A Roadmap for Tennessee's Advanced Energy Economy

Tennessee Advanced Energy Business Council

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Introduction

Supported by a variety of national and regional economic indicators, there is increasing evidence that Tennessee's advanced energy sector is poised for a period of sustained growth. The Tennessee Advanced Energy Business Council (TAEBC) was created to help facilitate this growth by championing the use and manufacture of advanced energy technologies as an economic development strategy. With an overview of the existing companies and research institutions in Tennessee that together form the foundation for continued growth of the design, manufacture and installation of advanced energy technologies, the Roadmap for Tennessee's Advanced Energy Economy seeks to provide the context for decisions by business and government leaders that could make a lasting contribution to Tennessee's economic base over the next decade.

Our optimism is well-founded. The *Advanced Energy Now 2014 Market Report*[1], published by Advanced Energy Economy, indicated strong growth globally and nationwide in the advanced energy market. Globally, advanced energy represents a $1.1 trillion dollar market. With estimated revenues in 2013 of $169 billion, the U.S. now represents 15 percent of the world market, up from 11 percent in 2011. More significant, excluding wind, U.S. advanced energy revenue grew 18 percent from 2011 to 2012 and 14 percent from 2012 to 2013. The most dramatic growth occurred in Solar PV revenue, which experienced a two-year increase from $8.2 billion to $16.2 billion, making the U.S. the world's third-largest market for solar PV. The Market Report's robust growth figures for hybrid and electric vehicles, biofuels and the use of advanced building technologies suggest that advanced energy technologies have gained the "critical mass" required for sustained expansion and integration into the mainstream economy.

Power Forward 2.0: How American Companies are Setting Clean Energy Targets and Capturing Greater Business Value[2] shows that Fortune 100 and Fortune 500 companies are increasing the demand for cleaner, more efficient sources of energy. The report found that 53 Fortune 100 companies reporting on climate and energy targets are collectively saving $1.1 billion annually through their emission reduction and renewable energy initiatives-which certainly qualify as advanced energy.

The states that provide not only the energy source, but also the technologies, products and workforce will win.

Power Forward 2.0 further indicates that 215 companies in the Fortune 500 have set targets in one of three categories and will be looking for ways to meet them: 1) greenhouse gas reduction commitments, 2) energy efficiency and 3) renewable energy. Many of these companies have Tennessee ties, including FedEx and General Motors.

Meanwhile, other areas of the advanced energy sector are introducing technologies that will contribute to this growth. Recent innovations, including some developed in Tennessee, hold out the promise for a new generation of nuclear technologies, lightweight composites, and

a wireless grid to transmit electricity. Similar breakthroughs have resulted in the adoption by industry of new pollution controls and the expanded use of natural gas vehicles.

TAEBC sees in these national trends an enormous opportunity for Tennessee. The opportunity includes, through the adoption of affordable technologies, a chance to reduce the state's per capita energy consumption and attract more Fortune 100 and Fortune 500 companies to Tennessee. Perhaps even more important, TAEBC believes that, in addition to the University of Tennessee, the Tennessee Valley Authority (TVA), Oak Ridge National Laboratory (ORNL) and the state's expanding automobile sector provide Tennessee with unique assets that together offer an unparalleled platform for collaboration, innovation, testing, and implementation of advanced energy technologies.

Our goal is to help business and government view Tennessee's advanced energy assets and challenges as an emerging sector that will play an increasing role in the state's economic development. The Roadmap provides an overview of Tennessee's economy and energy assets, a window into innovations that might transform the advanced energy sector, opportunities for greater energy efficiency, and a number of conclusions that TAEBC hopes will contribute to a discussion about how best to promote the growth of advanced energy technologies in Tennessee.

Three Distinctive Features of Tennessee's Energy Economy

As in every state, the potential for the expansion of advanced technologies will be shaped by economic factors and assets that are unique to Tennessee. The development of the TAEBC Roadmap identified three distinctive features of Tennessee's energy economy that together reflect the challenges and opportunities for the expansion of advanced energy technologies.

1. High Per-Capita Energy Consumption

The most distinctive feature of the state's energy economy--and perhaps the greatest opportunity for an investment in advanced energy technologies--is the fact that Tennessee ranks as the 20th largest user of energy, per capita, in the United States. The average residential consumer uses far more energy than consumers in almost all other states. In 2011, the average Tennessean used 87.8 million Btu's of electricity, ranking Tennessee the 4th highest consumer of energy in the residential sector.[3] Although trends over the last decade indicate the gap continues to narrow, among neighboring states, Tennessee electricity consumption was 9 percent higher than in North Carolina and 18 percent higher than for the average consumer in Georgia.

In terms of industrial and commercial energy consumption per capita, Tennessee ranks as the 25th highest user. However, roughly 47 percent of energy consumed in Tennessee is for industrial and commercial purposes, while only 24 percent of Tennessee's total consumption is for the residential sector. Approximately 29 percent of Tennessee energy consumption falls in the transportation sector.[4]

Tennessee's experience to some degree distorts the correlation economists often draw between a state's energy consumption and economic vitality. Due in large measure to TVA's ability for several decades to provide low-cost residential power, Tennessee's per capita residential energy consumption has consistently been among the highest in the nation. Paradoxically, TVA's decision in 2007 to promote energy efficiency initiatives offers hope that historic patterns of energy consumption in Tennessee might gradually be reversed through the adoption of a combination of new energy technologies, government policies and TVA incentives designed to reduce residential demand for electric power. By 2010, energy efficiency programs had resulted in a savings of 143,000 megawatts of power, or about .14 percent of the state's power consumption.[5] While significant, the reduction in power consumption in Tennessee was roughly one-third of the national average.

While Tennessee's per capita use of residential energy remains high relative to the national average, significant opportunities exist to reduce energy use and generate savings in both the commercial and industrial sectors of the state's economy. Indeed, while Tennessee's ranking in both sectors is around the national average, commercial and industrial energy use represents more than 47 percent of the state's total energy consumption. The introduction of new advanced energy technologies, particularly in the automotive industry, holds the promise of substantial reductions of energy use, both in the manufacturing of vehicles and

in the amount of transportation energy used by the vehicles. The incorporation of similar technologies could have equally significant energy reductions for large commercial companies such as Federal Express.

Linked to TVA's effort to reduce residential power consumption is the agency's parallel desire to lower the volume of emissions from coal-fired plants that provide more than one-half of the state's electricity. Closing a substantial number of coal-fired plants will require an important discussion about future energy demand, leading to decisions regarding the possible deployment of both nuclear power and renewable energy sources as replacements. In both instances, success will depend upon the implementation of new energy technologies, some of which may be developed in Tennessee research institutions. In some instances, the ability to move these renewable energy technologies into the market will in turn depend upon providing entrepreneurs with available capital and the support services required to stand up a new company.

The effort to reduce emissions from coal-fired plants is supplemented by three initiatives that together would also reduce the use of fossil fuels in Tennessee's transportation industry. Joining with Oak Ridge National Laboratory, the state of Tennessee has allocated substantial funds to promote research and deployment of biofuels. Working with the same two partners, in 2011 Nissan chose Tennessee as one of the first five states to introduce the company's electric car. While they do not yet represent a large percentage of transportation energy consumption, both initiatives hold the promise for making a substantial contribution to the growth of Tennessee's advanced energy economy.

