ADVANCED ENERGY ECONOMY

ADVANCED ENERGY NOW 2016 MARKET REPORT

Global and U.S. Markets by Revenue 2011-2015 and Key Trends in Advanced Energy Growth

Prepared by Navigant Research

March 2016

ADVANCED ENERGY ECONOMY

the business voice of advanced energy

About Advanced Energy Economy

Advanced Energy Economy (AEE) 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 26 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.

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.

Advanced Energy Now 2016 Market Report

ADVANCED ENERGY ECONOMY
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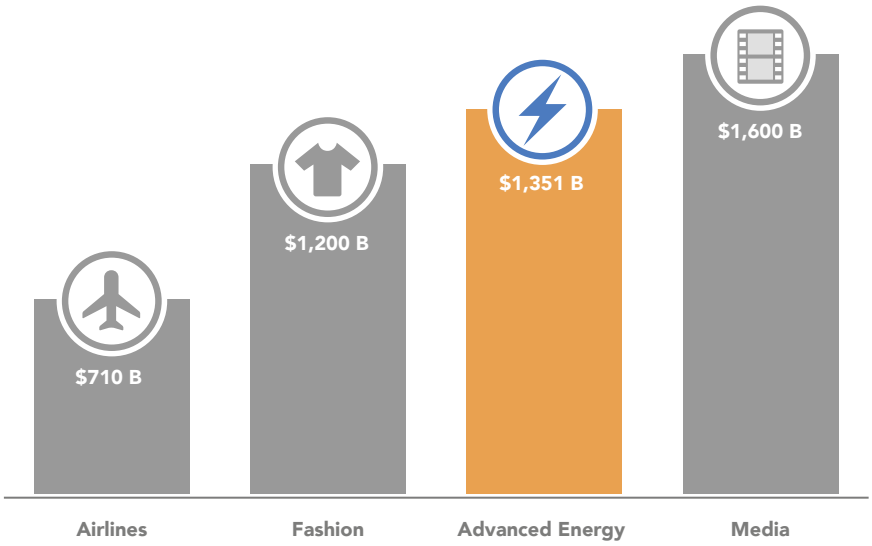
TABLE OF CONTENTS

ADVANCED ENERGY ECONOMY
the business voice of advanced energy

ADVANCED ENERGY MARKETS ARE BIGGER THAN EVER

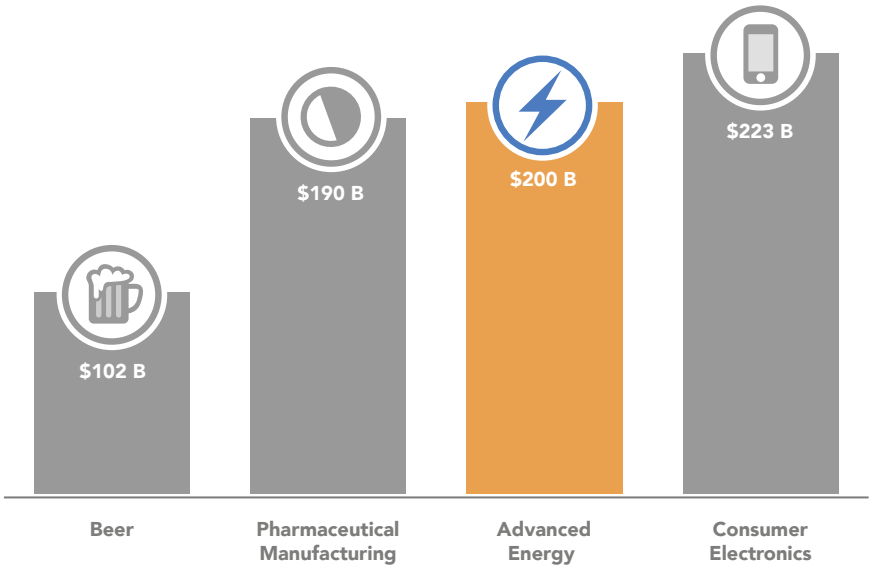
Advanced energy is a $1.4 trillion global industry, as big as fashion, twice the size of airlines, and nearly equal to worldwide spending on media. If global advanced energy were a country, it would be equal to Mexico in GDP.

Global Revenue by Industry, 2015



The U.S. advanced energy market is $200 billion, nearly double the revenue from beer sales, more than pharmaceutical manufacturing, and approaching wholesale consumer electronics. If U.S. advanced energy were a state, it would be nearly equal to Oregon in economic activity.

U.S. Revenue by Industry, 2015

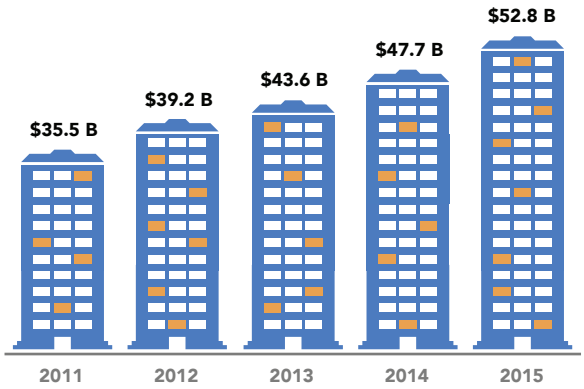


Over the past five years, advanced energy in the United States has grown 29%. Growth over last year was 1%, dampened by the effect of low oil prices on ethanol revenue data. Without Ethanol, U.S. advanced energy revenue grew 10% over last year, four times faster than U.S. GDP.

Advanced Energy Economy's *Advanced Energy Now 2016 Market Report* contains five years of revenue, starting with 2011. Highlights from the U.S. market include:

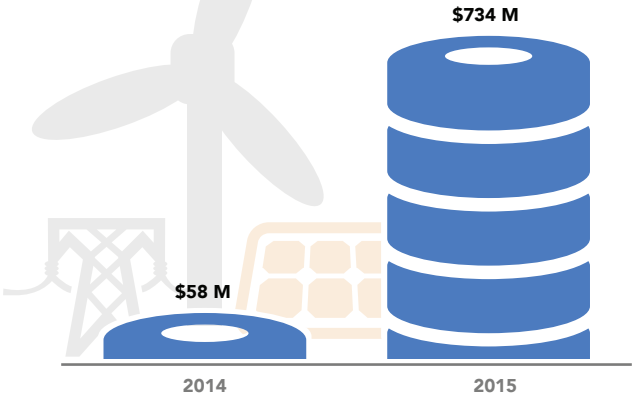
- Building Efficiency is the **largest advanced energy market segment, with $63.6 billion in revenue** and 50% growth over 2011, counting only products for which we have all five years of data.
- Solar continues to be a dynamic growth story in the U.S. Even as costs have declined by nearly 50%, revenue from **Solar PV reached $22.6 billion, up 21% over last year and nearly triple 2011 revenue.**
- Wind showed strong growth for the second year in a row, continuing to climb back from a low point in 2013 to reach **$14.4 billion in 2015, up 75% over last year.**
- At $743 million, revenue from Energy Storage grew **12 times over 2014.** This game-changing technology can provide grid support services, meet peak demand needs, and store variable renewable energy generation until it's needed.
- Ethanol revenue declined by a third over last year. The price of ethanol in the United States tends to follow the price of gasoline. Historically low oil prices brought Ethanol revenue from $40.9 billion in 2014 to $27.3 billion in 2015.
- Revenue from Plug-in Electric Vehicles in 2015 **grew seven times over 2011**. At nearly $5 billion, revenue from PEVs in 2015 was nearly half that of hybrids, a more established class of advanced vehicle.

U.S. Building Efficiency*

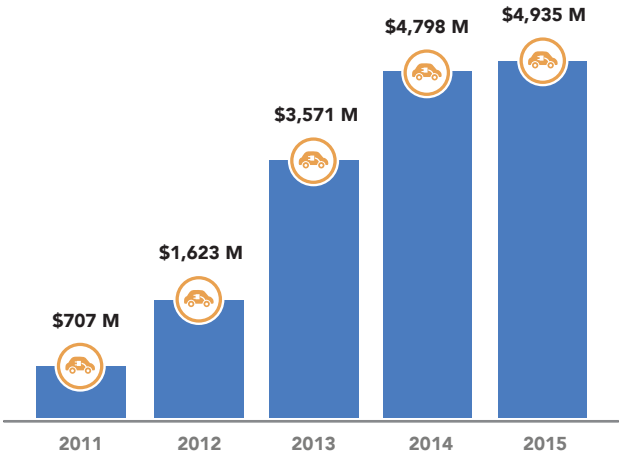


*Revenue shown only for product categories with revenue data for all years 2011-2015.

U.S. Energy Storage



U.S. Plug-in Electric Vehicles



Prepared by Navigant Research, *Advanced Energy Now 2016 Market Report* is the fourth 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 business association, advanced energy is a broad range of technologies, products, and services that constitute the best available technologies for meeting energy needs today and tomorrow.

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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 2016 Market Report is our fourth 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. Five years in, it is clear that advanced energy's trajectory is up – way up!

This year's edition shows global growth of 8% from 2014 to 2015, three times the rate of the world economy overall. U.S. advanced energy grew 1%, only because the total was dampened by a big decline in revenue from ethanol. Without counting ethanol, U.S. revenue was up 10% last year – four times the rate of U.S. GDP.

In 2015, advanced energy represented a $1.4 trillion global market and a U.S. market of $200 billion.

Worldwide, the advanced energy market was nearly twice the size of the airline industry, bigger than fashion and apparel, and close to global spending on media, from newspapers to movies to video games. In the United States, advanced energy was nearly twice the size of the beer market by revenue, bigger than pharmaceutical manufacturing, and nearly as big as the wholesale market for consumer electronics.

If the global advanced energy industry were a country, it would be equal in GDP to Mexico. If U.S. advanced energy were a state, it would be almost equal to Oregon in economic activity.

What's more, advanced energy is a thriving industry made up of a wide variety of businesses delivering all sorts of products to utilities, businesses, and consumers. For more detail on 52 specific advanced energy technologies and products – what they are, how they have been deployed, and the benefits they provide – see AEE's new catalogue, *This Is Advanced Energy*.

We are seeing a transformation in the way we make, manage, and use energy in this country and around the world. AEE, its member companies, and our partner organizations around the country are working to make the most of this transformation, for the benefit of consumers, the economy, and the nation.

Graham Richard
CEO, Advanced Energy Economy

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INTRODUCTION & METHODOLOGY

The *Advanced Energy Now 2016 Market Report* is the fourth 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 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, on-site and utility-scale solar power, and 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 right.

ENERGY SUPPLY

Electricity Generation

- Hydropower
- Gas Turbines
- Solar
- Wind
- Geothermal
- Marine
- Waste
- Biomass
- Nuclear
- Fuel Cells and Other DG

Electricity Delivery & Management

- Transmission
- Distribution
- AMI
- Micro-grids
- EV Charging Infrastructure
- Energy Storage
- Enabling IT

Fuel Production

- Ethanol & Butanol
- Biodiesel
- Biogas
- Synthetic Diesel & Gasoline
- Bio-oil
- CNG & LNG
- Hydrogen

Fuel Delivery

- Fuel Transportation Infrastructure
- Fueling Stations

ENERGY DEMAND

Building Efficiency

- Building Design
- Building Envelope
- HVAC
- District Energy, CHP, CCHP
- Water Heating
- Lighting
- Appliances & Electronics
- Enabling IT/Demand Response

Transportation

- Propulsion Systems
- Vehicle Design & Materials
- Freight Logistics
- Land Use & Infrastructure Design
- Enabling IT

Industry

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

Download the *Advanced Energy Now 2016 Market Report* at info.aee.net/reports

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. Beginning with *Advanced Energy Now 2014 Market Report*, Navigant Research has continued to track global and U.S. advanced energy revenue annually. *Advanced Energy Now 2016 Market Report* contains final annual revenue from 2011 to 2014 and estimated revenue for 2015 to provide both a snapshot of market size at the present time and growth trends over the past five years.

Advanced Energy Now 2016 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 2016 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 limitations in 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 Heating, Ventilation, and Cooling (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*. Also, for a more complete picture of 52 individual technologies and products, in terms of description, current deployment, and economic and system benefits in the United States, see AEE's new catalogue, *This Is Advanced Energy*.

