



**ADVANCED  
ENERGY  
ECONOMY**

# ADVANCED ENERGY NOW 2015 MARKET REPORT

Global and U.S. Markets by Revenue 2011-2014 and Key Trends in Advanced Energy Growth

Prepared by Navigant Research



March 2015

## About Advanced Energy Economy

Advanced Energy Economy is a national association of businesses and 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 technologies for meeting energy needs today and tomorrow. AEE's mission is to transform public policy to enable rapid growth of advanced energy businesses. AEE and its State Partner organizations are active in 25 states across the country, representing roughly 1,000 companies and organizations in the advanced energy industry.

Visit Advanced Energy Economy online at: [www.aee.net](http://www.aee.net).

## About Navigant Research

Navigant Research, a part of Navigant Consulting's Energy Practice, is a market research and advisory group that provides in-depth analysis of global clean technology markets with a specific focus on the commercialization and market growth opportunities for emerging energy technologies. Our client base includes Fortune 1000 multinational technology and energy companies, government agencies, utilities, investors, industry associations, and clean technology pure plays. We provide these companies with market research reports, custom research engagements, and subscription-based research services. Navigant is focused across four research programs: Energy Technologies, Utility Transformations, Transportation Efficiencies, and Building Innovations.

Additional information about Navigant Research can be found at [www.navigantresearch.com](http://www.navigantresearch.com).



*Advanced Energy Now 2015 Market Report*

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## ADVANCED ENERGY NOW 2015 MARKET REPORT – HIGHLIGHTS

*Advanced Energy Now 2015 Market Report* is the third annual report of market size, by revenue, of the advanced energy industry, worldwide and in the United States. As defined by Advanced Energy Economy (AEE), a national association of businesses that are making the energy we use secure, clean, and affordable, advanced energy is a broad range of technologies, products, and services that constitute the best available technologies for meeting energy needs today and tomorrow.

Prepared for AEE by Navigant Research, *Advanced Energy Now 2015 Market Report* draws on more than 60 previously published Navigant Research studies on specific industry categories and covers four years of industry revenue. The results must be viewed, however, as a conservative assessment of advanced energy market size. Navigant Research has used strict definitions within product categories in order to distinguish advanced energy from conventional energy products. Also, U.S. market revenue counts only domestic sales of products and services and does not include revenue from exports, understating the economic scope of the U.S. advanced energy industry.

### Summary Findings – U.S. Market

- In the United States, the advanced energy market reached just under **\$200 billion – making up 15% of the global market.**
- **U.S. advanced energy revenue grew 14% from 2013 to 2014 – five times greater than the U.S. economy overall.**
- **The Electricity Generation segment surged back, jumping 47% to \$45.8 billion in 2014.**
  - Wind power rebounded to \$8.2 billion from \$2.1 billion in 2013 – with a strong pipeline in place for 2015.
  - **Solar PV grew 39% year-on-year to \$22.5 billion, capping four-year growth of 173% – nearly tripling revenue of \$8.2 billion.**
  - **The natural gas revolution in the United States also, for the first time, translated into an increase in sales of new generating equipment, with revenue from natural gas turbines up 48%, to \$6.4 billion.**
- **Revenue from Building Efficiency products and services – the largest segment of U.S. advanced energy – has grown 43% over four years.**
- In Transportation, **revenue was down 19% for hybrid vehicles but up 34% for plug-in electric vehicles, while light duty and heavy duty natural gas-powered vehicles both jumped 26% in revenue in 2014.**
- **In Electricity Delivery and Management, revenue from electric vehicle charging infrastructure was up 31% to \$201.5 million, a seven-fold increase over the past four years.**

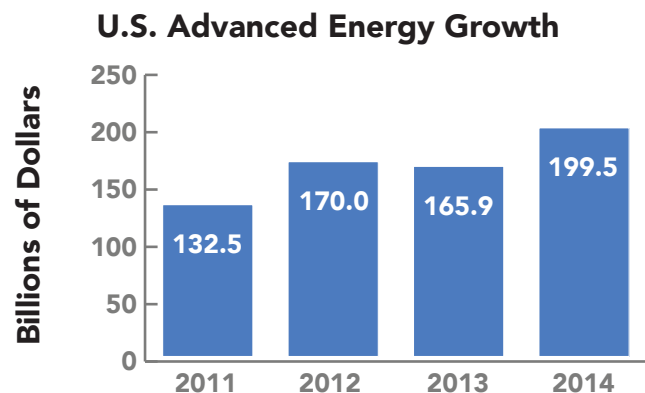


Figure 1.1 (Source: Navigant Research)

## Summary Findings – Global Market

- For 2014, advanced energy grew to just under \$1.3 trillion in global revenue, a 12% increase over 2013.
- Year-over-year increases in all seven segments made 2014 the biggest growth year for advanced energy worldwide since Navigant Research began tracking the industry for Advanced Energy Economy in 2011.
- Electricity Generation, the largest segment of advanced energy by revenue, grew strongly, up 16% over 2013.
  - Revenue from **wind power jumped 40%**, to \$95 billion globally, after a decline in 2013.
  - After a sharp decline from 2011 to 2012 and slow growth in 2013, **hydropower was up 45%** in 2014, to \$122 billion.
- Transportation grew 8% in 2014, to \$373 billion, driven by **strong growth in revenue from hybrid (+40%) and plug-in hybrid (+80%) vehicles**.
- **Building Efficiency grew 12%**, to \$209.5 billion, up 40% over four years, led by commercial and residential energy efficiency retrofits and zero net energy buildings.
- The fastest growing segment of advanced energy was Electricity Management and Delivery, up 33% to \$67.9 billion after a down year in 2013. Revenue from **transmission investments was up 400%** over 2013, with **HVDC transmission revenue up 61%** to \$6.1 billion, and **transmission system upgrades jumping nearly twenty-fold**, from \$694 million to 12.6 billion.



## ENERGY SUPPLY

Electricity Generation	Electricity Delivery & Management
<ul style="list-style-type: none"> <li>• Hydropower</li> <li>• Gas Turbines</li> <li>• Solar</li> <li>• Wind</li> <li>• Geothermal</li> <li>• Marine</li> <li>• Waste</li> <li>• Biomass</li> <li>• Nuclear</li> <li>• Fuel Cells and Other DG</li> </ul>	<ul style="list-style-type: none"> <li>• Transmission</li> <li>• Distribution</li> <li>• AMI</li> <li>• Micro-grids</li> <li>• EV Charging Infrastructure</li> <li>• Energy Storage</li> <li>• Enabling IT</li> </ul>
Fuel Production	Fuel Delivery
<ul style="list-style-type: none"> <li>• Ethanol &amp; Butanol</li> <li>• Biodiesel</li> <li>• Biogas</li> <li>• Synthetic Diesel &amp; Gasoline</li> <li>• Bio-oil</li> <li>• CNG &amp; LNG</li> <li>• Hydrogen</li> </ul>	<ul style="list-style-type: none"> <li>• Fuel Transportation Infrastructure</li> <li>• Fueling Stations</li> </ul>

## ENERGY DEMAND

Building Efficiency	Transportation
<ul style="list-style-type: none"> <li>• Building Design</li> <li>• Building Envelope</li> <li>• HVAC</li> <li>• District Energy, CHP, CCHP</li> <li>• Water Heating</li> <li>• Lighting</li> <li>• Appliances &amp; Electronics</li> <li>• Enabling IT/Demand Response</li> </ul>	<ul style="list-style-type: none"> <li>• Propulsion Systems</li> <li>• Vehicle Design &amp; Materials</li> <li>• Freight Logistics</li> <li>• Land Use &amp; Infrastructure Design</li> <li>• Enabling IT</li> </ul>

## Industry

- Manufacturing Machinery & Process Equipment
- Industrial Combined Heat & Power

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## FOREWORD

Advanced Energy Economy (AEE) is the pragmatic voice of business leaders who are working every day to make the energy we use secure, clean, and affordable. AEE also represents a dynamic industry consisting of corporations with global impact, growth companies, and start-ups. All these companies are delivering energy technologies, products, and services across our country and around the world.

*Advanced Energy Now 2015 Market Report* is our third annual report on the size, growth, and trends in the advanced energy market, globally and in the United States. It traces the growth of our industry since publication of *Economic Impacts of Advanced Energy* in 2013. Beginning with that report, Navigant Research has been tracking global and U.S. revenue for AEE, with 2011 as the baseline.

This year's edition shows growth of 12%, which is the biggest increase in the global market for advanced energy in the four years we've been tracking it. The U.S. market grew 14% in 2014, five times the rate of the national economy.

As this year's report shows, advanced energy is a nearly \$1.3 trillion global market and a U.S. market of just under \$200 billion. That makes the global advanced energy market as big as the apparel and fashion industry worldwide, and almost four times the size of the semiconductor industry. In the United States, the market for advanced energy is bigger than the airline industry, equal to pharmaceuticals, and nearly as big as consumer electronics.

Advanced energy is a thriving industry made up of a wide variety of businesses. For this report, revenue has been compiled from seven broad industry segments and 41 subsegments, representing more than 80 distinct products and services. It is the most comprehensive accounting of the advanced energy marketplace done to date. But it is still only a partial picture of the economic opportunity offered by advanced energy going forward.

We are seeing a transformation in the way we make, manage, and use energy in this country and around the world. This transformation is driven by dynamic changes in technology, policy, and markets. AEE, its member companies, and our partner organizations around the country are working to make the most of this transformation. This will benefit consumers, the economy, and the nation.



Graham Richard  
CEO, Advanced Energy Economy

# INTRODUCTION & METHODOLOGY

The *Advanced Energy Now 2015 Market Report* is the third annual report of market size, by revenue, of the advanced energy industry, worldwide and in the United States.

As defined by Advanced Energy Economy, a national association of business leaders with the goal of making the energy we use secure, clean, and affordable, advanced energy is a broad range of technologies, products, and services that constitute the best available technologies for meeting energy needs today and tomorrow. 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 and utility-scale 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 not only to serve the domestic market but to export goods and services into the global energy markets.

Advanced energy consists of seven broad industry segments and 41 subsegments, each of which contains multiple product categories. The segments and subsegments of advanced energy are enumerated in the figure below:

Transportation	Fuel Production	Fuel Delivery	Building Efficiency
<ul style="list-style-type: none"> <li>• Propulsion Systems</li> <li>• Vehicle Design and Materials</li> <li>• Freight Logistics</li> <li>• Land-use and Infrastructure Design</li> <li>• Enabling Information Technology</li> </ul>	<ul style="list-style-type: none"> <li>• Ethanol and Butanol</li> <li>• Biodiesel</li> <li>• Biogas</li> <li>• Synthetic Diesel and Gasoline</li> <li>• Bio-oil</li> <li>• Compressed Natural Gas and Liquefied Natural Gas</li> <li>• Hydrogen</li> </ul>	<ul style="list-style-type: none"> <li>• Fueling Stations</li> <li>• Fuel Transportation Infrastructure</li> </ul>	<ul style="list-style-type: none"> <li>• Building Design</li> <li>• Building Envelope</li> <li>• Heating, Ventilation, and Air Conditioning (HVAC)</li> <li>• District Energy, Combined Heat and Power (CHP), and Combined Cooling Heating and Power (CCHP)</li> <li>• Water Heating</li> <li>• Lighting</li> <li>• Appliance and Electronic Equipment</li> <li>• Enabling IT/Demand Response</li> </ul>
Industry	Electricity Generation	Electricity Delivery and Management	
<ul style="list-style-type: none"> <li>• Manufacturing Machinery and Process Equipment</li> <li>• Industrial Combined Heat and Power</li> </ul>	<ul style="list-style-type: none"> <li>• Hydropower</li> <li>• Gas Turbines</li> <li>• Solar</li> <li>• Wind</li> <li>• Geothermal</li> <li>• Marine</li> <li>• Waste</li> <li>• Biomass</li> <li>• Nuclear</li> <li>• Fuel Cells and Other Distributed Generation</li> </ul>	<ul style="list-style-type: none"> <li>• Transmission</li> <li>• Distribution</li> <li>• Advanced Metering Infrastructure</li> <li>• Microgrids</li> <li>• Electric Vehicle Charging Infrastructure</li> <li>• Energy Storage</li> <li>• Enabling Information and Communication Technology</li> </ul>	

## Sizing Advanced Energy Markets

The first attempt to quantify the size of the global and U.S. advanced energy markets was *Economic Impacts of Advanced Energy*, prepared by Pike Research (now Navigant Research) and published in January 2013. *Economic Impacts of Advanced Energy* presented revenue data across the 41 subsegments of advanced energy for 2011, and estimates for 2012. Building off *Advanced Energy Now 2014 Market Report*, which covered revenues from 2011 to 2013, *Advanced Energy Now 2015 Market Report* includes 2011 revenue, 2012 revenue, updated revenue for 2013, and estimated revenue for 2014 to provide both a snapshot of market size at the present time and growth trends over four years.

*Advanced Energy Now 2015 Market Report* draws on more than 60 previously published Navigant Research studies on specific industry categories for the most comprehensive assessment of advanced energy markets to date. However, the results presented in *Advanced Energy Now 2015 Market Report* must be viewed as a conservative assessment of advanced energy market size. Though this is the most comprehensive study yet performed, it is not exhaustive, due to the nature of available data, and it is purposely conservative in methodology:

- Identified subsegments or product categories that have not been independently studied by Navigant Research are not included, leading the size of some segments 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 excluding revenue from installation and other services, and other subsegments exclude revenue from multiyear projects still in development.
- 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.
- In some product categories, such as hydropower, nuclear, and gas turbines, projects can take between two and 10 years to complete, making tracking of annual capital investment 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).
- Operations and maintenance revenue is not included, nor is refurbishment revenue, which can be substantial for certain subsegments.
- U.S. market revenue counts only domestic sales of advanced energy products and services and does not include revenue from exports, understating the economic scope of the U.S. advanced energy industry.

It should also be noted that Navigant Research has utilized strict definitions within product categories, in order to distinguish advanced energy from conventional energy products. For instance, in the Building Efficiency segment, not all HVAC installations are counted, only HVAC installations associated with energy-specific commercial retrofits, new HVAC systems that exceed local code compliance, ground-source heat pumps, and systems deployed in high-efficiency homes. The parameters for advanced water heating are even more restrictive: this category includes only residential water heating as specifically used in high-efficiency homes.





For more detailed information on individual subsegments and product categories, see *Economic Impacts of Advanced Energy*.

It is the goal of *Advanced Energy Now* market reports to include new data as they become available each year, in order to better characterize the true scope of advanced energy markets. Thus *Advanced Energy Now 2014 Market Report* quantified several product categories that were not included in *Economic Impacts of Advanced Energy*. A new category quantified this year is residential energy efficient lighting (in the Lighting subsegment of Building Efficiency). Revenue from this new category is included in subsegment, segment, and overall totals only for the years there are data available. For that reason, care must be taken in comparing results from different years.

In *Advanced Energy Now 2015 Market Report*, all growth rates between years (e.g., 2013 to 2014; 2011 to 2014) are calculated using only those product categories for which market data are available for both years being compared, unless otherwise noted. In all cases, data are described in order to capture the overall trend of particular industry growth or contraction in a given year or time period.



## OVERVIEW AND SUMMARY FINDINGS

For 2014, the advanced energy market grew to just under \$1.3 trillion in estimated global revenue, up 12% over 2013 and 3% higher than 2011. Year-over-year increases in all seven segments made 2014 the biggest growth year for advanced energy worldwide since Navigant Research began tracking the industry for Advanced Energy Economy in 2011. This growth was led by Building Efficiency (up 12%) and a 40% jump in wind power revenue, which drove Electricity Generation up 16% overall.

In the United States, the advanced energy market reached just under \$200 billion in 2014, an increase of 14% over 2013, capping a four-year rise of 38% since 2011. (Figure 1.1) While growth has been consistent in most advanced energy segments over the four years, sharp contraction in wind power in 2013 was, by itself, enough to result in a nearly 4% decline in the U.S. advanced energy market overall that year. In 2014, return to growth in wind (up 300% over 2013), continued surge in solar PV (up 39%), 48% leap in revenue from natural gas turbines, and 16% revenue growth in the Building Efficiency segment helped drive the U.S. advanced energy market to just under \$200 billion for the first time.

### Advanced Energy Growth

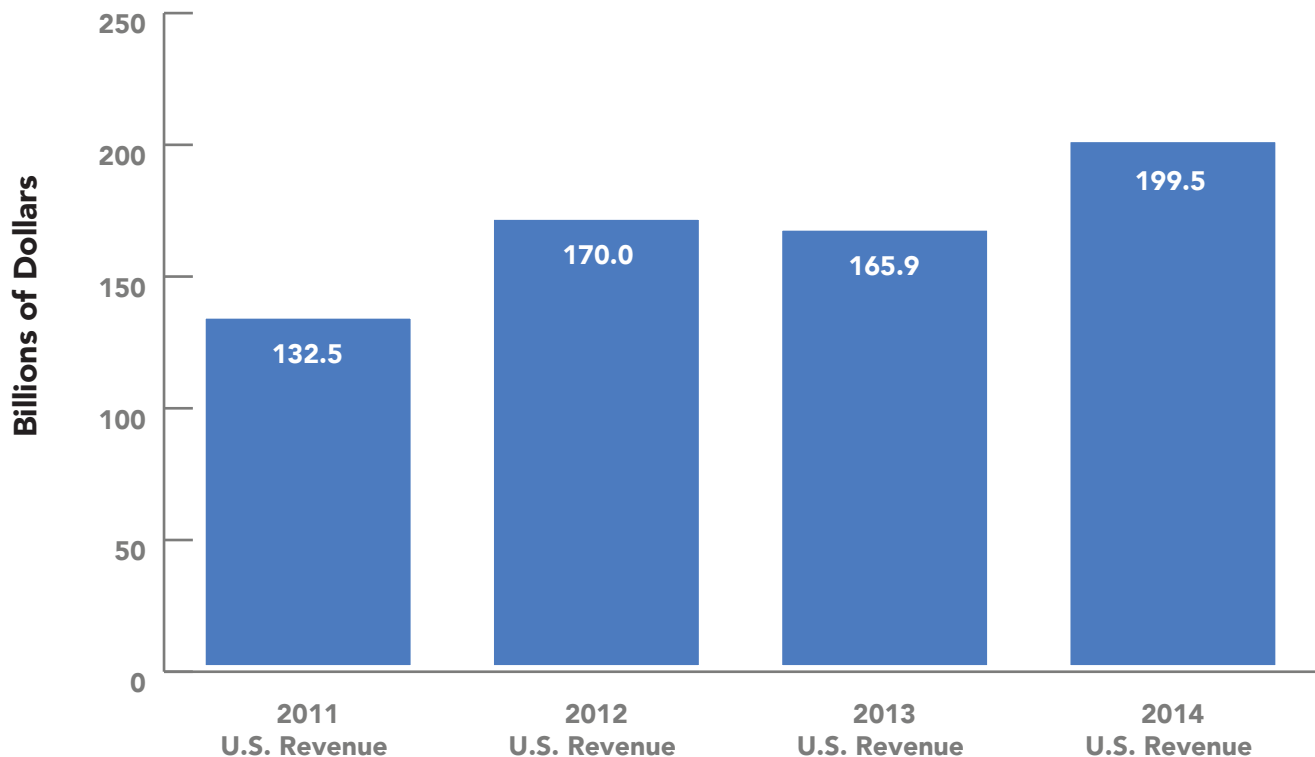


Figure 1.1 (Source: Navigant Research)

Globally, Electricity Generation, the largest advanced energy segment at \$426 billion, grew strongly, up 16% over 2013, though still down 21% compared with 2011. (Table 1.1) Revenue from wind power jumped 40% to \$95 billion globally after a decline in 2013, most of it in the United States. Though up 45% to \$122 billion in 2014, hydropower is still at half of its 2011 peak (\$257 billion).