Meanwhile in Memphis, Tennessee's largest employer, Federal Express, is partnering with the Department of Energy to test the ability of hydrogen fuel cells to reduce carbon emissions while simultaneously lowering costs in Fed Ex's enormous fleet of delivery trucks by as much as 40 percent. Managed through a partnership that includes Smith Electric Vehicles and Plug Power, the $3 million project will equip 20 delivery trucks with lithium-ion batteries combined with a 10-kilowatt Plug Power hydrogen fuel cell system.[6]

The following represents an overview of the sources of energy generation and consumption in Tennessee.

Electricity Consumption – In February 2014, Tennessee generated approximately 6.5 million megawatt hours of electricity. Of that total, 46 percent of the state's electricity was produced from coal (a drop of more than 15 percent since 1999), 35 percent from nuclear energy and 14 percent from hydroelectric power. Approximately 43 percent of the power was distributed to residential consumers, with the remainder divided evenly between the industrial and commercial sectors.[7]

As consumption trends slowly change, the mix of Tennessee's energy production sectors is experiencing a historic transition. While coal will continue to be an important part of Tennessee's energy inventory, two factors - one economic and one environmental - will likely serve to lessen coal's relative position over the next two decades. Tennessee's coal mining industry, once among the nation's largest, now ranks fifth lowest among the 25 coal-

producing states. The decline of coal production in Tennessee coincides with TVA's long-term plan to lower the utility's fossil emissions through the gradual replacement of 36 units at 11 coal-fired power plants.[8]

The lost capacity will be replaced by a combination of energy sources. At 11.7 million megawatts in 2013, Tennessee's net electricity generation from hydroelectric power was the third highest of any state east of the Mississippi River. Although price volatility remains a challenge to long term planning, one can anticipate that over the next decade, natural gas produced by 106 units will assume a larger portion of TVA's energy portfolio. Indeed, by 2012, hydroelectric and natural gas together accounted for more than 20 percent of Tennessee's energy generation - the highest total since the construction of TVA's nuclear inventory.[9]

Consumption of Transportation Fuels – Tennessee's per capita rate of fuel consumption, while relatively high, does not mirror that of electricity. The average Tennessean in 2011 consumed 488 gallons of gasoline, a rate about 10 percent higher than in North Carolina and five percent higher than Virginia and Georgia, but about eight percent lower than in Alabama and Mississippi and roughly the same rate of consumption as in Kentucky.[10] While in the future the aggregate number of gallons consumed will in part reflect continued population growth, steadily improving rates of vehicle fuel efficiency, as well as price volatility, should gradually reduce per capita consumption.

2. A Gap in Personal Income

While the size has fluctuated over the last three decades, there remains a historic gap between personal income in Tennessee and the national average. Although related indirectly to energy, this gap presents an opportunity in some regions of Tennessee to promote advanced energy as a vehicle for new companies and jobs.

During a period from the early 1980s through the early 1990s that coincided with the rapid growth of the state's automotive industry, Tennessee's per capita income ranking rose from the high 40s to the low 30s. By 1995, exceptionally strong economic growth during the previous decade had brought income for Tennesseans within about 92 percent of the national average. Discounted for the state's generally low costs for housing, electricity and taxation, the standard of living for most Tennesseans - relative to the national average - was at its highest level in modern history.

After a decade of historic economic expansion, Tennessee saw its per capita income growth slow compared to the rest of the United States. Between 1990 and 1995, Tennessee's per capita income grew by 29 percent, substantially faster than a national growth of 20 percent. Tennessee has since struggled to keep pace. While the U.S. per capita income rate grew by 72 percent between 1995 and 2010, income for Tennesseans increased by only 64 percent. Predictably, slower growth in Tennessee's economy was accompanied by a reversal of the recent trend toward reaching the average U.S. per capita income. From the high water mark of 92 percent in 1995, Tennessee's per capita income by 2012 had dropped to 88 percent of the national average, the lowest ratio in 17 years.[11]

Tennessee also required a longer period to recover from the economic deterioration that occurred from 2008-2010. The state's unemployment rate of 6.7 percent in March 2014 represented the first time Tennessee had matched the national jobless figure since 2008. In addition to a recent decline in personal income associated with a sustained increase in unemployment, Tennessee's economy has a second feature important to policymakers. Statewide rates of unemployment and personal income serve to distort Tennessee's economic picture, in which some regions are doing quite well while others continue to perform far below the state average. In March 2014, 19 of Tennessee's 95 counties had double-digit rates of unemployment, most more than three points above the national average. Meanwhile, the Nashville and Knoxville regions boasted jobless rates more than a full point below the national average.[12]

This income and employment disparity among Tennessee's regions is part of the context for discussing the state's potential for creating advanced energy technology jobs. A growing number of financially constrained local governments are looking at distributed generation and energy savings performance contracts as ways of reducing utility costs for schools and other government buildings. The private sector increasingly is looking to cleaner sources of energy to power manufacturing facilities, office buildings and data centers as a means of meeting sustainability goals and assuming more control over electricity costs. Many rural communities burdened with sustained double-digit unemployment may be particularly receptive to the idea of transitioning the local economy to include more advanced energy jobs, particularly in the area of growing and transporting feedstock for biofuels. Likewise, the state of Tennessee has considerable flexibility in authorizing incentives for companies to locate in communities of high unemployment. Laid against the backdrop of a $1.1 trillion global economic opportunity presented by advanced energy, the state's economic profile, and in particular the need to promote new jobs in a number of depressed regions, will be important factors in future discussions of how best to encourage the continued growth of an advanced energy economy in Tennessee.

3. The Potential of Three Major Players

Initiatives from three distinct components of Tennessee's economy - the Tennessee Valley Authority, Oak Ridge National Laboratory (co-managed by the University of Tennessee), and the automotive sector, including the massive assembly plants of General Motors, Nissan and Volkswagen - will have a disproportionate influence on the direction and success of the state's efforts to promote an advanced energy economy. The ability to understand the assets that these three major economic players bring to the discussion, as well as their willingness to combine these assets in support of advanced energy technologies, will to a large extent shape the opportunities for sustained expansion of the advanced energy economy in Tennessee.

Since its creation in the 1930s, the Tennessee Valley Authority has played a major role in the growth of Tennessee's manufacturing base and, more recently, in efforts to reduce the volume of sulphur and carbon emissions in the state's air. Owned by the U.S. government and financed from ratepayer revenues, TVA's mission includes use of the agency's resources to improve environmental quality and foster economic development. The scope of TVA's energy portfolio makes it possible to pilot, incentivize and evaluate a variety of innovative clean technologies including superconducting transmission cable, smart grids, next-generation

batteries and solar panels, and appliances for low-energy homes.

Increasingly, Tennessee's inventory of clean technologies is the beneficiary of breakthrough discoveries at Oak Ridge National Laboratory, the nation's largest energy research institution. The presence of new facilities such as the Spallation Neutron Source and the nation's most powerful supercomputer have placed the Laboratory at the forefront of innovation for biofuels, energy storage, solar technology and nuclear power. A close relationship with the University of Tennessee has resulted in the Laboratory becoming a vital part of the state of Tennessee's economic strategy with successive governors.

In many respects, the initiatives of both TVA and Oak Ridge National Laboratory are responsive to efforts by Tennessee's automotive manufacturers to promote clean technologies, both in their products and in the operation of their manufacturing facilities. In Smyrna, Nissan has made a historic investment in the design and manufacture of batteries and electric cars in Tennessee. In Chattanooga, Volkswagen operates Tennessee's largest solar park, where 13 million kilowatt hours are produced annually to power 12 percent of the enormous manufacturing facility.[13] Each of Tennessee's automotive manufacturers is looking over the horizon to innovative technologies and materials such as carbon fiber that will reduce weight and increase fuel efficiency.