It is the goal of the annual *Advanced Energy Now* market reports to include new data as they become available, in order to better characterize the true scope of advanced energy markets. Thus some editions have quantified product categories that were not included in *Economic Impacts of Advanced Energy* or in prior editions of the market report. In cases where that has occurred, revenue from the new categories has been included in data tables for the years those data are available. For that reason, care must be taken in comparing results from different years.

In *Advanced Energy Now 2016 Market Report*, growth rates between 2011 and 2015 are calculated (and depicted in accompanying graphs) using only those product categories for which market data are available for all years. No new products or categories have been added in the 2016 edition, so 2014 and 2015 estimated revenue are directly comparable for all segments and subsegments.

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OVERVIEW AND SUMMARY FINDINGS

For 2015, the advanced energy market totaled nearly $1.4 trillion in estimated global revenue, up 8% over 2014 and 17% higher than 2011, counting only products for which we have five years of revenue data. The global market for advanced energy in 2015 was twice as big by revenue as the airline industry,[1] bigger than the global fashion industry,[2] and approaching worldwide spending on media and entertainment.[3] (Figure 1.1) From 2014 to 2015, advanced energy revenue grew at more than three times the rate of the world economy overall.[4]

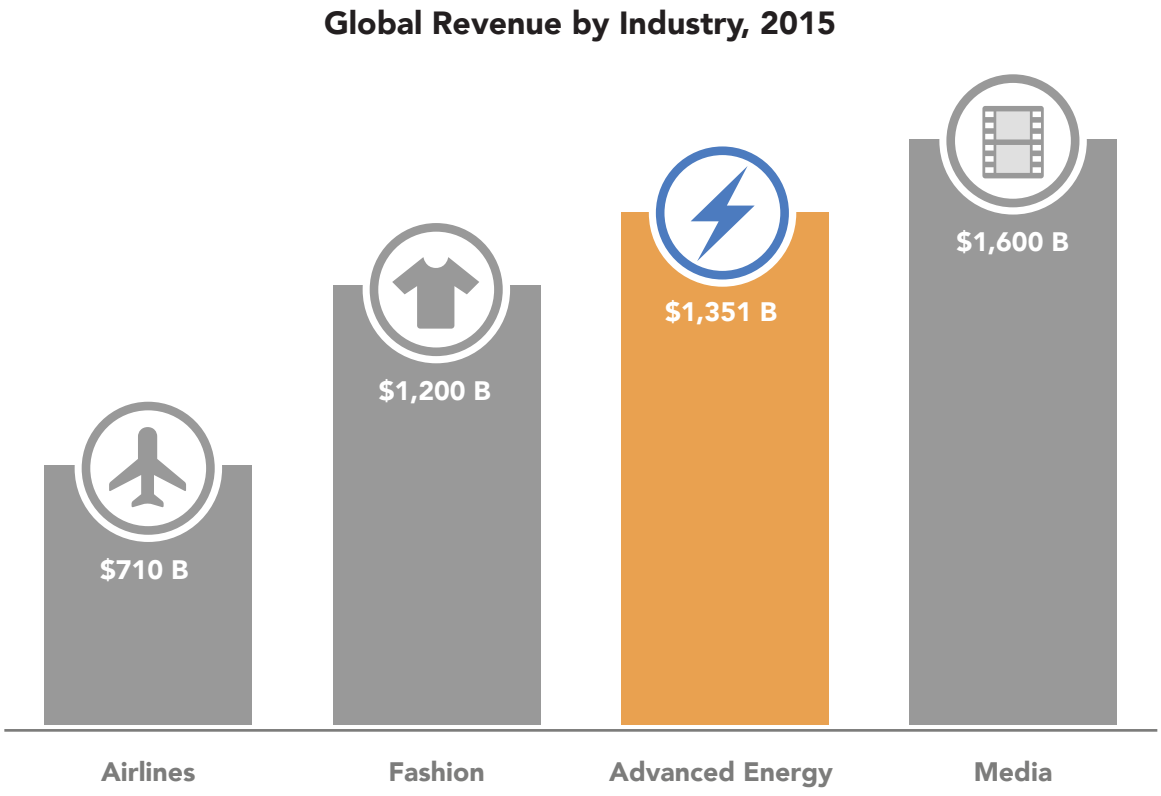


Figure 1.1 (Source: Navigant Research)

Five of the seven advanced energy segments saw growth over 2014, with only Fuel Delivery (down 64% to $983 million) and Fuel Production (down 18% to $121.6 billion) showing declines. (Table 1.1) For the second year in a row, Electricity Generation remained the largest advanced energy segment with $441.3 billion in revenue (up 9% over 2014), led by growth in Solar, Wind, and Hydropower, followed by Transportation with $413.3 billion (up 13%), led by Clean Diesel Vehicles. The largest year-on-year growth was in Electricity Delivery and Management, growing 19% to $94.4 billion, led by Transmission investments.

1. http://www.iata.org/pressroom/pr/Pages/2015-12-10-01.aspx
2. https://maloney.house.gov/sites/maloney.house.gov/files/documents/The%20Economic%20Impact%20of%20the%20Fashion%20Industry%20--%20JEC%20report%20FINAL.pdf
3. https://www.mckinsey.com/~/media/McKinsey/dotcom/client_service/Media%20and%20Entertainment/PDFs/McKinsey%20Global%20Report%202015_UK_October_2015.ashx
4. www.worldbank.org/en/publication/global-economic-prospects

Global Revenue by Segment (millions)

Segment	2011	2012	2013	2014	2015 (estimate)
Transportation	$325,914	$315,865	$343,577	$365,095	$413,345
Transport and Non-transport Fuel Production	$110,667	$138,644	$141,855	$148,062	$121,596
Fuel Delivery	$2,207	$1,926	$2,606	$2,718	$983
Buildings	$117,981	$133,710	$147,100	$207,746	$236,260
Industry	$30,576	$33,325	$38,495	$40,828	$43,403
Electricity Generation	$461,729	$408,674	$333,882	$404,428	$441,285
Electricity Delivery and Management	$35,410	$65,403	$51,151	$79,527	$94,354
Global Total	**$1,084,484**	**$1,097,547**	**$1,058,666**	**$1,248,403**	**$1,351,227**

Table 1.1 (Source: Navigant Research)

In the United States, the advanced energy market reached $199.9 billion in 2015, an increase of 1% over 2014, and up 29% since 2011. The U.S. advanced energy market in 2015 was nearly double the U.S. beer market,[5] larger than pharmaceutical manufacturing,[6] and close to the wholesale market for consumer electronics.[7] (Figure 1.2)

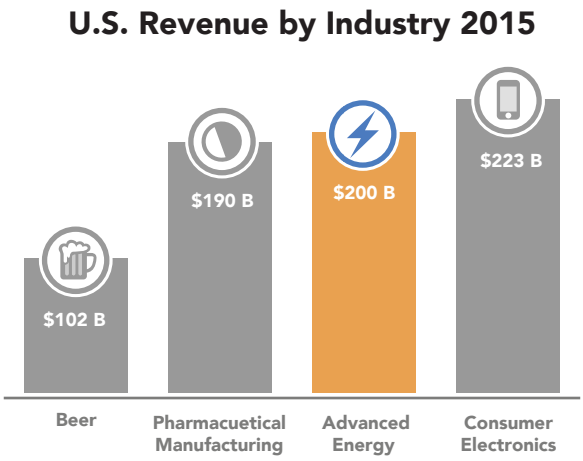


Figure 1.2 (Source: Navigant Research)

Growth in the U.S. advanced energy market overall was impacted by persistently low oil prices in 2015. Ethanol pricing is highly correlated with oil prices. So, while production increased slightly, from 14.3 to 14.7 billion gallons as the federal Renewable Fuel Standard was fulfilled, ethanol revenue dropped 33%, from $40.9 billion to $27.3 billion.

Without counting ethanol, the U.S. advanced energy market grew 10% in 2015, or four times the growth of U.S. GDP. [8]

Four of the seven U.S. advanced energy segments experienced growth over 2014. (Table 1.2) Accounting for more than 30% of total U.S.

5. https://www.brewersassociation.org/statistics/national-beer-sales-production-data/
6. http://www.firstresearch.com/Industry-Research/Pharmaceutical-Manufacturing.html
7. http://www.cta.tech/News/News-Releases/Press-Releases/2015-Press-Releases/New-Tech-to-Drive-CE-Industry-Growth-in-2015,-Proj.aspx
8. http://www.bea.gov/newsreleases/national/gdp/gdpnewsrelease.htm

advanced energy revenue in 2015, Building Efficiency led all segments for the second year in a row, reaching $63.6 billion, up nearly 11% over 2014. Electricity Generation was the second largest advanced energy segment, at $52.3 billion in 2015, and also experienced the second largest year-on-year growth, at 18%, led by Solar, Wind, and Natural Gas Turbines. Following the global trend, Electricity Delivery and Management experienced the largest year-on-year growth, 24%, reaching $18.2 billion in 2015, similarly led by Transmission investments. Reductions were seen in Fuel Delivery (down 31%), Transportation (down 9%, primarily driven by lower sales of Hybrid Vehicles, which were, like ethanol, affected by low gasoline prices), and Fuel Production (down 28%, primarily due to lower prices for ethanol).

U.S. Revenue by Segment (millions)

Segment	2011	2012	2013	2014	2015 (estimate)
Transportation	$11,709	$18,045	$25,106	$24,848	$22,546
Transport and Non-transport Fuel Production	$43,164	$47,337	$48,390	$49,048	$35,384
Fuel Delivery	$227	$378	$252	$283	$195
Buildings	$35,271	$39,229	$43,604	$57,386	$63,550
Industry	$4,202	$5,452	$6,733	$7,186	$7,703
Electricity Generation	$38,813	$43,943	$30,404	$44,537	$52,343
Electricity Delivery and Management	$8,055	$14,144	$10,599	$14,636	$18,165
U.S. Total	**$141,441**	**$168,528**	**$165,088**	**$197,923**	**$199,886**

Table 1.2 (Source: Navigant Research)

Five-Year Trends – Global

Over the past five years, five of the seven advanced energy market segments have seen growth worldwide, counting only products for which we have five years of revenue. Growth has been led by Electricity Delivery and Management (111%), Building Efficiency (60%), Industry (42%), and Transportation (24%). (Figure 1.3)

Within individual segments, significant growth in Transmission (334%), Electric Vehicle Charging Infrastructure (303%), Energy Storage (1,706%), and Enabling Information and Communication Technology (40%) led the Electricity Delivery and Management segment over the five years of

Global Growth by Segment, 2011-15*

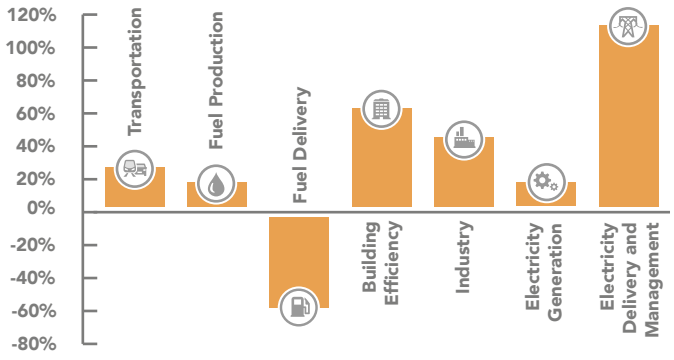


Figure 1.3 (Source: Navigant Research) - *Revenue shown only for product categories with revenue data for all years 2011 - 2015

tracking. Following the global financial crisis, China, the United States, and countries in Europe and elsewhere invested in transmission and smart grid infrastructure with stimulus funding. These regions have also led the deployment of large-scale generating assets, including the massive deployment of renewables since then, requiring significant investment in smart-grid transmission upgrades, high voltage transmission systems, and submarine transmission systems. As a result, electricity delivery and management investments have begun to build out the grid that will be required to accommodate electricity consumption and production in the 21st century.

Building Efficiency has seen modest but steady annual growth worldwide, becoming a force over the five-year period. Substantial growth has occurred in Building Envelope (100% growth), Appliances and Electronic Equipment (542%), Demand Response and Enabling Information Technology (70%), and Lighting (66%). As the nexus for multiple industries, Navigant Research expects Building Efficiency to continue to be one of the leading sectors of growth, as companies build out the next wave of clean, comfortable, connected buildings.