Transportation remained the second largest advanced energy segment worldwide, at \$373 billion in 2014, up 8% over 2013. Transportation has shown growth in three of the past four years, up 11% overall since 2011. Growth in 2014 was led by hybrid electric vehicles (up 40% to \$74 billion) and plug-in electric vehicles (PEV, up 80% to \$12.4 billion), though the largest product category worldwide remains clean diesel vehicles (\$244 billion, up 2% over 2013).

### Global Revenue by Segment (millions)

Segment	2011	2012	2013	2014 (estimate)
<b>Transportation</b>	\$325,914	\$315,865	\$343,577	\$372,663
<b>Fuel Production</b>	\$110,667	\$138,644	\$141,855	\$146,062
<b>Fuel Delivery</b>	\$2,207	\$1,926	\$2,606	\$2,757
<b>Building Efficiency</b>	\$117,981	\$133,710	\$147,712	\$209,542
<b>Industry</b>	\$30,576	\$33,325	\$38,495	\$40,828
<b>Electricity Generation</b>	\$532,342	\$359,802	\$366,361	\$426,347
<b>Electricity Delivery and Management</b>	\$35,410	\$65,403	\$51,151	\$67,896
<b>Global Total</b>	<b>\$1,155,096</b>	<b>\$1,048,674</b>	<b>\$1,091,757</b>	<b>\$1,268,094</b>

Table 1.1 (Source: Navigant Research)

Building Efficiency, the third largest segment globally, grew 12%, to \$209.5 billion, in 2014, with 40% growth since 2011. The largest product category in Building Efficiency is lighting, at \$103.6 billion, with commercial energy efficient lighting at \$54 billion and residential energy efficient lighting (quantified for the first time in this year's Market Report) at \$44 billion. The Building Envelope subsegment grew fastest year-over-year, up 18% to an estimated \$18.7 billion in 2014, driven by commercial and residential energy efficient retrofits, and zero net energy buildings.



The fastest growing advanced energy segment worldwide in 2014 was Electricity Management and Delivery, up 33% to \$67.9 billion after a down year in 2013. Revenue from transmission investments led the growth, up 400% over 2013 overall, with HVDC transmission revenue up 61% to \$6.1 billion, and transmission system upgrades jumping nearly twenty-fold, from \$694 million to 12.6 billion. Advanced metering infrastructure increased 11% in 2014, to nearly \$6.5 billion, while electric vehicle charging infrastructure had a breakout year with nearly \$594 million in revenue worldwide in 2014, representing 42% growth over 2013.

In the United States, Building Efficiency became the largest advanced energy segment with the addition of residential energy efficient lighting (\$9.7 billion), bringing total segment revenue to \$60 billion in 2014. (Table 1.2) Even excluding this new product category, the segment has grown steadily since 2011, up 43% over four years. (Figure 1.2) Growth last year was led by Building Envelope, up 28%, with 29% increase in revenue from energy efficiency homes (\$9.3 billion) and 22% increase in zero net energy buildings (\$266 million). Smart appliances more than doubled in 2014, to \$465 million. The United States continued to account for the majority of the global demand response market, with a 14% increase to \$1.25 billion in 2014 out of \$2 billion worldwide.

The Electricity Generation segment surged back in the United States in 2014, jumping 47% to \$45.8 billion. Wind power rebounded to \$8.2 billion from \$2.1 billion in 2013. Nearly half of total revenue for the segment – \$22.5 billion – came from solar PV, which continued its rapid climb. Solar PV revenue grew 39% year-on-year, capping four-year growth of 173% – nearly tripling 2011 U.S. revenue of \$8.2 billion. (Figure 1.3) The natural gas revolution in the United States also, for the first time, translated into an increase in sales of new generating equipment, with revenue from natural gas turbines up 48% year-over-year, to \$6.4 billion. (Figure 1.4) Hydropower orders in the United States grew an estimated 22%, surpassing \$1 billion in revenue, mostly for upgrades to existing facilities.

The U.S. Transportation segment was down 4% overall in 2014, to \$24.1 billion. Revenue from hybrid electric vehicles – the largest product

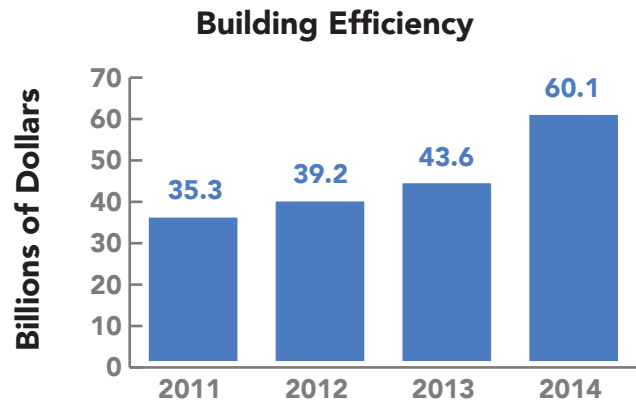


Figure 1.2 (Source: Navigant Research)

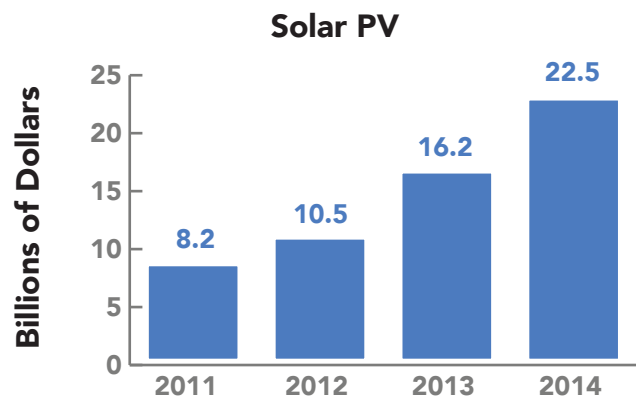


Figure 1.3 (Source: Navigant Research)

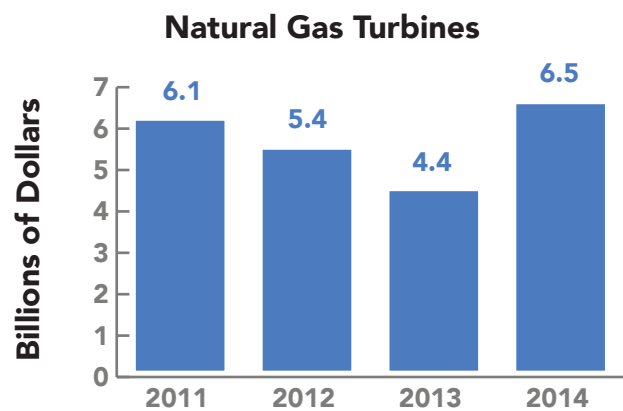


Figure 1.4 (Source: Navigant Research)



category with \$12.1 billion in revenue – was down 19% from 2013, but PEV sales continue to rise, up 34% in 2014, to \$4.8 billion. Both categories of natural gas-powered vehicles jumped 26% last year, with light-duty vehicles reaching \$1 billion in revenue, and heavy-duty trucks and buses garnering \$668 million. Fuel Production was up 4% in 2014, with revenue from ethanol essentially flat at \$39.1 billion. In Fuel Delivery, U.S. totals for commercial and light duty natural gas vehicle fueling stations are \$180.3 million and \$98.7 million respectively, both up 15% over 2013.

U.S. revenue in the Electricity Delivery and Management segment rose 23% from 2013, to an estimated \$13.1 billion in 2014. This includes more than \$4 billion from smart street lighting, systems that manage street lights remotely to detect burned out lamps, adjust to weather and traffic conditions, and flash in case of emergency, among other functions. Transmission infrastructure investment rebounded with 400% growth, resulting in revenue of \$2.9 billion in 2014, due to several large smart transmission system upgrades (which account for \$12.6 billion in 2014 revenue). At nearly \$2 billion in revenue representing 44% the global market in 2014, the U.S. microgrid market bucked the global trend with an increase of 21% compared to 2013. Electric vehicle charging infrastructure continues to show strong growth, up 31% to 2014 revenue of \$201.5 million. EV charging station revenue has risen seven-fold over the past four years.

### U.S. Revenue by Segment (millions)

Segment	2011	2012	2013	2014 (estimate)
Transportation	\$11,709	\$18,045	\$25,106	\$24,056
Fuel Production	\$43,164	\$47,337	\$48,390	\$49,048
Fuel Delivery	\$227	\$378	\$252	\$282
Building Efficiency	\$35,271	\$39,229	\$43,604	\$60,101
Industry	\$4,202	\$5,452	\$6,733	\$7,186
Electricity Generation	\$29,829	\$45,385	\$31,235	\$45,809
Electricity Delivery and Management	\$8,055	\$14,144	\$10,599	\$13,056
<b>U.S. Total</b>	<b>\$132,457</b>	<b>\$169,972</b>	<b>\$165,920</b>	<b>\$199,537</b>

Table 1.2 (Source: Navigant Research)



## TRANSPORTATION

In 2014, Transportation maintained its position as the second largest advanced energy segment with \$372.7 billion in revenue globally, representing 8% growth from 2013 and 11% since 2011. (Table 2.1) In 2014, Transportation represented 29% of total advanced energy revenue worldwide. Led by clean diesel vehicles with \$244 billion and hybrid electric vehicles (HEVs) with \$74.4 billion in revenue, all product categories experienced growth, except for light-duty natural gas vehicles. Plug-in electric vehicles (PEVs) continued their rapid ascent, with \$12.4 billion in global revenue in 2014, an increase of 80% over 2013, and a 567% increase since 2011. Natural gas trucks and buses continue to grow among fleets as natural gas prices stay low. Electric mobility options continue to expand with electric bicycles growing 12% in 2014, due to strong activity in China, and hot prospects in the U.S. market. Growth in fuel cell vehicles remained nearly flat at 1% in 2014, with an estimated \$1 million in revenue.

**Global Transportation Revenue by Segment (millions)**

Transportation	2011	2012	2013	2014 (estimate)
<b>Propulsion Systems</b>	\$325,914	\$315,865	\$343,517	\$372,569
<b>Enabling Information Technology</b>	\$0	\$0	\$60	\$94
<b>Transportation Subtotal</b>	<b>\$325,914</b>	<b>\$315,865</b>	<b>\$343,577</b>	<b>\$372,663</b>

Table 2.1 (Source: Navigant Research)

With total revenue down 4% from 2013, to \$24.1 billion, the United States represented 6% of the global advanced transportation market in 2014, down slightly from 2013, when the U.S. share was 7% – a testament to the strong growth taking place around the world. (Table 2.2) Revenue from hybrid electric vehicles – the largest product category with \$12.1 billion in revenue – was down 19% from 2013, but PEV sales continue to rise, up 34% in 2014, to \$4.8 billion. Clean diesel vehicles, the second largest product category at \$5.2 billion in 2014, was up 2% over 2013, but both categories of natural gas-powered vehicles jumped 26% in 2014, with light-duty vehicles reaching \$1 billion in revenue, and heavy-duty trucks and buses garnering \$668 million. The United States is expected to remain the leading country for PEVs and smart parking systems, with estimated market shares of 39% and 46% in 2014, respectively. The outlook for both electric vehicles and natural gas trucks and buses look particularly bright given continued battery price reductions and low-cost natural gas.

## U.S. Transportation Revenue by Segment (millions)

Transportation	2011	2012	2013	2014 (estimate)
<b>Propulsion Systems</b>	\$11,709	\$18,045	\$25,075	\$24,013
<b>Vehicle Design and Materials</b>	\$271	\$487	NA	NA
<b>Freight Logistics</b>	\$0	\$0	NA	NA
<b>Land-Use and Infrastructure Design</b>	\$0	\$0	NA	NA
<b>Enabling Information Technology</b>	\$0	\$0	\$31	\$43
<b>Transportation Subtotal</b>	<b>\$11,709</b>	<b>\$18,045</b>	<b>\$25,106</b>	<b>\$24,056</b>

Table 2.2 (Source: Navigant Research)

## Plug-in Electric and Natural Gas Vehicles Show Growth

Governments globally are keen to see wide-scale adoption of alternative fuel vehicle technologies as a solution to both environmental and energy security issues. As such, national, state, and local governing bodies have provided a range of incentives to early adopters in efforts to jump-start the market. In the past year or two, market dynamics have taken a favorable turn, with rapid reductions in battery and natural gas prices. Electricity and natural gas have now taken center stage as near-term alternative fuel solutions, though for different reasons and for different vehicle applications.

Plug-in electric vehicles (PEVs) are now an established segment of the global light duty vehicle market and are growing quickly, with 567% revenue growth worldwide between 2011 and 2014. Natural gas vehicles (NGVs) have made inroads in heavier commercial vehicle segments in North America while the established light duty NGV markets in Europe and some Asia Pacific countries are growing as well.



## Plug-in Electric Vehicles

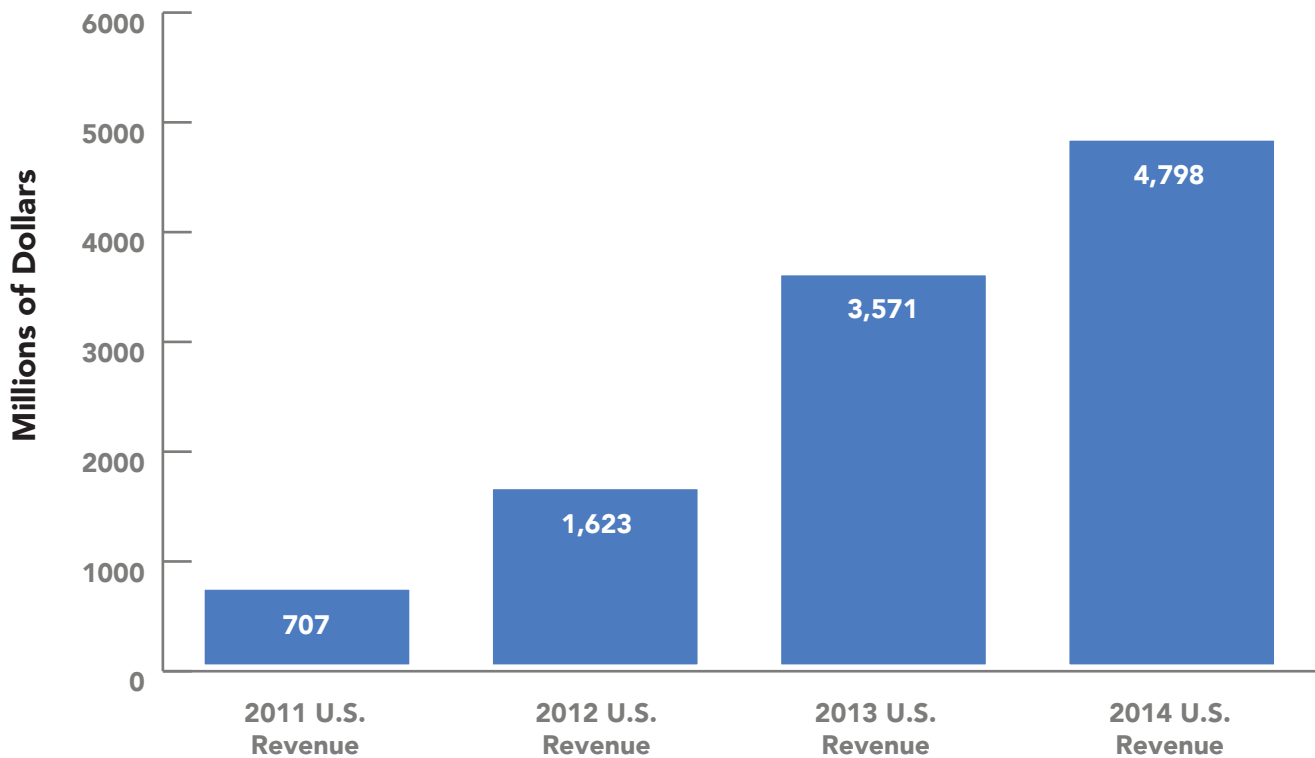


Figure 2.1 (Source: Navigant Research)

Initial purchase price premiums for PEVs over conventional gas- and diesel-powered internal combustion engine vehicles are declining thanks to battery cost and energy density improvements. Operational cost savings from lower fuel and maintenance costs on top of government incentives in many markets make PEVs cost-competitive with conventional vehicles. While recent declines in the price of oil have reduced the energy cost benefit of electric drivetrains over gasoline and diesel power, electricity cost savings are still significant as electric motors provide a substantial efficiency improvements over gasoline or diesel.