The last decade has witnessed a growing willingness among the three major entities in Tennessee's energy economy to partner in the deployment of innovative technologies. In one of the most creative initiatives, TVA, Nissan and Oak Ridge National Laboratory joined to explore a variety of issues that accompany the charging and energy storage of electric cars. The TAEBC *Roadmap* views the ability to replicate this kind of cooperation as a key factor in expanding Tennessee's clean technology economy.

While the automotive sector represents what may be the single largest opportunity to expand the use of advanced energy technologies, significant opportunities also exist within other key clusters in which Tennessee, because of geography and a mature industrial base, has a competitive advantage. Examples include logistics, transportation and distribution services, chemical products and plastics, and advanced manufacturing.

Tennessee's Foundation for Advanced Energy

Tennessee over the last decade has laid a solid foundation for the continued development of the state's advanced energy economy. A 2010 study conducted by the Brookings Institution identified Tennessee, with more than 76,000 jobs, as having the nation's 14th largest "clean economy."[14] For the purposes of developing an advanced energy roadmap, the relevant technologies include the manufacture, distribution, installation and service of products designed to diversify energy sources, mitigate pollution, and reduce greenhouse gas emissions. In Tennessee the industry also includes a substantial research and development sector dedicated to enhancing the potential to expand the integration of advanced energy technologies into the state's economy. Using this broader definition of "advanced energy technology," the industry represents a diverse workforce that includes scientists exploring new techniques to produce biofuels, workers manufacturing electric car batteries, and technicians installing solar panels.

In addition to the more conventional technologies, nuclear power also occupies a unique role in the state's advanced energy inventory. While it does not qualify as a renewable energy source, nuclear energy represents to many an acceptable alternative to the production of power by fossil fuels. Approximately one-third of the state's electricity is generated by nuclear power, with just under one-half produced by coal-fired plants. Regardless of one's perspective on nuclear power, its presence in Tennessee's economy, and the likelihood that it will remain a major part of Tennessee's energy inventory for some time, are reasons for its inclusion in the advanced energy discussion.

Finally, advanced energy technologies are not limited to the category of energy production. An array of innovations designed to reduce energy consumption are a critical component of efforts to reduce both power costs and carbon emissions. Many of these energy-efficiency technologies are already in the marketplace and have been adopted by Tennessee power consumers. Significantly, these innovations include advanced fossil fuel technologies - some manufactured in Tennessee. While they do not represent a replacement of existing fossil fuel power, their ability to reduce the volume of fossil fuels required for power generation and accompanying carbon emissions is an important contribution to the advanced energy inventory.

The absence of a universally accepted definition of advanced energy jobs compromises efforts to measure the industry in every state, including Tennessee. Further complicating the task is the presence in existing industries and supply chains of advanced energy jobs that are not always captured by data surveys. Both factors contribute to the lack of a comprehensive central data source to receive and distribute information on advanced energy technologies. Despite these limitations, the Brookings study represents a reasonable snapshot of the advanced energy jobs in Tennessee.

As with most data, an attempt to characterize Tennessee's advanced energy economy requires interpretation. Entitled Sizing the Clean Economy, the Brookings Institution's 2010 study identified all employment in "the sector of the economy that produces goods and services with an environmental benefit." Using this liberal definition, Brookings estimated the presence

in Tennessee of approximately 76,000 advanced energy jobs. At 2.8 percent of the statewide workforce, the total was the sixth-highest concentration of clean technology jobs in the country.

Table 1: Brookings Advanced Energy Jobs Estimates, 2010

Category	Number of Jobs	Percent of TN Advanced Energy Economy
Greenhouse Gas Reduction, Environmental Management, and Recycling	33,411	44%
Energy and Resource Efficiency	25,794	33%
Education and Compliance	7,700	10%
Agricultural and Natural Resources Conservation	5,544	7%
Renewable Energy	3,582	5%
Total	**76,031**	**100%**

In Table 1, a closer look at Tennessee's advanced energy jobs indicates that 44 percent are found in Greenhouse Gas Reduction, Environmental Management, and Recycling, a category that includes waste collection and recycling and - unique among most states - a multi-billion dollar environmental remediation project in Oak Ridge funded by the Department of Energy to remove legacy wastes generated at nuclear facilities during the Manhattan Project and the Cold War. While the decontamination and demolition efforts in Oak Ridge have a clear environmental benefit, much of the work, including security and other support personnel, would not fall within more conventional definitions of "advanced energy jobs."

More consistent with these conventional definitions is Tennessee's second-largest advanced energy technology category, Energy and Resource Efficiency, with approximately 25,800 jobs. The segments with the most jobs in this category were Professional Energy Services (8,400), HVAC and Building Control Systems (6,800), Appliances (3,500) and Energy-Saving Building Materials (3,100).

The Renewable Energy category comprised approximately 3,600 jobs, found primarily in the Hydropower (2,200) and Solar Photovoltaic (1,000) categories.

Additional segments that often fall within the category of "advanced energy technologies" in Tennessee were generally small but growing. The Electric Vehicle Technologies segment increased from no jobs in 2003 to 184 jobs in 2010, a number that did not reflect the transition of Nissan's Smyrna plant in 2013 to the manufacture of electric cars. Wind increased from none to 209, and Biofuels/Biomass increased from 15 to 70 during the same period. Significant job growth in advanced energy jobs also occurred in the categories of professional energy services and regulatory compliance.

The Economic Impact of a Growing Renewable Sector

While still small in relative terms, expanded use among both small and large businesses indicates that the manufacture and adoption of renewable energy technologies will play an expanded role in Tennessee's power generation. From the Volkswagen assembly plant in Chattanooga to family-owned Wampler's Farm Sausage in Loudon, advanced energy technologies, including a growing number in the renewable sector, are an increasing presence within Tennessee's commercial and industrial economy.

Despite these notable successes, considerable opportunity exists to expand the state's renewable energy portfolio. Indeed, Tennessee's relative progress in adopting renewable energy depends to a large extent upon one's perspectives regarding the appropriate role of hydroelectric power, whether and how nuclear power plays a part in a clean energy discussion, and if wind power will be purchased from outside Tennessee and included in the state's renewable portfolio.

In February 2014, TVA generated or bought just over 1.2 million megawatt hours of renewable power, including hydroelectric production, wind contracts from the Midwest, solar, landfill methane, and biomass. The total represented more than 15 percent of the state's electricity from renewable sources, a figure slightly above the U.S. average. The ratio is somewhat distorted, however, by the fact that much of Tennessee's current inventory of renewable energy is not the result of recent efforts to promote renewable energy or reduce energy consumption. Some 89 percent of Tennessee's renewable energy inventory comes from power generated at TVA dams built in the mid-twentieth century. Biomass constitutes 10 percent with wind and solar together only about 1.0 percent of the state's renewable energy sources. The primary role of biomass is in electricity generation, largely in the form of industrial combined heat and power operations that use wood biomass as the fuel source. Stated differently, just over one percent of Tennessee's power is generated by renewable sources other than hydroelectric dams.[15]

The 2014 snapshot does not fully capture the beginnings of a nascent renewable energy industry that appears to be taking root in Tennessee, influenced in part by the state's geography. While wind patterns in Tennessee do not offer the same opportunity for power generation as enjoyed by states in the Midwest and Southwest, the Department of Energy estimates that potential capacity for wind power could be as high as 5,000 megawatts.[16] Since 2010, TVA has opted to purchase more than 1,500 MW of power generated by wind turbines located outside the Tennessee Valley.