The 6% market decline in Electricity Generation between 2011 and 2015 is explained by two important trends. First, 2011 was dominated by massive hydroelectric projects in China. Though rebounding from a low of $84.3 billion in 2013, Hydro revenue in 2015 was still $40 billion below the 2011 level of $185.3 – a gap that, by itself, more than accounts for the $20 billion decline in Electricity Generation overall. Second, solar PV has seen a doubling of annual deployment since 2015, but also almost a halving of price – meaning that revenue numbers, while impressive enough (22% growth from 2011 to 2015), understate the remarkable growth of the worldwide solar industry. Wind (54%), Geothermal (155%), and Fuel Cells and Other Distributed Generation (61%) saw increases globally between 2011 and 2015, while declines were marked in Biomass (82%), Nuclear (56%), and Gas Turbines (16%).

With coverage limited to Natural Gas Vehicle Fueling Stations, Commercial Natural Gas Vehicle Fueling Stations (for trucks and other large vehicles), and Hydrogen Fueling Stations, Fuel Delivery is the smallest segment by revenue, and especially subject to annual fluctuations, largely tied to oil prices. In 2011, when oil prices hovered around $100 per barrel, Natural Gas Fueling Stations looked promising – and Fueling Station revenue hit a peak. However, with a 70% drop in oil prices since mid-2014 (to mid-$30 per barrel in early 2016), natural gas fueling stations have become far less attractive, and took an especially sharp fall last year. Additionally, China, as the leading market for natural gas fueling stations, has seen an economic slowdown, further explaining the 55% decline in revenue since 2011.

Five-Years Trends – United States

In the United States, five of the seven advanced energy market segments have seen growth over the past five years, led by Transportation (91%), Industry (83%), Electricity Delivery and Management (72%), Buildings (50%), and Electricity Generation (29%), counting only products for which we have five years of revenue. (Figure 1.4)

Building Efficiency, the largest segment of the U.S. advanced energy market, saw 50% growth over the past five years, with steady increases

U.S. Growth by Segment, 2011-15*

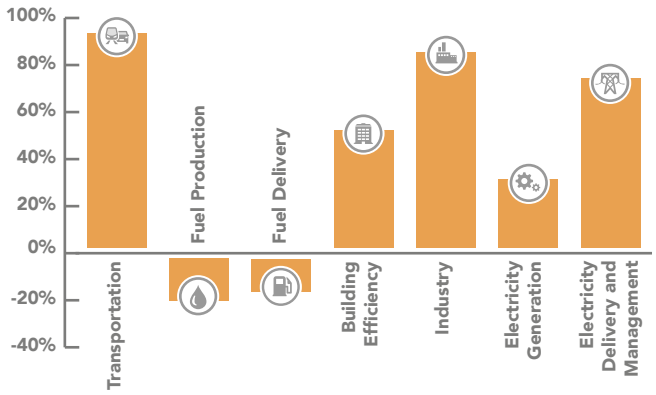


Figure 1.4 (Source: Navigant Research) - *Revenue shown only for product categories with revenue data for all years 2011 - 2015

across all subsegments. Notably, Appliances and Electronic Equipment saw 350% growth, followed by Building Envelope and Demand Response & Enabling Information Technology, each at 61%. Lighting grew 54% over the five-year period, counting only categories for which we have five years of revenue.

Electricity Generation, the second largest U.S. segment, also experienced strong five-year growth, at 29%. Solar stood out for market growth, with Solar PV nearly tripling, from $8.2 billion to $22.6 billion – all the more remarkable given the decline in solar prices during this period. Revenue from Natural Gas Turbines grew 160% over this period, with a particularly big jump in 2014, followed by 14% growth last year. Growth in Wind of 11% masks a rollercoaster over the five-year period, with revenue as high as $25.5 billion (2012) and as low as $2.1 billion (2013). But 2015 was strong (up 75% year-over-year to $14.5 billion) and the long-term extension and phase out of the federal Production Tax Credit should provide the type of policy certainty that facilitates growth over the coming years.

Showing the biggest percentage growth, the U.S. Transportation segment is made up of a variety of advanced vehicles, as defined by their propulsion systems. (Figure 1.5) All experienced significant growth over the 2011-15 time period. The largest category, Hybrid Electric Vehicles (HEVs), declined 19% in both 2014 and 2015, from $15 billion to $9.9 billion, as gasoline prices fell, but the category still achieved five-year growth of 38%. Plug-in Electric Vehicles (PEVs) had the fastest growth over the past five years (598%), though starting from a smaller base. Sales of PEVs have been less affected by low gasoline prices, as customers choose these vehicles not for incremental improvements in gas mileage, but as "statement" cars that are a true break from gasoline-powered car ownership.

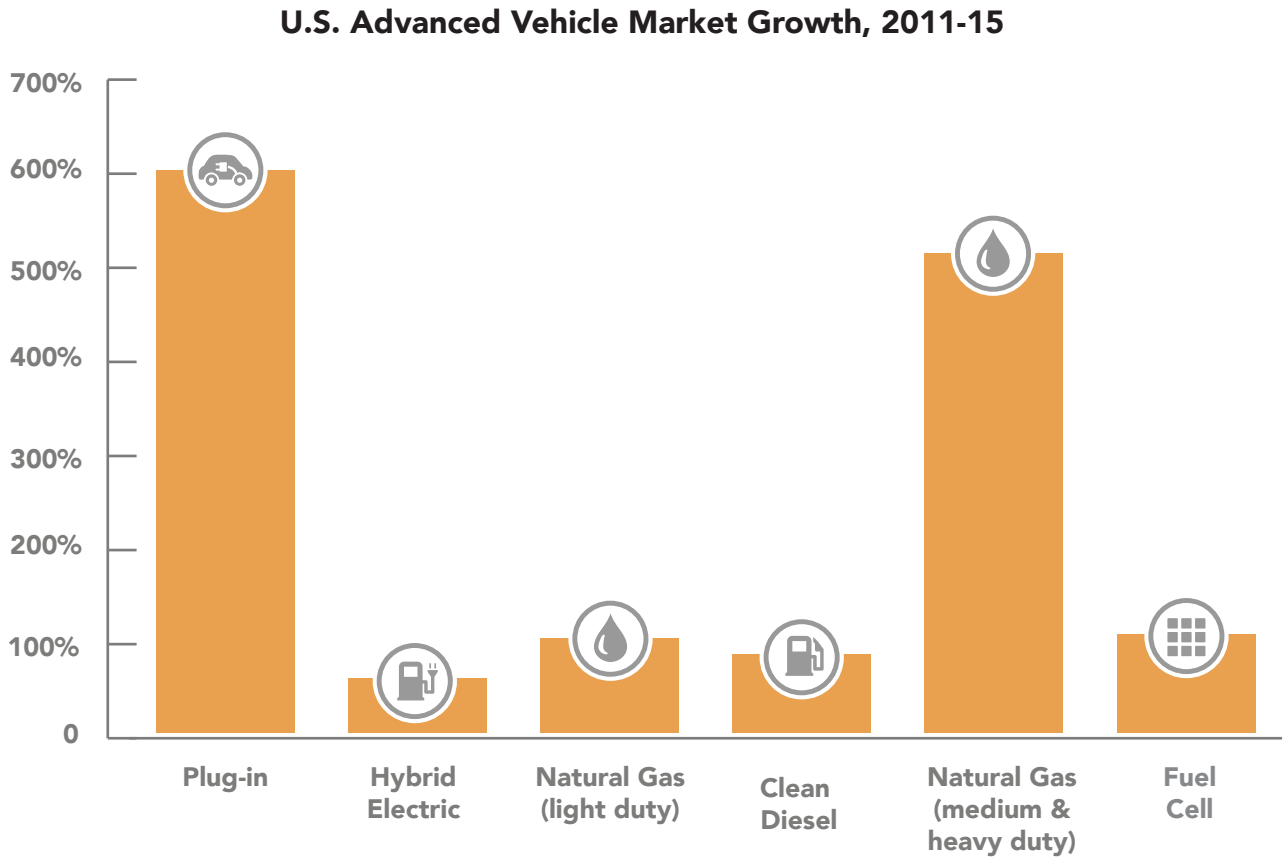


Figure 1.5 (Source: Navigant Research) - *Revenue shown only for product categories with revenue data for all years 2011 - 2015

By 2015, PEVs accounted for $4.9 billion, or half as much revenue as the far more-established hybrid vehicle class, and a third of total Electric Vehicle (EV) sales. Though not as dominant in the United States as they are in

Europe, Clean Diesel Vehicles made steady progress, reaching $6.1 billion in revenue in 2014, before declining 2% last year. Clean Diesel Vehicle revenue rose 83% over the five-year time period, but prospects for these vehicles in the United States remain uncertain in the wake of the Volkswagen emissions-cheating scandal. Also growing robustly over the 2011-15 period were heavy-duty Natural Gas Trucks and Buses (510%), and light-duty Natural Gas Vehicles (100%).

The Industry segment experienced the second largest growth between 2011 and 2015, at 83%. Within that segment, Industrial Energy Management Systems (IEMS) and Industrial Combined Heat and Power (CHP) experienced growth each and every year since 2011. Industrial CHP Systems grew from $1 billion in 2011 to $3.4 billion in 2015 (232% growth), while IEMS grew from $3.2 billion to $4.3 billion (36%) in the five-year period.

Electricity Delivery and Management also experienced strong five-year growth, increasing from $8.1 billion in 2011 to $13.9 billion in 2015 (up 72%). Following the global trend, leading subsegments for growth included Energy Storage (807%), Transmission (560%), and Electric Vehicle Charging Infrastructure (510%).

Due primarily to low oil prices, which drove down ethanol prices and hindered the takeoff of advanced biofuels, Fuel Production reached a five year low in 2015, with $35.4 billion in revenue, down 18% since 2011. For the upcoming years, EPA is proposing a slight increase in the Renewable Fuel Standard. Most of the growth is expected to come from advanced biofuels, which are set to increase 35% in 2016, while conventional biofuels (grain-based ethanol) are expected to grow only 6% in the same period. Similar to the global trend, Fuel Delivery, the smallest segment, declined 14% over the five-year period.

TRANSPORTATION

Transportation was the second largest advanced energy segment worldwide in 2015, with $413.3 billion in revenue, an increase of 13% over 2014, and up nearly 24% since 2011 when counting only products for which we have all five years of data. (Table 2.1) The Clean Diesel Vehicles product category, with revenue of $288.1 billion, up 18% over 2014, continues to lead growth among advanced vehicles. Sales of Clean Diesel Vehicles dropped 2% in the United States, to $6 billion, as the impact of the Volkswagen (VW) emission scandal had not yet reached the global marketplace.

Global Transportation Revenue by Segment (millions)

Transportation	2011	2012	2013	2014	2015 (estimate)
Propulsion System	$325,914	$315,865	$343,517	$365,068	$413,305
Freight Logistics	$0	$0	$0	$0	$0
Land-Use and Infrastructure Design	NA	NA	$0	$0	$0
Enabling Information Technology	NA	NA	$60	$28	$41
Transportation Subtotal	**$325,914**	**$315,865**	**$343,577**	**$365,095**	**$413,345**

Table 2.1 (Source: Navigant Research)

HEVs took more of a hit in the market in 2015. Hybrids remained the second largest product category, with $58.8 billion in revenue in 2015. But the global market for these higher fuel efficiency vehicles declined 12% from 2014 – likely the effect of low gasoline prices and greater competition from PEVs. Low prices at the pump did not have the same effect on PEVs, which capped five consecutive years of strong growth, jumping 58% in 2015 to reach $19.5 billion globally in 2015 – more than 10 times the 2011 market. In the United States, revenue from PEVs rose 3% in 2015, to $4.9 billion, but that total was seven times 2011 revenue of $707 million. (Figure 2.1) Consumers have a growing variety of EV options that are declining in price as battery costs have dropped significantly during this time.