Further benefits from PEVs are emerging from the integration of PEVs with the grid. Utilities in the United States are finding economic value from PEV adoption and many are looking to grow the market in their service territories through purchase incentives and the development of lower electricity rates in return for managed charging. Development of vehicle-to-grid integration (VGI) technologies stand to further improve the value of the PEV to the utility and the economic case for the PEV purchase, not to mention offering a new revenue stream for utilities concerned with lost revenue from rapid adoption of distributed generation technologies (further discussed in the Electricity Generation section).

While the growth of PEVs has been significant, it does have limitations. Batteries are not yet able to fulfill the driving requirements of many larger commercial vehicles in medium duty and heavy-duty classes. As such, the market for PEV technologies in these classes has been relatively weak compared to the light duty market. Alternatively, natural gas is better positioned for commercial vehicle applications.

The low cost of natural gas compared to gasoline and diesel strengthens the business case for fleets to adopt NGVs and for energy companies to develop fueling infrastructure. Energy cost savings are greatest in vehicle





applications with high mileage requirements. As such, interest is growing in the development of natural gas infrastructure that could supply a large market of heavy duty long-haul trucks that travel more than 60,000 miles per year. Similar efforts are underway in China and in Europe, where the use of natural gas in vehicles is far more common than in North America.

### Natural Gas Vehicles (all types)

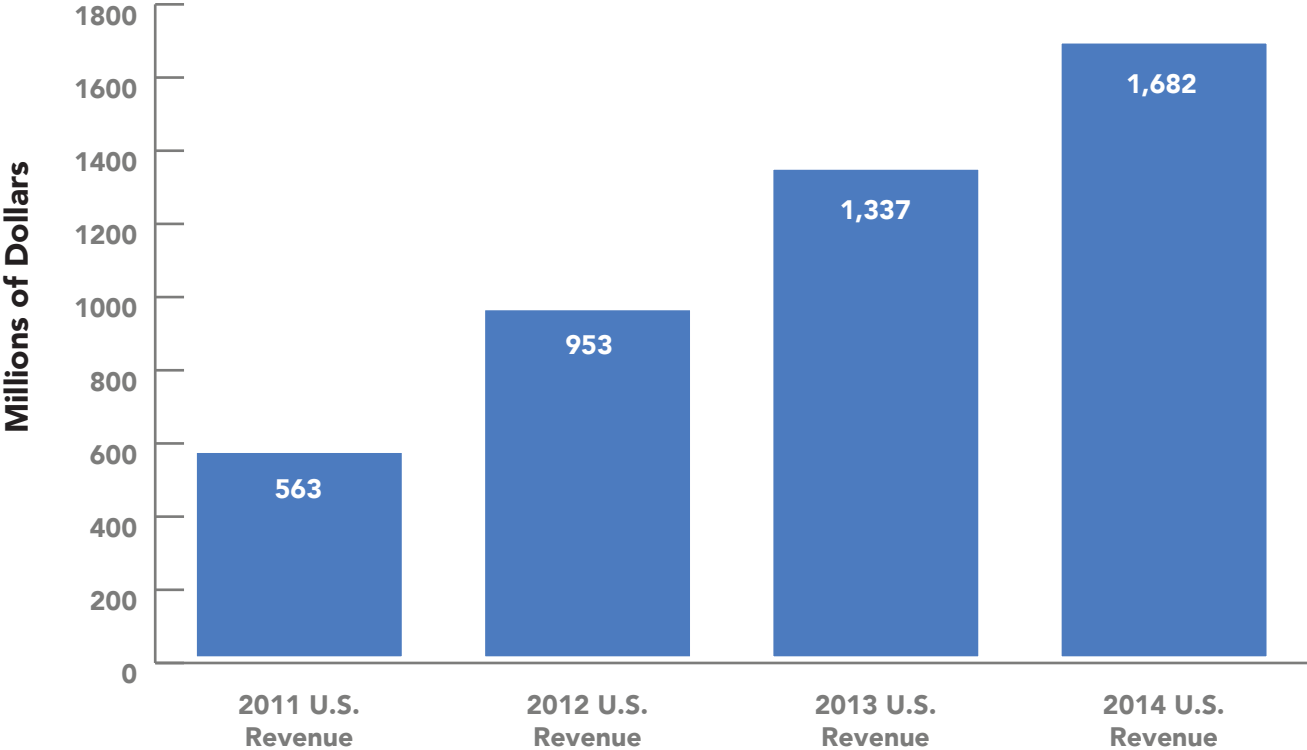


Figure 2.2 (Source: Navigant Research)

Navigant Research estimates that PEV sales in 2014 surpassed 320,000 units globally, 60% above 2013 levels. PEV sales are highest in the United States, with plug-in hybrid electric vehicles (PHEVs) holding a slight edge over battery electric vehicles (BEVs). Navigant Research expects 2015 to exhibit strong growth over 2014 (around 72%) due to vehicle introductions in the SUV segment from Tesla and Volvo, and introduction of the next generation Chevrolet Volt. Though the United States is the largest market, China is the fastest growing. PEV sales in the country grew five-fold from 2013 to 2014, largely on the introduction of the plug-in hybrid BYD Qin. Navigant Research forecasts PEV sales in the country will likely double in 2015 and grow to nearly 725,000 vehicles by 2023.

NGV growth has also been significant globally with sales in 2014 up 44% over 2009. Nearly 2.5 million NGVs were put on the road worldwide in 2014. Navigant Research forecasts the global market will near 4.1 million vehicles by 2023. The United States represents just a small fraction of the NGV market, with just over 45,000 unit sales in 2014; however, it is one of the fastest growing markets, with sales in 2014 four times greater than in 2009. U.S. NGV sales are concentrated in commercial vehicle applications, with around 40% of sales being in the medium and heavy-duty segments and over 50% of sales in the light-duty truck segment, with the remainder being passenger cars.



# Smart Parking Systems Grow in North America, Globally

Drivers searching for parking are estimated to be responsible for about 30% of traffic congestion in cities. Historically, cities, businesses, and property developers have tried to match parking supply to growing demand for parking spaces. It has become clear, though, that simply creating more parking spaces is not sufficient to address the problem of congestion. New approaches using smart parking systems look to provide a more balanced view of parking that better manages the relationship between supply and demand.

Smart parking can be defined as the use of advanced technologies for the efficient operation, monitoring, and management of parking within an urban mobility strategy. The global market for smart parking systems reached \$93.5 million, with the United States representing 46% market share, and offering a strong growth opportunity for companies offering services in the United States and overseas. A number of technologies provide the basis for smart parking solutions, including vehicle sensors, wireless communications, and data analytics. Smart parking is also made viable by innovation in areas such as smartphone apps for customer services, mobile payments, and in-car navigation systems. At the heart of the smart parking concept is the ability to access, collect, analyze, disseminate, and act on information on parking usage. Increasingly, this information is provided in real-time from intelligent devices that enable both parking managers and drivers to optimize the use of parking capacity.

Large-scale smart parking pilots in San Francisco and Los Angeles, as well as smaller projects in other cities, have put North America at the forefront of the smart parking market. Many cities are looking at their parking strategies, and it is likely that smart parking systems will have role to play in at least some parts of those cities. A detailed assessment of San Francisco's SFpark program demonstrated benefits to the city and drivers. Drivers have been able to find parking spots five minutes quicker on SFpark blocks, vehicle miles traveled have been significantly reduced, and local sales tax revenue has gone up. Navigant Research forecasts the smart parking system market in North America will grow at a 22% compound annual growth rate (CAGR) through 2020, reaching a market size of \$136.7 million.

Smart street parking is the most complex and dynamic sector of the smart parking market. Today, many projects are in the pilot stage in cities in North America and Europe, but initial successes suggest that many of these pilots will expand rapidly into full-scale city projects. Cities in Latin America and Asia Pacific faced with growing congestion problems are already showing an interest in learning from North American and European experiences and will look to adapt smart parking solutions to their own requirements. Navigant Research estimates that by 2020, there will be more than 950,000 sensor-enabled on-street smart parking spaces globally.

Much of the innovation in the parking market is coming from startups and small companies. Smart parking solution providers, parking data aggregators, and mobile payment companies are changing the way parking is seen by operators and users. Other players in the parking and smart city market also see the potential for advanced parking solutions. Information technology companies, telecommunications providers, city infrastructure suppliers, and service companies are all looking at parking as a spearhead application for their other smart city solutions and services. Navigant Research projects annual revenue will grow to \$356.5 million by 2020, representing a CAGR of 29%. During this period, the smart parking systems market will rapidly transition from the pilot stage to becoming an accepted technology for city management.



# Electric Bicycles, Motorcycles, and Scooters On the Way

A generational shift in the United States is underway when it comes to car culture. While there are a number of contributing social and economic factors, over the last decade, the number of miles driven by the average American has been falling. At the same time, advanced mobility options, drive trains, and fuel sources have increased significantly. Growth in public transit options, car-sharing, and electric vehicles are all contributing to the transformation of personal mobility. Millennials in particular are seeking alternatives to car ownership while decreasing battery costs are making electric mobility products more affordable.

One of the fastest growing industries is the electric power two-wheeler (e-PTW) industry (including e-bicycles, e-scooters, and e-motorcycles). The United States is expected to achieve significant growth over the coming years as new products become available and several large manufacturers enter the market.

While current sales in the U.S. are relatively low due to high purchase prices, low consumer awareness, and limited product offerings, this is expected to change in the coming years. For the 2015-2024 time period, Navigant Research projects a CAGR of 38.4% in the U.S. e-motorcycle market, 17.9% in the e-scooter market, and 5.5% in the e-bicycle market.

**Forecast: Vehicles Sold, U.S.**

Technology	2015	2024
E-Bicycles	172,516	278,974
E-Scooters	4,934	21,756
E-Motorcycles	2,021	37,667

Table 2.3 (Source: Navigant Research)

While the e-motorcycle market is currently the lowest volume e-PTW market in the U.S., it is also the most likely high-growth area. This is largely due to the current size of the gasoline-powered motorcycle market and the expected market entry of several large industry players over the next few years. The acquisition of Brammo by Polaris Industries in January of 2015 has kick-started this process. Polaris owns the Indian and Victory lines of motorcycles that are often referred to as Harley-like road cruisers. While the existing inventory of e-motorcycles from Brammo will be sold, future products are expected to take the style of Polaris’ Indian and Victory brands. The company is planning to release an electric version of the Victory in the summer of 2015.

With 5,400 employees and revenue of over \$4.4 billion in 2014, Polaris is the first large motorcycle manufacturer to seriously enter the e-motorcycle space. Yamaha, one of the Big Four Japanese motorcycle manufacturers (along with Honda, Kawasaki, and Suzuki), has announced its intention to enter the market in 2016, and Navigant Research projects that Harley Davidson will begin selling their much anticipated LiveWire e-motorcycle in 2018. Big brand recognition, expansive dealer networks, and improved products (expected due to large R&D budgets), is expected to significantly increase the market size of North America’s e-motorcycle industry.



Currently, China is by far the largest market for e-PTWs. However, restrictions on urban transportation, the maturity of the market, and lower than expected GDP growth are resulting in a stagnating market. Manufacturers are looking to several emerging markets around the world to maintain and increase sales. Countries such as the U.S., as well as Indonesia, India, Thailand and Vietnam are likely to be major targets.

### Estimated e-PTW Market Share, China

Technology	2015	2024
E-Bicycles	91%	84%
E-Scooters	96%	77%
E-Motorcycles	98%	88%

Table 2.4 (Source: Navigant Research)



## FUEL PRODUCTION

In 2014, Fuel Production was the fourth largest advanced energy segment with an estimated \$148.1 billion in revenue globally, representing a 4% increase from 2013, and a 34% increase from 2011. (Table 3.1) Ethanol and butanol, including both sales of fuel and investment in refinery infrastructure, continued to be the leading source of revenue with a combined \$78 billion in revenue, representing 2% growth over 2013. Sales of ethanol and butanol reached 25.8 billion gallons in 2014, up from 23.4 billion in 2011, with most of that volume made up of ethanol. Sales of compressed natural gas and liquefied natural gas for transportation contributed estimated revenues of \$43.3 billion worldwide in 2014, up 15% from 2013 and 88% from 2011. Biodiesel sales and new biodiesel refinery infrastructure saw a 3% dip to \$21.3 billion in 2014, though still 19% higher than 2011. Biodiesel sales totaled 7.4 billion gallons, up from 6 billion gallons in 2011. Sales of bio-oil and biomethane, including revenue from refineries and production plants, all experienced reductions ranging from 5% to 98% compared to 2013, with much of the drop in refinery investment in these still-developing fuel types. Synthetic diesel saw a positive 15% growth over the same period of time.

The U.S. Fuel Production segment reached \$49 billion in 2014, up from a revised 2013 total of \$48.4 billion, and 18% higher than 2011. (Table 3.2) Sales of ethanol in the United States totaled an estimated 14.2 billion gallons, representing \$39.1 billion in revenue, essentially flat compared with 2013. Biodiesel sales and biorefinery infrastructure were the next largest sources of revenue, with a combined \$3.9 billion, down 19% from 2013, though new biodiesel refinery infrastructure capacity of 137 million gallons was added in 2014. Bio-methane, bio-oil, and synthetic diesel and gasoline reached a combined estimated \$3.2 billion in revenue from fuel sales and infrastructure investment in the U.S. 2014.



## Global Fuel Production Revenue by Segment (millions)

Fuel Production	2011	2012	2013	2014 (estimate)
<b>Compressed Natural Gas and Liquefied Natural Gas</b>	\$23,018	\$31,486	\$37,654	\$43,302
<b>Ethanol and Butanol</b>	\$68,140	\$84,240	\$76,645	\$77,956
<b>Bio-diesel</b>	\$17,882	\$20,432	\$21,993	\$21,342
<b>Synthetic Diesel and Gasoline</b>	\$1,580	\$1,938	\$4,693	\$5,394
<b>Bio-oil</b>	\$1	\$500	\$805	\$16
<b>Bio-methane</b>	\$47	\$48	\$65	\$51
<b>Hydrogen</b>	\$0	\$0	\$0	\$0
<b>Fuel Production Subtotal</b>	<b>\$110,667</b>	<b>\$138,644</b>	<b>\$141,442</b>	<b>\$146,750</b>

Table 3.1 (Source: Navigant Research)



## U.S. Fuel Production Revenue by Segment (millions)

Fuel Production	2011	2012	2013	2014 (estimate)
<b>Compressed Natural Gas and Liquefied Natural Gas</b>	\$504	\$581	\$883	\$1,016
<b>Ethanol and Butanol</b>	\$39,140	\$41,730	\$40,371	\$40,932
<b>Bio-diesel</b>	\$3,135	\$4,231	\$4,751	\$3,859
<b>Synthetic Diesel and Gasoline</b>	\$372	\$438	\$2,368	\$3,206
<b>Bio-oil</b>	\$0.6	\$345	\$2	\$16
<b>Bio-methane</b>	\$12	\$12	\$16	\$19
<b>Hydrogen</b>	\$0	\$0	\$0	\$0
<b>Fuel Production Subtotal</b>	<b>\$43,164</b>	<b>\$47,337</b>	<b>\$48,390</b>	<b>\$49,048</b>

Table 3.2 (Source: Navigant Research)

## Biofuels Flow To Niche and Emerging Markets

The biofuels industry has made great strides in the past decade, with ethanol and biodiesel becoming established commodities traded on all continents and more than 32 billion gallons produced in 2014. But future growth is less certain, especially in terms of biofuel as an alternative fuel for ground transportation in developed countries. Still, there are significant opportunities in niche fuel markets, as well as new potential in emerging markets where bioenergy could play a greater role.

In the United States, in particular, the challenges to growth for biofuels for ground transportation are daunting. Falling gasoline consumption (due to more fuel efficient vehicles and changing driving patterns) and resistance from auto manufacturers to higher levels of ethanol in gasoline have created a “blend wall” preventing greater use of ethanol. Meanwhile, the highly sought after successor to corn-based ethanol, cellulosic ethanol, has not reached levels of production sufficient to fulfill federal requirements. Creating even greater uncertainty about future prospects, EPA changed its definition of cellulosic and advanced biofuels to include liquefied and compressed natural gas produced from biogas, including landfill gas. This will likely further dampen investor appetite for ethanol and biodiesel projects.



Finally, the push for bio-based alternatives to petroleum transportation fuels has been deflected by suddenly low oil prices (currently under \$50 a barrel) as well as growing interest in other alternatives, namely plug-in electric vehicles (PEV) and natural gas-powered trucks.

That said, the biofuels industry continues to advance on several fronts, in specialty fuel markets and, increasingly, in developing countries.

The commercial aviation industry, for example, has played an important role in driving research and development of biofuels for air travel as well as sending a strong demand signal to producers. More than 25 international carriers from all global regions have tested or piloted biofuels in the last three years. Navigant Research estimates these efforts have resulted in more than 60,000 biofuel miles flown. In early 2014, Boeing completed a test flight using a blend of 15% “green diesel” – a synthetic, drop-in substitute for diesel – and 85% petroleum jet fuel. To meet growing demand, several high-profile, dedicated biojet biorefinery projects have begun construction. Led by the Oslo Airport’s commitment to take in 660,000 gallons of biojet fuel beginning in March 2015, airports are also demonstrating a commitment to biofuels as playing a role in the future of aviation. Commercial aviation offers the advanced biofuels industry some notable advantages for market acceptance compared to competing against gasoline and diesel fuel, namely consolidated infrastructure and large, institutional customers capable of making strategic purchasing decisions. According to the International Air Transport Association (IATA), 1,600 airports worldwide fuel 95% of the world’s flights. This compares to more than 161,000 retail gas stations in the United States alone. This lowers the capital needed for infrastructure to bring fuel to the customer and streamlines contracting opportunities, which should accelerate commercial deployment of bio-jet fuel.

The U.S. Navy is also moving forward with its goal of sailing its Great Green Fleet in 2016. This initiative is a stem-to-stern overhaul aimed at integrating energy conservation into the U.S. fighting fleet, in part by powering ships and aircraft with biofuels. In anticipation, the Navy has procured nearly a half million gallons of advanced biofuels to support early testing and certification initiatives. Biofuels were also included in the Navy’s annual procurement for bulk fuels this year for the first time ever.