Also, TVA has approximately 131 MW of solar power in operation or in process of construction.

Researchers at Oak Ridge National Laboratory believe Tennessee's potential for solar power generation is roughly 80 percent than of states such as Arizona and Nevada, certainly enough sunshine to provide a credible foundation for expansion of the solar industry.[17] Likewise for biomass, studies conducted by the University of Tennessee indicate the state has approximately one million acres of marginal land - not suitable for food crops such as corn but ideal for growing biomass crops such as switchgrass that require less water and fertilization.

As much as any aspect of the renewable economy, both biomass and solar energy have been

vulnerable to market forces and government policies that to a large extent have remained unpredictable. Four factors - electric rates, installation costs, incentives, and tax rates - directly influence the demand for solar energy in Tennessee. Similarly, the commercial viability of biomass is determined not only by the fluctuating cost of gasoline, but also by the cost of producing biofuels, a challenge linked closely to the need and potential for technological breakthroughs. Among the most important of these factors is the Renewable Fuel Standard, a requirement from the Environmental Protection Agency that set amounts of biofuels be mixed in the fuel supply. An EPA proposal issued in November 2013 that would lower renewable fuel obligations has generated debate between biofuels supporters and the petroleum industry.[18]

A brief overview of renewable energy technologies in Tennessee provides the backdrop for investment and policy decisions by business and government.

Solar Energy – An advanced energy sector with substantial potential to expand, solar energy was not fully represented in the Brookings 2010 data. In 2013, Tennessee installed 25 MW of solar electric capacity, with approximately $109 million invested to install solar panels for residential, commercial, and utility use. Perhaps equally significant, the cost of average installed residential and commercial photovoltaic systems fell by four percent.

The 2012 National Solar Jobs Census reported that Tennessee is home to 125 businesses in the solar manufacturing, installation, sales and distribution, project development and “other” sectors.[19] The largest sectors in Tennessee’s solar supply chain are 57 installation companies, along with 31 in the manufacturing sector producing purified silicon, specialty solar glass, solar panels, balance of systems components, racking materials, and specialty solar products. A large portion of Tennessee’s solar companies are less than five years old with fewer than 25 employees.

Some of Tennessee’s solar companies have grown rapidly. Signal Energy of Chattanooga has expanded from a startup in 2005 to a business with 125 employees and annual revenues of more than $100 million. Similarly, since the company’s founding in 1996, Shoals Technologies Group of Portland has become one of the state’s largest companies to provide balance of system components for the solar industry.

Despite the relative success of these and other solar companies, the solar industry in Tennessee - as in many states - has been vulnerable to global forces that on occasion have provided unanticipated challenges, particularly to large manufacturing facilities. Meanwhile, severe fluctuations in European demand and Chinese supply have been balanced to some extent by a parallel decline in the cost of solar equipment and installation, leading to what some believe will be a gradual increase in consumer demand for the solar industry in Tennessee.

The global market is showing signs of rebounding. Major polysilicon producer Wacker Chemie reported an 11 percent increase in polysilicon sales in the first quarter of 2014, compared to the same quarter a year ago, as sales were bolstered by the strong recovery in global PV demand.

Wacker reiterated that the company’s new polysilicon plant in Cleveland, Tennessee, would be completed by the middle of 2015, with production expected to begin in the third quarter of 2015.[20]

The solar industry's growth in Tennessee has been promoted through focused efforts by the state of Tennessee, the Tennessee Valley Authority, Oak Ridge National Laboratory and the University of Tennessee. The goal of the collaboration is to drive innovation and to incentivize the solar industry as a means of both reducing fossil emissions and creating the foundation for long-term growth of a relatively new advanced technology industry.

The state of Tennessee has promoted renewable technologies through the Volunteer State Solar Initiative, funded by the U.S. Department of Energy and operated by the University of Tennessee. The 5-megawatt West Tennessee Solar Farm in Haywood County, one of the Southeast's largest solar installations, is a demonstration project that distributes power through TVA and the local electric cooperative. A second program, the Tennessee Solar Institute, funded the installation of 6.7 megawatts of solar power to more than 150 businesses and supported the development of the state's solar business supply chain.[21]

Wind Energy – While only a relatively small amount of wind power is generated in Tennessee, wind power's relative percentage of the state's power capacity could expand significantly. TVA's existing wind power site is located on Buffalo Mountain near Oak Ridge, with 15 large turbines and three smaller ones. Owned by Invenergy, the wind farm has a capacity of 29MW, enough to power approximately 3,800 homes.

In the near term, wind power's relative position in Tennessee's energy portfolio will be determined to a large extent by TVA policy decisions. As of January 2013, TVA had nine contracts to import 1,515 megawatts of wind power from the Midwest. Whether and how much Tennesseans increase their consumption of wind power will depend upon a number of financial and policy decisions, some to be resolved by TVA and others by external stakeholders who will evaluate the construction of power lines needed to transport wind power from the Southwest to Tennessee.

Clean Line Energy Partners of Houston, Texas, has entered a memorandum of understanding with TVA to deliver wind power from Oklahoma and Texas to Tennessee. Approximately $300 million will be invested in transmission facilities in western Tennessee that will support the project and its delivery of energy. This will generate millions of dollars in tax revenue that will benefit Tennessee.[22]

Prior to completing what would be America's largest power transmission line, the $2 billion proposal must receive an environmental impact evaluation from the U.S. Department of Energy as well as right of way approval through Arkansas. The project's first phase is designed to deliver 3,500 megawatts, comparable to the energy consumption of one million homes.[23]

Tennessee's Bioeconomy – A study conducted by the University of Tennessee concluded the state has the potential to produce more than one billion gallons of ethanol on an annual basis, a volume capable of replacing 30 percent of the state's current petroleum consumption. A combination of efforts by the Department of Energy, the state of Tennessee, the Memphis Bioworks Foundation, and private industry has laid the foundation for the development of biofuels as a significant sector in Tennessee's clean energy economy. Due in part to an extended period of uncertainty generated during the economic downturn in 2007-2011, anticipated

corporate investments in biofuels - like comparable investments in the solar industry - have been deferred in Tennessee pending a more stable national market for biofuels.

Meanwhile, many of the components are in place to sustain a biofuels industry in Tennessee. In 2007, the state legislature appropriated $70.5 million for the University of Tennessee Biofuels Initiative. The approach was comprehensive. Multi-year contracts with farmers helped establish a dedicated energy crop with 5,000 acres of switchgrass, a product that can produce 6-8 tons per acre on marginal land. The goal was to develop and commercialize cellulosic biofuels, which researchers view as a viable way to produce affordable alternatives to fossil fuels without raising food or feed costs. A partnership with Oak Ridge National Laboratory was dedicated to improving technologies used to create cellulosic ethanol and reduce the costs of biofuels production.

After the Biofuels Initiative program expired in June 2012, two companies were formed to carry on the initiative's vision. Genera Energy provides integrated, commercial biomass supply solutions for the advanced biofuels, biopower, and biobased products industries; TennEra conducts general research and development focused on technologies and processes for biomass fractionation, or separating cellulosic biomass components and commercial application of biorefinery co-products.