U.S. Transportation Revenue by Segment (millions)

Transportation	2011	2012	2013	2014	2015 (estimate)
Propulsion System	$11,709	$18,045	$25,075	$24,839	$22,532
Freight Logistics	$0	$0	$0	$0	$0
Land-Use and Infrastructure Design	NA	NA	$0	$0	$0
Enabling Information Technology	NA	NA	$31	$9	$13
Transportation Subtotal	**$11,709**	**$18,045**	**$25,106**	**$24,848**	**$22,546**

Table 2.2 (Source: Navigant Research)

Though from a very small base, Fuel Cell Vehicles (FCVs) experienced the largest year-on-year growth – 508% – to reach revenue of $3 million worldwide. And, in a milestone, Electric Bicycles surpassed $10 billion in worldwide revenue in 2015, up 8% over 2014, led by sales in Asia. (Table 2.1)

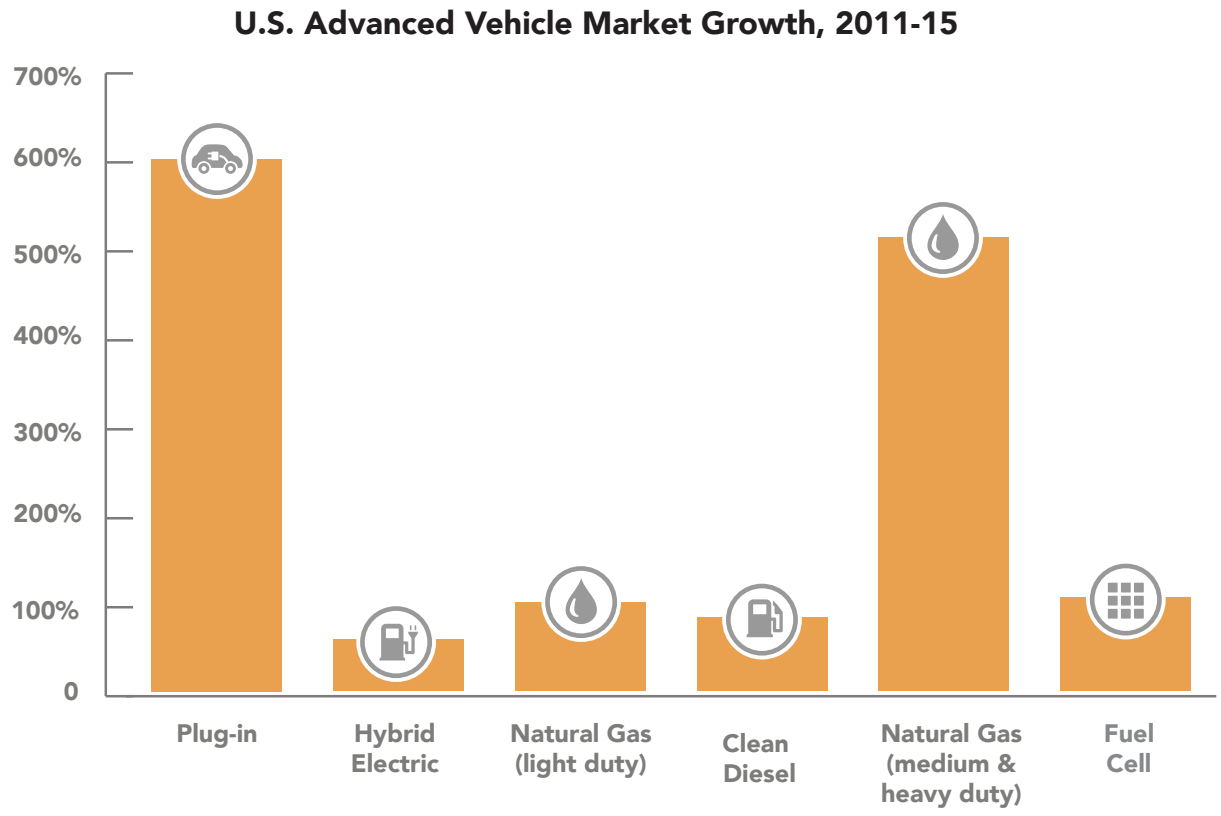


Figure 2.1 (Source: Navigant Research)

Revenue from sales of light-duty Natural Gas Vehicles (NGVs) reached $30.7 billion globally in 2015, a 15% increase over 2014, though U.S. sales fell 9%. While low natural gas prices helped, revenue from NGVs was hurt by low oil prices, and further by lagging fueling infrastructure in place for light-duty vehicles. A similar

story emerges for heavy-duty NGVs, with global revenue increasing to $5.9 billion, up 8% over 2014, but U.S. sales declining, down 7% to $623 million in 2015. Nonetheless, five-year U.S. growth for both classes has been significant – with light-duty vehicles at 100% growth and heavy-duty vehicles experiencing 510% growth compared to 2011. Similarly, while the overall U.S. Transportation segment was down roughly 10% in 2015 – it has experienced five-year growth of 91% when counting only products for which we have all five years of data. (Figure 2.1)

Lower Cost Li-Ion Batteries Boost Electric Vehicles

Despite lower prices at the gas pump, the prospects for EVs continue to be bright, in large part due to remarkable advances in EV storage technology. Early hybrid vehicles almost exclusively featured nickel-metal hydride (NiMH) batteries. Now, lithium ion (Li-ion) has taken over the hybrid sector, and dominates the Plug-in Hybrid Electric Vehicle (PHEV) and Battery Electric Vehicle (BEV) markets as well. Most new production hybrids, apart from the Toyota Prius, and all PHEVs and BEVs in 2015 were shipped with Li-ion batteries. While new battery chemistries are now being tested, and could make their way into market in the coming years, the focus through the early 2020s will remain on further lowering costs and improving the energy density (and resulting vehicle range) of Li-ion batteries.

While the market for Li-ion batteries for vehicle electrification is still developing, several companies have emerged as leaders. The most successful Li-ion battery manufacturers to date (LG Chem, Panasonic, Samsung SDI) are large and financially stable companies or their subsidiaries. These leaders provide Li-ion batteries to multiple markets, such as the consumer electronics and emerging stationary grid energy storage markets. But in the United States, Tesla Motors made news with its battery "gigafactory," now under construction in Nevada, and its claims that, without it, the company might not be able to source enough batteries for its BEVs and new Powerwall home energy storage product.

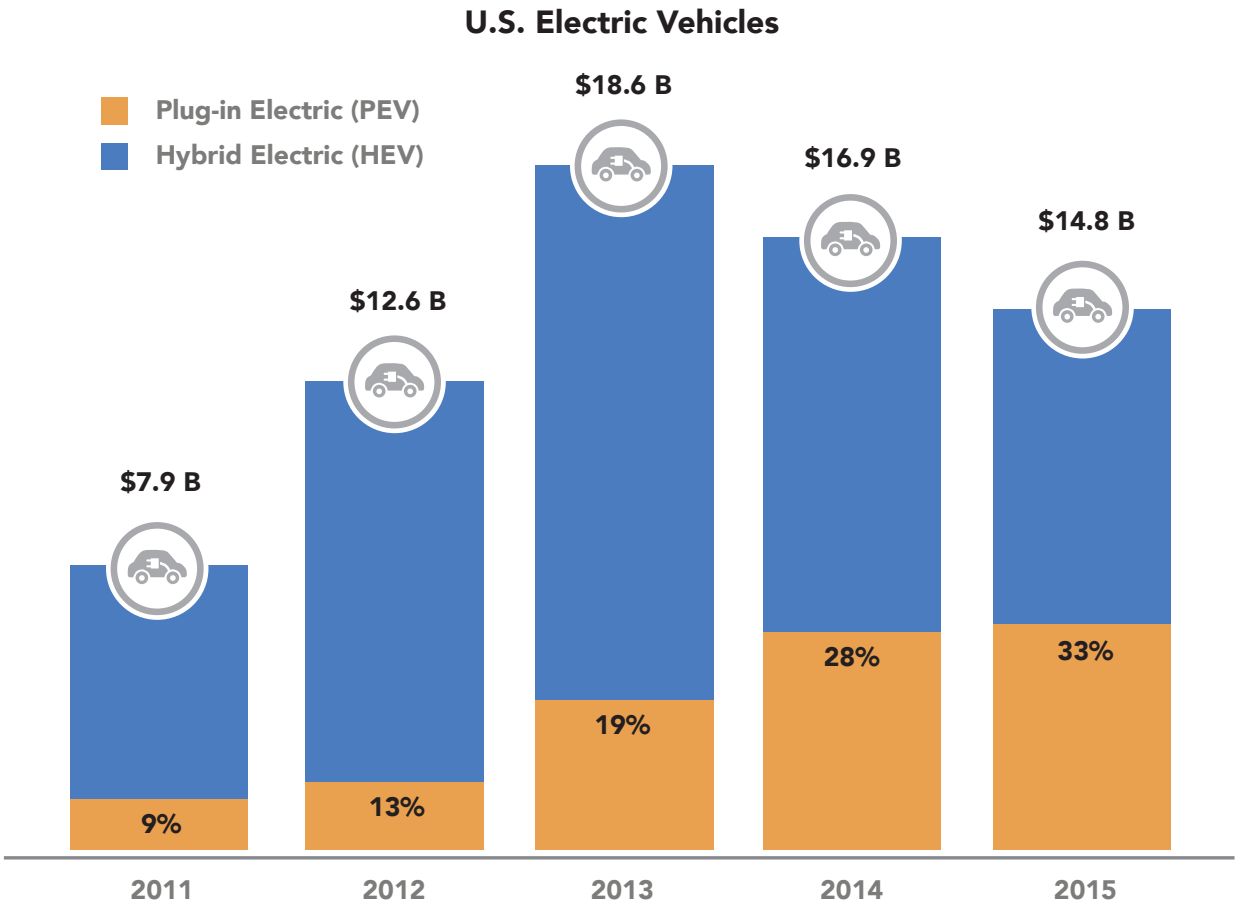


Figure 2.2 (Source: Navigant Research)

When designing electric or electrically assisted powertrains, automakers continue to tailor their design approach to each model, factoring in not only economy, but also power, energy, and range performance. Luxury brands have begun to focus on meeting the driver experience and vehicle performance bar that has been set in the BEV sector by Tesla's Model S.

Navigant Research expects two distinct BEV market segments to emerge and mature over the next five years: a large capacity sector, often with premium vehicles, with larger energy capacities and longer-range battery packs, and a second segment with lower capacity, shorter range, and a lower-cost class of battery packs geared for local driving and daily commutes.

Original equipment manufacturers (OEMs) have continued their efforts to improve the supply chain cost structure for battery manufacturers with consistent battery performance standards. They are also taking advantage of a maturing supply chain and manufacturing capacity gains to help reduce costs. But vehicle manufacturers continue to require unique battery pack specifications, challenging the gains made to date from supply chain efficiencies. Lower battery costs for the industry during the next decade will likely remain a function of manufacturing and supply chain efficiencies and incremental chemistry improvements rather than new chemistries, as any breakthroughs in energy or power density are likely to be tested for several years before an automaker incorporates them into a vehicle.

Revenue from sales of battery packs to auto manufacturers rose 14% globally, to $6.3 billion, from 2014 to 2015. That total was seven-and-a-half times the battery-pack revenue of $824 million in 2011. In the United States, battery pack revenue fell 17% in 2015, to $1.4 billion, due to declining sales of HEVs, but was still five times 2011 revenue of $271 million.

The global market for Li-ion batteries for HEVs and PEVs in automotive applications is expected to grow at a 2015-2020 compound annual growth rate (CAGR) of 32% in energy capacity, to 61.3 GWh. The majority (72%) of demand for Li-ion EV batteries will come from BEVs due to the larger battery packs typical of those vehicle types.

Clean Diesel – or VW at Least – Faces Identity Challenge

In the wake of the VW clean diesel emission scandal, compression ignition engines for light-duty vehicles are undergoing enhanced scrutiny, though the market for these vehicles remains strong globally. Clean diesel vehicles dominate the advanced vehicle market in Europe in a way they do not in the United States. But as VW has struggled to update more than 11 million diesel-powered vehicles globally in response to revelation of its emissions cheating, the German automaker has expressed a newfound interest in a different form of advanced transportation: electric vehicles.

Since it was developed by Rudolf Diesel in the early 20th century, the compression ignition engine has had the advantage of being more fuel efficient while producing greater torque than comparable spark ignition engines. Today's clean diesel engines are quieter, more efficient, more reliable, and cleaner than older diesel vehicles, thanks to innovations such as allowing for higher fuel-air mixing prior to combustion and the addition of re-circulated exhaust gas to the intake air stream.