But non-road transportation applications are not the only area where biofuels are gaining ground. In the emerging economies of Sub-Saharan Africa, Southeast Asia, and Latin America, the wide availability of biomass, combined with limited access to other sources of energy, provides promising opportunities to expand the use of bioenergy for many purposes. Conversion of agricultural waste into biogas to fuel generator sets, for example, can help anchor community microgrids. Such uses build off an established tradition of utilizing biomass for energy (e.g., burning wood or dung for cooking and heating) and rely on well-established technologies. All this makes the developing world an important growth opportunity for biofuels. While the refocus of investment away from ground transportation and toward a wider range of applications will mean less biorefinery capacity built through 2020, these niche opportunities are expected to result in the development of specialized capacity despite today’s cheap and plentiful oil.





### Ethanol Fuels (excluding refinery investment)

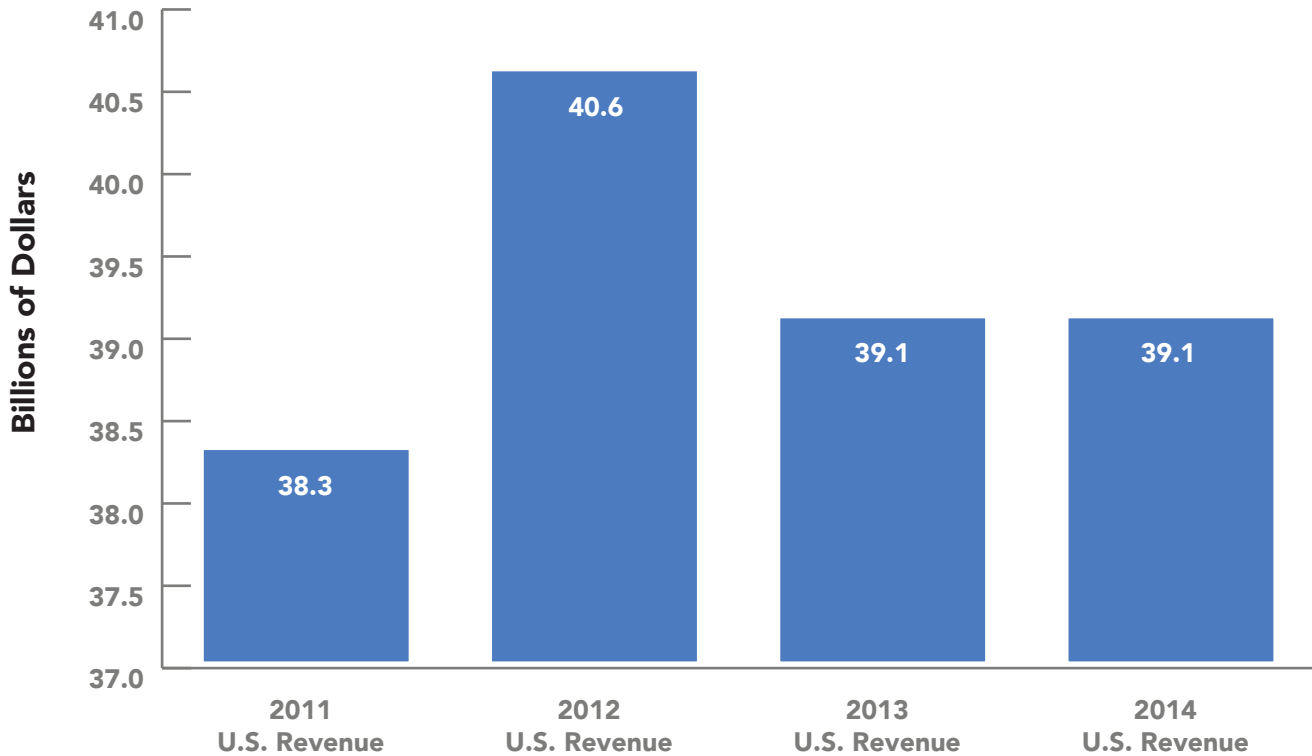


Figure 3.1 (Source: Navigant Research)

## Waste Shifts from Disposal to Resource Recovery

While one of the key indicators of a society's advance is the degree to which it can distance itself from its trash, waste is increasingly viewed as a strategic resource. Recently surpassing 7 billion people, the world's population is not only growing in number, but its propensity to consume is also accelerating. In 2014, an estimated 1.5 billion tons of municipal solid waste (MSW) was generated globally. This total is expected to surpass 2 billion tons annually within the next 10 years. According to the World Bank's 2012 report "What a Waste," the amount of MSW generated worldwide is growing faster than the rate of urbanization. With waste generation rates set to more than double over the next 20 years in low- and middle-income countries, the costs of managing waste disposal are expected to see a steep rise – but so are opportunities to leverage advanced technologies across the waste value chain.

A focus on waste as a strategic renewable resource for material and energy recovery is at the heart of an emerging smart waste revolution. Navigant Research estimates the Smart MSW market to generate more than \$40 billion in revenue over the next decade. Specifically, smart waste technologies enable greater levels of automation, integration of IT, utilization of data analytics, and the recovery of valuable materials and latent energy.

Energy recovery represents the largest and most mature segment in the MSW value chain. In the U.S. and other developed economies, MSW is increasingly diverted from landfills to advanced facilities for use as a feedstock for renewable power or advanced biofuels. Combustion-based waste-to-energy (WTE) infrastructure and landfill gas recovery projects make up the largest share of the energy recovery market, contributing to nearly \$500 million in annual revenue in the U.S. alone.



WTE technologies are incineration, biological, or gasification-based platforms that utilize waste as a feedstock for the production of electric and thermal energy. Robust, simple, and proven, incineration technologies currently lead the market. More than 800 WTE facilities are deployed in at least 40 countries. WTE facilities are much more advanced than incinerators, their outdated predecessors, typically employing sophisticated emissions control systems. Advanced thermal treatment of waste -- including technologies such as pyrolysis and gasification -- are claimed to be superior to mass burn incineration systems, but widespread deployment remains hampered by scale-up issues.

Landfill gas (LFG), or methane gas captured from waste as it decays in closed landfills, used to generate electricity is a standard technology for energy recovery employed in most industrialized countries. LFG can also be used in combined heat and power (CHP) systems or as a supplement to natural gas. Bioreactor landfills are an emerging engineered solution within the smart waste technology landscape that can increase the rate of production of methane at the landfill site for commercial purposes. Supported by organic waste bans in select states (such as Massachusetts) and cities (such as San Francisco), large-scale anaerobic digesters, which capture methane from food and wastewater in dedicated facilities, are also increasing in number.

Although the United States is in many ways a less mature smart waste market than Europe, with its zero landfilling initiatives, industry leaders like Waste Management and Republic Services have begun making strategic investments in advanced technologies. These include upgrading garbage truck fleets to run off natural gas and biomethane, optimizing truck routes using GPS and RFID tagging to reduce fuel spend, and converting MSW into high-value fuels and chemicals.



## FUEL DELIVERY

Fuel Delivery is the smallest of the advanced energy industry segments globally, with an estimated \$2.8 billion in revenue in 2014, an increase of 6% over 2013, and a 25% increase over 2011. (Table 4.1) The United States maintained its market share at 10% in 2014, with revenue of \$232 million (Table 4.2) and is positioned to remain at that level in the near future. Consistent with last year's report, fueling stations and fuel transportation infrastructure currently make up the Fuel Delivery segment, though revenue is available just for fueling stations.

Globally, revenue from natural gas vehicle (NGV) fueling stations serving cars, light-duty trucks increased 5% from 2013 to 2014, to \$1.3 billion, though it was down nearly 38% from a four-year peak of \$2.1 billion in 2011. These fueling stations typically utilize compressed natural gas (CNG). Commercial natural gas fueling stations, which serve long-haul trucking, primarily utilize liquefied natural gas (LNG). Revenue from these stations also grew 5% worldwide, to an estimated \$1.4 billion, in 2014. The commercial fueling station market has seen tremendous growth, though from a small base. With revenue in 2011 of just \$18.9 million globally, this subsegment of Fuel Delivery has seen 75X revenue growth in four years.

U.S. totals for commercial and light duty natural gas vehicle fueling stations are \$180.3 million and \$98.7 million respectively, both up 15% over 2013.

Hydrogen fueling stations reversed two years of declining revenue, reaching an estimated \$54.4 million in revenue worldwide in 2014, up 70% over 2013. In the United States, however, hydrogen fueling stations dropped to their lowest level of investment in the past four years, with \$2.4 million in revenue in 2014, compared to a peak of \$26.8 million in 2012. The success of competing alternative energy vehicles (PEVs and NGVs) in the United States has diminished hydrogen fueling station infrastructure prospects (outside of California, which has made hydrogen fueling a policy priority) in the near term, though the recent introduction of hydrogen fuel cell vehicles by Toyota and Hyundai, with models from GM and Honda also expected, may change that.

Though not quantified in this year's report, natural gas pipeline and LNG terminal construction represent significant advanced energy markets that fall under the Fuel Delivery segment. The Fuel Delivery total is therefore considerably understated.

### Global Fuel Delivery Revenue by Segment (millions)

Fuel Delivery	2011	2012	2013	2014 (estimate)
Fueling Stations	\$2,207	\$1,926	\$2,606	\$2,757
Fuel Transportation Infrastructure	\$0	\$0	NA	NA
<b>Fuel Delivery Subtotal</b>	<b>\$2,207</b>	<b>\$1,926</b>	<b>\$2,606</b>	<b>\$2,757</b>

Table 4.1 (Source: Navigant Research)

## U.S. Fuel Delivery Revenue by Segment (millions)

Fuel Delivery	2011	2012	2013	2014 (estimate)
Fueling Stations	\$227	\$378	\$252	\$282
Fuel Transportation Infrastructure	\$0	\$0	NA	NA
<b>Fuel Delivery Subtotal</b>	<b>\$227</b>	<b>\$378</b>	<b>\$252</b>	<b>\$282</b>

Table 4.2 (Source: Navigant Research)

## Fueling Stations Get Boost from Low Priced Gas

The low cost of natural gas is boosting market acceptance of natural gas vehicles, trucks, and buses, which in turn is increasing demand for the fueling infrastructure to support the growing fleets that use cleaner burning — and increasingly cheaper — natural gas as a transportation fuel.

Compressed natural gas (CNG) can now be used for a variety of vehicles, including cars and light-duty trucks, as well as medium- and heavy-duty trucks and transit buses, which do not travel far from fueling stations. Liquefied natural gas (LNG) is generally used for vehicles that travel longer distances, such as long-haul trucks. The reason for differing applications is that, while LNG holds more energy by volume than CNG, the fueling infrastructure for LNG is more expensive, driven by higher storage tank costs.

Navigant Research estimates there are approximately 23,000 natural gas fueling stations currently installed around the world, and that this could reach 29,000 by 2020. NGV fueling infrastructure already exists in a few countries such as Italy, Germany, Pakistan, and Iran. But in many parts of North America, Western Europe, and Asia Pacific, the development of refueling infrastructure is a key hurdle to growing adoption of these vehicles, particularly by private consumers. It is a chicken-egg dilemma common to alternative fuel vehicles: whether to develop expensive infrastructure while the number of NGVs remains relatively small or wait for additional vehicles on the road prior to infrastructure development. But as lower cost natural gas persists and NGV sales grow, that decision is becoming easier.



## Natural Gas Vehicle Fueling Stations (all types)

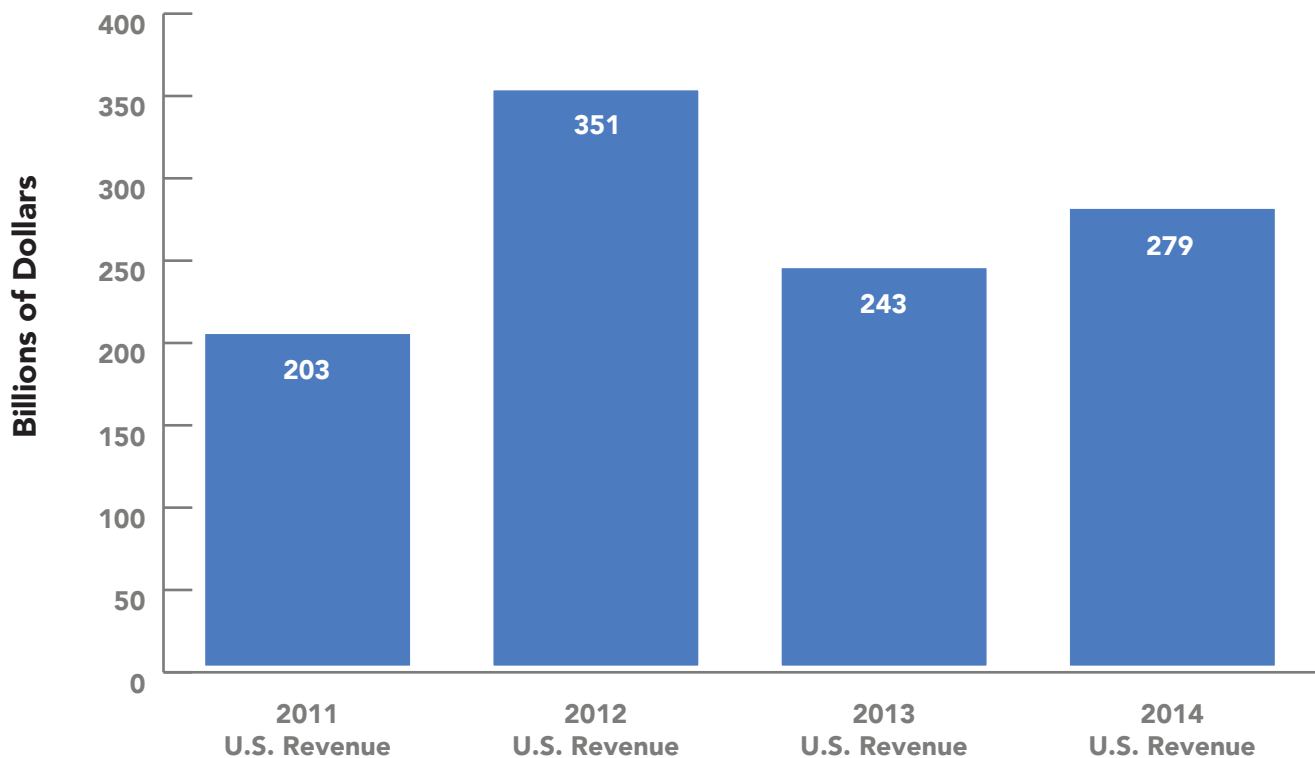


Figure 4.1 (Source: Navigant Research)

Many participants in the infrastructure market are focused on developing CNG fueling infrastructure in cities and suburban areas. CNG is used primarily to serve vehicles that travel within a metro area or between metro areas without refueling, due to shorter vehicle ranges. This infrastructure supports demand for NGVs within metropolitan areas. LNG is marketed as a diesel replacement fuel for vehicles that travel extended distances via known corridors. These corridors, often referred to as the “Natural Gas Highway,” follow existing truck traffic patterns and connect cities. In North America, interstate pipelines for natural gas often follow highway rights-of-way, making for relatively easy access for fueling stations.

In return-to-base-type fleet operations (buses, delivery vehicles, airport vehicles, or garbage trucks), vehicles may only need one fueling point. These fleets can be served by their own dedicated refueling points at the base, without need for public fueling stations. In North America and parts of Western Europe, the growth of NGVs continues to focus on fleets, so, the number of private stations is likely to continue to grow. However, both regions are seeing a push from station operators, natural gas wholesalers, and advocacy groups to make NGV refueling more open to the public.

The market for natural gas refueling stations is growing rapidly but is already crowded, with large, well-funded competitors. Clean Energy Fuels, based in Seal Beach, California, is one of the leading CNG and LNG refueling station installers in the United States. Founded by T. Boone Pickens, the company operates 184 natural gas refueling stations across North America. Blu is an LNG refueling station company based in Utah with stations in Georgia and Idaho, with plans to open 50 new LNG stations by 2015. Blu has begun offering LNG truck rentals in conjunction with PACCAR’s Kenworth brand.



Around the world, natural gas utilities and drilling companies are key players in NGV fueling infrastructure. For example, ENN Energy is a natural gas energy firm that operates more than 238 NGV fueling stations throughout China, in addition to owning natural gas drilling operations and more than 17,000 km (10,563 miles) of natural gas pipelines. Other companies active in the sector include Siemens, Royal Dutch Shell, and Trillium CNG.

The outlook for natural gas fueling stations is bright as costs are coming down and demand for NGVs is going up. When combined with electric vehicle charging (see the Electricity Delivery and Management segment) and, on a smaller scale, hydrogen fueling stations, the range of transportation fuel options is increasing, eating into the market share for diesel and gasoline.

## LNG Terminal Building Bonanza has Begun

International marine construction companies are seeing a bonanza of new projects as countries around the world approve massive new terminals for liquefied natural gas (LNG) – for imports in most cases, and for exports from North America, Australia, and some Southeast Asian countries. Altogether, this frenzy of port building – at a price tag of around \$10 billion apiece – could amount to hundreds of billions of dollars in investment over the next decade as seaborne trade in LNG climbs to meet rising demand, particularly in the energy-hungry countries of China, India, and other Asian nations.

Total deliveries of LNG were flat in 2013 compared to 2012, according to the BG Group, but this masks pent-up demand, as producers in the United States are ramping up export capacity and importing countries are rushing to build import terminals. BG Group forecasts that worldwide LNG demand is expected to increase at a rate of 5% annually through 2025, with much higher rates in the developing countries of Asia.

In September 2014, the U.S. Federal Energy Regulatory Commission (FERC) gave final approval to the Cove Point LNG facility, overruling the objections of environmental groups and bringing to four the number of U.S. export terminals officially approved and under construction. All told, 14 terminals are seeking approval by federal regulators in the United States – on the Gulf Coast, the East Coast, and in the Pacific Northwest. With big potential markets waiting not only across the Pacific, but also in Europe, U.S. oil and gas companies are eager for more export capacity to come online. There are also at least a dozen LNG terminals proposed along the coast of British Columbia.

With unrest in Ukraine giving rise to fears of disruptions of natural gas supplies from Russia, which provides 30% of Europe's natural gas, European governments and companies are scrambling to build new import facilities. Paradoxically, with international supplies limited and Japan, which relies more heavily on imported natural gas than any other country, soaking up much of the available supply at inflated prices, imports to Europe have declined in the last couple of years. The Gate terminal on the North Sea coast near Rotterdam was built with the support of the Dutch government to maintain the Netherlands' status as a regional gas hub. It is now running at 10% of capacity, according to The Economist.