One of Tennessee's most valuable biofuel assets is the Biomass Innovation Park research campus, located in Vonore, capable of producing 250,000 gallons of biofuels annually. Genera designed and built the Biomass Innovation Park to be the country's leading research and development facility for demonstrating and optimizing the feedstock supply chain.[24] In operation since 2011 and operated exclusively by Genera Energy, the Biomass Innovation Park is the nation's only commercial facility that can perform all the processes necessary to bridge "the farm gate and the biorefinery gate," ranging from biomass receiving and inventory management to size reduction and characterization.

A second major biofuels asset is the BioEnergy Science Center, located at Oak Ridge National Laboratory and funded by the Department of Energy. Established in 2007 with a research budget of $25 million annually, the Center works closely with the University of Tennessee and is dedicated to accelerating research toward the development by 2017 of advanced biofuels that can be produced at $3.00 per gallon. Breakthroughs in "cellulosic recalcitrance," or the ability of cells to resist the creation sugars used in making biofuels, would greatly reduce the cost of biofuels production and potentially lead to a sharp rise in consumer demand for biofuels.[25]

Also supporting the Tennessee bioeconomy is the Southeast SunGrant Center located at the University of Tennessee and funded by the U.S. departments of Agriculture, Energy, and Transportation. The SunGrant Initiative's mission is to revitalize rural communities with land-grant university research, education, and extension programs that focus on renewable energy and biobased, non-food industries.[26]

In West Tennessee, BioDimensions and the Agbioworks Regional Initiative of the Memphis Bioworks Foundation are leading supporters of bioenergy. Working through two subsidiary businesses, BioDimensions is focused on bringing biobased products to market. The first,

BioDimensions Renewable Oils, produces brassica oilseed crops for use in advanced biofuels.

The second, BioDimensions Delta BioRenewables, is working on processing sweet sorghum and energy beets for biobased products, such as ethanol. The Agbioworks Regional Initiative is committed to developing the "sustainable use of agricultural and forestry products to supply abundant food, biofuels, and biobased products." In 2009, the initiative completed the Regional Strategy for Biobased Products in the Mississippi Delta, a plan for developing a biobased economy in 98 counties of the Mississippi Delta.[27]

In addition to cellulosic ethanol, Tennessee is home to both corn ethanol and biodiesel plants. Two plants produce corn ethanol. Green Plains Renewable Energy operates a 120-million-gallon ethanol plant in Obion. Tate & Lyle operates a 105-million-gallon ethanol plant in Loudon. Biodiesel firms include Green Gallon Solutions in Cookeville and Sullens Biodiesel in Morrison. Each company produces in excess of two million gallons of biodiesel fuel annually.

Tennessee's bioeconomy also includes an expanding number of Tennessee's companies and municipalities seeking to reduce utility costs and the use of fossil fuels through the adoption of advanced energy technologies. An abundance of biomass in Tennessee's rural communities presents opportunities for the adoption of advanced energy technologies. In Lenoir City, ARiES Energy employs technologies capable of using almost any cellulosic material to generate power. Using a combination of solar energy and a 500-kilowatt biomass to energy gasification system, one of the region's oldest companies, Wampler's Farm Sausage of Loudon County, became a net-zero user of energy with no greenhouse gas emissions. Similarly, in Covington, PHG Energy of Nashville has installed a downdraft gasification system that uses recycled waste to generate power and save a substantial amount on annual utility bills.

Electric Vehicles – Another area of anticipated growth not fully represented in the 2010 Brookings study is the manufacturing of electric vehicles and electric batteries. In the fall of 2012, Nissan's manufacturing complex in Smyrna began producing 600-pound lithium-ion battery packs that fit into the bodies of the company's new electric car at the nearby vehicle assembly plant. The Smyrna battery plant is the largest lithium-ion auto battery factory in North America, employing 300 workers who produce battery packs for 2,000 cars a month. Should future sales meet Nissan's projection, the plant could expand employment to produce 200,000 battery packs annually.

Nissan began U.S. commercial production of the LEAF electric vehicle in January 2013 at its Smyrna, Tennessee manufacturing facility. With more than 100,000 vehicles sold, the Nissan LEAF is the world's largest selling electric vehicle. The Smyrna plant is expected to produce 150,000 vehicles annually by 2020.[28]

Nuclear Power – TVA's three nuclear plants generate approximately 6,600 megawatts of electricity, roughly one-third of Tennessee's energy total and enough electricity to power three million homes. The ratio is certain to grow with the continued closure of coal-fired plants and the addition in 2015 of a reactor at the Watts Bar plant. A strategy that simultaneously seeks to expand energy capacity and improve air quality cannot ignore the state's carbon-free nuclear industry. As evidence of the state's nuclear future, the Department of Energy is looking at

Tennessee as the potential site for the first of a new generation of nuclear reactors, much smaller in size and much cheaper in cost than conventional nuclear power plants. Patterned after the power source of nuclear submarines, “Small Modular Reactors” produce about 125 megawatts, can be operated in groups of one to six at a site, and are small enough to be loaded onto a rail car. TVA has submitted a license application to the Nuclear Regulatory Commission for the first Small Modular Reactor to be located near Oak Ridge. The Department of Energy has continued funding of the Small Modular Reactor program, with approximately $18 million allocated in 2014 to assist in design development.

During the design phase, the ability to attract private sector investors to finance a “first of its kind” technology will be a key component of the project’s viability.

Advanced Fossil Fuel Technology – Despite increased focus on renewable energy technologies, thermal power plants will continue to represent a major sector of Tennessee’s electricity production for the foreseeable future. Meanwhile, environmental regulations and public demand have combined to drive the development of advanced fossil fuel technology for existing coal-powered plants.[29] These technologies include steam turbines, turbogenerators, boilers, air quality control systems, and new methods for carbon capture and storage (CCS), all designed to improve efficiency and reduce carbon emissions.

The capture and permanent underground storage of carbon represent an essential part of the strategy for meeting future carbon emission reduction targets. Alongside the increased share of renewables, carbon capture technologies will bring competitive, flexible and sustainable clean power to the future low-carbon systems. Alstom, with two locations in Tennessee, is a leader in carbon capture technology. With projects ready for large-scale demonstration, Alstom anticipates commercialization of carbon capture technology by 2020.

Energy Efficiency – The growing ability of advanced energy technologies to generate power is supplemented by comparable progress in efforts to use similar innovations to reduce energy consumption. In Tennessee, the most significant progress in energy efficiency and demand response has been led by the Tennessee Valley Authority. In 2007, the TVA board adopted plans to promote energy efficiency and reduce consumer demand. The goal was renewed in 2010 with a commitment to become the South’s leader in energy efficiency. TVA established the “EnergyRight Solutions” program to encourage residential, business and industrial sectors to help TVA meet annual targets for efficiency and demand response through a combination of rebates, incentives, finance options, energy audits, and technical assistance to qualified contractors.

