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RESEARCH REPORT

Economic Impacts of Advanced Energy

U.S. and Global Market Size, Economic Impact, Tax Revenue Generation, Key Trends, and Representative Companies

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Prepared for:

AEEI ADVANCED ENERGY ECONOMY INSTITUTE

EXECUTIVE SUMMARY

I. Quantifying the Size and Economic Impact of Advanced Energy

Advanced Energy Economy Institute (AEEI) is a nonprofit educational and charitable organization affiliated with Advanced Energy Economy (AEE), a national association of business leaders with the stated goal of making the global energy system more secure, clean, and affordable. The organizations define advanced energy as a broad range of products and services that constitute the best available commercial technologies for meeting energy needs today and tomorrow. AEEI commissioned Pike Research – a Part of Navigant – to perform, for the first time, a quantitative and qualitative analysis of the advanced energy markets in the United States and globally.

The advanced energy industry consists of seven distinct market segments associated with energy demand (Transportation, Buildings, and Industry) and energy supply (Fuel Production, Fuel Delivery, Electricity Generation, and Electricity Delivery and Management). These segments are further divided into 41 subsegments, each consisting of multiple product categories. This report draws upon over 60 previously published Pike Research studies, as well as information maintained by Navigant Consulting's Energy Practice, to build an assessment of advanced energy markets measured by revenue generated by the individual product categories, globally and within the United States. In addition, the contribution generated by domestic revenues to U.S. Gross Domestic Product (GDP) and tax revenues is quantified.

This analysis provides, for the first time, a comprehensive quantification of advanced energy today. However, the result must be viewed as a conservative assessment, for though this may be the most comprehensive study available to date, it is not necessarily complete. Identified subsegments or product categories that have not been independently studied by Pike Research or Navigant Consulting are not included, leading the size of some segments, such as the Industry segment, to be significantly understated. The market revenue for most subsegments is based on the total installed cost of the technology. However, some subsegments only measure vendor revenue from equipment sales, while others exclude revenue from multiyear projects still in development. Operations and maintenance revenue is likewise not included, nor are refurbishments. In addition, a few identified subsegments may have significant economic impact, but are not easily measured as distinct markets and are considered here only qualitatively. Finally, the economic impact in the United States includes only the domestic content provided into the U.S. advanced energy markets, not the positive impacts associated with U.S. exports into similar global markets. The opportunity remains for additional studies to complete and expand this assessment of advanced energy.

II. Global and U.S. Advanced Energy Markets

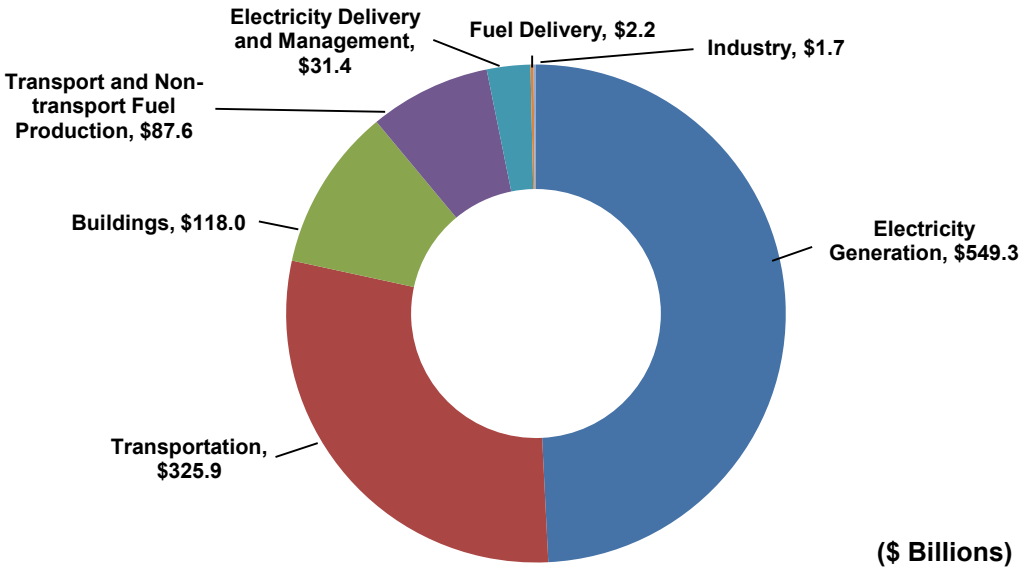
In 2011, global revenue from the seven advanced energy segments reached more than $1.116 trillion. The largest segment was Electricity Generation with $549.3 billion in 2011 revenues, accounting for 49% of the total, led by the Hydropower ($257.0 billion), Solar ($113.2 billion),

and Wind ($67.1 billion) subsegments. With $325.9 billion in revenues, Transportation was the second largest segment, despite quantification of only the Propulsion Systems subsegment. Sales of vehicles with advanced propulsion systems, including clean diesel, hybrid, plug-in electric, natural gas, and fuel cell, surpassed 10 million units worldwide in 2011.

Global advanced energy revenues for 2012 are expected to drop 6% to just over $1.048 trillion.[1] Although most subsegments are growing, some large subsegments are expected to contract in 2012 due to normal cyclical variations, resulting in overall revenue decline. In particular, Hydropower is expected to be smaller in 2012 compared to 2011 due to a drop in orders from China, where much of the activity is located. As a result, the Transportation segment is likely to become the largest global segment in 2012, growing to an estimated $385.0 billion and accounting for nearly 37% of all estimated advanced energy revenues.

Worldwide, the fastest growing subsegments between 2011 and 2012 are expected to be Bio-oil, Energy Storage, Electric Vehicle Charging Infrastructure, and Appliances and Electronic Equipment. All are starting from a small base but are expected to see relatively high growth in the coming years.

Chart 1.1 Advanced Energy Revenue by Segment, World Markets: 2011



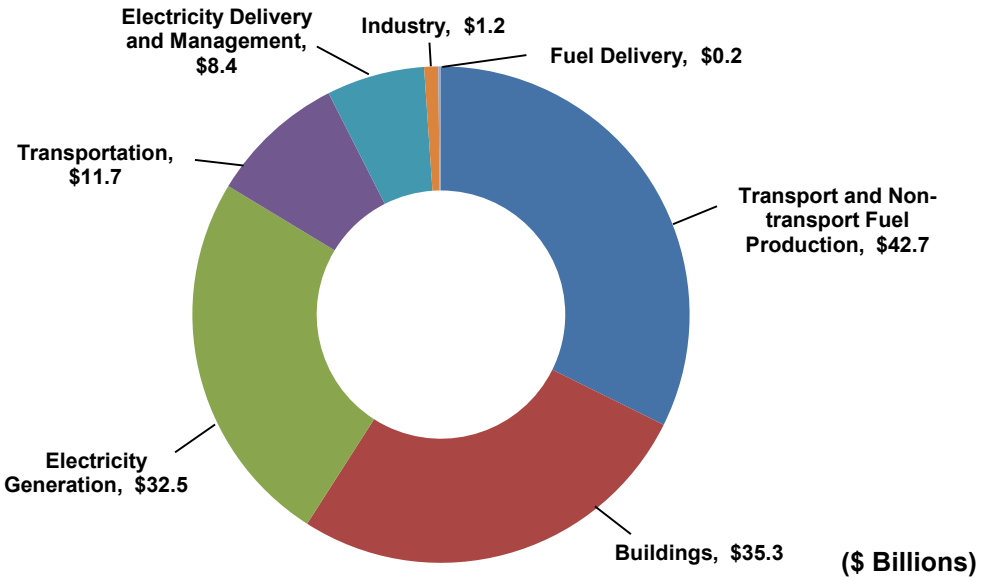
(Source: Pike Research and Navigant Consulting)

[1] 2011 revenues are based on actual revenue and installation data where available. 2012 data is estimated, as industry figures are often not finalized until the second quarter of 2013, and may vary even from estimates made late in 2011.

In the United States, the advanced energy market is expected to grow from $132.0 billion in 2011 to an estimated $157.0 billion in 2012, with its share of the global advanced energy market estimated to rise from 12% to 15%.

Ethanol was the biggest U.S. subsegment with revenues of $39.1 billion, which contributed to Fuel Production being the largest U.S. segment in 2011 at $42.7 billion. The next-largest segment, Buildings, accounted for $35.3 billion in 2011 revenues, led by the Heating, Ventilation, and Air Conditioning (HVAC) subsegment. The Buildings segment is expected to grow to $41.6 billion in 2012.

Chart 1.2 Advanced Energy Revenue by Segment, United States: 2011



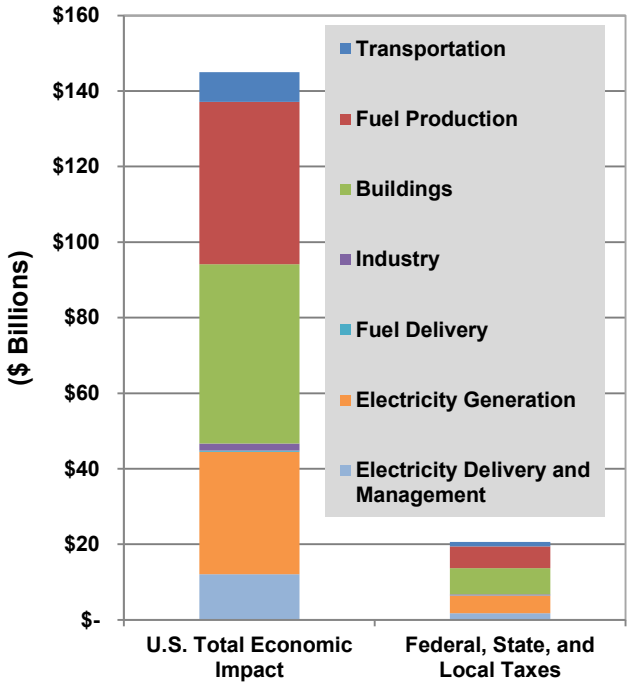
(Source: Pike Research and Navigant Consulting)

III. Advanced Energy Contribution to U.S. Economy and Tax Revenues

The $132.0 billion in U.S. revenues from the seven advanced energy segments in 2011 resulted in $145.0 billion in increased U.S. GDP.[2] This economic impact includes direct, indirect, and induced economic activity associated with the domestic content of industry investments driving U.S. revenues within the individual product categories examined. The economic impact of U.S. exports into global advanced energy markets is not captured in the contribution to U.S. GDP making this a conservative estimate.

The U.S. advanced energy industry contributed $13.9 billion in federal tax revenue in 2011, plus another $6.7 billion in state and local tax revenue, for a total tax contribution of $20.6 billion. These tax revenues are calculated as a share of the impact on U.S. GDP and likewise do not include the impact of U.S. exports into global markets.

Chart 1.3 Summary, Advanced Energy Economic Impact and Tax Generation, United States: 2011



(Source: Pike Research and Navigant Consulting)

[2] Gross Domestic Product is the sum of goods and services produced by labor and property located in the United States.

TABLE OF CONTENTS

Section 1
INTRODUCTION

1.1 Defining Advanced Energy

Advanced Energy Economy Institute (AEEI) is a nonprofit educational and charitable organization affiliated with Advanced Energy Economy (AEE), a national association of business leaders with the stated goal of making the global energy system more secure, clean, and affordable. The organizations define advanced energy as a broad range of products and services that constitute the best available commercial technologies for meeting energy needs today and tomorrow.

As defined in this way, advanced energy is not static but dynamic, as innovation and competition produce better energy technologies, products, and services over time. Today, electric and plug-in hybrid cars, natural gas-fueled trucks, high-performance buildings, energy-saving industrial processes, high capacity wind turbines, onsite solar power, and advanced nuclear power plants are all examples of advanced energy, as they diversify energy sources, reduce health and environmental costs to communities, and use energy resources more productively. Advanced energy represents an opportunity for U.S. companies and workers to not only to serve the domestic market but to export goods and services into the global energy market. The extent of this opportunity has never been quantified in one place.

1.2 Quantifying Advanced Energy Markets and U.S. Economic Impacts

AEEI commissioned Pike Research – a Part of Navigant – to perform a quantitative and qualitative analysis of advanced energy markets with the following specific goals:

- Quantify the U.S. and global advanced energy markets for the years 2011 and 2012 using revenue as the metric[3]
- Quantify the economic impact of the U.S. advanced energy industry in terms of its total contribution to Gross Domestic Product (GDP) and federal, state, and local tax revenues for the year 2011
- Describe the key trends affecting the advanced energy market and identify representative companies operating in each segment

The advanced energy industry consists of seven distinct market segments associated with energy demand (Transportation, Buildings, and Industry) and energy supply (Fuel Production[4],

[3] 2011 revenues are based on actual revenue and installation data where available. 2012 data is estimated, as industry figures are often not finalized until the second quarter of 2013 and may vary even from estimates made late in 2012.
[4] The full title of this segment is Transport and Non-Transport Fuel Production, but it is referred to as Fuel Production in the narrative of this report.

Fuel Delivery, Electricity Generation, and Electricity Delivery and Management). These segments are divided into 41 subsegments, as illustrated in Figure 1.1, each consisting of multiple product categories. This report draws upon over 60 previously published Pike Research studies that provide qualitative and quantitative analyses of product categories within these subsegments. Supported by additional information maintained by Navigant Consulting's Energy Practice, market revenue assessments for 2011 and estimates for 2012 were developed to provide a comprehensive view of advanced energy markets globally and within the United States.

Figure 1.1 Advanced Energy Segments and Subsegments

Transportation	Fuel Production	Fuel Delivery	Buildings	Industry	Electricity Generation	Electricity Delivery and Management
» Propulsion Systems	» Ethanol and Butanol	» Fueling Stations	» Building Design	» Manufacturing Machinery and Process Equipment	» Hydropower	» Transmission
» Vehicle Design and Materials	» Biodiesel	» Fuel Transportation Infrastructure	» Building Envelope	» Industrial Combined Heat and Power	» Gas Turbines	» Distribution
» Freight Logistics	» Biogas		» Heating, Ventilation, and Air Conditioning (HVAC)		» Solar	» Advanced Metering Infrastructure
» Land-Use and Infrastructure Design	» Synthetic Diesel and Gasoline		» District Energy, Combined Heat and Power (CHP), and Combined Cooling Heating and Power (CCHP)		» Wind	» Microgrids
» Enabling Information Technology	» Bio-oil		» Water Heating		» Geothermal	» Electric Vehicle Charging Infrastructure
	» Compressed Natural Gas and Liquefied Natural Gas		» Lighting		» Marine	» Energy Storage
	» Hydrogen		» Appliances and Electronic Equipment		» Waste	» Enabling Information and Communication Technology
			» Enabling IT		» Biomass	
					» Nuclear	
					» Other Distributed Generation	

(Source: Advanced Energy Economy Institute)

This analysis provides, for the first time, a comprehensive quantification of advanced energy today. However, the results must be viewed as a conservative assessment, for though this may be the most comprehensive study available to date, it is not necessarily complete:

» Subsegments or product categories not previously independently studied by Pike Research or Navigant Consulting are not included. Specifically, the Industry, Transportation, and Fuel Delivery segments are missing significant product categories in the current analysis. For example, the Fueling Station subsegment analysis includes natural gas and hydrogen fueling stations but does not include biofuel fueling stations, which is likely the largest product category.

» Revenue assessments for most subsegments are based on the total installed costs for the technology (i.e., they include the entire value chain). However, some subsegments, more

appropriately, measure only revenue from equipment sales, excluding installation or other potential services revenues.

» Except for the Hydropower, Nuclear, and Gas Turbines subsegments and Concentrating Solar Thermal Power (CSP) product category, projects under development are similarly not included.

» Operations and maintenance revenue is likewise not included, nor are refurbishments, which may be a large portion of certain subsegments, such as Nuclear.

» A few subsegments, such as the Freight Logistics, Land Use and Infrastructure Design, and Enabling Information Technology within the Transportation segment, have significant advanced energy impacts but have yet to be quantified as distinct markets. These are considered here only qualitatively.

» Finally, the U.S. economic impact analysis includes only the domestic content of revenues generated by the U.S. advanced energy markets and not the positive impacts associated with U.S. exports into global advanced energy markets.

The result is a fully supported, conservative view of the advanced energy markets, both globally and within the United States. The opportunity remains to expand this analysis in the future as the industries mature and independent market data becomes more readily available.

To the extent possible, revenues for each subsegment are based on the total installed costs of the various technologies. However, in some cases, a different point in the value chain, such as vendor equipment sales revenue, is the more appropriate and measureable indicator. In some cases, such as the Hydropower, Nuclear, and Gas Turbines subsegments, projects can take between 2 and 10 years to complete construction, making accurate annual tracking of actual construction activity difficult. For this analysis, the full total installed plant cost was assigned to the year in which orders were placed for the main components (e.g., turbines, reactor, generator equipment). In the case of the Concentrating Solar Thermal Power (CSP) product category, where projects typically take 2 to 3 years to complete, the full total installed cost was assigned to the year in which the project broke ground.