Nevertheless, imports from the United States are sure to increase, and the European Union sees the construction of new import terminals as a critical matter of regional energy security. Lithuania, for example, is due to open a massive new floating terminal in early 2015. New terminals are especially important along Europe's southeastern coast, as countries in the area are essentially captive customers to Russia's Gazprom.



Amos Hochstein, the acting U.S. special envoy and coordinator for international energy affairs, testified recently before the Senate Foreign Relations Committee, saying that “[there is a] critical need for Europe to improve its energy infrastructure by constructing new pipelines, upgrading interconnectors to allow bidirectional flow, and building new LNG terminals to diversify fuel sources... We support proposals to build LNG terminals at critical points on European coasts, from Poland to Croatia to the Baltics.”

The biggest building boom is underway in China, where three new import terminals came online in 2013 and at least two more were expected to begin operation by the end of 2014. Already, half of the world’s capacity for regasification (the conversion of LNG to conventional natural gas, for transport by pipeline) is located in Asia. “China’s imports of liquefied natural gas (LNG) are growing at a record pace as it aims to use cleaner fuels to cut smog in big cities, creating a powerful new source of demand that has the potential to reshape the market for the super-chilled gas,” reported Reuters. China’s LNG imports grew 35% in the first quarter of 2014 compared to the same period in 2013.

Meanwhile, new production is emerging from Southeast Asia, particularly in Indonesia and Papua New Guinea. Also, Singapore, which sits at the mouth of the Strait of Malacca, through which passes more than half of the world’s seaborne LNG, has formed ambitious plans to be the LNG trading hub for Southeast and East Asia. As more LNG terminals come online natural gas will only increase its disruptive force across today’s energy landscape, in both electricity generation and transportation.



## BUILDING EFFICIENCY

Building Efficiency is the third largest advanced energy segment globally, with an estimated \$209.5 billion in revenue in 2014, at 12% growth over 2013 worldwide and the largest segment in the U.S. market – for the first time in our four years of coverage – at \$60.1 billion.

Lighting is the largest Building Efficiency subsegment with estimated revenue of \$103 billion in 2014 (Table 5.1), led by commercial energy efficient lighting at \$54 billion. Residential energy efficient lighting (REEL) is a new product category added in this year's report. With revenue of \$44 billion in 2014, REEL is Building Efficiency's second largest product category globally and the largest category in the U.S. market, at \$9.7 billion. Even excluding this new product category, Building Efficiency experienced the strongest four-year growth of any segment globally, up 40% compared to 2011.

Heating, ventilation, and air conditioning (HVAC) is now the second largest subsegment with \$58 billion in revenue last year. The Building Envelope subsegment grew 18% to an estimated \$18.7 billion in revenue, driven by commercial and residential energy efficient retrofits, as well as zero net energy buildings (ZNEBs). Building Design followed with \$15.5 billion, up 12%, led by commercial energy efficient retrofit services, and \$2.4 billion in building information modeling, up 18% over 2013 and 59% compared to 2011.

Enabling information technology/demand response, defined as IT that can be used to better manage a building's energy use, reached an estimated \$6 billion in revenue globally in 2014. The United States continued to account for the majority of the global market, at \$3 billion in 2014, including \$1.25 billion of the \$2 billion demand response market worldwide. Also, home energy management systems reached \$365.6 million in 2014 revenue and experienced the strongest four-year growth compared to 2011, with a 727% increase compared to 2011. The global market for district energy and combined cooling, heating, and power (CCHP) fell slightly from 2013, with just under \$3 billion in revenue in 2014, but was still 32% higher than 2011, with the United States representing nearly 29% of that total at \$850 million. Water heating (defined as sales of energy efficient water heating technology in the residential market) and appliances and electronic equipment were the two smallest subsegments, with estimated \$2.1 billion and \$2.7 billion in 2014 revenue, respectively. Smart appliances grew a remarkable 927% since 2011, with the United States accounting for 17% of the 2014 market.

Overall, when excluding the new revenue category of REEL, U.S. Building Efficiency revenue grew 16% year-over-year, and 43% over the four years since 2011. (Table 5.2) Including REEL, Building Efficiency revenue in the United States reached \$60.1 billion in 2014.



## Global Building Efficiency Revenue (millions)

Building Efficiency	2011	2012	2013	2014 (estimate)
<b>Building Design</b>	\$11,537	\$13,039	\$13,932	\$15,544
<b>Building Envelope</b>	\$13,017	\$14,006	\$15,855	\$18,668
<b>Heating, Ventilation, and Air Conditioning (HVAC)</b>	\$44,383	\$49,613	\$53,923	\$57,962
<b>District Energy and Combined Cooling, Heating, and Power (CCHP)</b>	\$2,229	\$2,787	\$3,023	\$2,950
<b>Water Heating</b>	\$1,467	\$1,612	\$1,773	\$2,090
<b>Lighting</b>	\$41,329	\$47,212	\$52,770	\$103,613
<b>Appliance and Electronic Equipment</b>	\$266	\$613	\$1,412	\$2,733
<b>Enabling IT/Demand Response</b>	\$3,752	\$4,829	\$5,023	\$5,981
<b>Building Efficiency Subtotal</b>	<b>\$117,981</b>	<b>\$133,710</b>	<b>\$147,712</b>	<b>\$209,542</b>

Table 5.1 (Source: Navigant Research)



## U.S. Building Efficiency Revenue (millions)

Building Efficiency	2011	2012	2013	2014 (estimate)
<b>Building Design</b>	\$2,819	\$3,128	\$3,351	\$3,850
<b>Building Envelope</b>	\$8,720	\$9,645	\$11,919	\$15,239
<b>Heating, Ventilation, and Air Conditioning (HVAC)</b>	\$10,522	\$11,532	\$12,306	\$13,183
<b>District Energy and Combined Cooling, Heating, and Power (CCHP)</b>	\$814	\$925	\$1,189	\$850
<b>Water Heating</b>	\$1,138	\$1,197	\$1,357	\$1,490
<b>Lighting</b>	\$9,139	\$9,992	\$10,701	\$22,024
<b>Appliance and Electronic Equipment</b>	\$105	\$148	\$208	\$465
<b>Enabling IT/Demand Response</b>	\$2,020	\$2,663	\$2,572	\$2,999
<b>Building Efficiency Subtotal</b>	<b>\$35,271</b>	<b>\$39,229</b>	<b>\$43,604</b>	<b>\$60,100</b>

Table 5.2 (Source: Navigant Research)

## Smart Buildings Make Mark Around The Globe

2014 was a dynamic year for the smart buildings market, with noticeable major technology advances and a global economic boost through supportive government policies and programs. In addition, many vendors expanded their products and services targeted towards small and medium-size buildings, with building owners seeing real benefits from aggregating energy efficiency across their portfolio of smaller-scale facilities.

Though no official definition for smart buildings exists – the term refers to buildings that take an integrated approach to onsite electricity generation, energy management systems, and advances in commercial lighting and controls. Increasingly networked building controls cover a variety of building systems, including HVAC, lighting, fire and life safety, and security and access systems. These devices include a wide range of sensors, controllers, actuators, switches, air handlers, alarms, and detectors. When networked together by one or more protocols, they can drastically reduce energy usage and costs, alert building operators to repair and maintenance needs, and provide significant improvements in occupant comfort and safety.

Building energy management systems (BEMS) have emerged over the past two decades and have changed the marketplace by enhancing the abilities of traditional building control and automation systems that have been around since the 1950s. These systems are at the heart of the smart buildings market, and have recently dis-



played particularly significant advances in technology. Cloud-based data analytics have enabled deeper integration of onsite resources, data, and remote monitoring and control. A handful of state-of-the-art pilots are demonstrating the value of configurations that integrate distributed generation, onsite renewables, or extensive equipment monitoring and control with plug loads, PC power management, or data center infrastructure management through BEMS.

As a result, the global market for BEMS has increased 47% since 2011, estimated at nearly \$2.8 billion in 2014. (Figure 5.1) Growth within the United States has been similar, at 44% from 2011 to 2014, now valued at \$1.1 billion, or 38% the global market. Navigant Research expects the global market for BEMS to reach \$10.8 billion by 2024. North America and Europe are projected to continue leading in BEMS demand in the near term, but the Asia Pacific region is expected to display increasing activity and investment in the future.

### Building Energy Management Systems Revenue

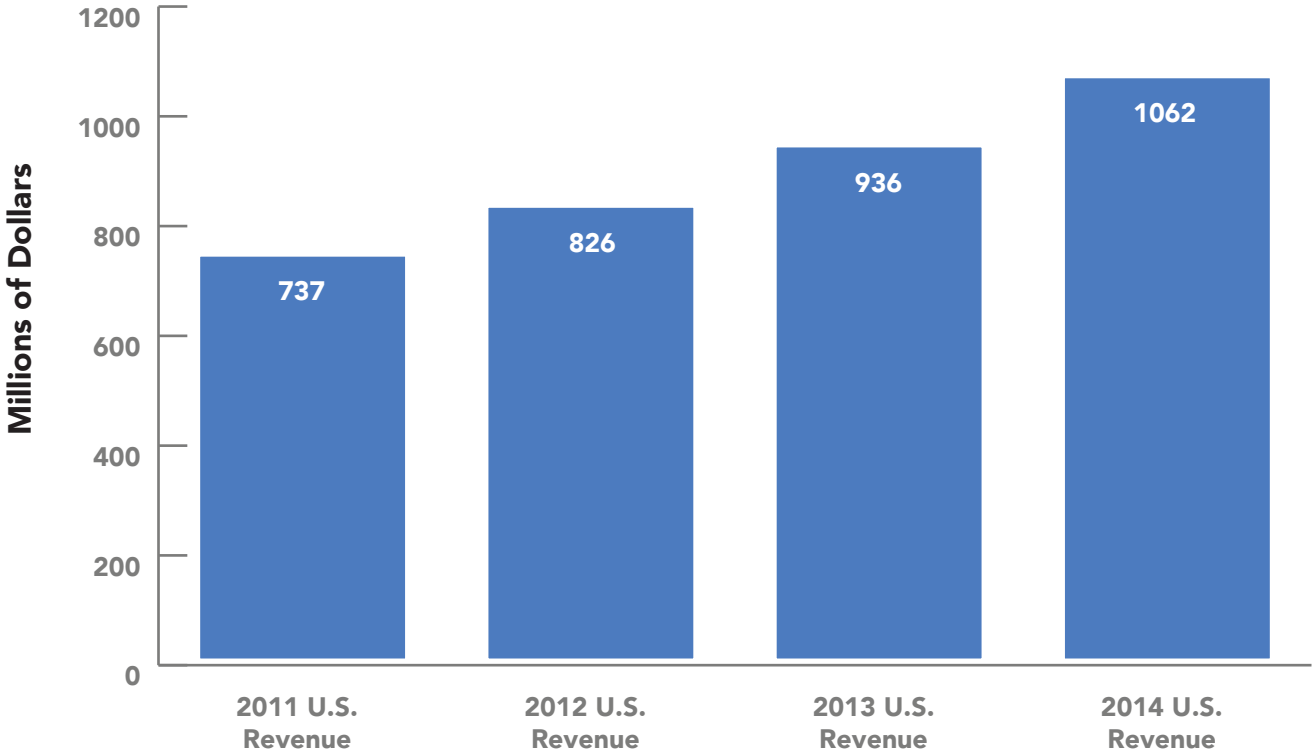


Figure 5.1 (Source: Navigant Research)

Globally, but particularly in North America and Europe, regulatory support and financing mechanisms for energy efficiency have coalesced to drive smart building investments for new buildings and retrofits in both the public and private sectors. In the United States, 25 states, representing approximately 60% of national energy consumption, now have energy efficiency resource standards. Not coincidentally, the U.S. market for energy service companies (ESCOs) has grown steadily, as it provides a low-risk financing mechanism for business owners to invest in smart building technologies to increase energy efficiency. Up 10% from 2013, Navigant Research estimates the 2014 market for ESCO services in the United States at \$611.2 million, not counting ESCO-installed HVAC equipment (\$4 billion nationally).



In Europe, where the markets encompassing a range of smart building technologies are the strongest, both European Union and individual state policies and financing are driving continued steady growth. Between 2007 and 2013, the European Commission provided approximately €5.5 billion in energy efficiency investments, with €290 million in financing for R&D. Individual member states, particularly the UK, Germany and the Scandinavian countries, are pursuing approaches that include energy efficiency targets, incentives, support of the ESCO concept, and new demo projects for innovative building-to-grid technologies.

Asia Pacific policies and markets remain fragmented, with Japan, Australia, and South Korea leading the pack on building energy efficiency. China has steadily increased support through its five-year plans, which have encouraged the adoption of energy monitoring technology, particularly in the public sector. Representing approximately 60% of global construction activity, China could become a standing example of how to implement energy efficient building concepts on a large scale.

A notable trend in the U.S. smart buildings market has been the increased targeting of small to medium commercial buildings. New technologies offer ever-increasing insight into energy use for these buildings, which can be aggregated across portfolios for reporting and incentive purposes. Typically, two paths to adoption have been recognized. The first, favored by small buildings, is an efficiency management path supported by utility-based programs that benchmark efficiency gains using advanced meter data. Medium-sized commercial buildings have followed a performance management approach, enabled by scaled-down BEMS tools and a growing energy management services market.

While advances in technology and a supportive market environment globally have bolstered the smart buildings market, barriers such as market fragmentation and access to capital will continue to challenge providers and potential adopters. With many technologies relatively new, there is still a learning curve for consumers in terms of understanding the purposes and capabilities of smart building technologies. Correspondingly, vendors remain focused on product development and marketing to increase awareness and appeal, and to make their products more accessible across different classes of customers.

## **Zero Net Energy: a Glimpse of Buildings Future**

Globally, building energy has moved into the spotlight due to the associated greenhouse gas impacts and rising energy costs. Until recently, zero net energy buildings (ZNEBs) have existed mostly on a conceptual level, with a small number of highly innovative pilots exploring the process of planning and execution of this technology. However, ZNEBs made significant headway in late 2014 after the federal General Services Administration (GSA) approved a recommendation from an internal task force to upgrade at least 50% of the federal government's building area to ZNEB — not a small number, considering that the GSA is the owner of more than 2% of all commercial buildings within the United States.

A ZNEB uses no more energy over the course of the year than it generates from onsite renewables. Called nearly zero energy buildings (nZEB) in the European Union, nZEBs bring together existing energy efficient technologies and on-site power generation to form a high-performance building. The most common choice of renewable power is solar PV, which is now being offered as an add-on option for some new-home developments. Other technologies that are playing a significant role in ZNEBs include energy efficient lighting (e.g., light-emitting diodes, or LEDs), advanced glazing and smart glass, advanced wall insulation, energy efficient heating, ventilation, and air conditioning (HVAC) systems, and energy management systems.



While pilots are focused on testing the investment savings in lower energy bills, the strongest driver for the adoption of ZNEBs is government policy. The Energy Performance of Buildings Directive of the European Union and California's evolving Title 24 building code are among the policies creating ZNEB markets for new commercial, new residential, and retrofitted commercial space. However, the most prominent zero energy codes are either in their early stages or a long way off. In the EU, the Energy Performance of Buildings Directive states that residential buildings subject to code compliance be zero net energy by 2019; commercial buildings must be zero net energy by 2021. Building code changes in the interim, revised every two to three years in each member state, will incrementally push toward this target.

In the United States, demand from early adopters has driven the growth of ZNEBs, with some states and municipalities being more proactive. One example is the City of Austin, Texas, which has mandated that all new residences built after 2015 be zero net energy. Several relevant policies, such as the U.S. federal government's requirement for ZNEB for federal facilities, which come into effect in 2030, will have similar effects to policies within the EU, only on a more limited scale.

In Asia Pacific, Japan has established a leading presence in the ZNEB market, but low energy building construction has grown throughout the region in recent years. High energy prices and preferences for green buildings in countries such as Singapore will drive activity. Given the few existing national regulations in the region for zero net energy construction, ZNEB adoption will be contingent on the local regulatory landscape. Though the near-term market outlook for ZNEBs indicates healthy growth, the long-term prospects for the market globally shows even greater promise. Navigant Research has estimated the 2014 global market at \$266 million, a 22% increase over 2013 revenue of \$218 million. In the United States, revenue is estimated at just under \$16 million, also a 22% gain from the previous year's \$13 million and a 60% increase over 2011 revenue of \$10 million.

Despite promising growth opportunities, the ZNEB market will still be limited in both the near and long term by incongruent policies in geographically close areas, and issues with technology standards. Defining a ZNEB is no simple matter, as it can depend on the energy source, the scale of the site, and, in some cases, the temporal nature of the energy use. These concepts are challenging for consumers and policy makers alike.

Similarly, cost premiums and financing models have not yet matured for ZNEBs. Technologies used for ZNEBs, such as triple pane glass and renewable energy systems are high in cost, and long payback periods (20-25 years for some products) are not feasible in the private buildings market where ownership typically changes every few years.

Regardless, this market will be highly dynamic in the next decade as regulations become more focused, product costs come down, and building owners face rising energy costs. Ambitious codes adopted across multiple continents could signal a movement that pulls the entire building ecosystem along.

## **Innovations Transform Residential Energy Use**

Today's consumers have more tools at their disposal than ever before – for reducing consumption, managing energy use, and generating power for their homes. New residential-focused technologies, cost reductions, and business models are creating opportunities for advanced energy companies while saving money for homeowners.



