automobile markets, respectively) have also announced policies favoring the sale of EVs and curtailment of petrol and diesel vehicles.

Figure 7: Projected Global Market Penetration of Electric Vehicles to 2040



Source: Jess Shankleman, "The Electric Car Revolution Is Accelerating," Bloomberg Businessweek, July 6, 2017, https://www.bloomberg.com/news/articles/2017-07-06/the-electric-car-revolution-is-accelerating (accessed September 18, 2017).

of building cars is falling so fast. The seismic shift will see cars with a plug account for a third of the global auto fleet by 2040 and displace about 8 million barrels a day of oil production—more than the 7 million barrels Saudi Arabia exports today."[76]

Long-term EV market expansion could have a significant impact on electricity markets. A recent report by the Brattle Group[77] suggests that switching to a largely electric fleet by 2050 could increase electricity demand by 56 percent over 2015 electricity sales. This would not only have an impact on utility demand but also on consumers and the environment. The Electric Power Research Institute notes that relative to internal combustion engines,

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[76] Jess Shankleman, "The Electric Car Revolution Is Accelerating," Bloomberg Businessweek, July 6, 2017, https://www.bloomberg.com/news/articles/2017-07-06/the-electric-car-revolution-is-accelerating (accessed September 18, 2017).

[77] Peter Maloney, "Brattle: Wider electrification key to averting both climate change and utility death spiral," *Utility Dive*, May 24, 2017,http://www.utilitydive.com/news/brattle-wider-electrification-key-to-averting-both-climate-change-and-util/443369/ (accessed August 25, 2017).

EVs can be more than twice as energy efficient, save 70 percent in fuel costs, and reduce CO_2 emissions by 75 percent.[78]

The speed of adoption of technology advances in decarbonizing electric grids and in electrifying the transportation sector will impact each of the four Atlantic Basin continents differently, but the movement toward environmentally beneficial electrification will inexorably move forward.

Conclusion

There is a long-term value to trans-Atlantic collaboration that tests and accelerates a new energy and transportation future characterized by local control and grid optimization, respectively enabling electrification and being enabled by electrification. Such collaboration would support economic development and prosperity, promote high quality jobs, complement ongoing discussions of resiliency and sustainability of the water-food-energy nexus, and promote community-level investment throughout the Atlantic Basin. The urban/rural rebalancing that could emerge through grid modernization and microgrid development would lead to improved transportation, water, food, and energy security and, hopefully, reduce the level of income disparity.

As has been shown through examples in this article, electric and energy cooperatives are functioning successfully or are under development on all four continents. In addition, economists and futurists point to the cooperative model as fulfilling emerging needs of people for greater control of their energy future. Existing cooperatives can play a catalyzing role in the Atlantic Basin with governments, for-profit corporations, and non-government organizations, innovating around technology development, technology transfer, and human resource development.

Grid modernization holds the key to economic advancement on all four continents. The efficiency of both connected grids and microgrids will be dependent on effectively managing the two-way flow of power and data. A dynamic grid creates for the first time in the history of electrification the opportunity to manage energy demand in real time and to enable a more resilient grid to better manage severe weather-related events. Combined efforts of government, research institutions, and universities are focusing

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[78] Mike Howard, "The City of Tomorrow: Smart, Electric," *EPRI Journal*, July 25, 2017, http://eprijournal.com/the-city-of-tomorrow-smart-electric/ (accessed August 25, 2017).

close attention on the information and control technologies that are in use or under development today. Existing electric utilities and cooperatives have unlimited partnership opportunities in that regard and should proactively engage in demonstration projects with existing research entities. The electrification of transportation systems and the decarbonization of the electric grid through increased penetration of renewable energy resources, each of which are enabled by grid modernization, represent a vision for the future that is environmentally and economically beneficial and, with deliberative actions to encourage local engagement and participation, can be inclusive of all members of society.

Three specific actions would help to accelerate this vision of a trans-Atlantic collaboration:

- Expansion of electricity and energy cooperative development through an intensive education process with government officials, policymakers, economists, and technologists about the cooperative option and the importance of collaboration and cooperation;
- Shared best practices and research and development for grid modernization and end-use energy management through collaborative efforts among government agencies, universities, and research institutions; and
- Public-private partnerships committed to gaining political, financial, technological, and human resource development support for the transition to environmentally beneficial electrification.