In 2012, TVA achieved 560 gigawatt hours of energy savings through the EnergyRight Solutions program. Since the launch of the EnergyRight Solutions program in 2008, more than 3,000 homeowners and 150 businesses have participated in the program. Approximately 1,600 gigawatt hours of energy needs to be avoided in the Tennessee Valley - the equivalent of a 900-megawatt power plant.[30]

Tennessee’s advanced energy economy is supported by the use of energy savings performance contracting (ESPC). ESPC enables building owners to reduce capital expenditures by using future

energy savings to pay for up-front costs of energy efficiency projects. The contract mechanism includes securing engineers to identify and evaluate energy-saving opportunities, development of engineering designs and specifications, arranging financing, management of the project to installation, and training staff for ongoing maintenance services. ESPCs have proved to be an effective tool for industry and government to upgrade or replace aging infrastructure with clean, efficient technologies that reduce the full life cycle cost of products such as HVAC systems.[31]

For example, The University of Memphis saved more than $1.1 million dollars annually over the 12-year contract by installing improved lighting, variable refrigerant systems, advanced steam trap and de-aerators, ultraviolet lighting, the treatment of cooling tower water, and boiler control upgrades. In the medical sector, Mountain State Health Alliance realized savings of more than $5 million through ESPC by installing energy management control and mechanical upgrades, lighting retrofits, cooling tower bypass piping, and the replacement of the incinerator and kitchen heaters.

The Emerging Use of Advanced Energy Technologies in Tennessee

Over the past decade, a variety of business and government consumers in Tennessee have begun to adopt advanced energy technologies at an accelerated pace. Equally significant is the fact that the use of advanced energy technologies has not been limited to large corporations or governments with substantial financial resources available for initial investments. A representative snapshot reveals that a variety of energy consumers in Tennessee, from the largest to the smallest, have adopted energy-saving technologies to lower utility bills, reduce the volume and cost of waste generation, and reduce their respective carbon footprint.

Technology: Waste to Energy Gasification

City of Covington

In 2012, the City of Covington contracted with PHG Energy of Nashville to construct a $2.5 million waste-to-energy gasification plant. Financed with Tennessee Municipal Bonds, the project was designed to convert wood trimmings and sewer sludge to electricity to offset 125 kW of energy used previously by the city's waste water treatment plant. The system's 12 ton-per-day capacity uses a downdraft gasifier to supply some 6 million Btus of producer gas per hour as the central technology. The gasifier enables the city to avoid the landfill cost of disposing approximately 10 tons of urban wood waste and two tons of sewer sludge each day.

Wampler's Farm Sausage, Loudon

One of the region's oldest privately-owned businesses uses locally-grown switchgrass as a feedstock to produce power from the hydrogen on-demand system. The PPI CHyP System is supplemented by 530 kW of solar photovoltaic panels installed in 2009 and 2011. The installation includes a series of CHyP Engines integrated into a fully automated process. Each individual CHyP Engine can produce enough hydrogen gas to generate 500 kW. The CHyP units are paired with a series of 375 kW gensets that provide power directly to the sausage manufacturing facility.

Technology: Solar Power

Campbell County Government

The installation in 2013 of 50-kilowatt solar systems at twelve schools has enabled Campbell County to generate additional funds for the county's school system. Working with Efficient Energy of Tennessee, the county signed a 20-year contract with TVA to purchase the power generated by the solar panels. The annual revenue stream from the solar panels is sufficient to pay for the 15-year cost of installation and annual maintenance, with funds left over dedicated to education. Campbell County anticipates the solar investments will produce nearly $1 million in additional revenues over the 20-year life of the project.

Volkswagen, Chattanooga

In January 2013, Volkswagen dedicated the largest solar installation at an automotive manufacturing facility in the United States and the single biggest solar installation in Tennessee. The 9.5 Megawatt solar system, built and operated by Silicon Ranch and Phoenix Solar, provides 12 percent of the power required for Volkswagen's massive Chattanooga assembly plant when in operation, and 100 percent of the power when not in operation.

Technology: Advanced Lighting

Thompson-Boling Arena, University of Tennessee, Knoxville

One of the nation's largest basketball arenas has installed an advanced energy technology, developed at Oak Ridge National Laboratory, featuring lights that are smaller, brighter and up to 85 percent more efficient than conventional arena metal halide lights. Developed by Oak Ridge-based LED North America and installed by Bandit Lites of Knoxville, the lights can be turned on or dimmed in seconds. Cooled by graphite foam, another ORNL technology, the ninety 400-watt LED lights produce 200 foot-candles per square foot, compared to the 130-foot candles output in the arena's previous lights.

Technology: Natural Gas as a Transportation Fuel

Pilot Flying J, Knoxville

The demand for compressed natural gas (CNG) is growing as an alternative fuel source. In 2010, Clean Energy Fuels Corp signed an agreement with Pilot Travel Centers of Knoxville to build, own and operate public access, compressed, and liquefied natural gas.

Technology: Smart Buildings

Nissan Paint Plant, Smyrna

Nissan's new paint plant is projected to be 30% more energy efficient than the body-on-frame plant it replaced. The new plant was designed and constructed with energy efficiency as part of the specification and replaces a vehicle paint plant that had been in operation since 1981.

Schneider Electric, Smyrna

Schneider Electric's Smyrna plant manufactures medium voltage switch gear and also houses a design center for engineered-to-order switchgear. In April 2013, the plant became certified under DOE's SEP program. SEP requires facilities to adopt ISO 50001, the international energy management standard, and demonstrate verified energy performance improvements of at least 5% over a three-year period. Through the adoption of SEP, the company documented an energy intensity improvement of 16% between 2008 through 2011. Efficiency measures have resulted in another 15% reduction in natural gas usage at the facility.

Technology: Pollution Control

Alcoa Aluminum, Alcoa

The aluminum industry, including associated power production, is responsible for about 1 percent of all man-made GHG emissions. Alcoa-Tennessee has reduced greenhouse gas emissions by 3.1 million metric tons, or 7 percent. The company established a new goal to reduce 2005 levels of total carbon dioxide equivalent (CO2e) intensity (refining and smelting) by 30 percent by 2020 and 35 percent by 2030.

Advanced Energy Innovations

A variety of new advanced energy technologies, developed and tested in Tennessee, offer business and government the opportunity to lower power costs, reduce the volume of fossil fuel emissions, increase the use of renewable energy sources, and stimulate the growth of advanced energy jobs.

TAEBC's effort to promote the expanded use of advanced energy technologies has the advantage of extensive support from one of the nation's most robust programs of energy research and innovation. The state's Carnegie I research institution, the University of Tennessee, since 2000 has been the co-manager of Oak Ridge National Laboratory. With a $1.6 billion budget, ORNL is the Department of Energy's largest energy research laboratory. The university and the laboratory have established a close working relationship, resulting in research partnerships that include biofuels, nuclear energy, and a variety of energy-related topics associated with the development of advanced materials. Aided by America's most powerful supercomputer and the Spallation Neutron Source, the world's foremost facility for the study of materials, The UT-ORNL partnership has emerged as a leading center of innovation for advanced energy technologies.

This innovation asset has been embraced by the Tennessee Valley Authority, which serves as a platform for testing many of the energy-saving technologies, and the state's automotive industry, which views the development of new lightweight materials and low cost biofuels as critical to their continued competitiveness in the international market place. Over the past decade, an increasing number of research and demonstration partnerships involving TVA, ORNL, UT, and the state's leading automotive companies have supported the innovation and deployment of new energy technologies and served to shape the landscape for future investments in Tennessee's advanced energy economy.

Against the backdrop of this unique collaboration among four of Tennessee's largest entities, the TAEBC *Roadmap* identified nine goals that together would represent a substantial expansion of Tennessee's advanced energy economy. In each instance, the goals are accompanied by a representative sample of innovative advanced energy technologies - either in the marketplace or in advanced stages of development - that provide business and local government with a growing potential for reduced energy consumption, expanded use of renewable energy, and economic investment.