Still, diesel engines produce higher emissions of particulate matter and nitrogen oxides. Over the past decade, tightening emissions limits in Europe, North America, and Asia have prompted the development of technologies to clean up these pollutants without sacrificing the benefits of diesel in performance and fuel consumption (and resulting CO_2 emissions) compared with gasoline-powered cars.

In September 2015, the U.S. Environmental Protection Agency (EPA) announced publicly what had been alleged for some time: VW diesels were not as clean in the real world as they were in regulatory compliance tests. The resulting scandal has cost the jobs of numerous executives and managers within VW Group and will likely cost the company tens of billions of dollars in fines, lawsuits, and modifications to millions of cars already sold.

The "defeat device" revealed in VW diesel cars in 2015 has called into question the emissions performance of clean diesels more generally, though there is currently no evidence that other manufacturers have circumvented tailpipe emission standards in a similar manner. The use of this method by one manufacturer also does not entirely negate the significant improvements in recent years with diesel vehicles of all classes, including the 90% of heavy-duty vehicles powered by diesel, one-third of which is clean diesel. Companies including Daimler, BMW, and General Motors (GM) remain committed to diesel as part of their technology portfolios for reducing fuel consumption and CO_2 emissions in a cost-effective and customer-friendly manner.

Despite the VW controversy in the United States, sales of Clean Diesel Vehicles globally grew strongly in 2015, with revenue up 18% – the biggest year-over-year increase of the past four years – to $288.1 billion worldwide. Revenue in the much-smaller U.S. Clean Diesel Vehicle market was down just 2% in 2015, to $6 billion, from a 2014 peak of $6.1 billion.

While any long-term implications of the VW scandal on the clean diesel market are as of yet unknown, it is clear that VW is now becoming the latest major automaker to show new enthusiasm for EVs. In a recent restructuring, VW has created a dedicated battery car division. VW has already committed to offering plug-in variants (both PHEV and BEV) of all of its mainstream models by 2020; its premium Audi division expects 25% of its sales to be PEVs by 2025.

Navigant Research projects that PEV sales will grow at a CAGR of 21% over the next decade, hitting more than 2.7 million annual sales by 2024. With GM launching the Chevrolet Bolt EV with a 200-mile range and $30,000 price (after incentives) in 2016, significant progress is clearly being made on making electrification appealing to mainstream consumers. VW has announced it will introduce a mass-market BEV as well, entering into competition not only with the Chevy Bolt but also the Tesla Model 3, when it goes into full production next year.

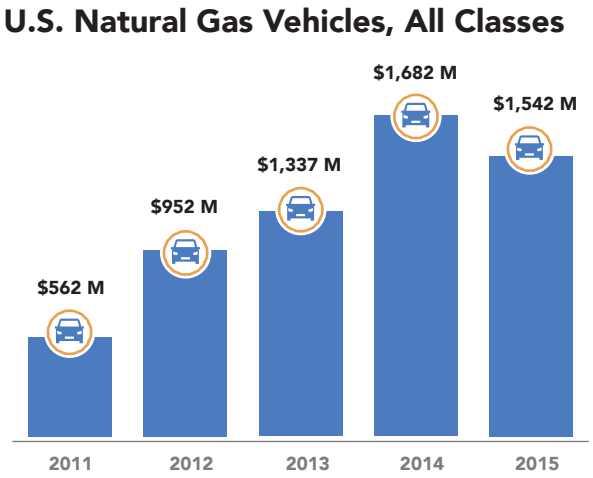


Figure 2.3 (Source: Navigant Research)

Natural Gas Vehicles Slow Down due to Low Oil Prices

The unexpected collapse of world oil prices that began in late 2014 persisted throughout 2015 and even accelerated late in the year, driving both manufacturers and consumers to reevaluate their alternative fuel strategies particularly around NGVs. With oil prices now expected to remain well below $100 per barrel for at least several more years, much of the operating cost advantage of NGVs that helped offset the acquisition cost premium has evaporated, particularly in North America. In other regions of the world, natural gas still holds a cost advantage, although not to the degree it has in recent years.

Revenue from worldwide sales of light-duty NGVs grew 15% from 2014 to 2015, but at $30.7 billion barely surpassed the 2013 revenue mark of $30.5 billion. In the United States, revenue from these vehicles fell 9%, to $919 million, but was still double 2011 revenue of $460 million.

In Europe, the longtime leader in light-duty NGVs, Fiat Chrysler Automobiles (FCA), is being challenged by VW. While FCA has the expertise and technology to challenge Ford for leadership in the North American truck and van NGV markets, any expansion of NGV availability beyond the Ram 2500 is unlikely in the near- to midterm as a result of low gasoline and diesel prices. Even Honda, the most stalwart advocate of light-duty NGVs in North America, discontinued the Civic NG in 2015 after selling only about 16,000 units in more than 16 years on the market. Sales of conventional gasoline Civics consistently exceeded 300,000 units annually in the same period.

Which is not to say these automakers don't see value in NGVs for themselves. At the same time the Civic NG was discontinued, Honda opened a large compressed natural gas (CNG) refueling station at its Marysville, Ohio, factory to supply trucks that deliver parts from suppliers daily. FCA also opted to convert its fleet of 179 class-8 trucks that deliver parts between plants in Michigan and surrounding states to CNG and install a CNG fueling facility at its Detroit terminal.

Refueling infrastructure is an issue for NGVs, in the usual chicken-and-egg fashion. Without a critical mass of vehicles on the road and reasonable prospects for growth, station operators are unwilling to invest in fueling equipment—and without ready access to refueling stations, retail customers do not buy NGVs. However, because natural gas is well-suited to larger vehicles, such as refuse trucks and buses, which are often used in limited geographies, fleet operators can take advantage of the low fuel cost by installing private stations in vehicle depots.

In addition to sustained low oil prices, several factors could dampen short-term prospects for NGVs, including slowing economic growth in Brazil, Russia, India, and China (the BRIC countries), and political tensions in various

regions, including the Middle East. Ongoing political tensions in Eastern Europe could also affect supply and the prices of gas exports from Russia to Western Europe. A significant economic slowdown in China is hurting overall consumer demand, particularly for new vehicles. Meanwhile, battery suppliers and OEMs, including LG Chem, GM, and Tesla, are demonstrating significant progress in battery cost and capacity, potentially giving BEVs a leg up over NGVs as alternatives to gasoline- or diesel-fueled vehicles.

Still, Navigant Research expects the global market for light-duty NGVs to grow at a CAGR of 4% from 2015 to 2025, surpassing 3.4 million vehicles by 2025. North American growth is expected to remain low compared to other global markets due to high acquisition costs for NGVs and a low price delta between natural gas and liquid fuels. Asia-Pacific is projected to be the largest regional market, accounting for over 45% of sales in 2025. NGVs are more affordable in Asia-Pacific where vehicles are typically equipped with less expensive but heavier type-1 gas cylinders rather than the lighter type-4 cylinders used in North America. Medium- and heavy-duty NGVs should continue to see more solid growth over the next decade, as they provide an alternative to diesel, and natural gas remains more practical in some ways than electrification for heavy vehicles. A global CAGR of just under 10% is projected to bring total sales of these larger NGVs to more than 676,000 by 2025, with Asia-Pacific accounting for more than 90% of that volume.

FUEL DELIVERY

Fuel Delivery is the smallest advanced energy segment, though, as in previous editions of this report, natural gas pipeline and liquefied natural gas (LNG) terminal construction are not included due to lack of available data. They do, however, represent significant advanced energy markets that fall under the Fuel Delivery segment, meaning that the total is therefore considerably understated. As one of the segments with the fewest contributing subsegments, comprised only of Natural Gas Fueling Stations for commercial- and light-duty vehicles and Hydrogen Fueling Stations, the annual total is especially susceptible to volatility. In 2015, the global market significantly declined, down 64%, to $983 million in revenue, from its five-year high of $2.7 billion. (Table 3.1)

Global Fuel Delivery Revenue by Segment (millions)

Fuel Delivery	2011	2012	2013	2014	2015 (estimate)
Fueling Stations	$2,207	$1,926	$2,606	$2,718	$983
Fuel Transportation Infrastructure	$0	$0	NA	NA	NA
Fuel Delivery Subtotal	**$2,207**	**$1,926**	**$2,606**	**$2,718**	**$983**

Table 3.1 (Source: Navigant Research)

The largest subsegment globally remained light-duty NGV Fueling Stations, with $783 million in revenue, down 41% from 2014. Commercial NGV Fueling Stations, for larger vehicles, also faced substantial decline, down 94% to $87 million in 2015. After three years of declines, however, Hydrogen Fueling Stations took a leap, to $113 million in revenue, representing 623% growth over 2014's $16 million, and more than double the previous high-water mark of $49 million in 2011.

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

Fuel Delivery	2011	2012	2013	2014	2015 (estimate)
Fueling Stations	$227	$378	$252	$283	$195
Fuel Transportation Infrastructure	$0	$0	NA	NA	NA
Fuel Delivery Subtotal	**$227**	**$378**	**$252**	**$283**	**$195**

Table 3.2 (Source: Navigant Research)

In the United States, Fuel Delivery faced a moderate decline of 14%, with $195 million in revenue in 2015, also down from its five-year high of $378 in 2012. (Table 3.2) Also following the global trend, investment in light-duty Natural Gas Fueling Stations was the largest source of revenue, with $108 million in 2015, followed by commercial Natural Gas Fueling Stations with $55 million, though down 40% and 45% respectively, year-on-year. Hydrogen Fueling Stations was the smallest source of revenue, with $32 million in 2015, but as was the case globally, that was a big jump from 2014, when U.S. Hydrogen Fueling Stations generated just $4 million in revenue – and the first time revenue for these fueling stations exceeded the previous five-year high of $27 million in 2012. (Figure 3.1)

As discussed in the following trend stories, navigating the chicken-and-egg conundrum of infrastructure build-out coming along with vehicle deployments is a critical element to market growth. EVs are successfully navigating that chasm, and natural gas can capitalize on the vast pipeline network in place. By comparison, hydrogen FCVs are at a disadvantage, with fueling infrastructure only just beginning to be put in place.

Hydrogen Infrastructure Needed for Fuel Cell Vehicle Growth

The global market for NGVs and BEVs has grown significantly over the past five years. This growth is a result of finding a viable path in navigating the chicken-and-egg problem of vehicles and infrastructure. FCVs are grappling with an even more difficult form of that challenge. While BEVs and NGVs built off of existing electrical grids and natural gas distribution systems, hydrogen fuel infrastructure is essentially starting from scratch.

Overall, the driver for FCVs among some major automakers is the search for a drivetrain that can enable a shift away from petroleum dependence, while meeting consumer and regulator demands. If BEVs reach an upper limit in range that is below that of a typical gas car, fuel cells could be an attractive, even necessary, option for longer drives, faster refueling, and/or larger vehicles. OEMs are making continued improvements in FCV performance, specs, and price, but will need fueling infrastructure for FCVs to gain consumer acceptance. The chicken cannot come before the egg; the two must arrive together.