It should further be noted that the focus of the market data is primarily on new investments, capital improvements, and the sale of products and services – not, for example, the sale of electricity generated by installed technologies in the Electricity Generation segment. Sales of advanced fuels such as ethanol and biodiesel, however, are included in the Fuel Production segment.

For all reasons cited above, the findings of this analysis should be considered conservative and understate the total value of the advanced energy markets domestically and globally. A description of the sources of revenue used in the analysis is included in Section 13, along with a description of the methodology for calculating each segment's contribution to U.S. GDP.

Section 2
SUMMARY FINDINGS

2.1 Advanced Energy is a $132.0 Billion U.S. Market and a $1.1 Trillion Global Market

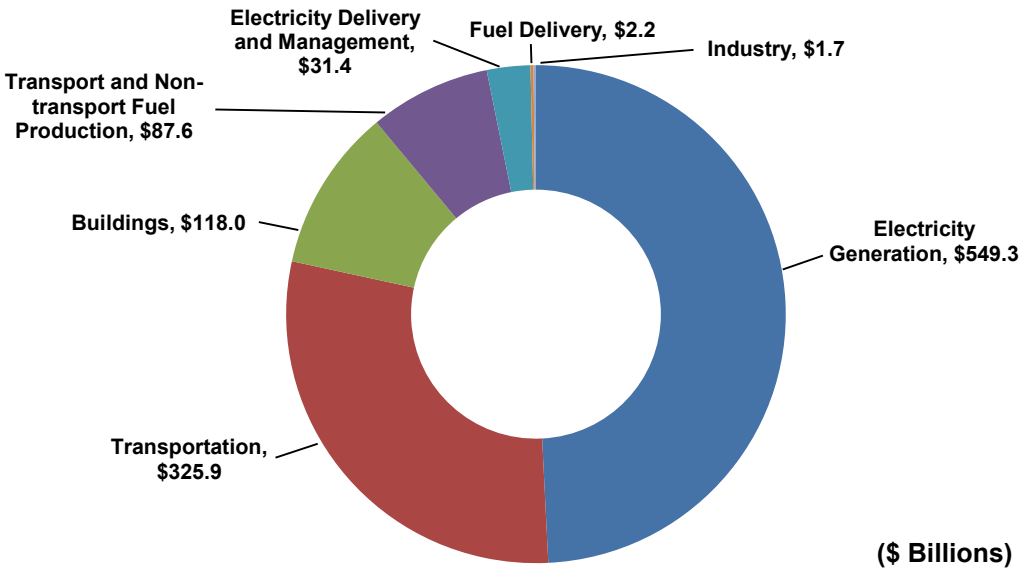
The global advanced energy market is large, geographically diverse, and consists of a wide variety of technologies at different levels of maturity. The competitive landscape includes the full spectrum of companies from start-ups to multinationals, including state-owned enterprises. The range of technologies covered in this analysis highlights the range of technological innovation taking place today. With technologies at varying levels of maturity, advanced energy will only continue to expand in the coming years. Due to the broad definition of advanced energy, its expansion or contraction is not disproportionately affected by impacts from any one particular country's economic situation or policies.

In 2011, global revenue from the seven advanced energy segments was $1.116 trillion, led by the Electricity Generation segment, which accounted for 49% of total revenues. This segment was driven by Hydropower, followed by the Solar and Wind subsegments. Transportation was the second largest segment with 2011 revenues of nearly $326.0 billion, which accounted for 29% of the global market, as sales of clean diesel vehicles surpassed 7.3 million units. These two segments were followed by the Buildings segment with revenues of $118.0 billion and Fuel Production with revenues of $87.6 billion. The bottom three segments, Electricity Delivery and Management, Fuel Delivery, and Industry, combined for $35.4 billion in global revenues in 2011, representing 3% of the total advanced energy market. Several segments, including Transportation, Fuel Delivery, and Industry, have significant subsegments that have not been quantified in this analysis, and are, therefore, underrepresented in the overall totals.

Although most advanced energy subsegments are expected to exhibit growth from 2011 to 2012, the overall global advanced energy market is expected to decrease 6% in 2012 due to an estimated reduction of $180.7 billion in the Electricity Generation segment. This is due to a decrease in revenues from Hydropower because of a significant decline in orders from China compared to 2011. The only other segment expected to see a year-on-year reduction is Fuel Delivery, down 13% compared to 2011, due to a decrease in new fueling stations in the Asia Pacific region.[5] The five other segments are expected to achieve the following year-on-year growth rates: Electricity Delivery and Management: 40%, Fuel Production: 22%, Buildings: 19%, Transportation: 18%, and Industry: 11%.

[5] The Fuel Delivery segment only includes data for natural gas and hydrogen fueling stations. Revenue totals for the largest product category, Biofuel Fueling Stations (for ethanol and biodiesel), were not included due to lack of available data.

Chart 2.1 Advanced Energy Revenue by Segment, World Markets: 2011



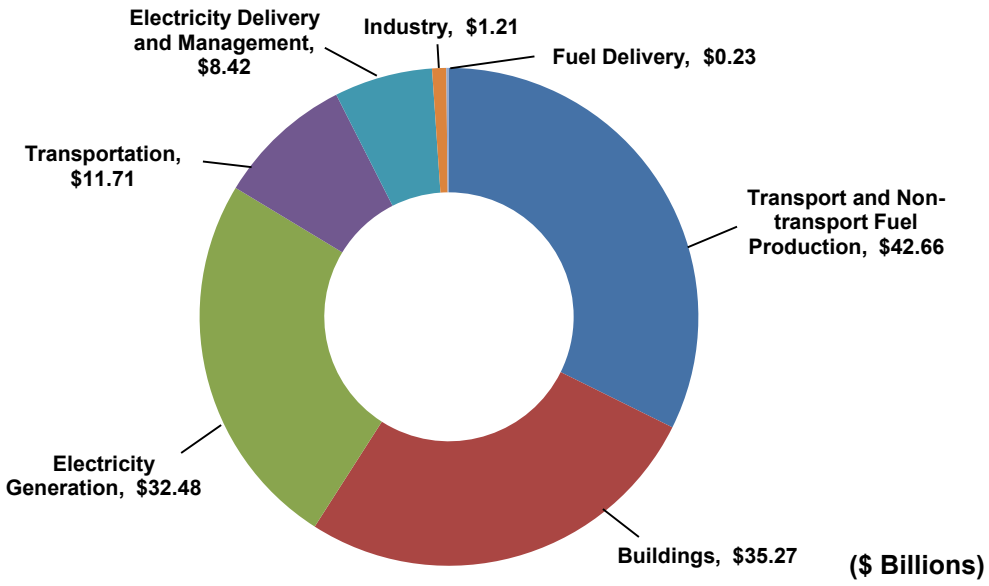
(Source: Pike Research and Navigant Consulting)

In 2011, the U.S. advanced energy market reached $132.0 billion, representing nearly 12% of the global market. The largest segment, Fuel Production, generated $42.7 billion in revenues, accounting for almost one-third of the entire U.S. advanced energy market that year. This was due primarily to revenue from sales of ethanol and capital investments in ethanol biorefinery infrastructure. Buildings was the second largest segment in 2011, with revenues of nearly $35.3 billion, followed closely by Electricity Generation at $32.5 billion, which represented 27% and 25% of the 2011 U.S. advanced energy market, respectively. Revenues from sales of products and services in the Heating, Ventilation, and Air Conditioning (HVAC) and Lighting subsegments together accounted for 56% of the Buildings segment. Revenues representing the total installed costs of wind turbines accounted for 40% of the Electricity Generation segment. The U.S. Transportation segment reached $11.7 billion in revenues led by sales of nearly 270,000 hybrid electric vehicles (HEVs). The bottom three segments, Electricity Delivery and Management, Industry, and Fuel Delivery generated nearly $10.0 billion in combined revenues, accounting for 7.5% of the total U.S. advanced energy market in 2011.

The 2012 U.S. advanced energy market is expected to increase 19% compared to 2011, with $157.0 billion in revenues, as the U.S. share of the global advanced energy market rises from 12% to 15%. All seven segments are estimated to experience year-on-year growth rates ranging from 10% (Fuel Production) to 121% (Fuel Delivery). The largest jump on a revenue basis is expected to be the Transportation segment, adding $7.0 billion in revenues compared to 2011 (60% growth). This will be led by a more than doubling of clean diesel vehicle sales and moderate growth in HEV sales. The Buildings segment is expected to add $6.3 billion more in revenues (18% growth) compared to 2011, led by increased revenues from the Lighting and

HVAC subsegments. Electricity Generation is expected to generate $4.7 billion more in revenues compared to 2011 (15% growth) led by Wind, with a developer rush to complete projects before the scheduled expiration of the Production Tax Credit (PTC) at the end of 2012. The Industry and Electricity Delivery and Management segments are estimated to have year-on-year growth rates of 28% and 27%, respectively.

Chart 2.2 Advanced Energy Revenue by Segment, United States: 2011

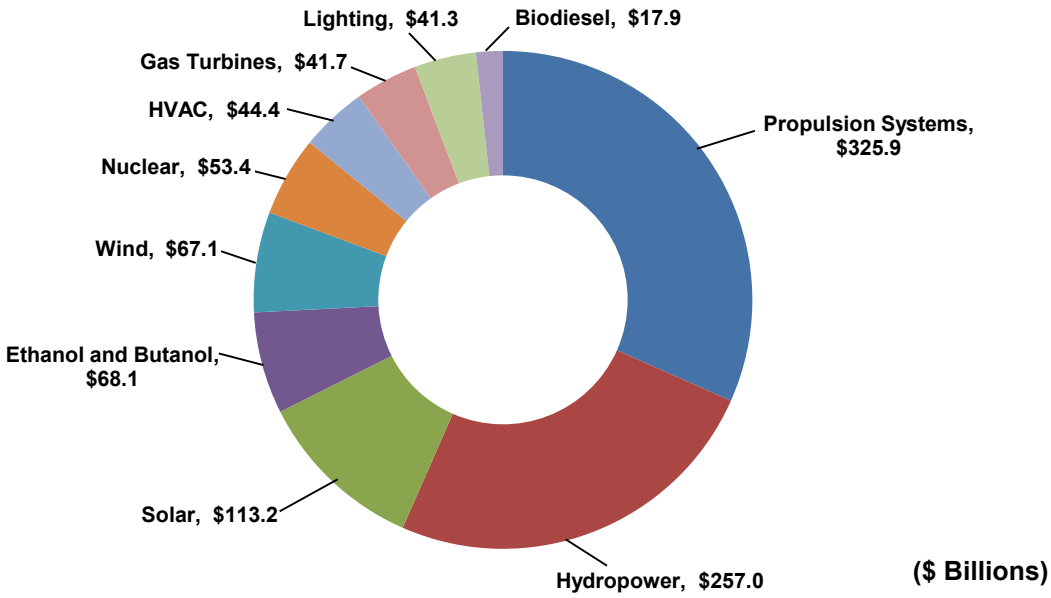


(Source: Pike Research and Navigant Consulting)

2.2 Top Subsegments

Global revenues from the top 10 advanced energy subsegments in 2011 reached $1.030 trillion, accounting for 92% of all advanced energy revenue. The same top 10 subsegments are expected to drop to a combined $948.6 billion in 2012 and account for 90% of the advanced energy market.

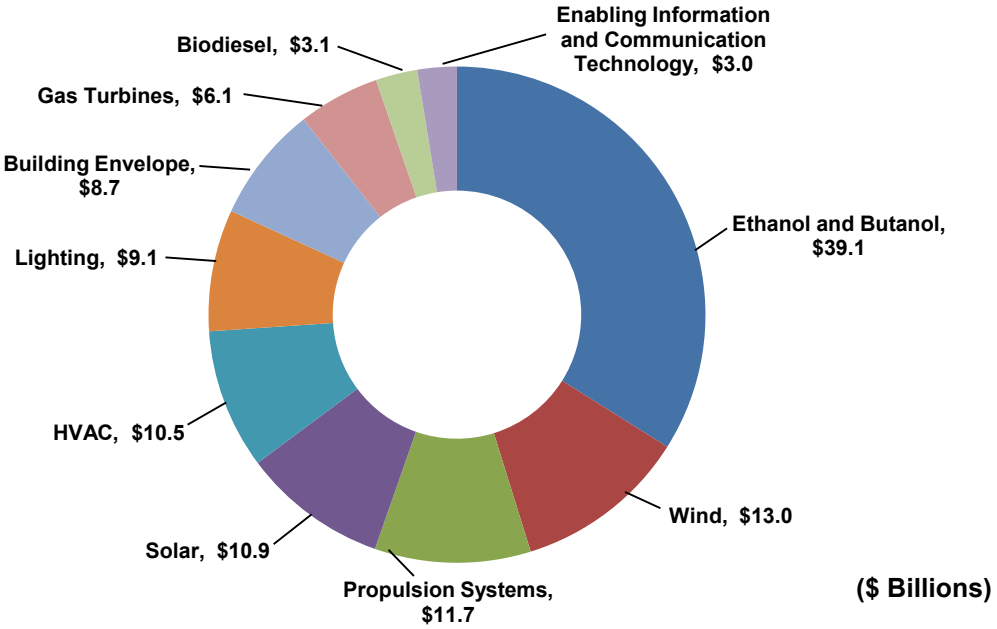
Chart 2.3 Top 10 Advanced Energy Subsegments by Revenue, World Markets: 2011



(Source: Pike Research and Navigant Consulting)

Revenues from the top 10 U.S. advanced energy subsegments in 2011 accounted for $115.3 billion, or 87% of all U.S. advanced energy revenue. The same top 10 subsegments are expected to grow to a combined $136.8 billion in 2012 and account for 87% of the U.S. advanced energy market.

Chart 2.4 Top 10 Advanced Energy Subsegments by Revenue, United States: 2011



(Source: Pike Research and Navigant Consulting)

2.3 2011 Advanced Energy Contribution to U.S. Gross Domestic Product

The economic impact data includes an evaluation of the impacts that occur due to the investment or purchase of the end product (i.e., “direct effects”), those that arise due to the economic activities of the supply chain involved in the production of the investment or end product (i.e., “indirect effects”), and those that occur due to the spending of the wages and other personal income generated by the economic activities by the investment and its suppliers (i.e., “induced effects”).

The revenues described for most of the segments and subsegments in this analysis capture the value added to the product along the entire value chain: from raw materials through final installed product. Thus the economic impacts modeled from these revenues include both the direct impacts associated with the end purchase of the product as well as the indirect impacts on the various suppliers contributing to the end product. The induced spending is the product of combined direct and indirect spending multiplied by industry-specific economic impact multipliers. Tax revenues are calculated as a share of the impact on U.S. GDP.

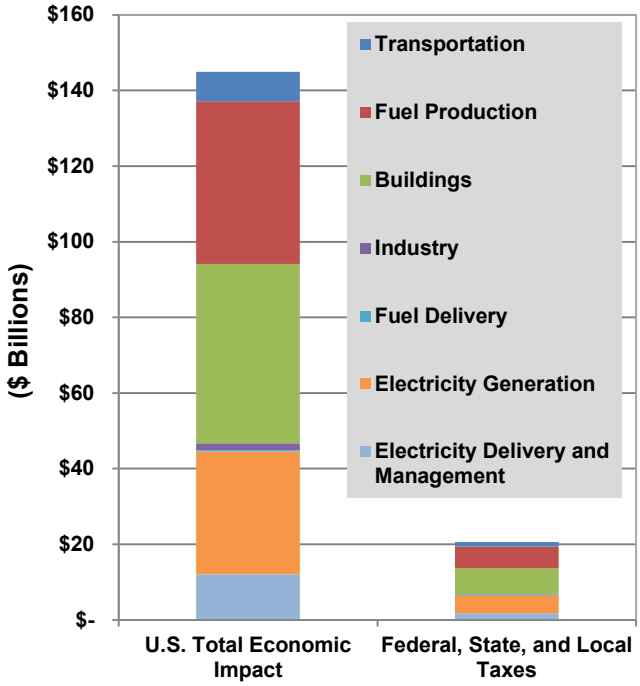
Of the $132.0 billion in U.S. revenues from the seven advanced energy segments in 2011, an estimated $97.0 billion is derived from domestic content that may impact U.S. GDP. This spending generated a total of $145.0 billion in increased U.S. GDP. While non-domestic content is excluded from the GDP analysis, U.S. exports to global advanced energy markets do contribute to U.S. GDP. However, this is not included in this analysis, as estimates of U.S. advanced energy exports to global markets were not readily available for each of the product categories in each subsegment.