1. Reducing power costs through greater energy efficiency

Resource: Oak Ridge National Laboratory, TVA

Commercial and industrial buildings consume about 73 percent of electricity and 55 percent of natural gas, a largely untapped opportunity for the deployment of energy-saving technologies. A variety of affordable technologies in the ZebrAlliance project coordinated by ORNL and TVA demonstrate the opportunity for substantial reductions in both energy use and cost. Even for lower-income residential consumers, advanced energy technologies provide the ability to build and operate low-cost homes with low or even net zero energy costs, meaning that the house produces more electricity that it consumes. The advanced energy technologies

already available on the market for both commercial and residential buildings include:

Water Heaters – Tennesseans spend from $200-600 annually on heating their water. An advanced energy technology developed at ORNL in cooperation with General Electric enables consumers to use less than one-half the energy of a conventional 50-gallon tank water heater. In Ashland City, A.O. Smith, a company with seven decades' experience, manufactures some of the most energy-efficient water heaters available, including a tankless water heater that measures less than two cubic feet. A.O. Smith has an array of new advanced energy water heaters in late stages of innovation.

Geothermal Heat Pumps – The development of a variable speed enables the heat pump to use only the energy required instead of running at a constant speed. The heat pump can power heating, air conditioning and water heating from a single source, with cost savings as much as 65 percent.

Commercial Roofing – Over the past decade, energy efficiency research has been focused on "cool roofing," which utilizes light-colored materials such as thermoplastic polyolefin to reflect sunlight and solar energy away from a building to keep it cooler. By simulating building energy consumption based on the type of roofing membrane and amount of insulation installed, a Cool Roof Calculator helps consultants, architects, roofing contractors and facility managers determine the most efficient and cost-effective roof system for a particular building.

Combined Heating and Power (CHP) – CHP is the production of two forms of useful energy - typically electricity and heat - from a single fuel source. CHP offers benefits to commercial and industrial users in terms of energy efficiency and emissions reductions by optimizing the use of heat that would otherwise be wasted when generating power.

2. Expanding the use of solar energy

Resource: Oak Ridge National Laboratory, University of Tennessee

Commercial and residential investments in solar energy have been limited in part by costs associated with installation, efficiency and maintenance. Reducing these costs involves some of the most fundamental questions in chemistry, physics, and material science. Working in cooperation with the Department of Energy's SunShot initiative, UT and ORNL are making solar energy increasingly cost-competitive with other forms of electricity.

Self-cleaning Solar Panels – Surface obstructions such as dust and sand can reduce the reflectivity of solar panels and the efficiency of PV cells by as much as 50 percent. Scheduled routine manual cleaning and brushing with deionized water has been a costly and labor-intensive solution. To reduce cost and enhance efficiency, ORNL is developing a low-cost, transparent, self-cleaning coating that can be applied on most surfaces using conventional painting or spraying methods.

Avoiding the Shade – University of Tennessee and ORNL researchers are developing an advanced "Cascaded H-Bridge Inverter" that adjusts to transient shading conditions and provides maximum value of power output available to solar systems.

"Plug and Play Solar Systems" – As the costs of solar PV modules continue to fall, "soft" costs and other non-module hardware costs, such as electronics and mounting hardware, now account for as much as one-half of the total costs of solar systems. The Department of Energy has funded the development of "plug-and-play" photovoltaic (PV) systems that can be purchased, installed and operational in one day. The Department's goal is to spur solar power deployment by reducing non-hardware, or "soft" costs, such as installation, permitting, and interconnection.

Reducing Solar's "Soft Costs" – The Department of Energy estimates that "soft costs" often represent as much as 64 percent of the total cost of installing solar panels. During Phase I of the U.S. Department of Energy's Rooftop Solar Challenge, the University of Tennessee team set out to make solar power more accessible in four jurisdictions across Tennessee by streamlining permit processes, updating planning and zoning codes, improving standards for connecting solar power to the electric grid, and increasing access to financing. The four jurisdictions included Knoxville, Franklin, Nashville, and Memphis.[32]

3. Increasing the role of hydroelectric power

Resource: TVA

Producing 11.7 million MW in 2013, TVA's 29 hydroelectric dams represent roughly 90 percent of Tennessee's renewable energy portfolio. As in other renewable energy sectors, TVA's adoption of new technologies will expand the capacity of hydroelectric power.

Hydro Turbines – TVA has installed a new generation of hydro turbines in 59 of the 110 hydro units in the utility's hydroelectric fleet, some of which are more than 70 years old. Each of the new units increases total power capacity by 22 megawatts. Modernization of the hydroelectric dams has added 531 MW to the TVA system.

4. Increasing options for renewable energy through better battery storage

Resource: Nissan, Oak Ridge National Laboratory

One of the greatest obstacles to expanded use of renewable energy technologies such as solar, wind, and electric vehicles has been the limits of power storage in conventional batteries. To casual observers, batteries inside a package may appear to be a simple product. In fact, from a chemical perspective, batteries are an extremely complex combination of materials that hold the key to the viability of a range of advanced energy technologies, from electric vehicles to wind and solar energy. Anticipated breakthroughs in battery storage technology will redefine the potential for the renewable energy industry.

Vehicle Batteries – Tennessee-based Nissan North America has announced plans to expand the range of its electric vehicles by approximately 50 percent. Due out in 2016-17, the new battery technology would boost the current battery from 24 kilowatt hours to 36, extending the vehicle's range from 84 to 130 miles. An even larger 42-kWh battery pack would yield a range of 150 miles.[33]

Longer Lived Batteries – Working with components 100,000 times thinner than a human hair, researchers at ORNL have developed a new generation of all-solid lithium-sulphur batteries. The innovative low cost battery has approximately four times the energy density of conventional lithium-ion technologies.

5. Developing biomass and biofuels for the state's rural communities

Resource: Oak Ridge National Laboratory, University of Tennessee, Memphis Bioworks Foundation

As the biofuels industry responds to turbulence in international markets, researchers in Tennessee continue to make breakthroughs in the design and potential uses of biofuels. The innovations are of particular importance to Tennessee's rural counties with agriculture-based economies.

Blended Fuels – A start-up company has licensed an Oak Ridge National Laboratory technology that directly converts ethanol into a hydrocarbon blend-stock for use in transportation fuels. The blend-stock can be mixed with gasoline at higher concentrations than ethanol's current limit of 10 percent and can also be added to diesel and jet fuel. The technology will be in demand by existing corn-based ethanol production plants, as well as new refineries seeking to convert non-food crops such as switchgrass, poplar wood, and corn stover into biofuels.

Petroleum Substitutes – The University of Tennessee focuses on converting plant matter such as lignocellulose, found in the cell walls of energy crops, into biofuels. Using plant materials to take the place of plastics and other hydrocarbons in materials lessens the demand for petroleum and creates, in addition to biofuels, other products that are biodegradable with net reductions in carbon dioxide emissions.

Biomass Feedstock – In partnership with the University of Tennessee, Genera Energy participated in a five-year state-funded effort to demonstrate the economic feasibility a cellulosic ethanol industry. At the project's conclusion in 2012, Genera, renamed TennEra, focused on biomass crop production and supply chain logistics, partnering with the University of Tennessee Research Foundation to pursue commercial biomass supply opportunities. Meanwhile, the Regional Biomass Energy Feedstock Partnership, comprised of the University of Tennessee together with the U.S. Departments of Energy and Agriculture, seeks to produce biomass feedstock use to make ethanol at cost-competitive prices.