While the growth in solar PV may have garnered the most attention in the residential energy sector, several other technologies are now hitting the market and generating strong returns. Indeed, the global residential lighting market is on the verge of a major transformation. High efficiency light-emitting diode (LED) lamps adoption is accelerating at an astonishing rate, while remote control of connected lights is on the cusp of becoming commonplace. Additionally, the movement toward more all-encompassing home energy management systems (HEMS) and – to an even greater extent – home automation, of which smart lighting is a part, is steadily gathering pace. U.S. revenue from HEMS leaped from \$44 million in 2011 to \$150 million in 2012, and has grown steadily since, reaching an estimated \$366 million in 2014. (Figure 5.2)

### Home Energy Management Systems Revenue

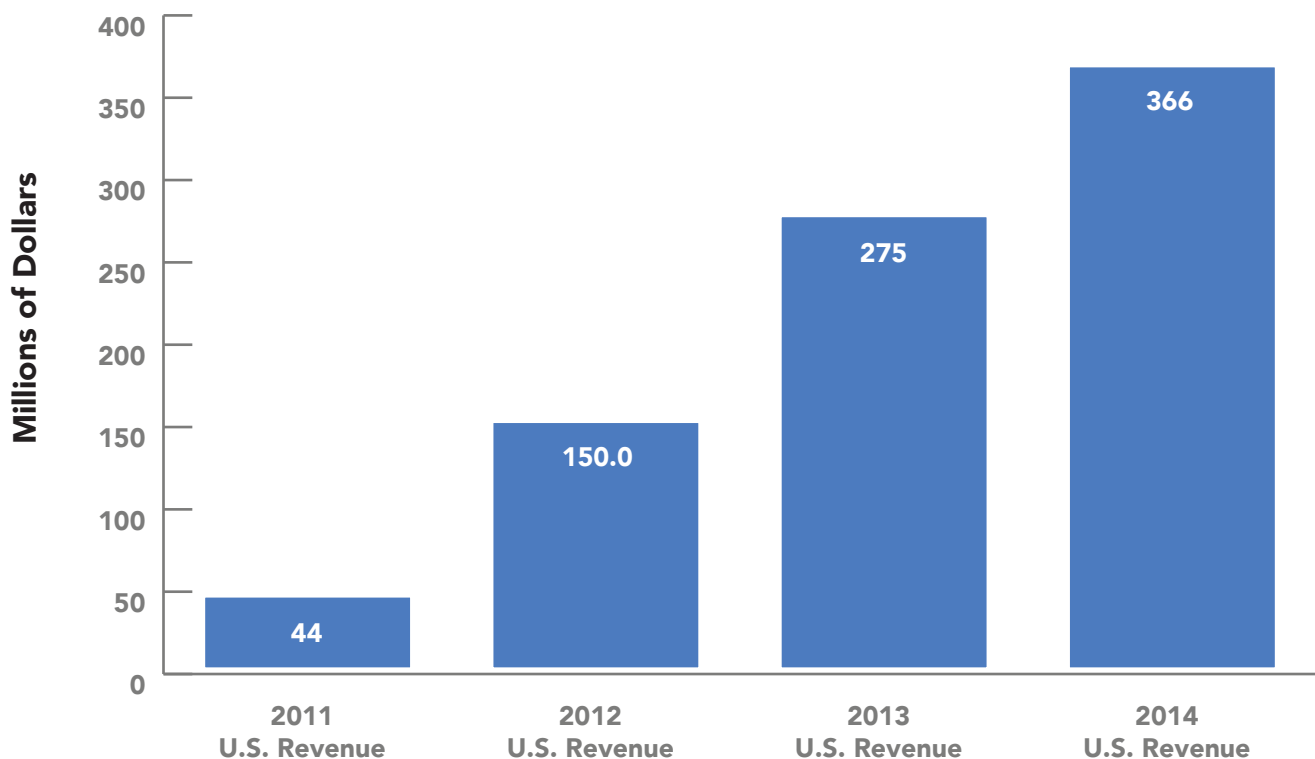


Figure 5.2 (Source: Navigant Research)

A number of factors are working in concert to drive forward the market for residential energy efficient lighting and lighting controls. Falling LED costs, various regulations and codes, and the rise of the smart home are some of the most important. Still more expensive than compact fluorescent bulbs (though longer lasting and higher in efficiency), LEDs are coming down in price quickly, as vendors are locked in a fierce race to produce the lowest-cost products. Start-up Cree made a splash by introducing the first \$10 LED, a 40W equivalent, in March 2013, but the space is increasingly competitive, with active participation from lighting giants like Philips and GE. Quantified now for the first time, the U.S. residential energy efficient lighting market is estimated by Navigant Research at \$9.7 billion, the largest product category by revenue in the Building Efficiency industry segment.

One key aspect of these residential energy innovations will be the software tools and cloud-based services used to integrate and manage the systems. Currently, energy management software is focused mainly on a single application. For instance, plug-in electric vehicles (PEV) have embedded software for managing the flow of energy from the grid, and HEM software focuses on energy consumption and ways to be more efficient. However,



integrated systems – where solar PV arrays, battery storage systems, PEVs, and smart appliances talk to each other – create the need for tools that manage a more complex environment.

To date, few companies have tackled this problem in a comprehensive fashion, mainly because the market is immature. However, Navigant Research expects energy management software (and firmware) to become a key enabler of market growth, acting as the automated glue that helps systems operate efficiently and in harmony. On the residential side, companies like Opower, Silver Spring Networks, Ford, Toyota, Google (now owner of Nest), EcoFactor, and iControl Networks are the early innovators in the sector and will roll out new services as the residential energy innovation market continues to gain traction.



## INDUSTRY

Industry is the sixth largest advanced energy segment globally, with an estimated \$40.8 billion in 2014 revenue. (Table 6.1) As in previous reports, Industry is comprised of two subsegments quantified here, Industrial Combined Heat and Power (CHP), with 2014 worldwide revenue of \$28.5 billion (up 5% from 2013, 37% from 2011), and Manufacturing Machinery and Process Equipment, with global revenue of \$12.3 billion (up 9% from 2013, 26% over 2011). Industrial energy management systems is the only product category quantified within Manufacturing Machinery and Process Equipment.

U.S. revenue in the Industry segment increased 7% in 2014 to an estimated \$7.2 billion, and up 71% over the four years starting in 2011. (Table 6.2) Industrial CHP revenue in the United States grew to \$3.2 billion in 2014, up 5% over 2013 and 216% over four years. U.S. Manufacturing Machinery and Process Equipment (consisting entirely of industrial energy management systems) continued to see growth at 8% compared to 2013, reaching just under \$4 billion in 2014, and up 25% compared to 2011.

### Global Industry Revenue (millions)

Industry	2011	2012	2013	2014 (estimate)
<b>Manufacturing Machinery and Process Equipment</b>	\$9,773	\$10,513	\$11,340	\$12,315
<b>Combined Heat and Power</b>	\$20,803	\$22,812	\$27,155	\$28,513
<b>Industry Subtotal</b>	<b>\$30,576</b>	<b>\$33,325</b>	<b>\$38,495</b>	<b>\$40,828</b>

Table 6.1 (Source: Navigant Research)

### U.S. Industry Revenue (millions)

Industry	2011	2012	2013	2014 (estimate)
<b>Manufacturing Machinery and Process Equipment</b>	\$3,184	\$3,414	\$3,669	\$3,969
<b>Combined Heat and Power</b>	\$1,018	\$2,038	\$3,064	\$3,217
<b>Industry Subtotal</b>	<b>\$4,202</b>	<b>\$5,452</b>	<b>\$6,733</b>	<b>\$7,186</b>

Table 6.2 (Source: Navigant Research)



# Connectivity, Analytics Drive Energy Management

Industrial companies that have high energy consumption rates can benefit immensely from understanding and managing energy consumption within their facilities and throughout the entire enterprise. The implementation of an industrial energy management system (IEMS) has become critical to this understanding. An IEMS provides the capability to bring information and knowledge of all aspects of energy-related matters into the present, where cost-effective tactics can be employed to reduce inefficiencies and avoid high demand charges.

Large equipment manufacturers such as Schneider Electric, Siemens, Invensys, and Rockwell Automation have been leading suppliers to this market for a long time. The landscape is shifting, though, and large IT companies like SAP and IBM are becoming more influential, due to their capability for handling large datasets and their experience with enterprise-level business analytics. Smaller niche companies are also participating in the IEMS market with unique product and service offerings, often in partnership with larger, more established vendors to gain access to the market.

**Industrial Energy Management Systems Revenue**

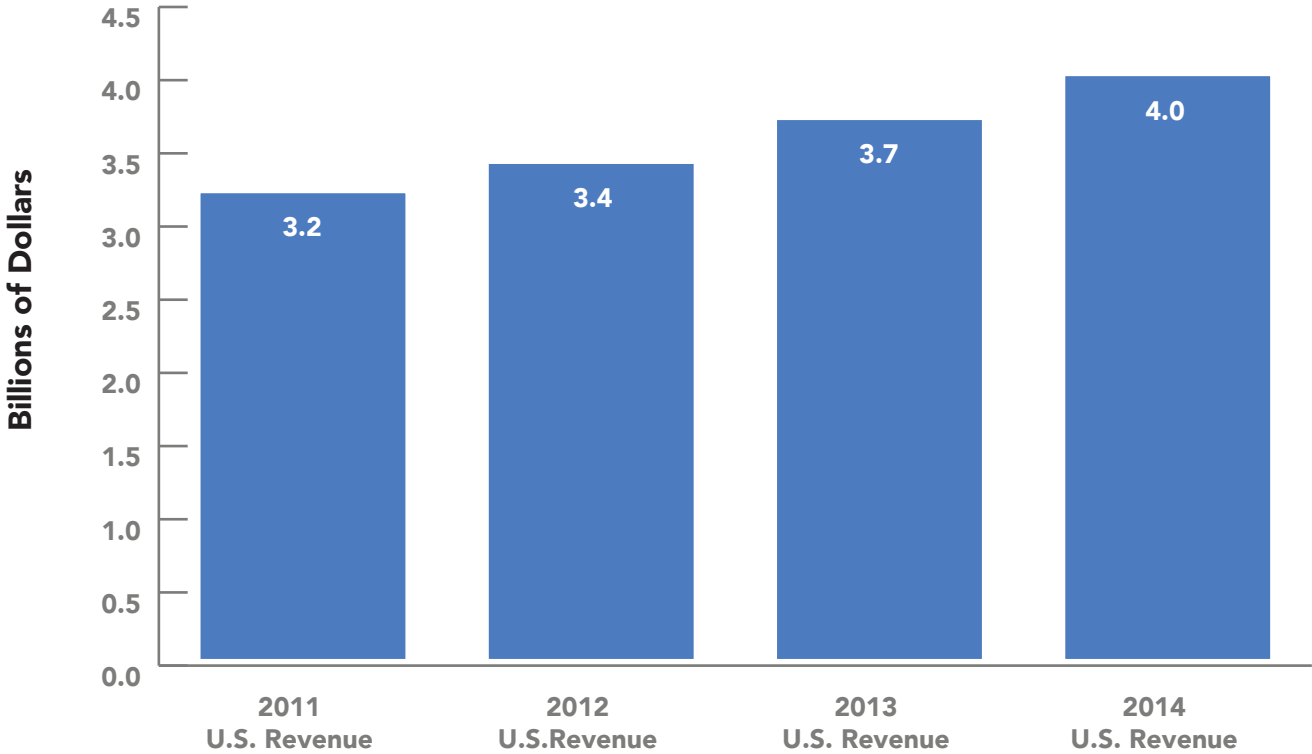


Figure 6.1 (Source: Navigant Research)

Global IEMS revenue across software and services was \$12.3 billion in 2014, up 9% over 2013 and 26% over the past four years. The total IEMS market in the United States grew to just under \$4 billion in 2014, 8% over 2013 and 25% compared to 2011. The North American market (of which the United States represents around 90%) is the largest region for IEMS revenues globally, with a slim lead over Europe. Though U.S. industrial companies have been relatively conservative in spending during the recent recession, more robust investment in IEMS is expected as companies look to meet competitive challenges and start to assimilate new innovations, enter new



capital spending cycles, and recover from earlier contraction. That's because inefficient energy use carries with it heavy penalties, in the form of high costs from excess energy consumption and onerous utility demand charges.

A number of trends are driving the evolution of industrial energy management systems and offer significant opportunities for new and existing data-driven companies to optimize energy consumption for the world's most energy intensive sectors. One is the wave of innovation driven by machine-to-machine technologies that are underpinning the emergent "Internet of Things." Communication networks and intelligent devices are creating a greater level of connectivity and delivering new insight into industrial operations. The industrial Internet of Things comprises machine learning software, data analytics, intelligent sensors, and machine-to-machine (M2M) communication technology that can capture data from machines, process it, and use it to adjust operational characteristics or performance. Machine-to-machine communications are not new in industrial facilities but they are now reaching a level of complexity and scale that changes the degree of insight and control available.

The finer grained control and deeper insight into performance offered by intelligently connected systems also enable finer tuning of energy management programs. However, further work needs to be done on the standardization of protocols for industrial communications and integration. In the United States, this is an area of focus for the National Institute of Standards and Technology, which is working on a number of programs to support smart manufacturing, with industry support.

An associated area of innovation is the use of advanced analytics to improve energy efficiency in industrial operations. Better forecasting and predictability connected to energy-related sourcing and consumption can provide another level of improvement in energy management. Forecasting is beneficial in an industrial setting for materials and resource management, better use of production facilities, cost avoidance, and a host of other areas. However, creating a standard approach to energy forecasting in highly variable use situations is a difficult proposition.

Other improvements are being made by focusing on immediate circumstances and delivering real-time information that can allow for continuous optimization in current operations. Faster processing speeds and inexpensive storage have allowed big data to be processed and served up to users in real-time, or near real-time, on the floor of an industrial facility. Operators can now see important aspects of production processes as they are happening, allowing for adjustments on the fly, as incremental improvements can add up to big savings over time. Built-in alerts tailored to a specific facility or process tell operators when critical adjustments need to be made. Over time, the automation of the process, based on historical analysis and rules-based intervention, can eliminate human error and make minute efficiency-related adjustments while the process is running.

More generally, the lines between the production and corporate environments are blurring. IEMS vendors are elevating the reporting of energy-related data to the enterprise level. They are providing more detailed visibility into operational metrics in a format that is understandable and useful to any level of an organization. Energy-related data and information have traditionally been the responsibility of personnel who were closest to its use, while the cost of energy (along with payment for it) was relegated to the accounting function – many times when the energy bill was received. Now this information is available to a variety of enterprise functions in real-time for an ongoing and up-to-date holistic view of the organization.

Energy is fast becoming another input that needs to be managed on a proactive basis, utilizing the most up to date data available. As IEMS products and services become ever more sophisticated, energy data can be combined with other business intelligence data to provide a more complete and actionable picture of overall business performance.



# Industrial CHP Continues to Hold Strong Potential

Combined heat and power (CHP), also known as cogeneration, simultaneously generates electricity and useful heat in an integrated system. This application of technology achieves greater levels of overall efficiency than separate heat and power systems because heat that is wasted in conventional electric generating systems is recovered and put to use. CHP systems can reach thermal efficiencies up to 85%. CHP provides highly efficient electricity and process heat to many industries in the United States; 83 GW of CHP capacity are installed in the United States, which is approximately 8 percent of the national electricity generation capacity and 12 percent of annual power generation. Navigant Research estimates the vast majority of CHP is used for industrial applications, 80% to 90% of the total.

CHP is a type of distributed generation, which is located at or near the point of consumption. It can be deployed quickly, cost effectively, and with few geographic technical limitations. New turbines for CHP systems are typically most cost-effective down to 500 kW and new reciprocating engines down to 50 kW, which significantly increases the number of sites where CHP can be installed. CHP can use both fossil and renewable fuels, such as biogas, waste, and biomass. Natural gas remains the most common fuel source in the United States, at 69%. There is currently significant policy support for CHP systems in the United States. In a 2012 executive order, President Obama called for 40 GW of new, cost-effective industrial CHP by the end of 2020, which would increase installed capacity by approximately 50%. The U.S. Department of Energy has provided technical assistance on CHP to U.S. commercial and industrial businesses since 2007, through its Regional Clean Energy Application Centers. The next generation of this effort is regional Combined Heat and Power Technical Assistance Partnerships. The CHP Technical Assistance Partnerships will focus on market opportunity analyses, education and outreach, and technical assistance for individual facilities. The partnerships will be supported with \$11 million over four years.

The global market for CHP systems in 2014 is estimated at \$28.5 billion in 2014, with the United States representing 11% of that total. Recent additions of CHP capacity have been concentrated in New York, California, Texas, and Connecticut. But Industrial CHP has significant room to grow, with the chemicals, pulp and paper, and food manufacturing industries representing some of the biggest opportunities. The American Council for an Energy-Efficient Economy (ACEEE) estimates that 130 GW of CHP potential can still be found in all types of existing facilities – and less than 1% of this technical potential has been installed annually in recent years.



## Industrial CHP Revenue

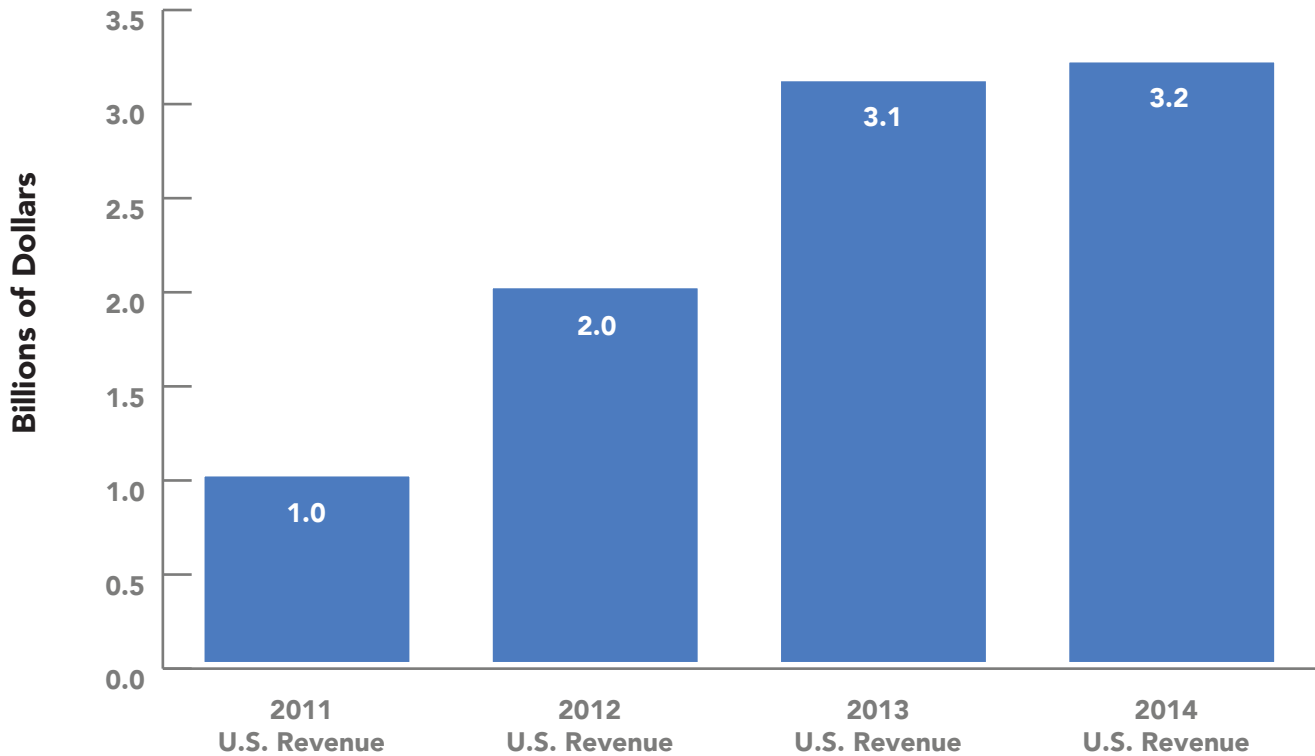


Figure 6.2 (Source: Navigant Research)

Some emerging CHP technologies are in development, as presented in 2014 at the U.S. DOE Advanced Manufacturing Office Peer Review. A combined heat, hydrogen, and power, or tri-generation (CHHP), system is in testing at an industrial site. Also, an advanced gas turbine-based, ultra-low NO<sub>x</sub> CHP system is under development, which is expected to achieve 84% system efficiency and meet California Air Resource Board emissions criteria.