2.4 2011 Advanced Energy Contribution to Federal, State, and Local Tax Revenue Generation

In determining tax revenues, Navigant's Tax Revenue Model was utilized to calculate federal, state, and local tax revenues generated by an increase in economic activity. This model has been used in numerous prior economic impact studies. The tax revenue generated is calculated by applying an effective tax rate to the increase in a measure of economic activity (e.g., employee earnings or value added). For example, investment in a manufacturing plant will generate increased employment at the plant and increased indirect and induced employment at other locations. Federal, state, and local governments will experience increased tax revenues from the taxes on the wages generated by the increased employment.

As a result of the $145.0 billion increase in GDP, $13.9 billion in federal tax revenue and $6.7 billion in state and local tax revenue was calculated as a share of this increase.

Chart 2.5 Summary, Advanced Energy Economic Impact and Tax Generation, United States: 2011



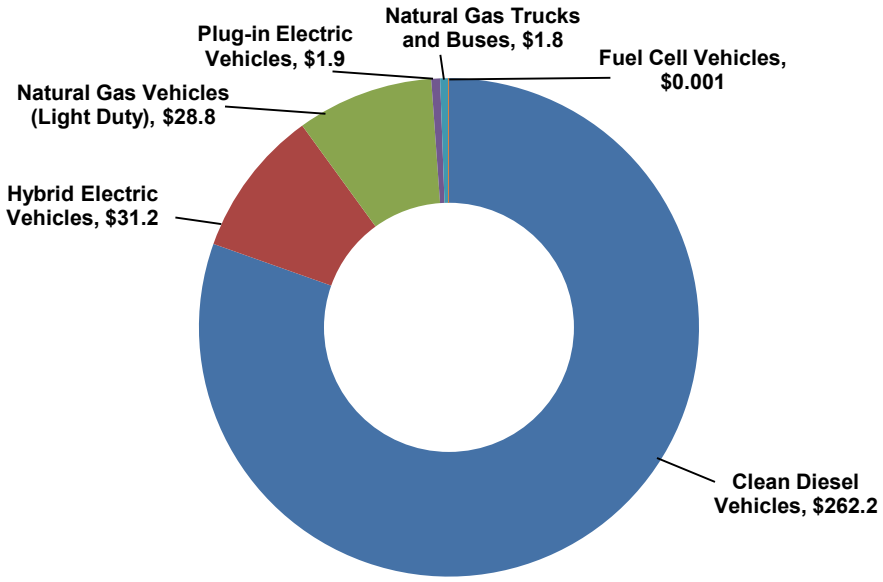
(Source: Pike Research and Navigant Consulting)

Section 3
TRANSPORTATION

3.1 Transportation Market Grows to Include Varying Sources of Fuel and Improves Logistical Efficiencies

The Transportation segment is composed of five subsegments: Propulsion Systems, Vehicle Design and Materials, Freight Logistics, Land Use and Infrastructure Design, and Enabling Information Technology. This section provides a quantitative analysis for Propulsion Systems, and a mostly qualitative analysis of the remaining categories. Therefore, the following analysis understates the true Transportation segment market size. Nonetheless, Transportation was the second largest advanced energy market segment by revenue in 2011 at $325.9 billion. This total is expected to grow to $384.7 billion in 2012, which would make Transportation the largest segment by market value, accounting for nearly 37% of all advanced energy revenues. Propulsion Systems is the only subsegment that is quantified and is broken out by product category in Chart 3.1 for the year 2011.

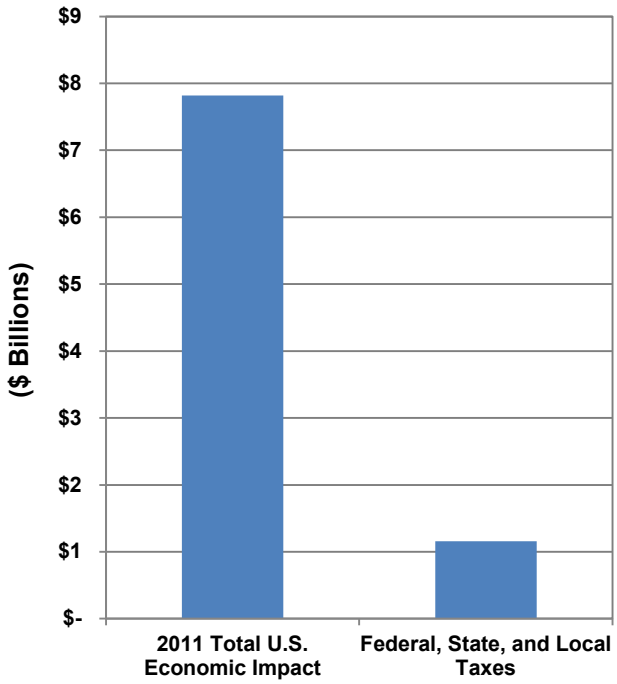
Chart 3.1 Propulsion System Subsegment Revenue by Product Category, World Markets: 2011



(Source: Pike Research and Navigant Consulting)

The Transportation segment in the United States had an overall economic impact on 2011 U.S. GDP of $7.8 billion, derived from the domestic content associated with the U.S. Transportation segment revenue. This economic activity generated $789.7 million in federal tax revenue and an additional $366.0 million in state and local tax revenue. This economic impact does not include the additional economic benefits of Transportation segment exports from the United States to global markets.

Chart 3.2 Transportation Segment Economic Impact and Tax Generation, United States: 2011



(Source: Pike Research and Navigant Consulting)

3.1.1 Propulsion Systems

Advanced propulsion systems are the engines and fuel supply systems that allow cars, trucks, trains, ships, and aircraft to use fuel more efficiently, thereby lowering emissions. They also allow these vehicles to make use of advanced fuels. Data in this section refers primarily to sales of road transport vehicles[6], not to the propulsion system components alone. 2011 revenue from global sales of all product categories including Clean Diesel Vehicles, Plug-in Electric Vehicles (PEVs), Hybrid Electric Vehicles (HEVs), Natural Gas Vehicles (NGVs), and lease sales to consumers for Fuel Cell Vehicles (FCVs) totaled nearly $325.9 billion. In 2011, 7.3 million clean diesel vehicles were sold worldwide, accounting for 71% of advanced energy vehicle sales and $262.2 billion in revenue. Clean diesel vehicles represent approximately 50% of new vehicle sales in Europe, compared with less than 2% in the United States. This is largely due to the high price of gasoline in Europe, which drives demand for fuel-efficient cars, but is also due to the fact that diesel fuel is typically less expensive than gasoline. By contrast, diesel is typically more expensive than gasoline in the United States, reducing the benefit of the lower fuel consumption that diesel technology offers. By unit sales, NGVs represented 18% of the global market, followed by HEVs at 10%, and combined sales of PEVs and FCVs at less

[6] Forklifts also included.

than 1%. The overall 2012 Propulsion System market is expected to grow 18% in revenues with a fairly similar distribution to 2011, resulting in an estimated combined sales total of more than 12 million vehicles.

The United States only captured 4% of the global market of vehicles with advanced propulsion systems in 2011, representing $11.7 billion in revenues; revenues are expected to rise to $18.7 billion in 2012. The U.S. market is led by HEV sales, which totaled 269,000 units in 2011 and is expected to have a compound annual growth rate (CAGR) of 5% between 2012 and 2020. Sales of clean diesel vehicles, FCVs, and PEVs are each expected to more than double in 2012, compared to 2011, while the U.S. NGV market is expected to grow 33%. NGVs in the United States are sold almost exclusively to the fleet market and accounted for only 5% of 2011 U.S. advanced propulsion market revenue. In 2011, the Toyota Prius accounted for 51% of total U.S. HEV sales.

Representative Companies:

- Agility Fuel Systems
- BAF Technologies
- Boeing
- Bosch Group
- Daimler
- General Motors
- Tesla Motors
- Toyota
- Volkswagen
- WebEx

3.1.2 Vehicle Design and Materials

The advanced Vehicle Design and Materials subsegment includes any improvements to vehicular structure that allow for equal (or better) performance with the use of less energy. Examples of advanced vehicle design and materials include using lightweight carbon fiber to build cars and trucks, designing more aerodynamic trains, and installing winglets on older airplanes to reduce drag. In the passenger vehicle space, Ford and Aptera are working on lighter, more aerodynamic cars, while aerospace company Boeing works to reduce weight and drag in airplane design. Pike Research has not yet quantified the market for the majority of these products and services. Battery packs for PEVs are the only product category included in this analysis, so the overall size of the Vehicle Design and Materials subsegment is significantly understated. PEV battery pack sales revenue is included in the Propulsion Systems subsegment, but is broken out here in order to provide a sense of this individual piece of the value chain. In 2011, global revenue from battery pack sales for PEVs reached $823.9 million. 2012 revenues are expected to more than double to $1.9 billion from sales of an estimated 138,000 units.

The United States captured 33% of the market for PEV battery packs in 2011, accounting for $271.3 million in revenue. Lithium ion (Li-ion) batteries are beginning to appear in HEVs; however, the market for Li-ion batteries in the transportation sector will be driven primarily by plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs), which require much larger battery packs than HEVs. U.S. revenues for 2012 are estimated to be $488.0 million, or 25% of the total PEV battery pack market.

3.1.3 Freight Logistics

Global and local trade involves extensive movement of goods by ship, rail, air, and road. Advanced energy products and services specifically optimize transportation logistics for energy efficiency; they include inter-modal shipping containers and advanced analytics for delivery scheduling and routing. Pike Research has not yet quantified the markets for such products and services but has identified the role that route analytics have in optimizing the use of commercial electric and/or hybrid delivery vehicles. Cost and operational efficiency are the primary drivers for adoption of advanced energy freight logistics products and services.

It is also worth noting that freight logistics companies are often test beds for new propulsion technology, with precise knowledge of how fleet vehicles are used (miles driven and when serviced). As a result, new advanced propulsion technology is often tested in these fleets when factors of the drive cycle can easily be monitored. Vehicles within these fleets include medium duty trucks that utilize clean diesel, gasoline HEVs, NGVs, and BEVs.

3.1.4 Land Use and Infrastructure Design

Integrated land use planning and associated transportation infrastructure dramatically impact energy use and efficiency within given communities. The scale and scope of such efforts vary widely, and quantification of these impacts is not included within the scope of this analysis. However, the idea of smart cities, defined as the integration of technology into a strategic approach to sustainability, citizen well-being, and economic development, is becoming a unifying concept for evaluating the value of these efforts. Though not explicitly included in this analysis, Pike Research has estimated global investment in smart city technologies, including utilities, transportation, buildings, and government, at over $4 billion in 2011, and it is forecast to exceed $15 billion by 2020. Key technologies underlying these investments include advanced control systems, communications, sensor networks, analytics software, and internet services.

3.1.5 Enabling Information Technology

The adoption of advanced information technology, from the internet to mobile communications, has been transformational in many ways, including reducing transportation energy use. The digitization of work and information products, from telecommuting and online collaboration tools to online news sources and digital readers, has the potential to reduce travel, transportation, and commercial building energy needs. The impacts are exceptionally broad, varied, and diffuse, and hence, not explicitly quantified in this analysis. Yet, they are no less real.

Section 4
FUEL PRODUCTION

4.1 Ethanol and Biodiesel Sales and Refinery Investment Increase in United States and Globally

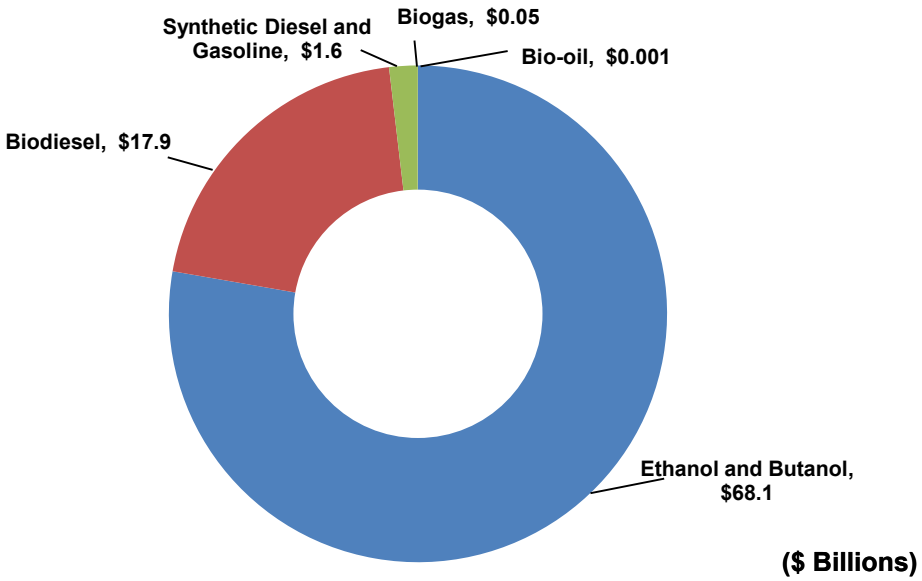
Representative Companies:

- Abengoa Bioenergia
- Air Products
- BP Biofuels
- Honeywell's UOP
- KiOR
- LanzaTech
- POET
- Solazyme
- Tyson Foods
- Waste Management

In 2011, Fuel Production was the fourth largest technology segment by market size, with revenues of $87.6 billion, accounting for 8% of the overall advanced energy market worldwide. With revenues of $68.1 billion, sales of ethanol fuel and ethanol biorefinery capital investments were the primary revenue drivers, followed by biodiesel fuel sales and biodiesel biorefinery capital investments at $17.9 billion. Revenues from sales of synthetic diesel and gasoline, bio-oil, biogas, hydrogen fuel, and associated refinery capital investments amounted to more than $1.6 billion, representing 2% of revenues within the Fuel Production segment. In recent years, the United States, Brazil, and the European Union have been the three largest markets worldwide (both as producers and consumers) and have typically accounted for 80% to 90% of global production of these fuels. In 2012, an increase in demand and production capacity in these markets is expected to increase global ethanol and biodiesel sales by 18% and 12%, respectively.

In 2011, the United States accounted for 49% of the total Fuel Production segment, with revenues of $42.7 billion. With combined sales of ethanol and biodiesel expected to increase by just 2% in 2012 to an estimated 14.9 billion gallons, the U.S. overall share of the global Fuel Production market is expected to drop to an estimated 44% in 2012. Current government targets for biofuel demand in the United States are 15.2 billion gallons for 2012 and 26 billion gallons by 2018.

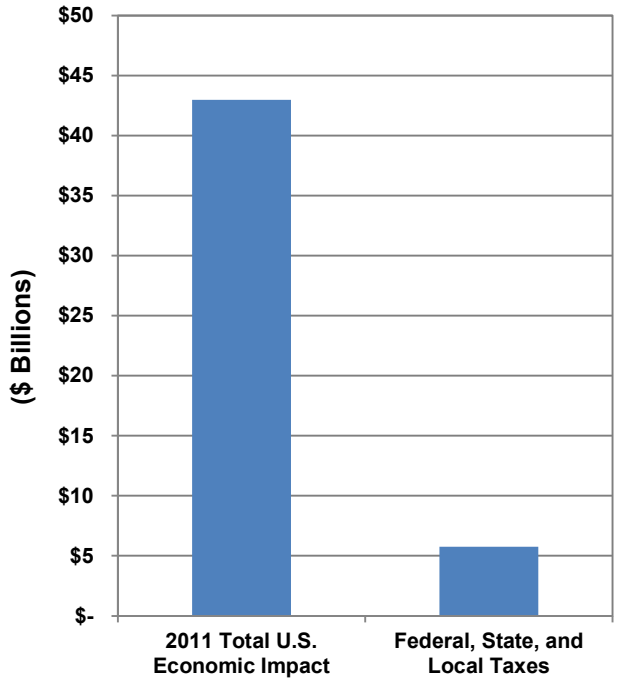
Chart 4.1 Transport and Non-transport Fuel Production Revenue by Subsegment, World Markets: 2011



(Source: Pike Research and Navigant Consulting)

The Fuel Production segment in the United States had an overall economic impact on 2011 U.S. GDP of $43.0 billion, derived from the domestic content associated with U.S. Fuel Production segment revenue. This economic activity generated $3.8 billion in federal tax revenue and an additional $1.9 billion in state and local tax revenue. This economic impact does not include the additional economic benefits of Fuel Production segment exports from the United States to global markets.