6. Modernizing the electric grid

Resource: TVA, Oak Ridge National Laboratory, University of Tennessee

An increasingly antiquated electrical grid at any point in time may be losing as much as 50 percent of the power transmitted. The result is an enormous added demand on an already strained system as well as the loss of hundreds of millions of dollars annually for Tennessee consumers.

Advanced Grid Technologies – Planning for the future of the electric grid requires anticipating the innovation and integration of a variety of new technologies on an existing grid system. TVA is working with research partners to understand and demonstrate new advanced energy technologies in transmission, energy storage, and renewable generation that will reshape the grid's operation. Included in this analysis is a licensed ORNL technology that provides real-time status of the grid and critical energy sectors that enables a more swift response to major power disruptions.

The Future Grid – The University of Tennessee's CURENT program, funded by the National Science Foundation and the Department of Energy, envisions a nationwide grid that is monitored and controlled to provide reliability, lower cost, and more full utilization of energy storage. Research areas include power conversion, integration of renewable energy resources into the grid, distributed generation and micro grids.

7. Improving fuel efficiency

Resource: Volkswagen, Ford, Chrysler, Oak Ridge National Laboratory, University of Tennessee

Tennessee's automotive industry, including a growing number of Tier 1 and Tier II suppliers, is looking to a number of advanced energy technologies to improve fuel efficiency demanded by government and consumers. The technologies include enhanced engine performance and new materials that will make possible significant reductions in vehicle weight and improvements in gas mileage.

Carbon Fiber – Some believe lightweight carbon fiber, made from the waste product of biofuels production, has as much potential as any advanced energy technology to contribute to Tennessee's economic growth. Working with a Carbon Fiber Consortium that includes Volkswagen and Ford Motor Company, ORNL researchers have developed carbon fiber that is 40 percent lighter with comparable strength as the aluminum and steel currently found in cars and trucks. Should the researchers succeed in manufacturing the carbon fiber at a competitive cost, the potential to dramatically reduce fuel costs in both the automotive and airline industries is enormous.[34]

High-Efficiency Engines – A partnership between ORNL and Chrysler is developing an advanced cast aluminum alloy for a next generation high-efficiency engine. In addition to being lighter than current engines, the new alloy for cylinder heads would be capable of sustaining higher pressure and temperature.

8. Extending the life and improving the efficiency of nuclear power plants

Resource: Oak Ridge National Laboratory, University of Tennessee, TVA

With more than one-third of Tennessee's electricity generated by nuclear energy, the state's economy will be affected by advanced energy technologies that will extend the life of existing reactors, reduce the volume of spent fuel generated, and enhance safety performance.

Reactor Simulation – Using ORNL's Titan supercomputer, capable of 27.000 trillion calculations per second, and data provided by TVA's Watts Bar nuclear plant, scientists at ORNL's Consortium for Advanced Simulation of Light Water Reactors have successfully completed the first full-scale simulation of an operating nuclear reactor. Understanding the reactor performance at increased levels of detail will make it possible to increase power output, extend the reactor's life, and reduce waste byproducts.

9. Making fossil fuels cleaner and more efficient

Resource: Oak Ridge National Laboratory, Volkswagen

Fossil fuels currently account for more than 80 percent of U.S. energy production and are projected to remain a significant energy source in the future. Advancements in fossil fuel technology will enable fossil fuels to remain competitive in a low-carbon economy. Accelerating the introduction of innovative, clean fossil energy technologies ready for deployment at commercial-scale will ensure access to affordable, clean energy from all domestic energy resources.

Clean Diesel – At Volkswagen, clean diesel technology delivers more torque, lower fuel consumption and reduces CO2 emissions compared with equivalent gasoline engines. Volkswagen's newest and most fuel-efficient TDI Clean Diesel engine will power the 2015 Golf, Beetle, Passat, and Jetta.

More Efficient Fossil Fuels – At ORNL, the Department of Energy sponsors research in low-carbon power systems and efficiency improvements for fossil-powered vehicles, including a broad suite of combustion engine lubrication and emissions testing services and equipment. Researchers use fluorescence spectroscopy to determine the amount of fuel dilution in engine oil, which can occur as fuel-efficient engines are operated in advanced combustion modes to meet increasingly lower emissions regulations.

Conclusions

The information contained in the Tennessee Advanced Energy Business Council's Roadmap for Tennessee's Advanced Energy Economy suggests a number of conclusions about both the challenges and opportunities for the growth of the state's advanced energy economy. Perhaps more than most states, Tennessee's energy profile has a number of unique characteristics. The ability to understand the origins of these characteristics, and, more importantly, how they relate to Tennessee's economic future, are critical factors in assessing how advanced energy technologies can play an expanded role in the creation of new jobs and the growth in the state's personal income.

1. **With a rank of fourth highest, per-capita residential energy consumption and 25th in commercial and industrial sectors in the nation, Tennesseans can deploy advanced energy technologies to help substantially reduce the amount of electric power they use without a compromise in their standard of living or business practices.** Decades of cheap, abundant power predictably produced a culture of consumption among Tennessee homes and businesses. Energy reduction efforts have been positive, but remain significantly less than in most other states. While for some consumers the adoption of advanced energy technologies is motivated by an effort to promote environmental sustainability, for others the decision is a simple desire to reduce power costs. The largely untapped energy efficiency sector offers the greatest opportunity for investments in affordable advanced energy technologies.

2. **Advanced energy technologies represent a growing sector of Tennessee's economy.** A number of indicators suggest a gradual and sustained growth in jobs associated with the manufacturing, installation and operation of advanced energy technologies, particularly in the sectors of energy efficiency, solar power, and electric vehicles. The fact that many of these new jobs reside in small businesses increases the possibility of advanced energy companies locating in the state's rural communities to service local demand.

3. **An increasing number of innovative technologies will be commercially available over the next five years.** Tennessee has an enormous inventory of advanced energy technologies at or near commercial viability. The presence of research capabilities at Oak Ridge National Laboratory and the University of Tennessee, an innovation platform provided by TVA's role as the nation's largest utility, and the desire for greater energy efficiency among the state's automobile industry, together form a unique opportunity to test advanced energy technologies and push them into the marketplace.

4. **Policy impacts the expanded use of some advanced energy technologies.** In this case, policy may be interpreted as corporate and governmental. The Roadmap illustrates an increased demand from the private sector to deploy advanced energy technologies into its processes or end products and the willingness of Tennessee businesses to incorporate advanced energy to increase competitiveness and save money. Some technologies hit policy challenges in that existing policy might create unnecessary barriers to market entry or public officials might need to reconsider entire systems in order to keep pace with market demand and innovation. For example, should breakthroughs in battery storage technology produce a

substantial increase in the number of electric vehicles, new demands will be placed on current technologies associated with the grid as well as electric transformers. Likewise, if carbon fiber technology can greatly reduce vehicle weight and improve fuel efficiency, states such as Tennessee may be forced to restructure a highway program whose funding is currently based upon the number of gallons of gasoline sold. The Environmental Protection Agency's draft rules to regulate carbon emissions from hundreds of fossil-fired power plants across the U.S. will impact market opportunities to deploy advanced energy technologies.

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