Recent interest in CHP is driven in part by low natural gas prices and the need for industrial facilities to replace aging boilers to comply with new pollution standards or lower maintenance costs. As a growing number of industrial companies look for cost-effective options to reduce energy costs, CHP in particular represents a promising near-term opportunity utilizing a well-established technology.



## ELECTRICITY GENERATION

Electricity Generation remained the largest advanced energy segment in 2014, with an estimated \$426 billion in revenue worldwide, representing 16% growth over 2013. (Table 7.1) For the fourth year in a row, hydropower led all product categories with \$122.5 billion worth of orders and 18.8 GW of capacity. China continues to build out massive hydropower plants to meet the needs of its growing economy, and additional construction of hydro is underway in Russia, Laos, Chile, and Peru. In wind power, 2014 was a record-breaking year, with an estimated 51 GW of capacity installed worldwide, representing \$94.6 billion in revenue. In wind as well as hydro, China led the global market, with 45% of installations in 2014, for 23.3 GW of capacity; China is now home to 114 GW of installed wind capacity. Solar PV was the third largest subsegment in Electricity Generation, with an estimated \$90.3 billion in revenue – more than 10 GW each installed in China and Japan, and nearly 7 GW in the United States. Together, these three countries represent more than half the global solar PV market, as the European market contracted for the third straight year. Still, the United Kingdom remains a strong market for solar PV.

Natural gas generating capacity is another growth story. Over the past few years, low prices for natural gas, especially in the United States, have translated mostly into higher utilization of existing capacity rather than expansion. But now, orders for combined cycle and simple cycle gas turbines are on the rise – up 13% and 11% respectively – over 2013. Together, sales of natural gas-fired turbines accounted for \$48.5 billion in revenue worldwide, surpassing orders for new nuclear facilities (\$38.2 billion). With their fast ramping capabilities, gas turbines work especially well in diversified electric power portfolios that include variable resources like wind and solar.

Geothermal (up 2%) and biomass (down 8%) power plant activity remained relatively flat globally compared to 2013, with markets of \$1.5 billion and \$13.5 billion, respectively, in 2014. Biomass is increasingly seen as a cost-effective fuel source that can replace coal in a power plant entirely or “co-fired” with coal. Fuel cells and other distributed generation subsegments continue to gain momentum (particularly in combined heat and power applications) with \$7.7 billion in revenue and 16% growth in 2014.

In the United States, Electricity Generation reached \$45.8 billion, representing 48% growth over 2013 – the largest percentage increase among advanced energy segments. (Table 7.2) Nearly half of total revenue for the segment – \$22.5 billion – came from solar PV, which continued its rapid climb. Solar PV revenue grew 39% year-on-year, capping four-year growth of 173% – nearly tripling 2011 U.S. revenue of \$8.2 billion. (Figure 7.1) Solar PV continues to see dramatic price declines, continued success of the residential solar lease, a massive pipeline for utility-scale power plants, and growing activity outside of the core states such as California and New Jersey.

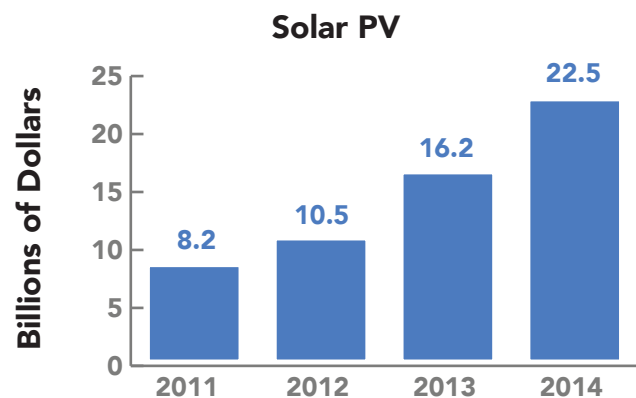


Figure 7.1 (Source: Navigant Research)

Wind power returned to growth in 2014, quadrupling its 2013 revenue of \$2.1 billion to \$8.2 billion, and setting the stage for an even bigger 2015. Together, wind and solar represent two-thirds of the U.S. Electricity Generation market and more than half of all new generation capacity installed in 2014.

Also, the natural gas revolution in the United States finally translated into sales of new generating equipment, with strong growth in orders for both natural gas combined cycle (45% year-on-year revenue growth) and simple cycle gas turbines (65% increase) from companies such as GE, Siemens, and Alstom, resulting in associated revenues of \$5.1 billion and \$1.3 billion respectively in 2014. (Figure 7.2) Hydropower orders in the United States grew an estimated 22%, surpassing \$1 billion in revenue, mostly for upgrades to existing facilities. There were no new orders placed for U.S. nuclear power plants or commercial-scale marine power in 2014.

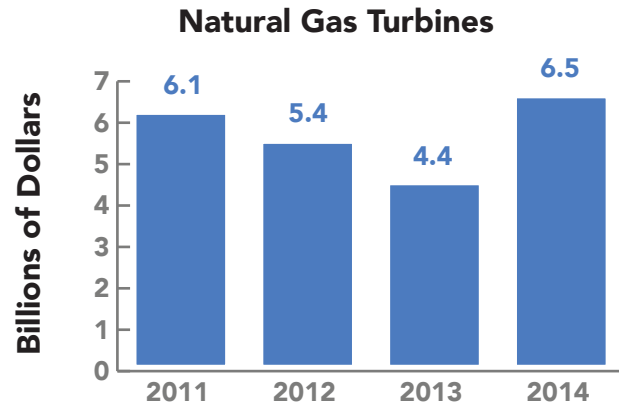


Figure 7.2 (Source: Navigant Research)

### Global Electricity Generation Revenue (millions)

Electricity Generation	2011	2012	2013	2014 (estimate)
Solar	\$96,193	\$87,672	\$96,828	\$94,800
Wind	\$67,069	\$82,111	\$67,685	\$94,575
Geothermal	\$666	\$1,730	\$1,470	\$1,500
Hydro	\$256,984	\$91,260	\$84,331	\$122,492
Marine	\$300	\$140	\$0	\$0
Waste	\$4,700	\$2,750	\$5,910	\$5,065
Biomass	\$10,500	\$7,200	\$14,700	\$13,500
Nuclear	\$53,433	\$47,944	\$45,672	\$38,225
Gas Turbines	\$41,742	\$37,986	\$43,147	\$48,490
Fuel Cells and Other Distributed Generation	\$755	\$1,009	\$6,618	\$7,700
<b>Electricity Generation Subtotal</b>	<b>\$532,342</b>	<b>\$359,802</b>	<b>\$366,361</b>	<b>\$426,347</b>

Table 7.1 (Source: Navigant Research)



## U.S. Electricity Generation Revenue (millions)

Electricity Generation	2011	2012	2013	2014 (estimate)
<b>Solar</b>	\$8,246	\$11,850	\$19,519	\$25,950
<b>Wind</b>	\$12,993	\$25,460	\$2,060	\$8,252
<b>Geothermal</b>	\$118	\$723	\$833	\$450
<b>Hydro</b>	\$1,202	\$942	\$845	\$1,027
<b>Marine</b>	\$30	\$0	\$0	\$0
<b>Waste</b>	\$640	\$290	\$550	\$270
<b>Biomass</b>	\$300	\$600	\$900	\$882
<b>Nuclear</b>	\$0	\$0	\$0	\$0
<b>Gas Turbines</b>	\$6,117	\$5,428	\$4,363	\$6,447
<b>Fuel Cells and Other Distributed Generation</b>	\$182	\$91	\$2,165	\$2,531
<b>Electricity Generation Subtotal</b>	<b>\$29,829</b>	<b>\$45,385</b>	<b>\$31,235</b>	<b>\$45,809</b>

Table 7.2 (Source: Navigant Research)

## Wind Booms in China, Rebounds in U.S., with Full Pipeline

China continued to deploy wind power at a remarkable rate, installing an estimated 23.3 GW in 2014, a 45% increase over 2013. China accounted for 45% of the 51 GW installed globally in 2014, representing \$94.6 billion in revenue. This is the most wind ever installed by a single country in a single year, bringing China's cumulative wind capacity to over 114 GW. For comparison, all of Europe installed an estimated 12.8 GW last year, representing modest growth over the 12 GW installed in 2013.

It is very likely that the Chinese wind market will continue to post big numbers. The National Development Reform Committee's wind power development roadmap calls for wind to account for 17% of China's total electricity production by 2050. In order to reach this target, 200 GW of wind power will need to be installed by 2020, 400 GW by 2030, and 1,000 GW by 2050. China's "Big 5" state-owned power producers have developed the vast majority of the country's wind power to date and benefit from having the global manufacturing hub in their backyard. The top wind turbines vendors in China in 2014 were the same as last year, with Goldwind in the lead followed by United Power and Mingyang.



The U.S. wind power market recovered in 2014 from the severe setback of the year before. Approximately 4.8 GW of wind went online in 2014, representing \$8.2 billion in revenue, up from just over 1 GW and just \$2.1 billion in revenue in 2013, which was down from the 2012 peak of \$25.5 billion. This brings U.S. cumulative capacity to 65.8 GW.

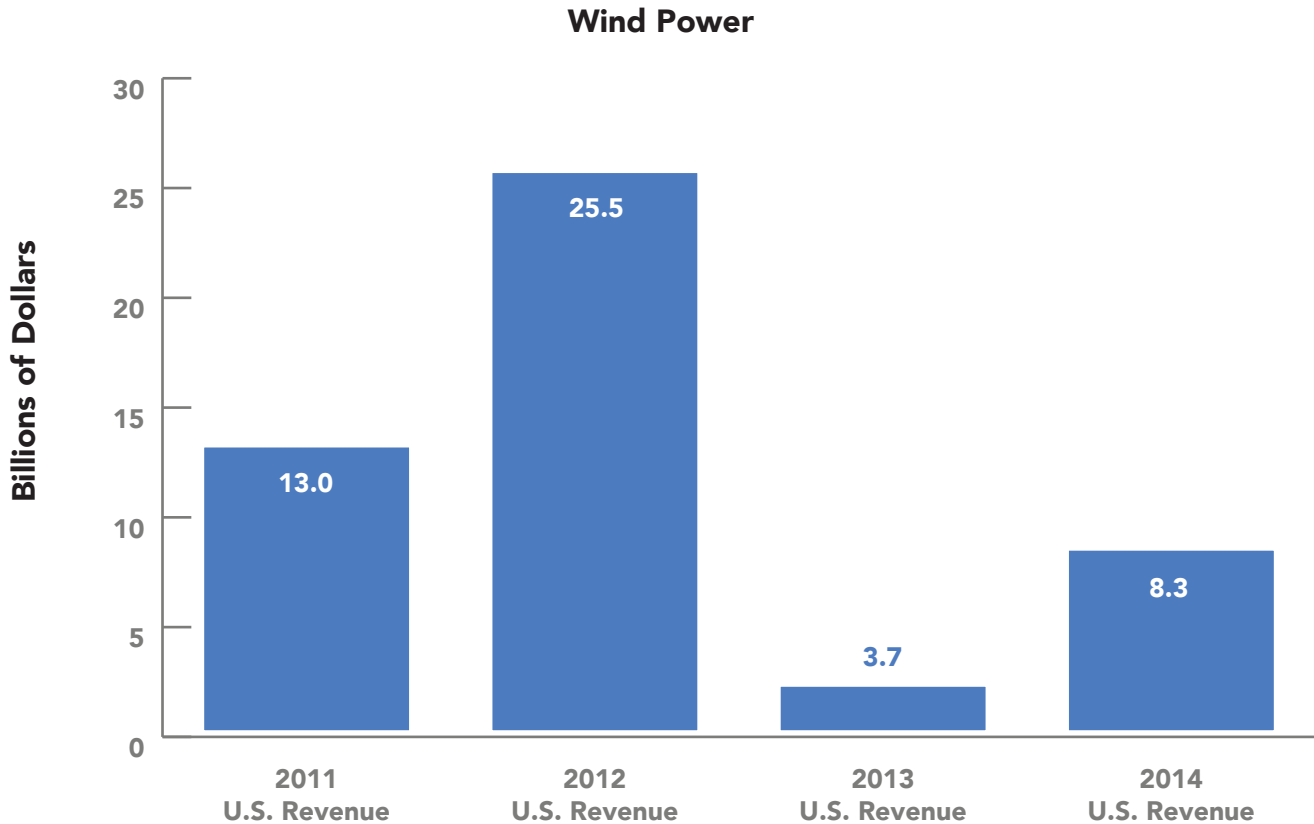


Figure 7.3 (Source: Navigant Research)

The rebound in 2014 was the result of the one-year extension in 2013 of the production tax credit (PTC) and investment tax credit (ITC). Flexible “commence construction” language allowed projects that began construction or spent at least 5% of expected capital expense prior to January 1, 2014, to be eligible for the credits. This provided for a recovery in the U.S. wind market in 2014 and sets the stage for a particularly big 2015, since over 12 GW of wind projects are under construction, which would nearly match the 2012 record of 13 GW of wind was installed.

Of the current 12 GW wind pipeline in the U.S., 10 GW is in Texas alone. The boom in Texas results from a confluence of factors: continuing rise in electricity demand, excellent wind resources, and completion of the Competitive Renewable Energy Zone (CREZ) transmission expansion. CREZ is a nearly \$7 billion project that has brought online nearly 3,600 miles of new transmission capacity, accommodating over 18 GW of generating capacity. It is the result of a plan to coordinate the effort of wind developers with needed transmission expansion. Texas’s strong economic growth, abundance of natural gas to complement wind generation, and experimentation with energy storage make it a key state to watch in 2015 for how grid operators manage this mix of generation resources. The top wind turbine vendors in the United States in 2014 in order were GE, Vestas, and Siemens.





Europe is the leading market for offshore wind as massive and highly efficient 5 MW and 7 MW wind turbines are going up off the coast of Germany, the United Kingdom, and the Netherlands, though costs remain high as developers navigate harsh open sea environments. While onshore wind was a success story in the United States, offshore wind's long awaited takeoff suffered a major blow in early 2015 with new and potentially show-stopping complications for the long-awaited 468 MW Cape Wind offshore wind development. The two major utilities that had agreed to buy the majority of Cape Wind's output upon completion pulled out of their power contracts, citing the developer's inability to secure financing and achieve contractually agreed upon construction milestones. The outcome is still uncertain pending legal disputes between the stakeholders but the prognosis is poor for the developer to revive the contracts and thus the project, at least in the near term.

The on again, off again nature of the key PTC and ITC federal incentives remains a particularly difficult challenge for the offshore wind industry, which typically needs a longer lead time for development. In contrast with the United States, China already had nearly 600 MW of offshore wind operational by the end of 2014 and is expected to exceed 1.5 GW of offshore wind by the end of 2016.

## **New Hydropower in Developing Markets, Upgrades in the United States**

Hydropower is a mature technology that has tapped most of the resources available in developed countries, with the exception of Canada, which continues to eye large hydro projects. Despite this, there are still hydro opportunities available in the United States. An estimated \$4 billion worth of orders were made over the past four years, mostly to repower and/or upgrade aging hydroelectric plants, develop small projects, and create energy storage (pumped hydro), totaling 618 MW of installed capacity.

Globally, the picture is quite different. Developing countries such as China, Russia, Laos, Chile and Peru continue the development of new large hydroelectric plants. Orders for these new developments accounted for roughly 85.4 GW of new capacity in the past four years, representing \$550.1 billion in revenue.

Just in 2014, China commissioned nine projects of over 2GW in capacity – including portions of the Xiluodu hydro project, the third largest hydro plant in the world, with approximately 12.6 GW of capacity from 18 turbines of 700 MW each. Russia also finished the works in its Buguchany Dam on the Angara River, toward the border with Mongolia. The plant has a capacity of almost 3 GW and was built at a cost of \$2.6 billion. Additional projects in Asia are Laos's Xe Pian–Xe Namnoy with 410 MW capacity worth \$1 billion and the 290 MW Nam Ngiep 1 project worth \$643 million.

In Latin America, Chile, Peru and Costa Rica developed the largest hydropower projects. Chile took the lead with a \$2 billion investment in its 531 MW Alto Maipo run-of-the-river plant, which is now under construction, followed by Costa Rica's Reventazon plant, which involved an investment of almost \$1.4 billion to develop 305 MW of capacity. Peru has two projects with a similar capacity. The Chaglla plant on the Huallaga River in Peru cost \$1.2 billion and has a capacity of 462 MW while the Cerro del Aquila plant's 500 MW capacity will need only \$900 million of investment by the time it is finished in mid-2015.