Chart 4.2 Fuel Production Segment Economic Impact and Tax Generation, United States: 2011



(Source: Pike Research and Navigant Consulting)

4.1.1 Ethanol and Butanol

Global ethanol sales totaled 23.4 billion gallons in 2011 and are estimated to reach 24.4 billion gallons in 2012, with associated revenues of $65.9 billion and $77.5 billion, respectively. Annual capacity additions to ethanol refineries totaled 678 million gallons per year (MGY), representing $2.2 billion in capital investment in 2011. New capacity additions in 2012 are estimated to total 2,051 MGY, resulting in an estimated $6.8 billion of investment in ethanol refineries in 2012. Although the conventional ethanol market – defined as ethanol fuel produced from food-based resources like corn starch and sugarcane – is expected to continue growing over the next decade, the next wave of technologies, which include cellulosic ethanol conversion processes and biobutanol production, are expected to gain traction in the market. Numerous macroeconomic trends are driving demand for cellulosic ethanol – including concerns over energy security, food versus fuel, and the environment – but commercial competitiveness of cellulosic ethanol in the short-term remains limited. Although not yet in commercial production, biobutanol's drop-in compatibility with existing infrastructure and

greater energy density provide significant advantages over ethanol fuel, and it is expected to capture an increasing share of investment worldwide.

In the United States, 2011 revenues from the sale of ethanol reached $38.3 billion and are expected to grow to $40.6 billion in 2012. Production growth in 2012 has been limited by severe drought and higher corn prices. Driven by strong policy support, an expansion in corn production, tax credits, and the Federal Renewable Fuel Standard (RFS), U.S. ethanol production saw a rapid expansion in the 2000s, growing at a nearly 21% CAGR between 2000 and 2009. Ethanol production has since plateaued, with just a 1% CAGR between 2010 and 2012. This slowdown corresponds with a general downward trend in biofuels investment, which is attributable to uncertainties around market demand, resulting from an impending "blend wall" – the point at which ethanol production exceeds the legally permissible blend ratio for ethanol and gasoline – and a limited risk appetite among investors for first-of-kind advanced biorefineries. Efforts to expand E85 (85% ethanol, 15% gasoline) fuel in the market have also stalled, contributing to persistent uncertainty around future ethanol demand in the United States. As a result, future growth in cornstarch-based ethanol production in the United States is likely to occur at the margins through higher corn yields and improved conversion efficiency, rather than through construction of new ethanol biorefineries.

4.1.2 Biodiesel

Biodiesel can be used instead of, or blended with, petroleum diesel, most commonly in diesel engines or as heating oil in blends of 5% to 20% biodiesel (B5–B20). Biodiesel is produced by the transesterification of vegetable oil or animals fats, a conventional chemical conversion process that breaks down the oils or fats into their constituent molecules, forming biodiesel as the main product and glycerin as a byproduct. Global biodiesel sales totaled nearly 6 billion gallons in 2011 and are estimated to reach 6.5 billion gallons in 2012. Global revenues from sales of biodiesel are expected to grow from $16.9 billion to $18.9 billion during this time. In 2011, annual capacity additions to biodiesel refineries amounted to 340 MGY, representing $981.8 million in capital investment. New capacity additions in 2012 are estimated to total 532 MGY, resulting in an estimated $1.5 billion of capital investment in biodiesel refineries in 2012. The European Union currently leads biodiesel production globally, but the European Commission's recent proposal to phase out support for food-based biofuels would likely hamper further biodiesel market growth across the region, as well as in countries currently exporting biodiesel to the European Union. While the United States, Brazil, Argentina, and China have expanded production capacity in recent years, limited market pull is likely to result in only modest growth globally in 2012.

2011 revenue from U.S. sales of biodiesel reached $2.9 billion in 2011 and is expected to grow to $3.2 billion in 2012. The lapse of a $1 per gallon biodiesel producer's credit at the end of 2009 led to a precipitous decline in biodiesel production during 2010, and to the closing of 52 of the nation's 190 biodiesel plants. Due in part to the extension of the producer's tax credit and to the RFS mandates for biomass-based diesel, production rebounded in 2011,exceeding 1 billion gallons, and has continued to grow steadily. Under the RFS, the 2012 U.S. biodiesel market is expected to grow by 200 to 300 MGY, assuming adequate access to feedstock

(typically soybean oil in the United States). However, expansion of production capacity for renewable diesel (see below) – a higher-performance fuel than conventional biodiesel – poses a potential threat by competing for feedstock and funding.

4.1.3 Synthetic Diesel and Gasoline

Synthetic diesel and gasoline, sometimes called "renewable diesel" or "renewable gasoline," describes fuels that are chemically similar to traditional diesel and gasoline, but that are produced from non-petroleum feedstocks including municipal solid waste and non-food biomass. Global synthetic diesel and gasoline sales totaled 169 MGY in 2011 and are expected to grow 84% to 311 MGY in 2012. Revenues from sales of synthetic diesel and gasoline are expected to grow from $507.0 million to $933.0 million during this time, due to demand drivers including strong market pull for "drop-in" alternatives to gasoline and diesel that can utilize existing infrastructure. Production of renewable diesel via hydrotreating of vegetable oils has led advanced biofuel commercialization globally in recent years, but it faces limitations with respect to feedstock access. A range of synthetic gasoline and diesel conversion technologies, such as gasification and Fischer-Tropsch synthesis, which can use more abundant and lower cost non-food feedstocks, have only produced limited quantities of fuel to date but are currently moving from demonstration-scale facilities to commercial scale. Overall, in 2011, 330 MGY of new advanced biorefinery infrastructure for production of synthetic gasoline and diesel was added, with hydrotreating-based renewable diesel capacity accounting for the largest share of added capacity. In 2012, 188 MGY of new production capacity is expected to be added, with several first-of-kind advanced biorefineries coming online. The corresponding capital investment associated with these infrastructure additions are $1.1 billion in 2011 and $1.0 billion expected in 2012.

In the United States, sales of synthetic diesel and gasoline reached 45.1 million gallons in 2011 and are expected to reach 82.2 million gallons in 2012. Annual capacity additions are anticipated to drop from 75 MGY in 2011 to 13.3 MGY in 2012. Among advanced biofuel categories, demand for aviation biofuels is currently having the greatest impact on synthetic diesel biorefinery construction, since conversion pathways used to produce renewable diesel and jet fuel are similar. At the end of 2011, the U.S. Navy committed to buying 450,000 gallons of hydrotreated renewable diesel and aviation biofuel from Dynamic Fuels, the largest single government purchase of any biofuel in U.S. history. The Navy has also worked closely with Boeing, consortia of commercial airlines, and governmental agencies (Department of Agriculture, Department of Energy, and Department of Transportation) to develop supply chains for the expansion of aviation biofuels production. Renewable diesel, accordingly, has emerged as a near-term growth opportunity in the United States with at least 200 MGY of production capacity projected to come online in 2013.

4.1.4 Bio-oil

Bio-oil is a type of advanced fuel that is created through the pyrolysis (rapid thermal decomposition) of biomass. Wood byproducts such as bark and branches, algae, perennial grasses, and the non-edible parts of corn can be used as inputs to the bio-oil production

process. Bio-oil, like petroleum, requires upgrading, but the resulting products can be used for many of the same purposes as petroleum-based fuels, including as industrial boiler fuel. Global bio-oil (also known as pyrolysis oil or biocrude) sales totaled 35,000 gallons in 2011 and are expected to grow to 120,000 gallons in 2012, with associated revenues of $100,000 and $350,000, respectively. Within the industry, advanced biofuel research and investment efforts are increasingly targeting opportunities to produce specific end-products and to commercialize conversion processes. These processes produce intermediate chemicals such as ethylene, BDO (1,4-Butanediol), butadiene, and succinic acid that can be further refined into various end-products.

The United States accounted for 74% of bio-oil sales in 2011 and is expected to increase its market share to 87% in 2012. In April 2012, the U.S. Department of Energy (DOE) announced up to $15 million in funding for demonstration of biomass-based oil precursors (bio-oil for renewable transportation fuels). The DOE will fund between 5 and 10 projects by the end of 2012 to produce bio-oil prototypes that can be tested in oil refineries. The prototype bio-oils, produced from a range of feedstocks including algae, corn and wheat stovers, dedicated energy crops, and wood residues, will be used to develop comprehensive technical and economic analyses of how bio-oil production can be expanded to commercial scale. The goal of the DOE's efforts is to isolate technologies and pathways to facilitate the commercialization of bio-oil production at scale, but also to underscore the nascent state of the commercial bio-oil market and of integration with existing petro-refinery infrastructure.

4.1.5 Biogas

Biogas is a gaseous fuel that is produced through the anaerobic digestion of organic matter. It occurs naturally in landfills (producing landfill gas, or LFG), or can be produced in digesters, creating anaerobic digester gas (ADG), for example, at wastewater treatment plants or elsewhere using animal waste or food waste. Global sales of methane-rich biogas amounted to 9.1 billion cubic feet (BCF) in 2011 and are expected to grow 22% in 2012 to 11.1 BCF. Revenue from sales of biogas via natural gas grid injection, bio-compressed natural gas (CNG), or bio-liquefied natural gas (LNG) totaled $27.4 million and $33.6 million in 2011 and 2012, respectively. In 2011, 2.2 billion cubic feet per year (BCFY) of new biogas capture and upgrading capacity was added globally; an estimated 2 BCFY is projected for 2012. Revenues from these capital investments reached an estimated $19.4 million in 2011 and are expected to reach $14.4 million in 2012. Despite improving market opportunities for biogas, raw biogas must be upgraded (or purified) before it can be injected into natural gas grid or used as a transportation fuel. Although there are a number of technology pathways for doing so, the costs are often prohibitive in the face of low-cost natural gas and isolated demand for gaseous fuels. Thus far, countries like Germany and Sweden have been early adopters of biogas as a transportation fuel.

The United States accounted for 30% of the global market for methane-rich biogas in 2011 and is expected to capture 28% market share in 2012. Biogas producers are increasingly turning to transportation fuel markets over power applications for near-term revenue via renewable identification number (RIN) credits under the RFS, as the value of renewable energy credits

(RECs) from the sale of power has declined in recent years. Truck and municipal fleets that follow pre-defined routes and return to a centralized fueling station are best suited for using biogas as a transportation fuel. This model is common among garbage trucks that operate around a landfill or municipal solid waste transfer station. Waste haulers such as Waste Management have been early adopters of this business model in the United States.

4.1.6 Hydrogen

With an estimated 31 million metric tons produced globally in 2011, hydrogen is widely used, in both liquid and gaseous form, and represents a large and mature industry. Hydrogen is used primarily for its chemical properties as an industrial gas; direct fuel use applications are still a very small portion of the hydrogen industry. Among direct fuel use applications, hydrogen can be used in fuel cells for transportation (e.g., buses, forklifts, light duty vehicles), and in stationary uninterruptible power supply (UPS) units, which make up the majority of commercial energy-related hydrogen sales today. There is also potential for use in scooters, locomotives, aircraft, and other applications, but these are not likely to see large-scale use in the short-term. It should be noted that hydrogen is technically an energy carrier, which means that, like electricity, it must be produced from some other primary energy source.

Hydrogen fuel production market data is not included in this analysis, but to provide a sense of the opportunity, Pike Research expects global demand for hydrogen fuel to reach over 400 million kilograms (kg) annually by 2020[7]. This reflects a forecasted 2010–2020 CAGR of 88% globally. Cumulative demand is projected to be relatively low – less than 50 million kg – from 2010 through 2014, driven primarily from the forklift sector in the United States and Canada. In 2015, demand is projected to reach an estimated 55 million kg, accelerating based on growth in the use of hydrogen in light duty vehicles (LDVs) and continued strong demand in the forklift sector.

Hydrogen fuel development for passenger cars is constrained by the chicken-egg problem between hydrogen fuel cell vehicle manufacturers, hydrogen fuel producers, and hydrogen fueling infrastructure companies. A joint approach to reduce risk among the three groups is required, such as that taking place currently in Germany and Japan where automakers are collaborating with fuel providers to build infrastructure that can meet hydrogen demand when commercial fuel cell vehicles are introduced in 2015.

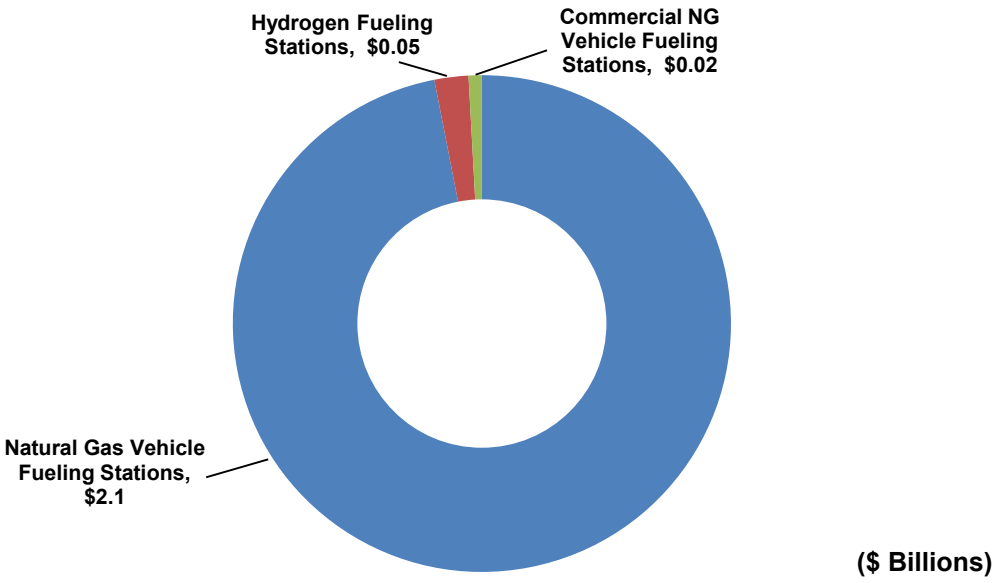
[7] A kilogram of hydrogen is approximately equal to a gallon of gasoline equivalent (gge) on an energy content basis.

Section 5
FUEL DELIVERY

5.1 Led by Developing World, Advanced Fueling Stations Gain Traction Worldwide

The Fuel Delivery segment consists of two subsegments: Fueling Stations and Fuel Transportation Infrastructure. This analysis only includes market sizing data for natural gas and hydrogen fueling stations, and, therefore, understates the actual size of the Fuel Delivery segment. Additional revenue from dedicated liquid biofuel fueling stations (such as for E85 in the United States) is another major source of revenue that falls under the Fueling Stations subsegment, but for which data is not currently available. This section includes a mostly qualitative analysis of the Fuel Transportation Infrastructure subsegment, which includes some industry estimates. Because only revenue from natural gas and hydrogen fueling stations was counted, Fuel Delivery was the second smallest advanced energy segment in 2011 with $2.2 billion in global revenues. Global revenues are anticipated to drop to $1.9 billion in 2012, due to a reduction of new fueling stations in the Asia Pacific region.

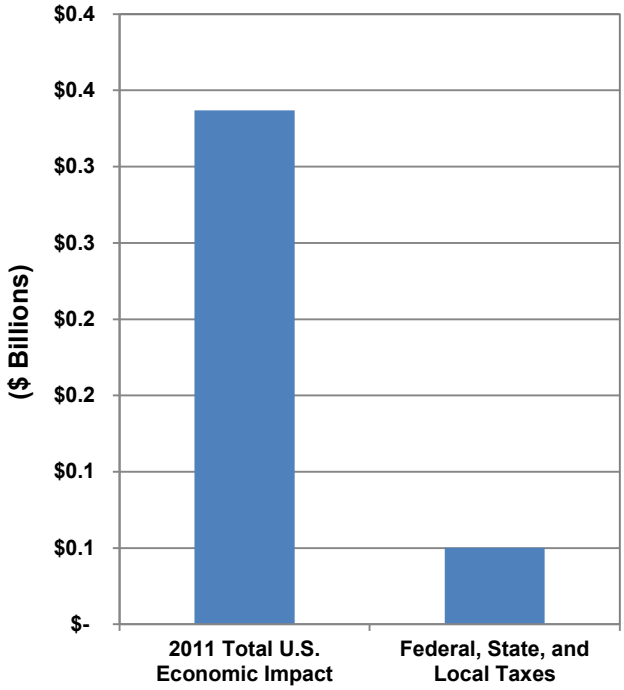
Chart 5.1 Fueling Stations Subsegment Revenue by Product Category, World Markets: 2011



(Source: Pike Research and Navigant Consulting)

The Fueling Station subsegment in the United States had an overall economic impact on 2011 U.S. GDP of $336.8 million, derived from the domestic content associated with U.S. Fuel Delivery segment revenue. This economic activity generated $34.4 million in federal tax revenue and an additional $15.8 million in state and local tax revenue. This economic impact does not include the additional economic benefits of Fuel Delivery segment exports from the United States to global markets.

Chart 5.2 Fueling Station Subsegment Economic Impact and Tax Generation, United States: 2011



(Source: Pike Research and Navigant Consulting)

5.1.1 Fueling Stations

Advanced fueling stations are those that are capable of supplying advanced fuels to the vehicles that use them. This includes fueling stations for liquid biofuels, CNG, LNG, and hydrogen. The infrastructure for both CNG and LNG refueling stations is very similar to that of a hydrogen refueling station. Therefore, many believe that if the infrastructure is in place for NGVs, the potential switch to hydrogen fuel could be much easier and less expensive.