In Hydrogen Fueling Station development, 2015 marked the high point of a bumpy five-year ride. After declining from $49 million for three years, and reaching a bottom at $16 million in 2014, worldwide Hydrogen Fueling Station Infrastructure leaped to $113 million in 2015. The U.S. market for Hydrogen Fueling Station Infrastructure has followed a similar pattern, sliding from $24 million in 2011 to $4 million in 2014, and then multiplying eight-fold, to $32 million, in 2015. (Figure 3.1)

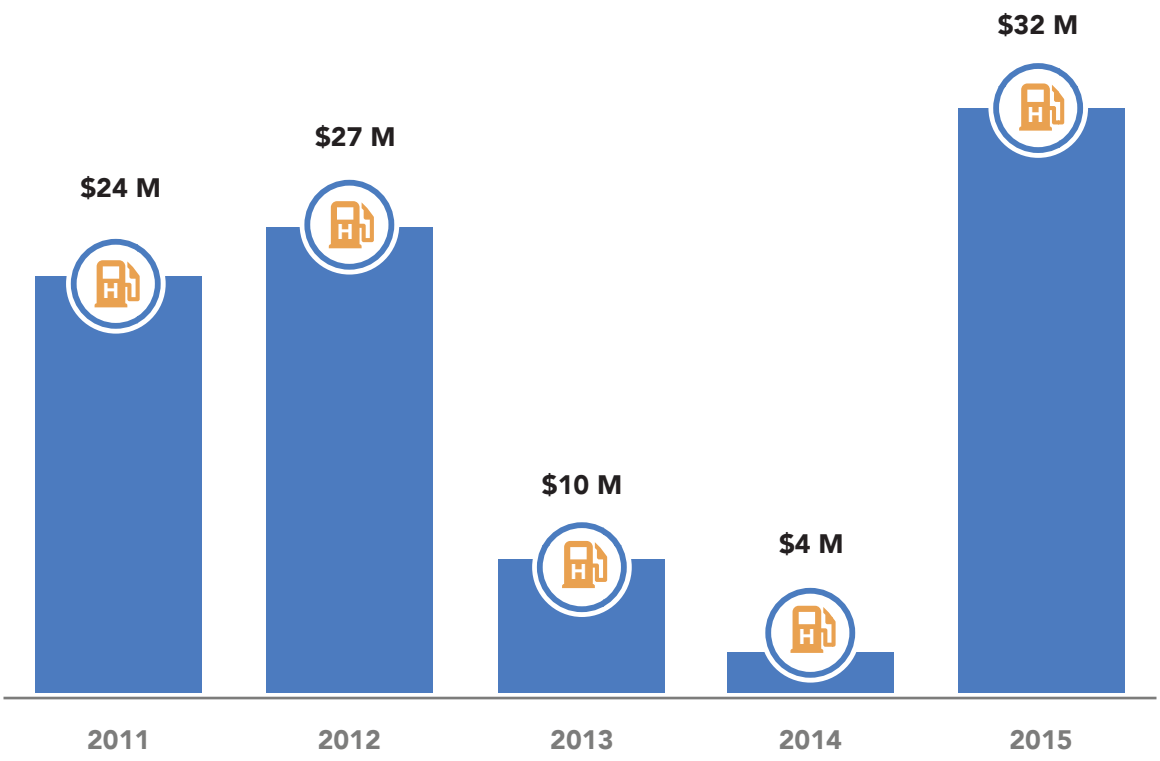


Figure 3.1 (Source: Navigant Research)

Hydrogen Fueling Stations typically take 18 to 36 months to construct and cost approximately $1 million apiece, so significant scale-up of hydrogen stations will take time. Germany, the United Kingdom, Japan, and South Korea are all making commitments to deploy hydrogen infrastructure. The most commercially viable locations for hydrogen infrastructure are in dense city centers, where vehicle owners from surrounding areas can access them without significant inconvenience. These countries are all significantly smaller than the United States, making it much easier to construct a network of fueling stations that effectively covers the entire country.

In the United States, California is the first state to make a commitment to accommodate FCVs. AB 8 was signed into law in 2013 and requires the state to report on the availability of hydrogen fueling stations in the state in order to identify areas where more investment is needed. The state is co-funding many of the 45 retail hydrogen fueling stations currently under development in California. Outside of establishing the infrastructure, some automakers that are making a push for FCVs—Hyundai and Toyota, for example—are trying to ease adoption in the state by including hydrogen fuel cost in the vehicles' lease. However, California is also an example of some of the challenges that the early FCV market will face. There are complaints about the availability of hydrogen in Southern California, as new fueling facilities for consumers are slowly added to the existing base of early research hydrogen stations.

Germany's H2Mobility program is designed to build new fueling stations in the country to meet demand as FCVs are introduced. Currently, there are 18 public fueling stations in the country. Daimler and industrial gas manufacturer, Linde Group, have had 20 fueling stations in the pipeline, costing approximately €20 million ($21.5 million); at least five of the 20 opened in late 2015. Additionally, the Hydrogen for Innovative Vehicles project (dubbed "HyFIVE") has the goal of expanding Europe's hydrogen fueling network between major cities and is currently seeing stations being built in Austria, Italy, Denmark, and the United Kingdom.

In Japan, the automakers are partnering in a major effort to build out infrastructure for their hydrogen vehicles. Honda, Toyota, and Nissan are part of an agreement between 10 Japanese gas companies to jointly develop a 100-station hydrogen highway in Japan. In South Korea, there are now 11 stations throughout the country. The Hyundai-Kia Motor Co. has been working with the government to increase the availability of these stations.

From Europe to the Far East, the effort to bring hydrogen to the road continues.

As Vehicle Sales Lag, Natural Gas Vehicle Infrastructure Sags

In order for any alternative to gasoline or diesel to be viable as a transportation fuel, refueling infrastructure needs to be readily available. In the arena of alternative fuels for transportation, natural gas has proven to be one of the most popular alternatives to traditional liquid fuels in many global markets. Natural gas for use as a transportation fuel is available in two forms, CNG and LNG, with the former being by far the more common. CNG is primarily used for vehicles that operate within a limited geographic region, while LNG is more commonly used for long-haul trucking applications. CNG is stored in high-pressure tanks at 3,000–3,600 psi and can be stored for extended periods of time. LNG is stored in low pressure, cryogenic tanks at -259°F.

Natural gas has a number of distinct benefits compared with other options, particularly for larger vehicles. As a resource, natural gas is widely distributed around the globe, and with newer extraction techniques, such as horizontal drilling and hydraulic fracturing, usable supplies have risen significantly in the past decade. As a result, prices have fallen to less than half of the peaks reached in 2005 and 2008.

However, in the last 12 months, low gasoline prices have begun to hurt demand for NGVs, which in turn discourages investment in infrastructure. As the price differential between the two fuels shrinks, the operating cost savings lag behind the premium in vehicle purchase price, which for light-duty NGVs is $7,000 to $15,000 and for medium- to heavy-duty NGVs is up to $50,000. U.S. revenue from sales of light- and heavy-duty NGVs was down 9% and 7%, respectively in 2015, though the two still combined for over $1.5 billion in total. (Figure 3.2)

U.S. Natural Gas Vehicles, all Classes

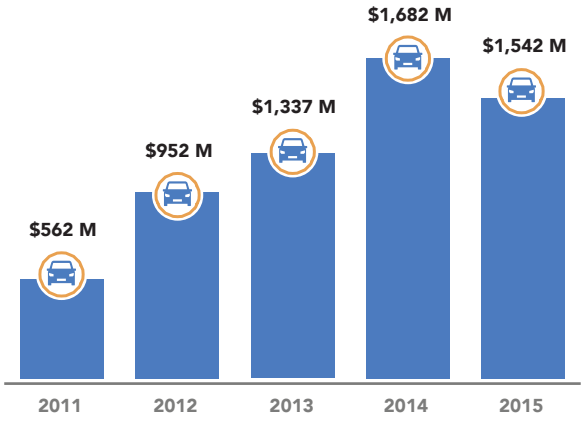


Figure 3.2 (Source: Navigant Research)

With NGVs struggling in the market, the U.S. market for Natural Gas Fueling Stations serving long-haul trucks was down 45% in 2015, with revenue of $55 million. For light-duty vehicles, revenue from Fueling Stations was down 40%, to $108 million. In total, the U.S. market in 2015 was $163 million. (Figure 3.3)

U.S. Natural Gas Fueling Stations, all Classes

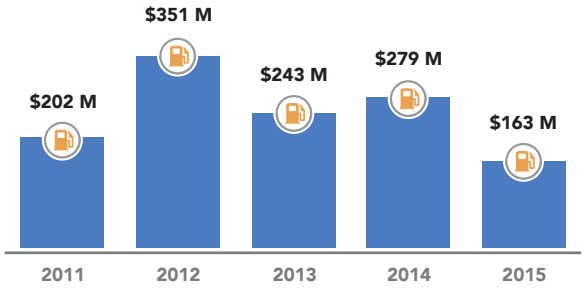


Figure 3.3 (Source: Navigant Research)

Despite facing difficult market conditions at the moment, natural gas still has its advantages. Where fueling stations are available, CNG and LNG are typically fast and convenient to use. Fast-fill CNG pumps and most LNG pumps can

be used to refuel a vehicle at speeds comparable to pumping diesel fuel. "Slow-fill" (low-pressure) systems, however, provide the convenience of filling lower duty cycle vehicles (vehicles that are less frequently used) wherever there is a connection to a natural gas distribution main. Compared to the batteries in EVs, natural gas has significantly higher energy density and longer potential range for larger, heavier vehicles. Natural gas-fueled engines also have reduced emissions of CO_2 and other pollutants compared to gasoline or diesel-fueled internal combustion engines.

As a result, the drive toward fueling infrastructure for NGVs continues. Clean Energy Fuels of Newport Beach, California, is the largest developer and operator of natural gas filling stations in North America. With more than 500 public and private stations in operation throughout 43 states, Clean Energy Fuels accounts for more than one-third of the 1,669 stations counted by the U.S. Energy Information Administration (EIA). In addition to operating public stations, Clean Energy Fuels runs stations for private operators, such as refuse collection companies, construction firms, transit bus fleets, and more than 40 airports. The airport facilities are typically used to fuel NGVs for inter-terminal transport, rental car companies, and hotels.

Most infrastructure investment is being made in private stations used by large truck or bus fleets. In late 2015, FCA announced a $40 million investment in Detroit to convert 179 parts-hauling trucks to CNG. The switch will give FCA the largest private fleet of CNG powered medium- and heavy-duty vehicles in the state of Michigan. In addition, the company also built a $5 million on-site CNG fueling station that was built by TruStar Energy and is the largest private CNG station in North America.

Also not scared away by low oil prices, Honda opened a massive fast-fill CNG refueling station at its Marysville, Ohio, assembly plant in August of 2015. With a capacity of 440,000 vehicles per year, the plant is among the largest in the country. The fueling station, built by Trillium CNG, services existing CNG vehicles while also encouraging suppliers and logistical partners to adopt and expand the use of NGVs.

Navigant Research projects that the total number of global NGV fueling stations will grow from approximately 23,000 in 2015 to nearly 39,000 in 2025. More than 80% of these stations are expected to be CNG stations to support light-duty NGVs, which are projected to account for 90% of the NGV fleet at that time.

FUEL PRODUCTION

With $121.6 billion in revenue worldwide, Fuel Production was the fourth largest advanced energy segment in 2015, but it suffered an 18% decline, due primarily to a sharp drop in revenue from Ethanol sales. (Table 4.1) With growth of 21%, to $52.4 billion, CNG and LNG surpassed Ethanol and Butanol ($46.2 billion), for the first time. The global CNG/LNG market has grown 128% since 2011, compared to a 32% decline during the same period for Ethanol and Butanol, which is the result of persistent low oil prices in 2015. Biodiesel was the third largest subsegment in 2015, with revenue of $19.7 billion, down 8% compared to 2014. Synthetic diesel and gasoline declined 42% to $3.1 billion. Both Bio-oil and Biomethane markets experienced strong growth, at 20% and 67% respectively, though from relatively smaller bases. Despite mixed performance across these subsegments, the advanced energy Fuel Production market has increased 10% overall since 2011.

Global Fuel Production Revenue by Segment (millions)

Fuel Production	2011	2012	2013	2014	2015 (estimate)
Compressed Natural Gas and Liquefied Natural Gas	$23,018	$31,486	$37,654	$43,302	$52,439
Ethanol and Butanol	$68,140	$84,240	$76,645	$77,956	$46,218
Biodiesel	$17,882	$20,432	$21,993	$21,342	$19,692
Synthetic Diesel and Gasoline	$1,580	$1,938	$4,693	$5,394	$3,142
Bio-oil	$1	$500	$805	$16	$19
Biomethane	$47	$48	$65	$51	$86
Hydrogen	NA	NA	NA	$0	$0
Fuel Production Subtotal	**$110,667**	**$138,644**	**$141,855**	**$148,062**	**$121,596**

Table 4.1 (Source: Navigant Research)

In the United States, Ethanol and Butanol remains the dominant alternative fuel, with revenue of $27.3 billion in 2015, though this represents a 33% drop compared to 2014 and a five-year low, due to lower ethanol pump prices. (Figure 4.1) The drop in U.S. Ethanol revenue contributed mightily to the global decline as well. According to Navigant Research, first-generation biorefineries concentrated throughout the Midwest currently account for just under half of global biofuels production capacity installed today. Looking ahead, EPA's revised Renewable Fuel Standard (RFS) calls for larger increases to come from advanced biofuels (35% increase in 2016), while conventional biofuels are expected to increase 6.5% in the same period. With oil prices expected to remain low throughout 2016, however, prospects for significantly increased revenue are slim.