The cost per megawatt of installed capacity varies widely depending on the difficulty of the project, the technology used, and the social and environmental mitigation costs. For example, the Alto Maipo run-of-the-river plant



cost \$3.9 million/MW to develop while super large-scale dams in China such as the Xiluodu Hydropower plant, were reported in 2003, when construction started, as low as \$0.6 million per MW (\$0.8 million/MW of today's dollars) – though Navigant estimates the true cost, including resettlement, cost overruns, and other non-included costs to push the final price tag significantly higher. All hydropower projects are unique. For example, the Xiluodu hydropower plant in China is almost 30 times larger than Alto Maipo and is using conventional turbines, while the Chilean project involves the construction of 67 kilometers (42 miles) of tunnels in the Andean range at depths of up to 1,700 meters (5,580 feet) and is using more expensive run-of-the-river technology. A Navigant study of hydropower projects found a range in installed costs of \$1 million to \$6 million per MW.

Hydropower projects often face strong public opposition due to the impact on local communities, ecosystems, and cost overruns – but remain the largest source of renewable energy in the world. Furthermore, due to its large reservoirs, hydro represents the largest and most cost-effective form of energy storage, able to meet demand as it fluctuates.

Companies such as Siemens, Alstom, and Voith are targeting developing countries where future growth is expected, including in Africa, which is home to six of the 10 fastest growing economies globally. Notably the Grand Inga hydropower project in the Democratic Republic of Congo could be the world's largest hydropower project with potential capacity of approximately 40 GW, larger than China's massive Three Gorges Dam.

## **Distributed Generation Spurs Review of Utility Rules**

The rise of distributed generation (DG) is one of the most important trends in the energy industry today. Traditional utility business models are challenged by the dramatic growth in the deployment of technologies that generate electricity onsite or at the distribution grid level, reducing the need to purchase power from central utility-scale generation facilities. Leading distributed generation technologies, including solar PV, small and medium wind, fuel cells, and natural gas generator sets, combined in 2014 for \$6.3 billion in revenue from installations in the United States, and \$35 billion globally.

In the United States, federal tax policies and state deployment targets have played a catalytic role in the adoption of DG technologies. The federal investment tax credit, currently in place through the end of 2016, has been instrumental in the growth of solar PV. Sixteen U.S. states have Renewable Portfolio Standards (RPS) with solar and/or DG provisions. California Gov. Jerry Brown has called for 12 GW of distributed generation in the state, and the state has in place a requirement on utilities to deploy 200 MW of distributed storage as part of an overall 2 GW energy storage target.

To date, DG has been more disruptive in Western Europe than in any other region. Utilities have lost hundreds of billions of dollars in market capitalization as DG reaches higher levels of penetration in leading countries such as Germany, the United Kingdom, and Italy. The prospect of similar disruption in the United States has prompted utilities, the DG industry, and regulators to seek out a balance that allows for DG growth without undermining the role of utilities in maintaining the grid. Such a balance would enable DG customers and utilities to take advantage of new revenue opportunities enabled by DG while fairly compensating utilities for ensuring electric service for all, including backup service for onsite power. The "Reforming the Energy Vision" proceeding underway at New York's Public Service Commission is one example of state regulators seeking to create a new regulatory framework for supporting distributed energy resources and upgrading the power grid in tandem. Along with policy incentives, strong technology and private sector business model innovation and dramatic cost reductions in solar PV, fuel cells, and enabling technologies such as inverters, racking, and other balance



of system components have helped DG approach long-sought “grid parity” with retail electricity rates in several states. New business models, including the solar lease, solar loans, and community solar, each of which is available in nearly half the United States, enable residential and commercial customers to get solar PV on their rooftop (or someone else’s) with little or no money down, and while typically saving 10-20% on their electric bills. SolarCity, SunRun, Vivint Solar, and Sungevity are among the companies that have rapidly expanded the “solar as a service” model around the country. The same model is also being applied by small and medium wind turbine providers such as United Wind.

Meanwhile, two Arizona utilities, Tucson Electric Power and Arizona Public Service, have taken the DG bull by the horns, proposing their own programs whereby they would own and operate rooftop solar installations and give a rebate to their host customers. These programs could save the average customer \$30 per month for 20 to 25 years. These programs are controversial, as competing solar installers see the utilities as exercising an unfair competitive advantage in the marketplace.



## ELECTRICITY DELIVERY AND MANAGEMENT

Electricity Delivery and Management is the fifth largest advanced energy segment globally, with an estimated \$67.9 billion in revenue in 2014, a 33% increase over 2013. (Table 8.1) Enabling information and communication technology (ICT) remained the largest subsegment with revenue of \$32.9 billion (up 12% from 2013). Enabling ICT includes grid communications networks and grid IT/OT software and services, such as meter data management, next generation customer information and billing systems, and advanced data analytics. It also includes smart street lighting, which continued to account for the majority (nearly 57%) of enabling ICT revenue, at \$18.6 billion worldwide in 2014. Transmission was the second leading subsegment with \$20.8 billion in revenue worldwide, led by smart transmission system upgrades (\$12.6 billion, up 1,713% from 2013) and high voltage direct current (HVDC) transmission systems (\$6.1 billion, up 61% from 2013). The high cost of such projects, which occur on an irregular basis, results in large year-on-year variability. Advanced metering infrastructure also increased 11% in 2014, to nearly \$6.5 billion, while electric vehicle charging infrastructure had a breakout year with nearly \$594 million in 2014, representing 42% growth over 2013.

On a global basis, several subsegments saw year-on-year declines, including advanced metering infrastructure (\$6.5 billion, up 11%), microgrids (\$4.4 billion, down 19%), distribution (\$2.3 billion, down 34%), and energy storage (\$461.7 million, down 29%). In contrast, electric vehicle charging infrastructure experienced 42% growth in 2014, with \$593.5 million in revenue worldwide.

U.S. revenue in the Electricity Delivery and Management segment rose 23% from 2013, to an estimated \$13.1 billion in 2014. (Table 8.2) Enabling ICT was the largest subsegment with \$6.3 billion – which includes more than \$4 billion from smart street lighting, systems that manage street lights remotely to detect burned out lamps, adjust to weather and traffic conditions, and flash in case of emergency, among other functions. As the second largest subsegment, transmission infrastructure investment rebounded with more than 400% growth, resulting in revenue of nearly \$2.9 billion in 2014, due to several large smart transmission system upgrades, which account for \$2.4 billion in 2014 revenue. At nearly \$2 billion in revenue representing 44% the global market in 2014, the U.S. microgrid market bucked the global trend with an increase of 21% compared to 2013.

Following the global trend, the U.S. saw an increase in distribution (\$272.2 million, up 9%) and some downward trends in advanced metering infrastructure (\$1.3 billion, down 16%), and energy storage (\$57.6 million, down 29%). However, growth in U.S. microgrid revenue, which includes revenue from distributed generation and energy storage equipment used in microgrids, bucked the global trend (\$2 billion, up 21%, continuing its strong four-year growth (93%). Electric vehicle charging infrastructure continues to show strong growth, up 31% from a 2013 revenue total revised sharply upward to \$150 million, with 2014 revenue of \$201.5 million, up 648% over four years.

## Global Electricity Delivery & Management Revenue (millions)

Electricity Delivery & Management	2011	2012	2013	2014 (estimate)
Transmission	\$9,808	\$17,894	\$6,110	\$20,767
Distribution	\$5,998	\$7,383	\$3,404	\$2,252
Advanced Metering Infrastructure (AMI)	\$6,273	\$6,514	\$5,805	\$6,463
Microgrids	\$3,737	\$4,400	\$5,479	\$4,416
Charging Infrastructure	\$127	\$355	\$417	\$594
Energy Storage	\$116	\$791	\$646	\$462
Enabling Information and Communication Technology	\$9,351	\$28,066	\$29,289	\$32,943
<b>Electricity Delivery &amp; Management Subtotal</b>	<b>\$35,410</b>	<b>\$65,403</b>	<b>\$51,151</b>	<b>\$67,896</b>

Table 8.1 (Source: Navigant Research)

## U.S. Electricity Delivery & Management Revenue (millions)

Electricity Delivery & Management	2011	2012	2013	2014 (estimate)
Transmission	\$1,147	\$2,133	\$576	\$2,883
Distribution	\$1,064	\$1,322	\$250	\$272
Advanced Metering Infrastructure (AMI)	\$1,648	\$1,681	\$1,387	\$1,378
Microgrids	\$1,012	\$1,265	\$1,623	\$1,957
Charging Infrastructure	\$27	\$92	\$154	\$201
Energy Storage	\$81	\$360	\$519	\$58
Enabling Information and Communication Technology	\$3,075	\$7,291	\$6,089	\$6,306
<b>Electricity Delivery &amp; Management Subtotal</b>	<b>\$8,055</b>	<b>\$14,144</b>	<b>\$10,599</b>	<b>\$13,056</b>

Table 8.2 (Source: Navigant Research)



# Energy Storage Poised to Shave Demand Charges

The energy storage market is in a process of transition. It is going from a large infrastructure market focused on pumped hydro and underground compressed air projects to an advanced energy technologies market, fueled by technological innovation, liberalized market structures, and supportive policies. While the global market still revolves around pumped storage, energy storage in the United States is all about new batteries and other technologies. This distinction accounts for recent market dynamics.

Overall, demand for energy storage is growing both globally and in the United States, but the numbers don't yet show it. Revenue for energy storage worldwide actually dropped from \$646 million in 2013 to \$462 million in 2014, and from \$519 million to \$58 million in the United States. That's because Navigant Research only includes completed projects and delivered products in revenue totals for a given year. In fact, 2014 was a landmark year for energy storage procurements by utilities and grid operators. Once these systems are commissioned over the next few years, market revenue will take off.

The energy storage market consists of three components – ancillary services, bulk storage, and distributed storage – and all three are growing. But, the breakout application for energy storage in the past 12 months has been distributed energy storage situated on the customer side of the meter. Both residential and commercial energy storage saw a surge of adoption worldwide. In the United States, commercial energy storage was by far the leading application in 2014, and the U.S. has become the number one market for commercial energy storage in the world.

For many industrial facilities, electricity consumption represents their highest operating cost, even higher than payroll. By using storage to supplement power from the grid when its electricity needs surge, a business can avoid high demand charges on electric bills by reducing its peak load (without necessarily curtailing actual electricity use). These charges can amount to 10% to 15% of electricity costs.

Demand charges are levied by electric utilities based on the maximum electricity demand of a customer within a specific period. There are two types of demand charges. The first is at the wholesale level, where customers get an annual capacity charge based on their load during the grid's peak hours during the year. The second comes at the retail level, where utilities impose a demand charge based on monthly peak usage. Monitoring these levels and taking action to reduce consumption just a few hours a year can have a disproportionate impact on electricity costs.

There are various ways to manage electricity use to reduce the peaks that drive up demand charges. Needlessly running multiple pieces of equipment at the same time can lead to high coincidental peak usage. With small adjustments, these devices can be sequenced or ramped up to reduce peak load while not hampering operations. Pre-cooling is another strategy to address high peak loads, whereby a building will use thermal storage (typically ice made overnight) to assist with air conditioning in the peak afternoon hours.

Demand charges are common in key distributed energy storage markets, including California, New York, Germany, Australia, Japan, and South Korea, though in some cases the charges are low where manufacturing is a strategically important industry sector. For example, 30% of Germany's gross domestic product (GDP) comes from the manufacturing sector.



California has been the most watched market for energy storage in the past year. Major legislative actions and market dynamics have combined to create a fast-growing market for energy storage. A 2010 state law, A.B. 2514, required the state's utilities to procure 1.3 GW of energy storage. Southern California Edison was the first utility to procure energy storage under these requirements and announced contracts for 261.1 MW of new energy storage capacity, five times the amount required under the new state law. Similar announcements are expected in 2015 from the state's other major investor-owned utilities.

Southern California Edison's procurement also introduced a unique model for energy storage deployment. SCE bought 100 MW of utility-side storage and an additional 160.6 MW of storage behind the meter. This 160.6 MW will be situated on SCE customers' property, with the benefits shared between the utility and the customer.

Globally, there are seven active government programs to support behind-the-meter storage installations, three of them in the United States, located in California and New York. Overall, \$230 million was available globally for customer-sited energy storage – most of it for advanced batteries. Although most programs have only been in place since 2013, California's programs have been active much longer and have been consistently renewed. Over time, California has adjusted the technical requirements for energy storage to account for the performance characteristics of many advanced technologies.

## Smarter Grid Technologies Make for Smart Cities

Cities are a focal point for some of the most profound economic, social, and technological issues facing the world today, not least of which is the need for cleaner and more efficient energy resources to meet the demands of an urban population that will expand by 2.4 billion people over the next 35 years. Numerous cities are now investigating new forms of energy delivery and management spanning all aspects of city operations – fundamentally changing the way energy is generated, distributed, and integrated within city limits.

Electricity networks are at the heart of a complex web of interdependencies. After all, power failures can have dramatic impacts on water, sewage, health, communication, and transportation systems. At the same time, the kind of technologies that make energy management and delivery smarter and more reliable in the face of hazards also contribute to an increasingly connected set of infrastructure services for city residents.

Smart grid investments are already helping utilities better cope with severe weather events and other outages, with densely populated urban areas among the biggest beneficiaries. Self-healing grid networks and automated demand response, for example, can mitigate the impact of such events on the network, while more accurate prediction of an event and its likely consequences enables crews dispatch to vulnerable areas earlier. Distributed generation will also play a growing role in the ability of cities to deal with events like Hurricane Sandy, which devastated the northeastern United States in 2012. New York, for example, is looking to increase use of distributed generation alongside other grid innovations that will provide an energy infrastructure better able to cope with future events of that scale.

An important aspect of the smart city concept is resilience – the ability of cities and communities to withstand or bounce back from catastrophic events, as well as manage the ongoing challenges facing urban communities. Resilience requires an assessment of each city's complex and interconnected infrastructure and institutional systems that span the physical, economic, institutional, and sociopolitical environment. Cities are now becoming much more involved in resilience planning and need to work with utilities and other agencies to develop integrated plans for emergency response.



Some of the most advanced examples of this thinking are being developed in Japan. The county's interest in more sustainable and resilient energy systems has been accelerated by the energy crisis resulting from the 2011 Great East Japan earthquake and tsunami. The Yokohama Smart City Project (YSCP) is a good example of the vision being developed by the Japanese government, city authorities, and major suppliers. YSCP is a large-scale pilot project focused on energy management at the household, district, and city level from 2010 through 2014. Participants – which include 4,000 households in a variety of housing types, as well as four office buildings, two commercial buildings, and a large factory – are receiving energy management systems (EMS). In addition to providing new infrastructure, the project is testing demand management policies for residential and commercial customers to reduce peak power demand. Project partners include the city of Yokohama; local power, water, and gas utilities; major telecom NTT; real estate developer Mitsui Fudosan; and Nissan Motor Co. Many Japanese and international smart grid device and service providers are contributing, including Accenture, Hitachi, NEC, Panasonic, Sharp, Sony, and Toshiba. Other cities with similar initiatives include Charlotte, NC; Worcester, MA; Amsterdam; London; Sydney, Australia, and several others. (See Table 8.3)

From the utilities' perspective, tying smart meter and smart grid deployments into a broader Smart City project has several advantages, including closer engagement with communities, individual consumers, and businesses; unique opportunities for testing on a citywide scale a range of advanced energy technologies, including distributed renewable energy, EV charging, and demand management; chances to offer new revenue generating energy services to city agencies as well as residents and businesses. Smart street lighting systems (5% revenue growth nationally from 2013 to 2014) and EV charging networks (31% growth) are just some of the areas where utilities are well positioned to help cities meet ambitious energy and infrastructure goals.





## Smart Grid, Smart City Projects

City	Project	Summary
<b>Amsterdam The Netherlands</b>	Amsterdam Smart City	Numerous energy and smart grid related projects including City-zen which spans smart distribution networks, smart homes, building efficiency programs, waste management, and demand management
<b>Charlotte North Carolina</b>	Envision Charlotte	As part of a cross-sector collaboration aiming to make Charlotte the most sustainable city in the United States, Duke Energy, Verizon, and other partners are working on the Smart Energy Now project, which aims to reduce energy consumption in Charlotte's uptown office buildings using smart grid technologies
<b>Dubai United Arab Emirates</b>	Dubai Smart City	As part of the broader smart city program, Dubai Electricity and Water Authority is deploying rooftop PV, smart meters, and smart grid technologies as well as EV charging infrastructure.
<b>Groningen The Netherlands</b>	PowerMatching City	A pilot to create a smart energy system and a total concept smart grid deployment that also involves automatic aggregated control of end-user systems.
<b>Issy-les-Moulineaux France</b>	IssyGrid	An extensive smart grid development project to enable energy optimization at the neighborhood level. Project partners include EDG, ERDF, Alstom, Schneider Electric, Bouygues Telecom, and Microsoft.
<b>London United Kingdom</b>	Low Carbon London	A £40 million (\$48 million) smart grid and energy efficiency project led by local distribution operator UK Power Networks. The project is looking at a range of issues, including the role of smart meters, EV charging, smart distribution networks, and renewable energy generation.
<b>Lyon France</b>	Smart Electric Lyon	A consortium of 20 partners led by EDF is delivering smart energy solutions to around 25,000 households in the Greater Lyon region.
<b>Malaga Spain</b>	Smartcity Malaga	A 5-year smart-grid demonstration project led by Endesa that launched in 2008 and was completed in 2013. The project included smart meter, smart grid, energy storage, and EV charging deployments as well as street lighting improvements.
<b>Sydney Australia</b>	Smart Grid, Smart city	A \$100 million demonstration project that deployed smart electric meters and other energy monitoring and management technologies to around 17,000 homes and tested a variety of smart grid programs in the Newcastle and Sydney area of New South Wales from 2010 to 2014
<b>Vienna Austria</b>	Aspen Smart city	A €40 million (\$55 million) smart city/smart grid project launched in October 2013; collaboration between Siemens and the utility Wiener Stadtwerke that plans to support a community of up to 20,000 people by 2030, including living and working environments
<b>Worcester Massachusetts</b>	Smart Energy Solutions	A program led by National Grid in cooperation with the city of Worcester and the state of Massachusetts to deploy 15,000 smart meters in the city as part of an energy management program alongside smart grid upgrades to the distribution network.
<b>Yokohama Japan</b>	Yokohama Smart City Project (YSCP)	A large-scale pilot project focused on energy management at the household, district, and city level from 2010 through 2014.

Table 8.3 (Source: Navigant Research)



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