Biofuel fueling stations compose the largest product category in the Fueling Station subsegment, with ethanol accounting for the vast majority of existing biofuel stations worldwide. In Brazil, ethanol derived from sugarcane is the primary advanced fuel, and in 2010, the country

had an estimated 35,000 ethanol fueling stations (with blends ranging from E20 to E100). Other countries like Sweden, which was home to 1,200 ethanol stations in 2010, rely on ethanol imports. As of late 2012, the United States had a total of 2,270 ethanol fueling stations (E85)[8]. However, Pike Research has not yet quantified the value of this market and, therefore, the total Fueling Stations subsegment market value is significantly understated.

Representative Companies:

- Air Products
- Chesapeake Energy
- Clean Energy Fuels
- General Electric
- "K" Line
- Kinder Morgan
- Linde
- Petrobras
- Praxair
- Royal Dutch Shell

In 2011, global revenues based on the total installed cost of LNG, CNG, and hydrogen fueling stations reached $2.2 billion. Worldwide, 2,245 fueling stations were added in 2011 with natural gas accounting for 99% of the total number of stations. In 2012, new global installations of natural gas and hydrogen fueling stations are expected to drop nearly 23%, with an expected 1,739 new fueling stations installed generating $1.9 billion. The Asia Pacific region, home to the highest number of advanced fueling stations (CNG, LNG, and hydrogen only) worldwide with 9,672, will be responsible for much of this reduced growth due to fewer NGV fueling stations coming online in Pakistan compared to 2011; Pakistan has more NGV fueling stations than any other country. Latin America, which is home to 5,032 advanced fueling stations, is expected to have the highest growth rate in the near-term.

The market in the United States added 141 natural gas and hydrogen fueling stations in 2011, generating $226.8 million in revenue, representing 10% of the global market value. Of those installations, 97% were natural gas fueling stations. Every state in the country, except for Hawaii, Iowa, and South Dakota, now has a natural gas fueling station. California leads the United States in number of hydrogen fueling stations. The 2012 U.S. market is expected to more than double compared to 2011 (an estimated $502.4 million in revenues) as a result of a rapid increase in the number of natural gas vehicle fueling stations installed.

5.1.2 Fuel Transportation Infrastructure

An efficient fuel transportation infrastructure is necessary in order to deliver advanced fuels from their production locations to the network of fueling stations that dispense them. Dedicated pipelines, trains, biofuel tankers/barges, and trucks are needed for some fuels, whereas others can be transported over the existing fuel delivery network. In general, the primary options for transporting relatively small volumes of fuel are rail and trucking. Over time, as fuel demand increases, investment in barges and eventually pipelines can be better justified. This infrastructure enables larger volumes of fuel to be delivered more efficiently and cost-

[8] United States Department of Energy, Alternative Fuels Data Center, October 2012.

effectively. For example, the vertically integrated Brazilian state-owned energy company, Petrobras, operates an extensive dedicated ethanol transport network via river barges, with the barges constructed by its subsidiary, Estaleiro Rio Tietê. For a given amount of fuel used, barges on the Tietê-Paraná waterway can reportedly move a unit of cargo 5 times farther than a truck can haul it on a Brazilian highway and 50% farther compared to rail.[9]

Another example is Kinder Morgan, one of the largest U.S. energy companies, which owns an interest in or operates about 75,000 miles of pipelines. Its pipelines transport natural gas, gasoline, crude oil, carbon dioxide (CO_2), and ethanol. In 2008, the company claimed to be the first to transport ethanol through a pipeline for commercial use, and it continues to move denatured ethanol and gasoline shipments through its Central Florida Pipeline from Tampa to Orlando. The company also moves biodiesel through its 115-mile Oregon Pipeline that spans from Portland to Eugene.

[9] "Petrobras Signs $251M Deal for River-Barge Transport of Ethanol", Biofuels Digest, September 2010.

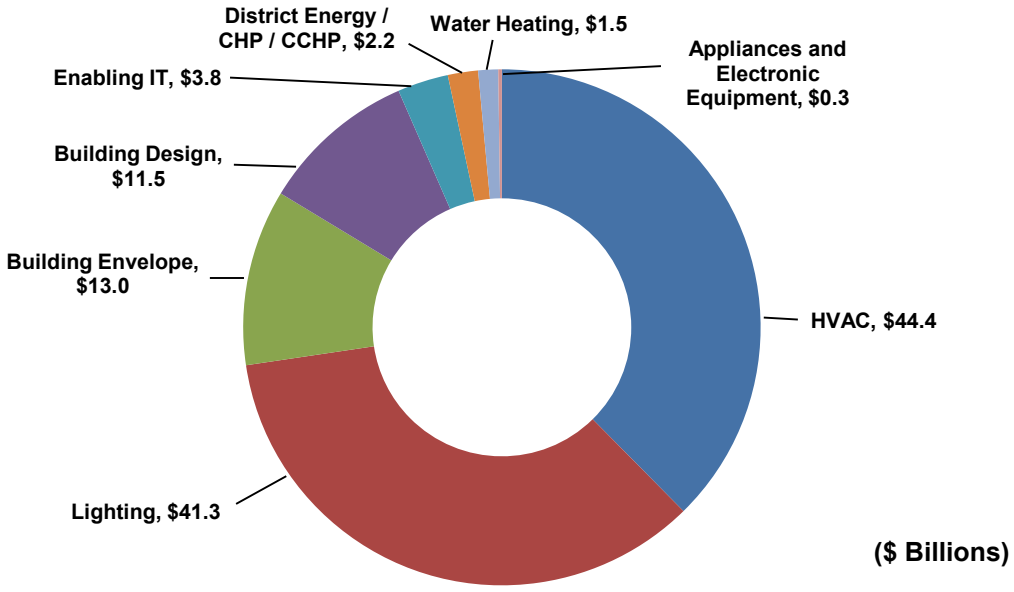
Section 6
BUILDINGS

6.1 High-Efficiency HVAC and Lighting Drive Advanced Energy in Buildings

With commercial and residential buildings responsible for approximately 40% of total U.S. energy consumption, these structures offer abundant opportunities for advanced energy efficiency and management. Advanced energy products and services cover the entire building design, construction, retrofit, and maintenance lifecycle and account for nearly 11% of total advanced energy revenue; global 2011 revenue from this segment was $118.0 billion. As building codes worldwide increasingly require more efficient materials and systems, separating advanced energy technologies from standard practice is challenging. This analysis offers a conservative view by focusing only on technologies that surpass the current energy efficiency status quo. Even with this conservative approach, the global advanced energy Buildings segment is expected to have robust growth of nearly 19% from 2011 to 2012.

Buildings segment revenue in the United States was $35.3 billion in 2011, with 2012 revenue expected to grow 18% to $41.6 billion. Lighting and HVAC combined to account for 55% of 2011 revenue, with advanced lighting technologies expected to grow almost 36% between 2011 and 2012. The Enabling IT segment includes advanced building systems that increasingly use sophisticated computing and communications technologies to optimize energy use. Though this subsegment accounts for less than 6% of U.S. advanced energy revenue in 2011, it represents one of the highest growth opportunities with 2011 to 2012 growth estimated at nearly 30%.

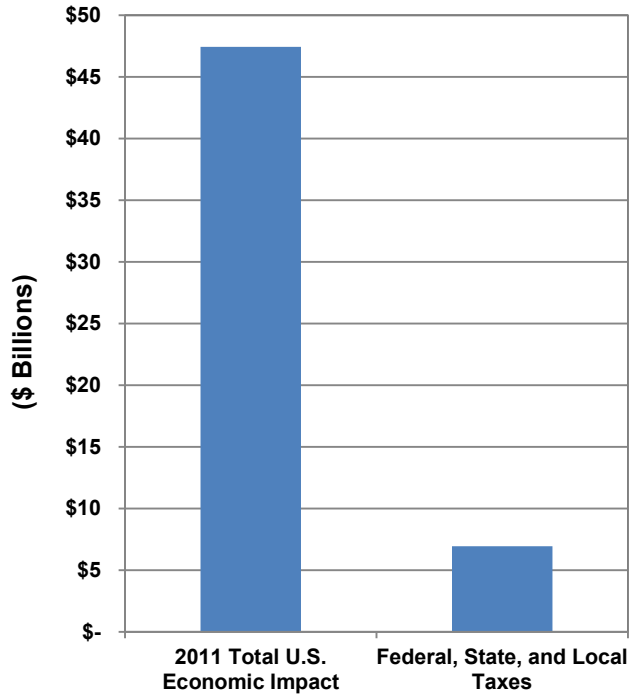
Chart 6.1 Buildings Revenue by Subsegment, World Markets: 2011



(Source: Pike Research and Navigant Consulting)

The Buildings segment in the United States had an overall economic impact on 2011 U.S. GDP of $47.4 billion, derived from the domestic content associated with U.S. Buildings segment revenue. This economic activity generated $4.7 billion in federal tax revenue and an additional $2.2 billion in state and local tax revenue. This economic impact does not include the additional economic benefits of Buildings segment exports from the United States to global markets.

Chart 6.2 Buildings Segment Economic Impact and Tax Generation, United States: 2011



(Source: Pike Research and Navigant Consulting)

6.1.1 Building Design

While energy-efficient building design uses strategies such as passive heating and natural lighting techniques, it also includes efforts to measure, evaluate, and design retrofits of existing buildings to dramatically reduce energy consumption. Providers of such services include energy services companies (ESCOs), which offer performance-based energy efficiency contracts, as well as standard commercial and residential suppliers and contractors. Building information modeling (BIM) tools help teams deliver high-performance buildings in new building designs and major renovations. Examining only the markets for BIM software, commercial retrofit design and commissioning services (ESCO-sourced or otherwise), and residential high-efficiency design services, global 2011 revenue exceeded $11.5 billion, with estimated growth of 13% in 2012.

The opportunity in the United States is similar despite recent challenges experienced by some ESCOs due to the recession, tight municipal government budgets, and a slower than expected

implementation of $2 billion of federal energy savings performance contract (ESPC) plans announced in late 2011. The U.S. Building Design subsegment, as described above, had revenue of $2.8 billion in 2011 with estimated growth of 11% to $3.1 billion in 2012. Utility demand-side management (DSM) programs, pushed by regulatory incentives, are driving energy redesigns ranging from modest system recommissioning to full-scale building retrofits.

6.1.2 Building Envelope

Global 2011 revenue for energy-efficient building envelopes – the elements that separate a building interior from the exterior environment, including insulation, glass, walls, and roofing – was $13.0 billion, representing 11% of the total Buildings segment. This analysis does not include most normal code-compliant construction spending, even as what were once advanced technologies become routine. Instead, the analysis focuses on leading zero net energy building development, high-efficiency homes[10], and commercial energy retrofits, yielding an especially conservative view of how advanced construction materials contribute to advanced energy.

Representative Companies

- Ameresco
- Autodesk
- C3
- Eaton
- EnerNOC
- Honeywell
- Johnson Controls
- Schneider Electric
- Siemens
- Veolia Energy North America

In the United States, U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) and other green building certification programs are serving as the basis for local codes and/or self-imposed corporate policies. These types of programs have driven advanced energy building envelope revenue of $8.7 billion in 2011, along with an estimated 11% growth in 2012. The bulk of this revenue stems from commercial building energy retrofits and high-efficiency homes (new and retrofit). Long-term, however, revenue from new commercial zero net energy buildings with more aggressive energy efficiency goals is forecast to grow at a 13% CAGR through 2025.

6.1.3 Heating, Ventilation, and Air Conditioning (HVAC)

HVAC systems associated with advanced energy applications include energy-specific commercial retrofits, new HVAC systems that exceed local code compliance, ground-source heat pumps, and systems deployed in high-efficiency homes. With 2011 global revenues of $44.4 billion, these HVAC systems make up the largest single Buildings subsegment (38%). Commercial retrofits made up nearly 90% this total, with approximately half of commercial retrofits supplied through ESCO contracting mechanisms.

[10] For this analysis, high-efficiency homes are defined as homes that exceed, by at least 15%, the 2009 International Energy Conservation Code (IECC), which sets minimum design energy performance standards for building shells, space conditioning, lighting, and appliance operation for a variety of global climate zones.

U.S. advanced energy HVAC revenue totaled $10.5 billion in 2011. Again, energy retrofits drove the largest portion of this revenue, supported by ESCOs serving primarily the municipal, university, state government, and healthcare (MUSH) sectors. Recent federal government initiatives (i.e., Executive Order 13514[11]) have aimed to dramatically improve efficiency within the large government building stock, driving significant spending on HVAC retrofits, among other approaches. Though some ESCOs struggle to extend their financing model beyond the federal and MUSH markets, commercial HVAC retrofits supported by other mechanisms still reflect over 40% of 2011 advanced energy HVAC revenue. Overall, U.S. revenue growth in the advanced energy HVAC subsegment from 2011 to 2012 is estimated at over 9%.

6.1.4 District Energy, Combined Heat and Power, and Combined Cooling, Heating, and Power

Combined heat and power (CHP) and combined cooling, heating, and power (CCHP) refer to generation of multiple forms of useful energy (usually electrical and thermal) in a single, integrated system. CHP and CCHP systems are often used in district energy applications that serve multiple buildings in an urban area, industrial park, or campus. Though this analysis does not capture the entire market for district energy, and, more specifically, does not include district energy provided as part of a public utility, the global 2011 market for CHP and CCHP systems used in commercial buildings and campuses (as opposed to industrial uses, discussed elsewhere) was $2.2 billion. While this is a small portion (~2%) of the overall advanced energy Buildings segment, 2011 to 2012 revenue growth is estimated at 25%. This represents one of the highest growth areas within the segment with a projected 10-year global CAGR (2012–2022) of over 17%.

The United States and Europe are currently the most developed markets for commercial CHP and CCHP systems, although with only $814.0 million in revenue in 2011, the United States has only begun to tap the market's potential. The significant decline in natural gas prices is sparking increased CHP and CCHP interest, driving nearly 14% estimated growth from 2011 to 2012 in the United States.

6.1.5 Water Heating

Advanced water heating for residential or commercial uses includes many options, ranging from more efficient conventional water heaters to those using renewable sources such as solar or biomass. This analysis examines only a slice of the overall subsegment, focusing on residential water heating as specifically used in high-efficiency homes, including efficient electric, natural gas, solar, and tankless water heaters. Note that this does not include high-efficiency water heater units installed in residences other than those defined as high-efficiency homes, making this a very conservative view that understates the overall use of high-efficiency water heating in regions outside the United States. Global revenue in 2011 for this slice of the Water Heating subsegment was just under $1.5 billion, $1.1 billion of which was in the United States.

[11] U.S. Executive Order No.13514, October 5, 2009, President Obama

Although retrofits are included in this definition of high-efficiency homes, new construction is a key revenue driver; hence, the overall opportunity has been impacted by the recent housing recession. Despite this, revenue growth between 2011 and 2012 is estimated at just below 6%.

6.1.6 Lighting

Revenue from energy-efficient lighting ranks alongside HVAC as one of the largest portions of the Buildings segment with 2011 global revenue of $41.3 billion (35% of total); this does not include residential replacement bulbs. Dramatic advances in lighting systems, including rapidly evolving LED technologies and intelligent controls, promise major reductions in lighting energy consumption for commercial, residential, and outdoor environments. Global revenue growth from 2011 to 2012 is estimated at 30%, reflecting the scale of the lighting opportunity.

U.S. advanced lighting revenue is estimated to grow even faster, from $9.1 billion in 2011 to $12.4 billion in 2012, with advanced commercial lighting accounting for more than 80% of the total. Though driven by the same energy efficiency retrofit dynamics as other categories in the Buildings segment, many of the advanced lighting projects can be justified on a simple return on investment basis. However, the revenue growth associated with the current replacement cycle is forecast to eventually ebb. Luminaire and lamp growth will slow as LED prices drop and the longer lifecycles reduce replacement rates. Nevertheless, intelligent control systems are expected to continue their growth through the end of the decade.

6.1.7 Appliances and Electronic Equipment

The energy efficiency of residential appliances and home consumer electronics is increasing due to regulations, standards, and consumer preference informed by energy ratings such as the U.S. ENERGY STAR program. Advanced energy technologies are involved in many of these improvements, but this analysis focuses only on smart appliances leveraging intelligent power management technology to drive better energy use, including potential interaction with the electricity grid. This market segment is nascent, estimated to make up less than 1% of the total household appliance market, with 2011 global revenue of only $266.2 million. The U.S. market is slightly less than half of the global total ($104.9 million). However, smart appliances are forecast to reach a 5% penetration of the overall global appliance market by 2020 and as much as 18% penetration in the United States. This would represent a 2012–2020 CAGR exceeding 65%, both in the United States and worldwide.