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

Fuel Production	2011	2012	2013	2014	2015 (estimate)
Compressed Natural Gas and Liquefied Natural Gas	$504	$581	$883	$1,016	$1,271
Ethanol and Butanol	$39,140	$41,730	$40,371	$40,932	$27,331
Biodiesel	$3,135	$4,231	$4,751	$3,859	$15,336
Synthetic Diesel and Gasoline	$372	$438	$2,368	$3,206	$3,564
Bio-oil	$1	$345	$2	$16	$0
Biomethane	$12	$12	$16	$19	$18
Hydrogen	NA	NA	NA	$0	$0
Fuel Production Subtotal	**43,164**	**47,337**	**48,390**	**49,048**	**35,384**

Table 4.2 (Source: Navigant Research)

For the first time, U.S. synthetic diesel and gasoline, with $3.6 billion in revenue for fuel sales and infrastructure, surpassed biodiesel sales and associated infrastructure investment of $3.2 billion. Indeed, with zero infrastructure investment revenue reported for either one in 2015, the synthetics beat out biodiesel on the basis of fuel sales, with revenue tripled over 2014. Biomethane experienced a 6% decline in 2015, to $18 million but is still 44% above 2011 sales. Meanwhile, Bio-oil declined 99% in 2015, to less than an estimated $100,000 in sales.

In total, the advanced U.S. Fuel Production market is down 18% compared to 2011, when volumes of fuels (especially ethanol) were similar, but prices were considerably higher.

Biofuels Continue to Confront the Blend Wall

On November 30, 2015, 12 months after its official deadline to propose the RFS levels for 2014 (that's right, 2014), EPA released the final annual percent standards for 2014, 2015, and 2016, and for the 2017 Biodiesel volume.

For 2014, EPA played it safe, matching the annual percent standards with the actual consumption of biofuels in transportation fuel, heating oil, and jet fuel in the contiguous United States and Hawaii. EPA increased slightly the total mandate from 9.2% to 10.1% of U.S. fuel consumption in the next two years. Under the new mandate, there are separate carve-outs for advanced biofuels, which include biomass-based diesel (biodiesel or renewable diesel produced from vegetable oils or animal fats) and cellulosic fuels (biofuel including biogas that is produced from plant matter), and a general pool that can be fulfilled with other biofuels including grain-based ethanol (defined as starch-based ethanol). Most of the growth in the annual percent standards is expected to come from advanced biofuels, which are set to increase 35%, from 16.5% to 20% of the total mandate in 2016. Conventional biofuels, in contrast, will grow by 6.5% in the same period. The new annual percent standards make no one really happy – neither the biofuel producers, who wanted the standards higher, nor the petroleum industry, which wants them gone altogether – which was probably the intention.

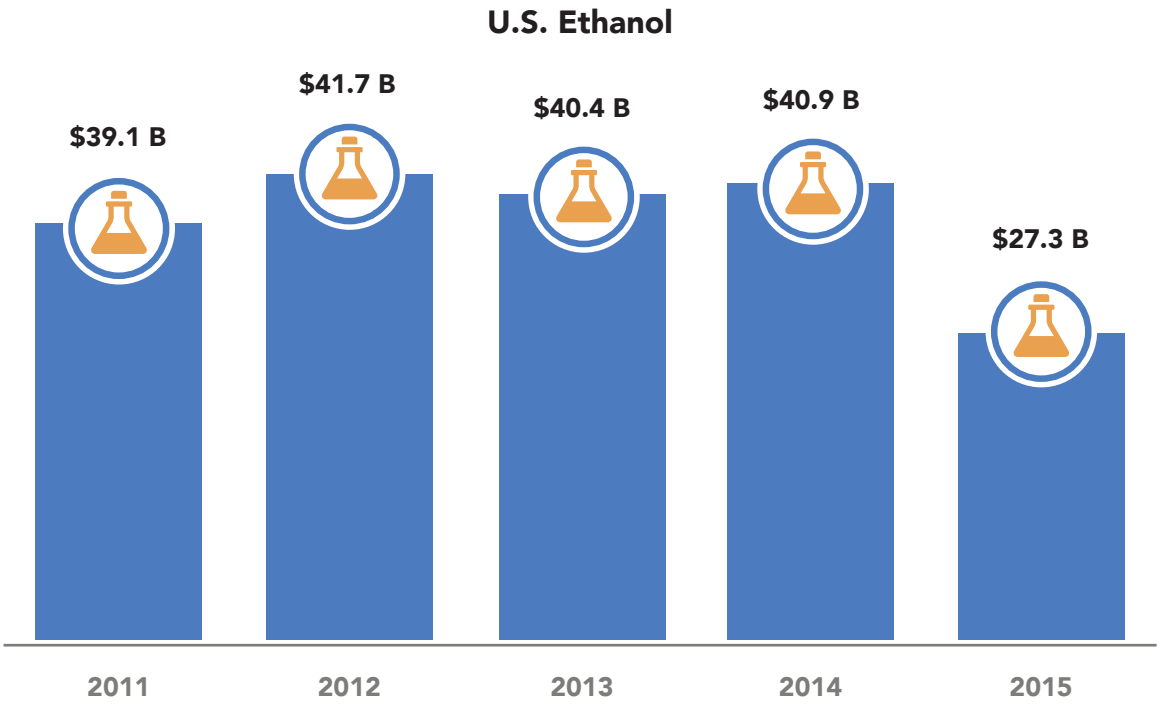


Figure 4.1 (Source: Navigant Research)

RFS was first introduced under President George W. Bush and later revised and expanded in 2007. Iowa has benefited mightily from the mandate, serving up a sea of corn and soybeans, both commodities that have played a crucial role in America's first-generation biofuels capacity growth. Since the revised standard went into effect, biofuels production in the United States has doubled. According to Navigant Research, conventional biorefineries (those that produce starch-based ethanol) concentrated in the Midwest currently account for just under half of global biofuels production capacity today.

For conventional biofuels, the new mandate is not good, but perhaps not surprising. In the original mandate, conventional biofuels had a target for 2015 of 15 billion gallons (1.6 billion gallons more than in the final mandate), but the increased use of ethanol has been limited by what the industry calls the "blend wall," the limit of 10% ethanol by volume that older gasoline engines can use in their fuel. As consumption of transportation fuel has slowed, due in part to more fuel-efficient vehicles, the blend wall has limited the growth of biofuel consumption.

The Renewables Fuel Association reported June 1, 2015 that operating capacity of the industry was 14.9 billion gallons per year, which implies that the mandate covered 92% of its capacity in 2015 and 98% in 2016. The mandate is high enough to support all the plants currently operating (although some might have to reduce their production). Leading producers like POET, Green Plains Renewable Energy (GPRE), and Abengoa are expected to do well.

Revenue generated by the ethanol industry dropped dramatically between 2014 and 2015, driven by the falling price of ethanol. During 2014 wholesale ethanol in the United States sold, on average, at $2.75 per gallon, while in 2015, the price averaged $1.74 per gallon (36% less). Globally, ethanol was sold at $2.97 on average during 2014, and at $1.87 per gallon in 2015. As a fuel substitute, the price of ethanol is highly correlated to the price of crude oil. In years when ethanol production exceeded the RFS mandate, ethanol has traded at around 70% of the price of gasoline, due to its lower energy content. The other factor affecting ethanol margins is the price of feedstocks (corn, sugar beet, and sugar cane). When the price of these feedstocks is too high relative to the price of ethanol, it forces some plants to shut down as they become unprofitable.

Largely as a function of a drop in price, revenue from the Ethanol product category dropped dramatically in 2015 – down 40% globally, to $45.6 billion, and 31% in the United States, to $27.1 billion. In both worldwide and U.S. markets, Ethanol revenue hit its lowest point in the five years Navigant Research has been tracking the industry for AEE.

The picture for the rest of the biofuel industry is rosier. The new annual percent standard for biomass-based diesel is high enough to absorb the current capacity. U.S. consumers used a record of nearly 2.1 billion gallons of biomass-based diesel in 2015. U.S. revenue from Biodiesel, fell slightly from $3.3 billion in 2014 to $3.2 billion in 2015 in line with global revenue, which also fell slightly – 2% – to $19 billion. The new annual percent standard will benefit producers like the Renewable Energy Group and Neste Oil – both large producers of biomass-based diesel.

In the new standard, EPA did keep a large carve-out for cellulosic biofuels. The United States used 127 million gallons of ethanol-equivalent cellulosic biofuels in 2015, 4 million gallons above the 2015 mandate. Although a lot of investment has gone into technologies to produce liquid fuels from cellulosic material, this segment of the biofuels industry has yet to achieve true commercial scale. Rather, it is biogas producers that are benefiting most from this mandate. Biogas is the product of the process of decomposing organic material – typically sewage slurry, manure, and food residues – in an oxygen free environment, known as anaerobic digestion. Biogas producers are supplying virtually all the cellulosic biofuels – 125 million gallons of ethanol equivalent – while only 2 million gallons of cellulosic ethanol were actually blended, even though biogas was approved as a cellulosic biofuel just halfway through 2014.

Renewable Natural Gas: a Fuel of the Future?

Biogas for commercial use is a product of anaerobic digestion, a method in which microorganisms break down organic matter in an oxygen-starved environment, and one of the oldest processing technologies. It is captured in modern landfills (landfill gas, or "LFG") and biodigesters, which treat a range of organic waste streams. While biogas is a combination of gases and other volatile impurities, its main component (50% to 70%) is methane (CH_4), the same as natural gas. As such, biogas can be combusted to produce electricity and heat. It can also be upgraded to pure biomethane or renewable natural gas (RNG) through the process of removing the impurities and other gases, making it suitable for transport by pipeline or compressed to fuel CNG vehicles.

Biogas power generation is widely utilized for on-site generation by industrial-scale facilities and distributed customers alike. Offering reliable baseload power to the grid, biogas enjoys favorable regulatory support in many national markets and is expected to play a significant role in meeting expanding renewable energy targets. The four main feedstock sources within the global biogas market are food waste, industrial, agricultural, and sewage.

Biogas feedstocks are available worldwide. However, logistical challenges associated with its collection, aggregation, transportation, and handling, coupled with poor energy density relative to fossil fuels, make power and fuel generation from biogas viable only where organic matter is available in large quantities and in continuous supply.

Overall, Biogas fuel production revenue and capital expenditures on processing equipment together was $86 million worldwide in 2015, up 67% from the year before and 83% over 2011. In the United States, Biogas revenue was down 6% from the recent peak of $19 million in 2015, but still up 44% from 2011, when it was $12 million. (Figure 4.2) But year-to-year variation is mostly due to the ebb and flow of capital investment in biogas facilities. Revenue from Biogas fuel production has risen steadily over the 2011-15 period, from $27 million to $57 million globally, and from $8 million to $13 million domestically.

In the United States, there are numerous companies that have formed in the last decade as biogas technologies have manifested. For example, Harvest Power operates an anaerobic digester in Orlando, Florida, in which food waste sourced primarily from the Walt Disney World Resort is used to produce enough electricity to meet the needs of 16,000 homes. 2G Energy Inc. is another U.S.-based company, which utilizes biogas for CHP plants. The company has over 40 biogas plants across North America ranging in capacity from less than 100 kW to over 2.8 MW. The Florida-based company utilizes LFG and sewage sludge from wastewater treatments as the primary sources of organic material for its CHP plants. Bluesphere, based in North Carolina, is currently building a 5.2 MW biogas plant in Charlotte, which is scheduled to be completed in 2016. The company is also building a biogas plant in Rhode Island, as well as multiple plants in Italy.

Driven by strong waste management and renewables integration policies, Europe is expected to hold its position as the leading region worldwide for the next decade, with Germany as the epicenter of global biogas production.