6.1.8 Enabling Information Technology

Information technology applied to building energy management is a small but growing area of the global advanced energy Buildings segment, with global 2011 revenue of $3.8 billion (3% of total) and an estimated 2011 to 2012 growth rate of 28%. Commercial building energy management systems (BEMS) – hardware, software, and services that monitor, measure, report, and even control HVAC, lighting, or other building systems – represent the largest portion of Enabling IT. Demand response (DR) systems and services (commercial and residential), which make buildings responsive to electric grid conditions, are also included. Enabling IT also encompasses home energy management (HEM) systems, a small part of the

2011 global revenue of just $93.0 million, but with a forecasted CAGR of over 40% through 2020.

In the United States, 2011 revenue for Enabling IT made up nearly 54% of the global total, driven by much higher U.S. adoption of demand response services. Advanced automated DR capabilities are being included within BEMS offerings, ultimately enabling broad real-time optimization of the advanced HVAC, lighting, water heating, and other systems described above.

Section 7
INDUSTRY

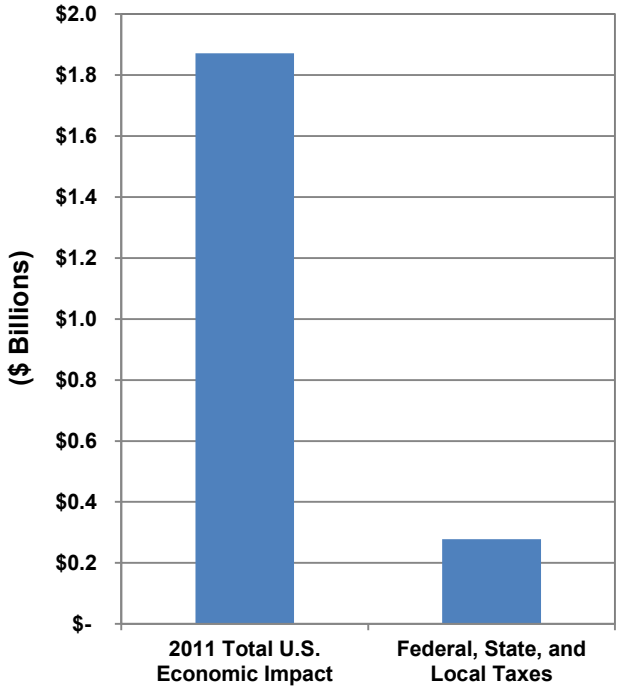
7.1 Advanced Industrial Energy Production and Management Solutions Provide More Options for Manufacturers

The Industry segment is made up of two subsegments: Manufacturing Machinery and Process Equipment and Industrial Combined Heat and Power. Due to lack of available data, only U.S. market data is included for the Manufacturing Machinery and Process Equipment subsegment. Furthermore, revenue from Industrial Energy Management Systems is the only product category included in that subsegment. Therefore, the market value for the Industry segment is considerably understated; as analyzed here, it is the smallest of the seven advanced energy segments with global revenues reaching $1.7 billion in 2011 and estimated to be just over $1.9 billion in 2012.

The U.S. Industry segment had revenues of $1.2 billion in 2011 with Manufacturing Machinery and Process Equipment representing 80% of revenues. 2012 U.S. revenues are expected to reach $1.5 billion, a 24% year-on-year increase.

The Industry segment in the United States had an overall economic impact on 2011 U.S.GDP of $1.9 billion, derived from the domestic content associated with U.S. Industry segment revenue. This economic activity generated $190.5 million in federal tax revenue and an additional $87.9 million in state and local tax revenue. This economic impact does not include the additional economic benefits of Industry segment exports from the United States to global markets.

Chart 7.1 Industry Segment Economic Impact and Tax Generation, United States: 2011



(Source: Pike Research and Navigant Consulting)

7.1.1 Manufacturing Machinery and Process Equipment

The machinery that carries out industrial processes, from molding automobile components to assembling computer chips, accounts for approximately 20% of energy consumed in the United States.[12] Sales of Energy Management Systems (EMSs), a small but important product category of the overall Manufacturing Machinery and Process Equipment subsegment, is the only measure of revenue in this analysis. An enterprise-wide EMS consists of energy measurement infrastructure (meters and submeters) connected to an energy management "intelligence" component that includes a communications network, computer hardware, and the energy management software. This system facilitates the monitoring of energy consumption and provides information to the facility's management so that they can make informed decisions

[12] "Engineer launches review of energy use in manufacturing", MIT News, November 2006.

from both an operational and financial perspective. The U.S. market for sales of industrial energy management system software and services reached $960.0 million in 2011 and is estimated to be more than $1.2 billion in 2012. As the economy recovers, capital spending by industrial and manufacturing companies is rising, as is capacity utilization. Although not quite to pre-recession levels, these numbers reflect a willingness by industry to look to the future with regard to plant refits and systems and equipment upgrades in order to prepare for future growth opportunities.

Representative Companies:

- ABB
- Capstone Turbine Corporation
- Caterpillar
- Chevron
- Comverge
- Dresser-Rand
- EnerNOC
- GE Energy
- Schneider Electric
- Siemens

7.1.2 Industrial Combined Heat and Power

In 2011, global vendor revenues from sales of industrial CHP systems amounted to $1.7 billion with an estimated 501 units shipped. Installations are mostly confined to developed markets in Northern Europe, South Korea, Japan, and the United States. Industrial CHP has gained the greatest traction in the chemical refining and manufacturing sector, which is likely to see growth with an increase in refinery construction in the Asia Pacific region and an uptick in industrial natural gas utilization in North America. Global shipments are estimated to reach 545 units in 2012, representing $1.9 billion in vendor revenue, an 11% increase compared to 2011.

In 2011, U.S. vendor revenue from sales of industrial CHP systems totaled $246.6 million from 71 units shipped. In August 2012, the Obama Administration issued an Executive Order[13] calling for an ambitious goal of an additional 40 GW of industrial CHP installed in the United States by 2020. The Order is expected to spur investment in building out industrial CHP and calls on states to provide incentives to drive new growth. Specifically, the Order is designed to encourage increased packaging of CHP as an energy efficiency measure in state energy plans and to encourage utility financing innovations, while also fostering more partnerships between utilities, energy efficiency service companies, and industrials. Still, growth is expected to be sporadic throughout the United States, confined to those pockets of the country where high electricity prices and incentives are sufficient to overcome high capital costs. In 2012, 83 units are expected to be shipped, generating $292.5 million in U.S. vendor revenues, a 19% increase compared to 2011.

[13] U.S. Executive Order No. 13624, August 31, 2012, President Obama

Section 8
ELECTRICITY GENERATION

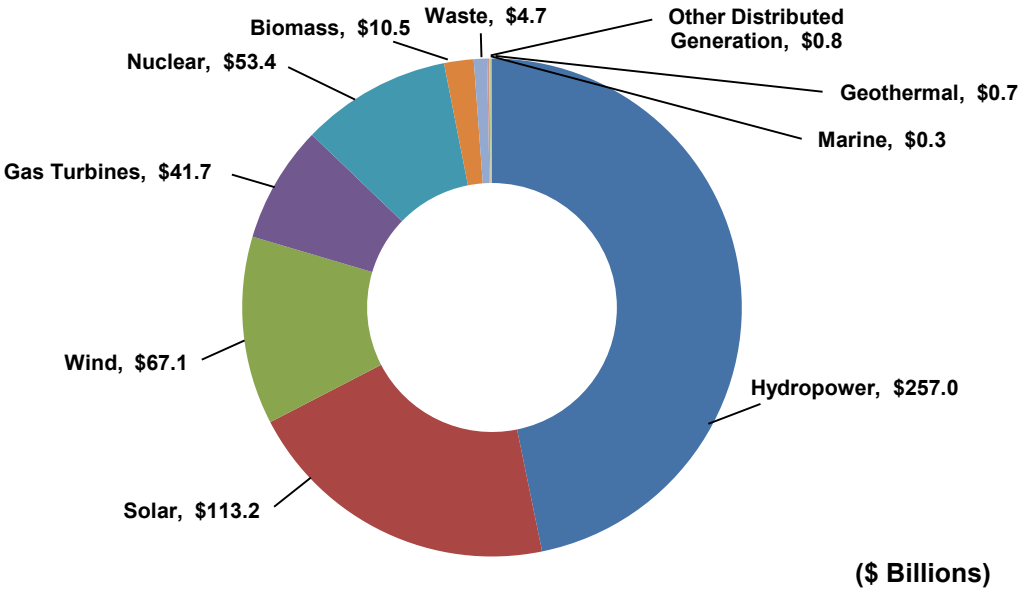
8.1 Hydropower, Solar, and Wind Leading Sources of Electricity Generation Revenue Globally

In 2011, Electricity Generation was the largest advanced energy technology segment by global market size with revenues of $549.3 billion,[14] accounting for 49% of the overall total. With revenues of $257.0 billion, Hydropower was the largest subsegment, followed by Solar and Wind at $113.2 billion and $67.1 billion, respectively. Together these three subsegments accounted for nearly 80% of the advanced Electricity Generation segment in 2011. In 2012, the Wind, Other Distributed Generation, and Geothermal subsegments are expected to see a 10%, 49%, and 123% increase in revenue compared to 2011, respectively. All other subsegments are estimated to have declining revenues during this time, including Hydropower (-65%), Marine (-53%), Waste (-42%), Biomass (-31%), Nuclear (-10%), Gas Turbines (-9%), and Solar (-7%). Hydropower is anticipated to experience the most significant decline in revenues, at nearly $166 billion, due to a decline in orders for new hydropower equipment in China. The result is an estimated Electricity Generation segment market size of $368.6 billion for 2012.

[14] Hydropower, nuclear, and gas turbine plants can take between 2 and 10 years to complete construction, making accurate annual tracking of actual construction activity difficult. Therefore, the full total installed plant cost was assigned to the year in which orders were placed for the main components (e.g., turbines, reactor, generator equipment). In the case of the Concentrating Solar Thermal Power (CSP) product category, where projects typically take 2 to 3 years to complete, the full total installed cost was assigned to the year in which the project broke ground.

In 2011, the United States accounted for 6% of the global Electricity Generation segment revenue; this number is estimated to grow to 10% in 2012. The United States is expected to see a more than 15% increase in revenues in 2012 to $37.2 billion (compared to $32.5 billion in 2011). Within the Electricity Generation segment in 2011, Wind was the largest source of revenue at $13.0 billion, followed by Solar at $10.9 billion, and Gas Turbines at $6.1 billion. These same three subsegments are estimated to represent 94% of the U.S. Electricity Generation segment by revenues in 2012, compared to 92% in 2011.

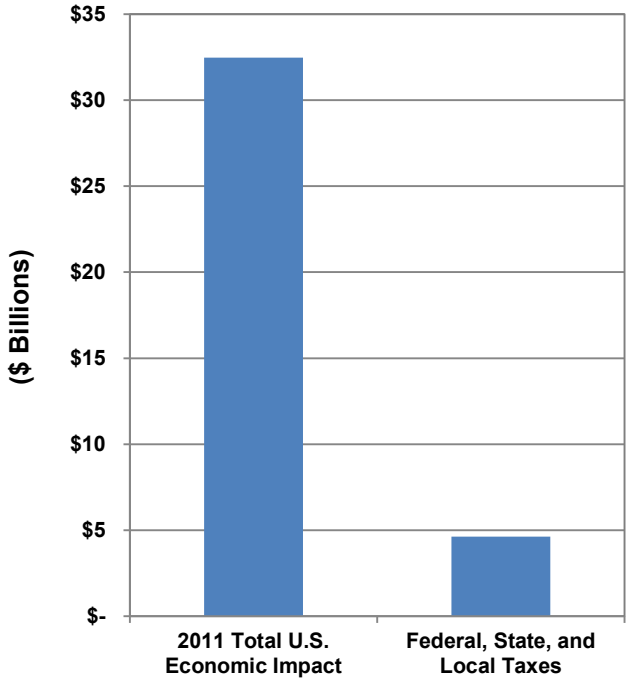
Chart 8.1 Electricity Generation Revenue by Subsegment, World Markets: 2011



(Source: Pike Research and Navigant Consulting)

The Electricity Generation segment in the United States had an overall economic impact on 2011 U.S.GDP of $32.5 billion, derived from the domestic content associated with U.S. Electricity Generation segment revenue. This economic activity generated $3.1 billion in federal tax revenue and an additional $1.5 billion in state and local tax revenue. This economic impact does not include the additional economic benefits of Electricity Generation segment exports from the United States to global markets.

Chart 8.2 Electricity Generation Segment Economic Impact and Tax Generation, United States: 2011



(Source: Pike Research and Navigant Consulting)

8.1.1 Solar

Among non-hydropower renewables, the Solar subsegment – including photovoltaics (PV) and concentrating solar thermal power (CSP) – was the largest source of revenue within the Electricity Generation segment in 2011 at $113.2 billion. Solar is expected to hold onto the top spot among non-hydropower renewables in 2012 but with a slight decrease in revenues to $105.0 billion. The year-on-year decrease is explained by a drop in new CSP projects breaking ground and continued solar PV total installed cost reductions. In 2011, Italy and Germany were the top solar markets and home to a combined 16.8 GW of solar PV installations, accounting for 59% of global installations. Global annual solar PV installations are expected to increase to

approximately 30 GW in 2012 and to grow at a CAGR of 18% between 2012 and 2018. An estimated 1.2 GW of CSP capacity broke ground in 2011, representing $6.3 billion in revenue.[15] CSP activity has been mostly limited to the United States and Europe; however, the Middle East, North Africa, and South Africa are likely to be regions for CSP expansion over the next 6 years.

Representative Companies:

- Areva
- Chevron
- GE Energy
- Goldwind
- Iberdrola
- Siemens
- Suzlon
- Westinghouse
- Weyerhaeuser
- Yingli Solar

In the United States, revenue from the Solar subsegment reached $10.9 billion in 2011, its largest annual total to date. Solar PV is bolstered by the 30% federal solar investment tax credit (ITC) on the books through 2016, rapidly declining hardware costs, and the growth of third-party financing. The import duties recently imposed by the U.S. Department of Commerce on Chinese solar cell and module manufacturers are expected to have limited negative impact on the long-term growth of U.S. solar PV installations. The abundance of low-cost solar PV modules on the market has caused some developers of larger projects to convert plans for CSP plants to solar PV. At the time of writing, there were three CSP plants under construction in the United States. Despite strong solar PV annual installation growth, U.S. Solar subsegment revenues are estimated to decrease slightly in 2012 to $10.5 billion due to continued solar PV price declines.

8.1.2 Wind

Global Wind subsegment revenues totaled $67.1 billion in 2011 and are expected to reach nearly $73.7 billion in 2012. As in recent years, onshore wind power capacity additions in 2012 are expected to be dominated by China, while Europe will lead in offshore deployment. China's most recent Five-Year Plan and overall wind power deployment targets call for 100 GW of cumulative grid-connected wind power capacity by 2015 and 200 GW by 2020, with 30 GW located offshore[16]. Revenues from offshore wind installations globally are forecast to experience a 37% CAGR between 2012 and 2018. During this time the United Kingdom is expected to lead the world in deploying offshore wind technology, followed by Germany.

[15] The full total installed cost for CSP projects were assigned to the year that a project broke ground, based on the National Renewable Energy Laboratory (NREL) list of CSP construction activity. In order to account for projects without a break ground date, a 2-year construction period for smaller projects (50 MW or less located mostly in Spain) and a 3-year construction period for larger U.S. projects (50 MW+) was assumed. Total installed cost includes engineering, procurement and construction costs, development costs, owners' cost, permitting, land costs, and financing during construction.

[16] Power Magazine, December 2012: http://www.powermag.com/issues/features/Renewable-Energy-Development-Thrives-During-Chinas-12th-Five-Year-Plan_5187_p3.html

In the United States, 6.8 GW of wind capacity was installed in 2011, generating $13.0 billion in revenues. In 2012, U.S. wind developers, rushing to complete construction on projects before the scheduled expiration of the federal PTC at the end of the year, are expected to add about 10 GW of capacity. This will result in an estimated $19.1 billion in revenues, a 47% increase compared to 2011. Expiration of the PTC, along with continued low natural gas prices, would make the U.S. wind market outlook dim in the near-term. However, the Cape Wind offshore wind project, the first in the nation to complete the federal permitting process in 2011, continues to move forward more than a decade after it was first proposed. The project, located off of Cape Cod in Massachusetts, is expected to come online in 2015 at more than 400 MW capacity. Despite this advancement and excellent resource potential for offshore wind in the Great Lakes and coastal areas, offshore wind is not expected to take off in the short-term due to higher costs (compared to onshore wind), regulatory constraints, and lack of financing.

8.1.3 Geothermal

In 2011, 136 MW of geothermal capacity was added globally, resulting in $666.4 million in revenues. For 2012, the estimate is 300 MW of new capacity. The relatively long and costly timeline for geothermal power project development will limit the market to slow, but steady growth in the short-term. Geothermal is forecast to have a 5% CAGR between 2012 and 2018. Countries with large available resource potential such as Indonesia, the United States, the Philippines, and Kenya will continue to lead development of this baseload renewable resource.

8.1.4 Biomass

In 2011, 3.5 GW of global biomass power capacity was added, generating revenues of $10.5 billion. Even though biomass installations and revenues are expected to drop 30% in 2012, primarily because of low natural gas prices, new installations are expected to continue steadily at 3 to 4 GW per year between 2013 and 2018. The European Union remains one of the more mature markets for biopower worldwide with Finland, Sweden, and the Netherlands as leaders in the utilization of biomass for heat and power applications. Biopower represents 14%, 7%, and 6% of electricity capacity in these countries, respectively. Large-scale (>100 MW) projects are being pursued in the United Kingdom as an alternative to (or co-fired with) coal, but several of these projects are being scaled back due to eroding economic drivers and questions surrounding the ability to source sufficient biomass resources under long-term contracts that meet increasingly stringent sustainability regulations.

In the United States, 100 MW of biomass power capacity was added in 2011, resulting in $300.0 million in revenues. In 2012, new capacity additions are expected to double, generating revenue of approximately $600.0 million. Revenue from biomass pellet exports was not included in the revenue calculation. Several utilities, including Georgia Power, Portland General Electric, and others have proposed to convert existing coal plants to biomass (known as repowering). In June 2012, Southern Company brought online the country's largest dedicated biomass power plant to date, with capacity of 100 MW (located in Texas). Other projects aim to co-fire biomass with coal in an effort to reduce operating expenses and comply with increasingly strict emissions regulations. Although Renewable Portfolio Standards (RPSs)

encourage biomass power utilization in most states, lower natural gas prices, feedstock supply risk, and environmental concerns are slowing project development and represent challenges to the viability of additional large projects.

8.1.5 Nuclear

Orders for nuclear power plant steam turbines and generator equipment reached 9.7 GW in 2011 with associated revenues (based on total installed plant costs) estimated at $53.4 billion.[17] The Fukushima nuclear reactor meltdown in Japan in March 2011 resulted in the German government announcing plans to phase out its eight nuclear power plants by 2022. Construction of new nuclear plants is expected to continue in other regions, led by China, although orders in 2012 are expected to drop 10% compared to 2011. The Slovak Republic, Russia, India, and the United States are among the countries where nuclear power plants are in planning or are under construction.

In the United States, 104 operating nuclear reactors currently provide approximately 20% of the country's electricity, with the newest unit brought online in 1996. Four new nuclear reactor units in Georgia and South Carolina are under construction. A fifth reactor (located in Tennessee) that was 80% complete before construction halted in 1988 has resumed construction. No new orders for U.S. nuclear power plants were placed in 2011 or expected in 2012, but 1 GW of potential expansion at existing U.S. nuclear plants – referred to as uprating – was approved by the U.S. Nuclear Regulatory Committee during this time.[18] Revenue from uprating, refurbishment, and maintenance was not included in this analysis but represents a large source of anticipated demand in the U.S. market. Despite the availability of federal loan guarantees, nuclear power development continues to face challenges from low-cost natural gas, regulatory delays, high construction costs, and public safety concern following the Fukushima meltdown.

8.1.6 Hydropower

As the most mature renewable energy technology, nearly 1,000 GW of hydropower is installed worldwide. Orders for hydropower turbines and equipment reached an estimated 39.5 GW of capacity in 2011, representing $257.0 billion in associated total revenue from the construction of hydropower plants that use those turbines.[19] Asia, led by China, continues to be the leading

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[17] Construction costs include purchase and installation of nuclear plant technology including engineering, procurement and construction costs, development costs, owners cost, permitting, land costs, and financing during construction. This includes the cost of the reactor, steam generator, steam turbine, generator, condenser, feedwater heaters, boiler feed pumps, emergency generators, fuel storage areas, containment building, turbine building, cooling system, and other safety equipment. Typical nuclear power plants are 1,000-1,700 MW for a single unit configuration. Plants sites are frequently designed for multiple units to reduce overall cost per kW installed.

[18] U.S. Nuclear Regulatory Committee, http://www.nrc.gov/reactors/operating/licensing/power-uprates/status-power-apps/approved-applications.html.

[19] Construction costs include revenue from purchase of hydropower turbines and equipment used in hydroelectric dams including engineering, procurement and construction costs, development costs, owners cost, permitting, land costs, and

market for hydropower and is home to the world's largest electricity generating facility, the Three Gorges Dam (22.5 GW capacity). Orders for new hydropower plants in China are expected to drop from 12.9 GW in 2011 to 8.5 GW in 2012, though such year-on-year swings are typical in this subsegment. In the past 10 years, 12.5 GW has been the average annual order capacity in China with the annual total ranging from 5.4 GW to 23.4 GW during this time. In addition to Asia, Latin America and South Asia are other regions of expected major hydropower activity in the next few years.

The U.S. Hydropower subsegment is expected to drop from $1.2 billion in 2011 to $942.5 million in 2012. In the United States, the focus is on upgrading existing hydropower facilities. In many cases, such as with the Bonneville Power Administration in the Pacific Northwest, hydropower plants are increasingly relied upon to provide load balancing services for variable renewable energy sources.

8.1.7 Marine

The nascent Marine subsegment, which encompasses wave, tidal stream, river hydrokinetic, ocean thermal, and ocean current technologies, had revenues estimated at $300.0 million in 2011, and this is expected to drop to $140.0 million in 2012 due to completion of a large marine power project in South Korea. The majority of projects are still in the pilot phase at testing centers based primarily in the United Kingdom. Large corporations, such as Siemens, Rolls-Royce, and Voith Hydro have entered this emerging industry through their own designs or via acquisition of technology companies. A number of 10 MW to 50 MW commercial projects are expected to come online in the next few years, the majority located in Europe. In the United Kingdom, the Crown Estate has successfully leased the rights to approximately 2 GW of marine energy that could be developed by 2020. In order to be successful, marine power technologies must prove they can operate at scale in extremely harsh conditions and be competitive with offshore wind from a levelized cost of electricity (LCOE) perspective; developers must also convince investors and utilities they can install projects on schedule. Revenues from installation of marine power systems are forecast to have a 56% CAGR between 2012 and 2018.

In 2012, the U.S. Federal Energy Regulatory Committee (FERC) issued Verdant Power the first-ever commercial license for its 1 MW tidal stream power project in New York City's East River. In addition, FERC provided approval of 100-plus preliminary permits to 20 companies to study the feasibility of developing projects around the country. The majority of these permits are for inland river-based hydrokinetic technologies, but also for some tidal stream and ocean wave power plants.

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financing during construction. This also includes generators, civil works (dam, penstock), valves, and control systems. Size can range from a few hundred kW to several thousand MW, as has recently been constructed in China, Canada, and Brazil.

8.1.8 Gas Turbines

In 2011, the Gas Turbine subsegment reached $41.7 billion[20] in associated total revenue from plant construction based on nearly 56 GW of orders for gas turbines and generator equipment. Gas turbine combined cycle units accounted for 74% of those orders. There was broad geographic distribution of orders with approximately 14 GW of orders coming from the Middle East, 10 GW from South Asia, and 8 GW from Central and South America. Globally, orders for gas turbine plants are expected to drop 10% in 2012 (compared to 2011) with associated revenues estimated at $38.0 billion.

The United States accounted for 15% of all turbine orders worldwide in 2011. Revenues associated with those installations amounted to $6.1 billion. Gas turbine combined cycle units accounted for 65% of 2011 orders, while simple cycle gas turbines accounted for 35%. U.S. orders are expected to drop 15% in 2012 with revenues estimated at $5.4 billion. Utilities are decreasing their reliance on coal, which has dropped from about 50% to 37% of U.S. electricity generation in recent years, in large part as a result of abundant low-cost shale gas coming onto the market. If natural gas prices remain low, there will be continued interest in gas turbine technology due to its relatively short construction timeline (which reduces construction risk), high plant efficiency, and ability to integrate into power markets where there is more variability.

8.1.9 Waste

Global revenues for electricity from waste reached $4.7 billion with 1.3 GW of new installed capacity among waste-to-energy (WTE) and biogas facilities in 2011. Biogas for electricity generation, which includes anaerobic digesters and landfill gas-to-energy facilities accounted for 93% of that revenue, led by small-scale digester installations across Germany. However, 2012 revenues for the Waste subsegment are expected to drop 42% to $2.8 billion, with installations estimated at 850 MW. Growth in Europe is expected to continue due to strong waste management policies, and Asia Pacific is expected to be a region of growth for landfill gas recovery.

The United States has generally been slower to adopt biogas capture and utilization technologies from anaerobic digesters due to considerable policy uncertainty, interconnection challenges, and the relatively low cost of grid electricity. It does, however, remain a market

[20] Revenue represents purchase and installation of turbines used in simple cycle and combined cycle plants including engineering, procurement and construction costs, development costs, owners' cost, permitting, land costs, and financing during construction. Simple cycle gas turbine plant construction cost also includes gas turbine, generator, grid interconnection equipment, and other ancillary systems. Combined cycle gas turbine power plant construction cost also includes gas turbine(s), generator(s), heat recovery steam generator, and steam turbine(s). Plants also include necessary ancillary systems required for balance of plant, including: condensers, feed water heaters, boiler feed pumps, a cooling system, buildings, grid interconnection equipment (substation), and control systems. Typical simple cycle gas turbines used for utility power generation applications range from approximately 50 MW up to 300 MW (or larger). Smaller gas turbine products are also available but are typically used in industrial and mechanical drive applications (such as compressor drive or pumping). Combined cycle power plants range from 50 MW to well over 1,000 MW.

leader in landfill gas-to-energy utilization. The U.S. market tallied an estimated $640.0 million in revenues in 2011 from waste, with biogas accounting for 97% of that total. Although emissions control technology has proven to be effective in minimizing WTE combustion facility emissions, local opposition issues and a high reliance on landfilling continue to impact WTE adoption in the United States. Conversely, anaerobic digestion of source-separated organic waste is gaining traction in municipalities where waste reduction efforts have strong policy support and in industrial applications such as food processing. Nonetheless, in 2012 the U.S. Waste subsegment is expected to contract nearly 55% compared to 2011, down to an estimated $290.0 million. This is explained by a drop-off in landfill gas-to-energy project development due to lower natural gas prices and reduced revenue potential from environmental attributes such as RECs.

8.1.10 Other Distributed Generation

The Other Distributed Generation subsegment includes fuel cells, microturbines, Stirling engines, and reciprocating engines. Fuel Cells is the only product category that is included in this analysis, and therefore, the subsegment size is understated. In 2011, global revenues from fuel cell shipments reached an estimated $754.7 million. 2011 marked the largest volume of fuel cell shipments ever; more than 20,000 fuel cell units shipped worldwide, with residential, auxiliary, and portable applications as the primary markets. Asia Pacific accounted for 55% of fuel cell shipment revenue. Within that region, Japan and South Korea were the primary markets where residential fuel cells account for the majority of sales. Japan's ENE-FARM government program subsidizes residential combined heat and power (resCHP) with nearly 20,000 units sold in 2011. South Korea, India, and the United States are also predicted to be leading markets for fuel cells in the coming years with global revenues expected to surpass $1.1 billion in 2012.

In the United States, 2011 revenues from shipments of fuel cells reached $182.0 million, accounting for 24% of the global market. On a capacity basis, North American companies (led by the United States) shipped more fuel cells than companies in any other region. The U.S. market is expected to drop to $136.4 million in 2012, down 25% from 2011. This is driven by an estimated 80% reduction in revenues from auxiliary power units. While no new pro-fuel cell policies are expected in the short-term, there is potential for polymer electrolyte membrane (PEM) fuel cell technology breakthroughs, in addition to advancements in direct methanol fuel cell (DMFC) systems that could lead to significant cost reductions and wider adoption in the next few years.

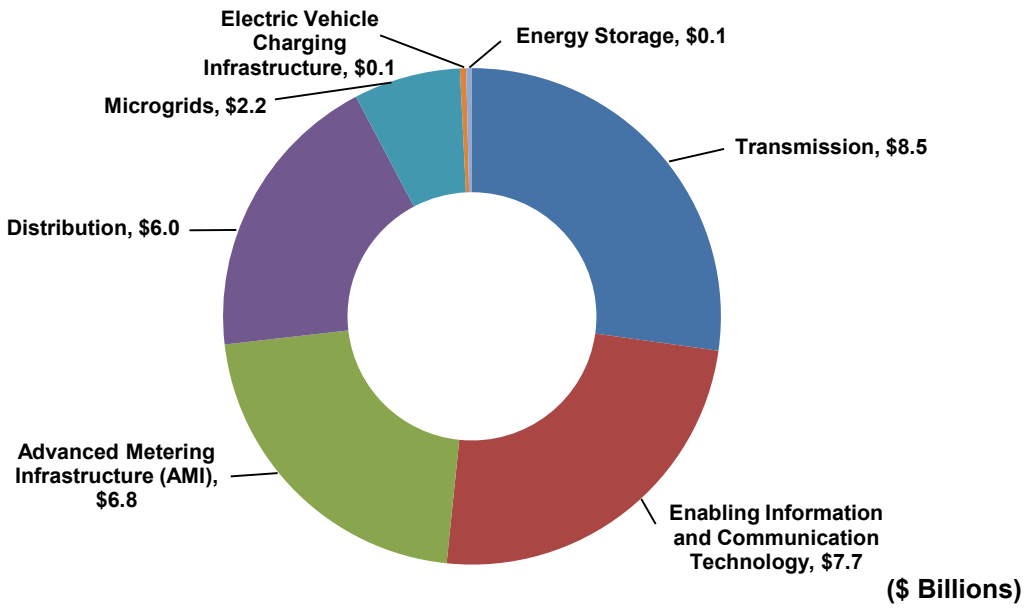
Section 9
ELECTRICITY DELIVERY AND MANAGEMENT

9.1 Advanced Energy Technologies for a Smarter, More Reliable Grid

The Electricity Delivery and Management segment consists of technologies applied toward modernization of the world's electrical power grid, including the use of modern computing and communications to create a so-called "smart grid." This grid modernization aims to transform the grid from a one-way power distribution system to a flexible two-way electricity network with improved efficiency, flexibility, and reliability. These advanced energy technologies, including transmission enhancements, distribution system automation, advanced metering, microgrids, energy storage, and IT systems, generated more than $31.4 billion of global revenue in 2011. Though representing a small percentage (3%) of the total advanced energy market, the Electricity Delivery and Management segment is poised to play an important role as the link between advanced energy supply and demand.

In the United States, grid evolution was already underway when the American Recovery and Reinvestment Act of 2009 (ARRA) funneled additional funds toward advancing and accelerating deployment of these technologies. Total 2011 vendor revenue was slightly more than $8.4 billion and is estimated to exceed $10.7 billion for 2012, for year-on-year growth of 27%. Revenue in 2011 was split between Transmission Systems (12%), Distribution Systems (21%), Advanced Metering (23%), and Enabling Information and Communications Technology and services (35%).

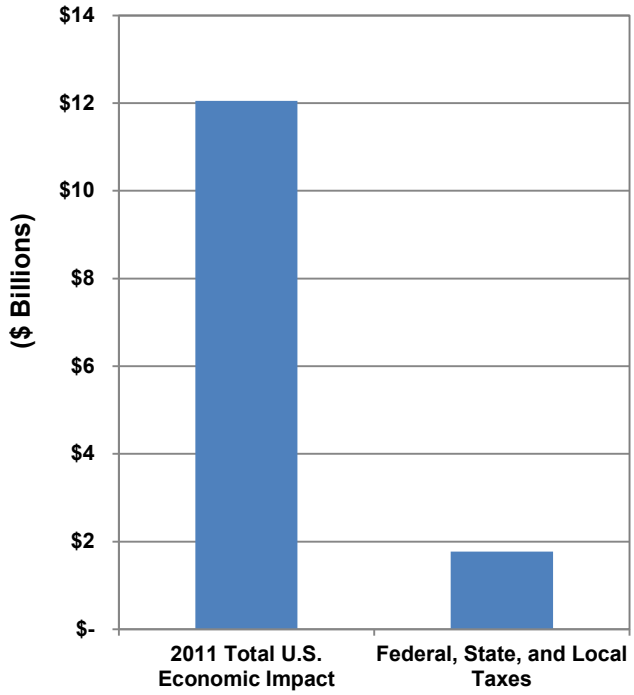
Chart 9.1 Electricity Delivery and Management Revenue by Segment, World Markets: 2011



(Source: Pike Research and Navigant Consulting)

The Electricity Delivery and Management segment in the United States had an overall economic impact on 2011 U.S.GDP of $12.1 billion, derived from the domestic content associated with the U.S. Electricity Delivery and Management segment revenue. This economic activity generated $1.2 billion in federal tax revenue, and an additional $562.2 million in state and local tax revenue. This economic impact does not include the additional economic benefits of exports associated with the Electricity Delivery and Management segment from the United States to global markets.

Chart 9.2 Electricity Delivery and Management Segment Economic Impact and Tax Generation, United States: 2011



(Source: Pike Research and Navigant Consulting)

9.1.1 Transmission

The transmission network is the high-voltage network that moves bulk power from power plants to load centers. Advanced energy transmission technologies include upgrades to traditional approaches, such as flexible alternating current transmission systems (FACTS) and high-voltage direct current (HVDC) systems, typically implemented as new transmission projects. Global 2011 revenues for these systems were just over $8.5 billion, including advanced AC transmission and full HVDC and submarine cable system project revenue. Growth estimates for 2012 are high; this is driven by major HVDC projects associated with Chinese grid expansion for connecting coal and wind generation between the country's interior and coastal cities, as well as the evolution of a European "supergrid," strengthening the continent's grid interconnections.

The United States is also set to see significant advanced energy transmission revenue growth from a 2011 revenue base of $1.0 billion, despite some regulatory uncertainty. Transmission capacity increases aimed at connecting new wind and solar capacity in Texas, the Midwest, and the Western states are driving factors, as are potential transmission flow changes due to coal-fired generation plant retirements.

9.1.2 Distribution

Smart grid evolution is most evident in the electrical distribution system, the medium-voltage network that delivers electricity from the transmission system to customers. The distribution system increasingly must support dynamic loads, distributed generation resources, and more interactive consumers. New substation and distribution automation technologies enabling adaptive, self-healing power networks are core to meeting these demands. Global 2011 revenues for automation vendors totaled nearly $6.0 billion, with 2012 estimates up to $7.4 billion for 23% year-on-year growth. The specific technologies vary regionally due to infrastructure design differences around the world, but the general goal is to increase power network intelligence, whether applied in new build-outs supporting China's growth or in upgrading existing substations in Europe and North America.

Representative Companies

- ABB
- AES Energy Storage
- ChargePoint
- Cisco Systems
- General Electric
- IBM
- Itron
- Landis+Gyr
- S&C Electric
- Siemens

In the United States, the primary focus has been improving grid reliability by automating distribution substations and associated feeder circuits. Vendor revenues reached nearly $1.8 billion in 2011 and are estimated at $2.2 billion for 2012, a 26% increase. These figures reflect projects accelerated by ARRA funding, however, many of these reliability and efficiency improvements (such as dynamic voltage control) have strong business cases even without government funding.

9.1.3 Advanced Metering Infrastructure (AMI)

AMI systems (perhaps better known as "smart meters") have the highest consumer profile of any smart grid technology. In addition to operational benefits, AMI allows utilities and consumers to track electricity consumption and pricing in real-time. This is necessary, for example, for pricing programs that reward peak load reductions, which in turn improve grid operational efficiency and reduce costs. 2011 global vendor revenue for AMI systems (not including utility installation spending) was nearly $6.8 billion, with major projects in China and the United States, and growing European deployments in response to European Union mandates.

In the United States, ARRA funding accelerated AMI deployment between 2010 and 2012, with 2011 revenue of $1.9 billion representing a peak in shipments. Revenue estimates for 2012 are just over $2.0 billion, which includes emerging managed services (including pre-payment services) business models. However, as ARRA funded programs end, AMI revenue is forecast

to see declines of up to 40% below the 2011 peak through 2013 and 2014 before beginning a gradual recovery. By the end of the decade, AMI technologies are forecast to cover more than 65% of all installed U.S. electrical meters.

9.1.4 Microgrids

Some institutional, military, educational, or private enterprises with their own local distribution networks are developing microgrids that independently generate and manage their own electricity, often integrating renewable sources, with the ability to connect or disconnect to/from the larger electrical grid. The Microgrids subsegment also includes remote communities with expensive or unreliable access to the main electricity grid, such as in developing countries and many parts of rural Alaska. Global 2011 Microgrid revenues, including equipment and services, reached nearly $2.2 billion with robust growth for 2012 estimated at 18%. Although remote microgrids make up the largest share (>80%) of the global market, some utility industry leaders see microgrid architectures, with their ability to manage variable generation resources and electricity demand locally, as the model for integrating distributed generation into future utility distribution systems.

Utilities in the United States have historically not been receptive to microgrids, citing competitive and safety concerns. New technical standards governing the interface between microgrids and the public grid, and increasing receptiveness by some utilities, promise to expand the U.S. market, which was $632.3 million in 2011, to an estimated $755.1 million in 2012. .

9.1.5 Electric Vehicle Charging Infrastructure

Charging systems for PEVs,[21] including private and public systems, yielded just $126.9 million in global revenue in 2011. However, the 2012 revenue estimate of $355.1 million demonstrates dramatic year-on-year growth of 180%, driven by the still nascent adoption of PEVs. The relatively slow adoption of electric vehicles (EVs) is pressuring the already challenging public charging infrastructure business models.

The EV charging infrastructure market in the United States is a relatively small percentage of the global market, with 2011 revenue of $26.9 million. However, 2012 revenue estimates of $92.5 million show significant growth. With more than a dozen companies aspiring to develop national charging infrastructure networks, steep competition combined with slow PEV sales is likely to drive industry consolidation.

9.1.6 Energy Storage

Energy Storage includes a variety of technologies to store electrical energy in order to better match supply with demand, help integrate variable generation sources, and provide ancillary

[21] This includes all-electric vehicles and plug-in hybrid vehicles.

services to the grid. With the exception of pumped hydropower, which is mature, energy storage technologies are just emerging for commercial applications. Global 2011 project revenues were $116.5 million, a small fraction of advanced energy revenues for Electricity Delivery and Management. Nevertheless, revenues are expected to grow as technologies mature and the business case for energy storage becomes more widely understood and accepted.

The United States accounted for a major portion (70%) of 2011 global revenue, supported in part by government Advanced Research Projects Agency-Energy (ARPA-E) research funding and by emerging federal and local regulations influencing deregulated market operations. For example, a recent "pay for performance" FERC Order encourages compensation for frequency regulation accuracy as well as capacity, rewarding a key energy storage advantage over traditional generation assets.

9.1.7 Enabling Information and Communications Technology

Utility and related spending in information technology (IT) and control room operating technology (OT) is expanding rapidly in support of the deployed field-based smart grid equipment. Global 2011 revenue from software and services reached $7.7 billion in 2011, and 2012 estimates of $9.4 billion demonstrate robust growth (23%). This analysis includes grid communications networks (beyond AMI) and grid IT/OT software and services, such as meter data management, next generation customer information and billing systems, and advanced data analytics. For many utilities, implementing new grid capabilities requires significant integration of separate information systems, not unlike the transformations that swept the financial, telecom, and manufacturing industries over the last two decades, with the hope of similar improvements in flexibility, efficiency, and productivity.

In many ways, the United States has been at the forefront of this transformation as AMI deployments reach high penetration levels and utilities begin to analyze and use the vast amounts of data now available from these systems. Revenue in 2011 was nearly $3.0 billion, coming from a mix of communications network upgrades, new customer information systems (CIS), emerging data analytics applications, and integration services supporting all of these. Estimates for 2012 see year-on-year growth of 20% with continued expansion expected over the next few years.

Section 10

ACRONYM AND ABBREVIATION LIST

Advanced Energy Economy Institute	AEEI
Advanced Energy Economy	AEE
Advanced Research Projects Agency-Energy	ARPA-E
Alternating Current	AC
American Recovery and Reinvestment Act	ARRA
Anaerobic Digester Gas	ADG
Battery Electric Vehicle	BEV
Billion Cubic Feet per Year	BCFY
Billion Cubic Feet	BCF
Building Energy Management System	BEMS
Building Information Modeling	BIM
Carbon Dioxide	CO_2
Combined Cooling, Heating, and Power	CCHP
Combined Heat and Power	CHP
Compound Annual Growth Rate	CAGR
Compressed Natural Gas	CNG
Concentrating Solar Power	CSP
Customer Information System	CIS
Demand Response	DR
Demand-side Management	DSM
Department of Energy (United States)	DOE
Electric Vehicle	EV
Energy Management System	EMS

Energy Savings Performance Contract ..... ESPC

Energy Services Company ..... ESCO

Federal Energy Regulatory Committee ..... FERC

Federal Renewable Fuel Standard ..... RFS

Flexible Alternating Current Transmission Systems ..... FACTS

Fuel Cell Vehicle ..... FCV

Gallon Gasoline Equivalent ..... gge

Gross Domestic Product ..... GDP

Heating, Ventilation, and Air Conditioning ..... HVAC

High-voltage Direct Current ..... HVDC

Home Energy Management ..... HEM

Hybrid Electric Vehicle ..... HEV

Information Technology ..... IT

International Energy Conservation Code ..... IECC

Investment Tax Credit ..... ITC

Kilograms ..... kg

Landfill Gas ..... LFG

Leadership in Energy and Environmental Design ..... LEED

Levelized Cost of Electricity ..... LCOE

Light Duty Vehicle ..... LDV

Liquefied Natural Gas ..... LNG

Lithium-ion ..... Li-ion

Low Carbon Fuel Standard ..... LCFS

Million Gallons per Year ..... MGY

Municipal, University, State government, and Healthcare ..... MUSH

National Renewable Energy Laboratory ..... NREL

Natural Gas Vehicle ..... NGV

Operating Technology ..... OT

Photovoltaic ..... PV

Plug-in Electric Vehicle ..... PEV

Plug-in Hybrid Electric Vehicle ..... PHEV

Production Tax Credit ..... PTC

Renewable Energy Credit ..... RECs

Renewable Fuel Standards ..... RFS

Renewable Identification Number ..... RIN

Renewable Portfolio Standard ..... RPS

Residential Combined Heat and Power ..... resCHP

Uninterruptible Power Supply ..... UPS

Waste-to-Energy ..... WTE

Section 11

TABLE OF CHARTS AND FIGURES

Section 12
ABOUT AEEI, PIKE RESEARCH, AND NAVIGANT CONSULTING

Advanced Energy Economy Institute (AEEI) is a national nonprofit charitable organization whose mission is to raise awareness of the public benefits of advanced energy, drive the policy debate on key topics, and provide a forum where leaders can address energy challenges and opportunities facing the United States. AEEI is associated with Advanced Energy Economy (AEE), a national association of business leaders who are making the global energy system more secure, clean, and affordable. Advanced energy encompasses a broad range of products and services that constitute the best available commercial technologies for meeting energy needs today and tomorrow.

Pike Research, a part of Navigant Consulting's global Energy Practice, is a market research and consulting team that provides in-depth analysis of global clean technology markets. The team's research methodology combines supply-side industry analysis, end-user primary research and demand assessment, and deep examination of technology trends to provide a comprehensive view of these industry sectors.

Navigant (NYSE: NCI) is a specialized, global expert services firm dedicated to assisting clients in creating and protecting value in the face of critical business risks and opportunities. Through senior level engagement with clients, Navigant professionals combine technical expertise in Disputes and Investigations, Economics, Financial Advisory and Management Consulting, with business pragmatism in the highly regulated Construction, Energy, Financial Services, and Healthcare industries to support clients in addressing their most critical business needs.

Navigant's energy consulting services are designed to benefit owners, manufacturers, regulators, and investors as we help them minimize risk and optimize performance in this critical, complex, and ever evolving industry. More information about Navigant can be found at www.navigant.com.

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Section 13
SCOPE OF STUDY, SOURCES AND METHODOLOGY, AND NOTES

13.1 Scope of Study

Under the sponsorship of the Advanced Energy Economy Institute (AEEI), Pike Research, a part of Navigant Consulting, has prepared this report as an independent, unbiased assessment of the size and scope of the economic impact of various advanced energy technology segments. This report provides readers from diverse backgrounds a means of quickly understanding the range, structure, and key economic attributes of advanced energy technologies globally and in the United States.

This report draws insight and data from over 60 previously published Pike Research reports, as well as data and analysis developed by Navigant Consulting's Energy Practice. Leveraging these extensive research sets, this report provides data and analysis for seven advanced energy segments as identified by AEEI: Transportation, Fuel Production, Fuel Delivery, Buildings, Industry, Electricity Generation, and Electricity Delivery and Management. Within these segments, there are 41 specific subsegments, of which 34 are included in this analysis. For some subsegments, a subset of all possible technologies (referred to as product categories) may be included in this analysis, as noted in the text.

This study quantifies global and U.S. technology revenue for 2011 (actual) and 2012 (estimated). The study also includes an economic analysis of the direct, indirect, and induced economic effects of the investments represented by this revenue activity on U.S. GDP in 2011 and on collection of local, state, and federal taxes.

13.2 Sources and Methodology

For each of the advanced energy segments and subsegments included in this report, two types of data are provided: revenue data (global and U.S; 2011 and, where possible, 2012) and economic impact data (U.S., 2011) as a result of the investments represented by the revenue data.

Revenue may be examined at different points within an industry's value chain. To the extent possible, the revenue data provided in this report is based on the point of end delivery of the value chain (i.e., total installed costs); however, in some cases, a different point in the value chain, such as vendor equipment sales revenue, is the more appropriate and measureable indicator. These differences are defined and noted in the report. In general, operations and maintenance revenue is excluded except where selected services are a primary means of delivering the technology (for example, managed service offerings or software-as-a-service). Double counting of revenue at multiple points in the value chain has been avoided. The resulting data in this report represents a conservative revenue estimate for each segment and in aggregate.

All revenue data in this study is derived from published Pike Research industry reports and internal Navigant Consulting information. Each Pike Research report is prepared utilizing a variety of research sources, a key component being primary research gained from phone and in-person interviews with industry leaders including executives, engineers, and marketing professionals. Pike Research analysts are diligent in ensuring that they speak with representatives from every part of the value chain, including but not limited to: technology companies, utilities and other service providers, industry associations, government agencies, and the investment community. Additional analysis includes secondary research conducted by Pike Research's analysts and its staff of research assistants, and combined with the analysts' industry expertise, this information is synthesized into the qualitative and quantitative analysis presented in Pike Research's reports.

Other data in this report is derived from Navigant Consulting's extensive work across the energy industry for government, regulatory, vendor, financial, and end-user clients. As part of this work, Navigant maintains data and continuing insights on a wide range of renewable and standard electricity generation, electrical grid technologies, and demand-side management technologies and services.

The revenues described for each of the segments and subsegments in this analysis capture the value added to the product along the entire value chain: from raw materials through final installed product. Thus the economic impacts modeled from these revenues include both the direct impacts associated with the end purchase of the product (i.e., investment) as well as the indirect impacts to the various suppliers contributing to the end product. The induced spending is the product of combined direct and indirect spending multiplied by industry-specific economic impact multipliers. Tax revenues are calculated as a share of the impact on U.S. GDP.

Experts within Navigant's Economics practice leveraged the revenue data described above to determine the direct economic impacts of each sector. The RIMS II Model, developed and maintained by the U.S. Department of Commerce, Bureau of Economic Analysis, was used to evaluate the economic impacts, including those that occur due to the investment (i.e., the "direct effects"), those that arise due to the economic activities of the supply chain involved in the production of the investment (i.e., the "indirect effects"), and those that occur due to the spending of the wages and other personal income generated by the economic activities by the investment and its suppliers (i.e., the "induced effects"). The modeling included aligning appropriate SIC industry codes and determining the amount of domestic content associated with each advanced energy segment.

For tax revenues, Navigant's Tax Revenue Model was utilized to calculate federal, state, and local tax revenues generated by an increase in economic activity. This model has been used in numerous prior economic impact studies. The tax revenue generated is calculated by applying an effective tax rate to the increase in a measure of economic activity (e.g., employee earnings or value added). For example, investment in a manufacturing plant will generate increased employment at the plant and increased indirect and induced employment at other locations.

Federal, state, and local governments will experience increased tax revenues from the taxes on the wages generated by the increased employment.

13.3 Notes

CAGR refers to compound average annual growth rate, using the formula:

CAGR = (End Year Value ÷ Start Year Value)$^{(1/steps)}$ – 1.

CAGRs presented in the tables are for the entire timeframe in the title. Where data for fewer years are given, the CAGR is for the range presented. Where relevant, CAGRs for shorter timeframes may be given as well.

Figures are based on the best estimates available at the time of calculation. Annual revenues, shipments, and sales are based on end-of-year figures unless otherwise noted. All values are expressed in year 2012 U.S. dollars unless otherwise noted. Percentages may not add up to 100 due to rounding.

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