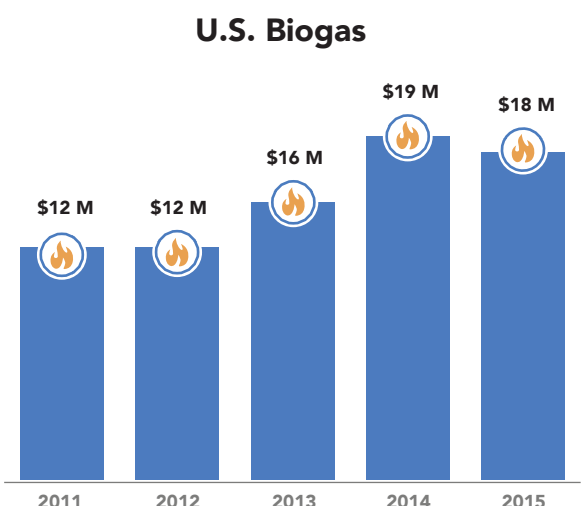


Figure 4.2 (Source: Navigant Research)

The European biogas market is currently led by on-farm digesters, with Germany accounting for 52% of total biogas production capacity, most of which is used for electricity production. In 2014, the country had 3,840 MW of installed capacity, the most biogas electricity generation capacity in the world.

In the United States, policies to enforce the composting and recycling of organic material are beginning to gain traction, which could spur more biogas development. Massachusetts is the first state to enact a food-waste disposal ban, which requires any entity that disposes of more than one ton of organic material per week to donate or re-purpose the material instead of sending it to a landfill. The material is to be used for a variety of applications including sending it to anaerobic digestion facilities to convert it to renewable natural gas. Should other states follow suit, biogas could be in a position to gain a substantial foothold in the renewable energy market.

ELECTRICITY GENERATION

Electricity Generation maintained its status as the largest advanced energy segment in 2015, with an estimated $441.3 billion in revenue worldwide, up nearly 19% from 2014, but down 6% from 2011, counting only products for which we have five years of data. (Figure 5.1) The global market decline between 2011 and 2015 is explained by two important trends. First, 2011 was dominated by massive hydroelectric projects in China. Though rebounding from a low of $84.3 billion in 2013, hydro revenue in 2015 was still $40 billion below the 2011 level of $185.3 – a gap that, by itself, more than accounts for the $20 billion decline in Electricity Generation overall. Second, solar PV deployment has doubled annually since 2011 while prices have fallen by almost half – meaning that revenue numbers, while impressive enough (22% growth from 2011 to 2015), understate the remarkable growth of the worldwide solar industry. Wind (54%), Geothermal (155%), and Fuel Cells and Other Distributed Generation (61%) saw increases globally between 2011 and 2015, while declines were marked in Biomass (82%), Nuclear (56%), and Gas Turbines (16%).

Global Electricity Generation Revenue by Segment (millions)

Electricity Generation	2011	2012	2013	2014	2015 (estimate)
Solar	$96,193	$87,672	$96,828	$94,800	$115,250
Wind	$67,069	$82,111	$67,685	$94,575	$103,273
Geothermal	$666	$1,730	$1,470	$1,500	$1,700
Hydro	$185,260	$149,098	$84,328	$133,871	$143,650
Marine	$300	$140	$0	$0	$0
Waste	$4,700	$2,750	$5,910	$2,954	$3,223
Biomass	$10,500	$7,200	$14,700	$13,500	$1,937
Nuclear	$40,805	$34,210	$14,300	$15,950	$18,068
Gas Turbines	$55,481	$42,755	$42,043	$40,199	$46,667
Fuel Cells and Other Distributed Generation	$755	$1,009	$6,618	$7,079	$7,517
Electricity Generation Subtotal	**$461,729**	**$408,674**	**$333,882**	**$404,427**	**$441,285**

Table 5.1 (Source: Navigant Research)

Despite variability, hydropower continues to be the largest subsegment of Electricity Generation, with revenue of $143.7 billion globally, up 7% over 2014, driven by large projects in China, Russia, and Latin America. Though several countries in Latin America may be pulling back from hydro following drought-induced reliability issues, opportunities for large-scale hydro development still exist, particularly outside the Organization for Economic Co-operation and Development (OECD) countries, such as the Democratic Republic of Congo's proposed 40 GW Grand Inga dam.

Solar was again (after just edging out Wind in 2014) the second largest subsegment worldwide, with $115.3 billion in revenue, including both Solar PV and Concentrating Solar Thermal Electric power plants. China continues to dominate solar deployment by a wide margin, with an estimated 17-19 GW of solar PV installed in 2015, roughly double the Japanese market, and nearly 2.5 times the U.S. market.

At $103.3 billion, Wind power experienced another year of solid growth globally, at 9% over 2014, and 54% growth over 2011. Again, China, with a wind target of 250 GW by 2020, continues to lead the global wind market, supplied almost exclusively by Chinese companies such as Goldwind and Ming Yang.

U.S. Electricity Generation Revenue by Segment (millions)

Electricity Generation	2011	2012	2013	2014	2015 (estimate)
Solar	$8,246	$11,850	$19,519	$22,110	$22,570
Wind	$12,993	$25,461	$2,060	$8,252	$14,450
Geothermal	$118	$723	$833	$450	$450
Hydro	$0	$386	$0	$897	$488
Marine	$30	$0	$0	$0	$0
Waste	$640	$290	$550	$348	$524
Biomass	$300	$600	$900	$882	$882
Nuclear	$12,287	$0	$0	$0	$0
Gas Turbines	$4,017	$4,542	$4,376	$9,204	$10,455
Fuel Cells and Other Distributed Generation	$182	$91	$2,165	$2,394	$2,524
Electricity Generation Subtotal	**$38,813**	**$43,943**	**$30,404**	**$44,537**	**$52,342**

Table 5.2 (Source: Navigant Research)

As global demand for coal has stalled even in countries such as China – home to half of global coal consumption – baseload power options such as natural gas are gaining market share. In 2015, the worldwide market for Gas Turbines increased to $46.7 billion, up 16% over 2014 after three years of decline.

Looking ahead, renewable energy is expected to make up the majority of net capacity additions in the near-term, with the International Energy Agency (IEA) forecasting as much as 700 GW by 2020.

In the United States, Electricity Generation was the second largest advanced energy segment, with $52.3 billion in revenue in 2015, a year-on-year increase of nearly 18%. Revenue in 2015 represented a five-year peak, led by Solar ($22.6 billion), Wind ($14.5 billion), and Gas Turbines ($10.5 billion). These three technologies represented almost all new U.S. capacity additions in 2015, a trend that is expected to continue over the next decade. Within Solar, revenue from Concentrating Solar Thermal Electric dropped to zero, from $3.4 billion in 2014, but U.S. Solar PV continued on its impressive growth path, up 21% in 2015 – its fourth straight year of double-digit growth – to $22.6 billion. (Figure 5.1) Wind revenue was up 75%, as the industry continued to rebound from its nadir – $2.1 billion in 2013, due to the temporary lapse in tax credits. (Figure 5.2) Revenue from Gas Turbines, both simple and combined cycle, was up 14%. (Figure 5.3)

The multi-year extension of the production and investment tax credits in late 2015, combined with increasing renewable portfolio standards in states and continued price declines, have put wind and solar PV on an upward trajectory for the next decade. Facing rapid growth in distributed generation in the residential, commercial, and industrial markets, some utilities are challenging net metering credits, which could result in hurdles in states with strong solar adoption, but the market outlook overall is bright. Fuel Cells and Other Distributed Generation, which includes natural gas generator sets, increased an estimated 5% to $2.5 billion in 2015. Down from a five-year peak in 2014, revenue from U.S. orders for hydropower plants dropped 46% in 2015, to $488 million, in a market that is highly variable. (Table 5.2)

Low-cost natural gas, high capital costs, and regulatory uncertainty have frozen orders for new nuclear power plants, with no U.S. revenue from completed installations since 2011, when $12.3 billion was reported. In 2015, federal regulators approved an operating license for Tennessee

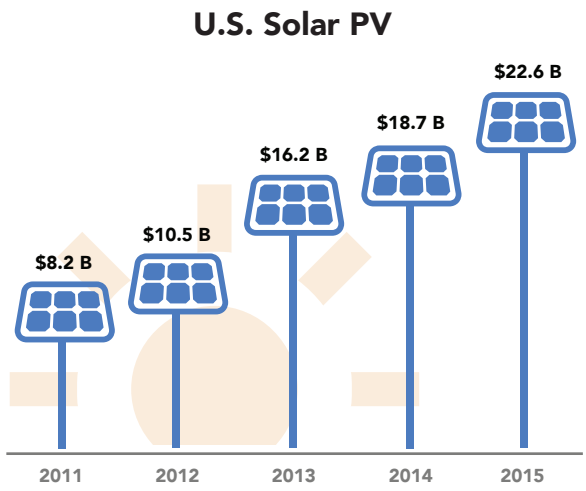


Figure 5.1 (Source: Navigant Research)

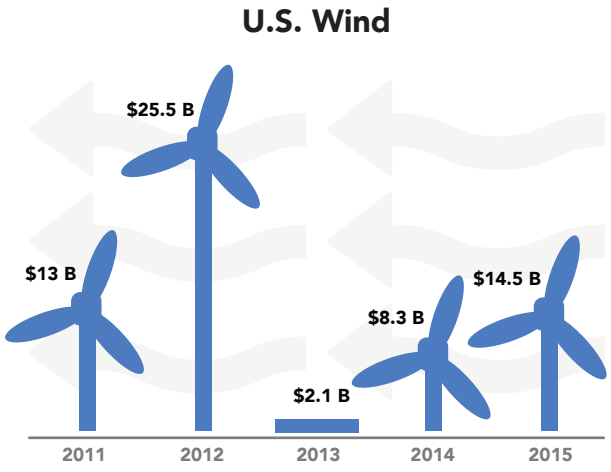


Figure 5.2 (Source: Navigant Research)

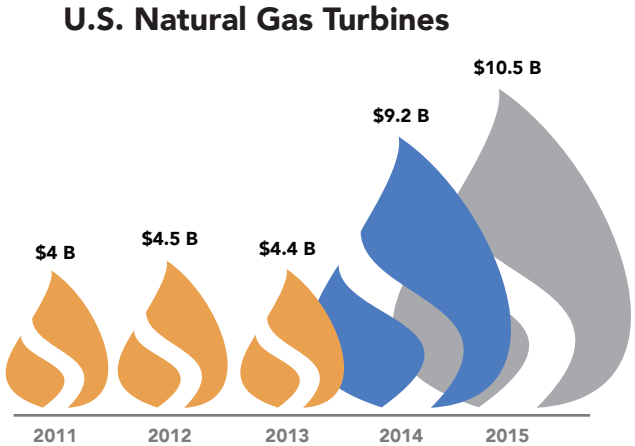


Figure 5.3 (Source: Navigant Research)

Valley Authority's 1,150 MW Watts Bar 2 unit – nearly 43 years after its initial permit to begin construction was granted. U.S. EPA's Clean Power Plan allows new nuclear to be credited as zero-emission generation, but whether states will commit to new nuclear plants as part of their compliance strategy remains to be seen.

With Lower Costs and Federal Backing, Solar PV Poised for Long-Term Growth

In a breakthrough year for the U.S. Solar PV industry, nearly 1 MW – enough to power more than 160 homes – was installed almost every hour in 2015. The cumulative solar PV installed capacity in the United States has now surpassed 27 GW. Revenue generated from installations of solar PV – across residential, commercial, industrial markets, and large utility power plants – reached an estimated $22.6 billion in 2015, a 21% increase over 2014, and growth of 174% since 2011. (Figure 5.4) Plus, the industry got an extension of the federal investment tax credit, with a gradual phase-down, through 2023.

The combination of technology cost reductions, renewable energy targets at the state level, business model innovation, and federal tax policy has made the United States one of the top three solar PV markets worldwide. The challenge to the traditional utility business model, particularly from on-site solar, continues to result in skirmishes at utility commissions across the country. Central to the debate is how much distributed solar should be allowed to be net metered (sold back to the grid), at what price, and how costs are allocated across ratepayers. These battles notwithstanding, Navigant Research forecasts more than 70 GW of new solar capacity additions, both large-scale and distributed, between 2016 and 2022, potentially bringing the cumulative installations above 100 GW, four times the current installed base.

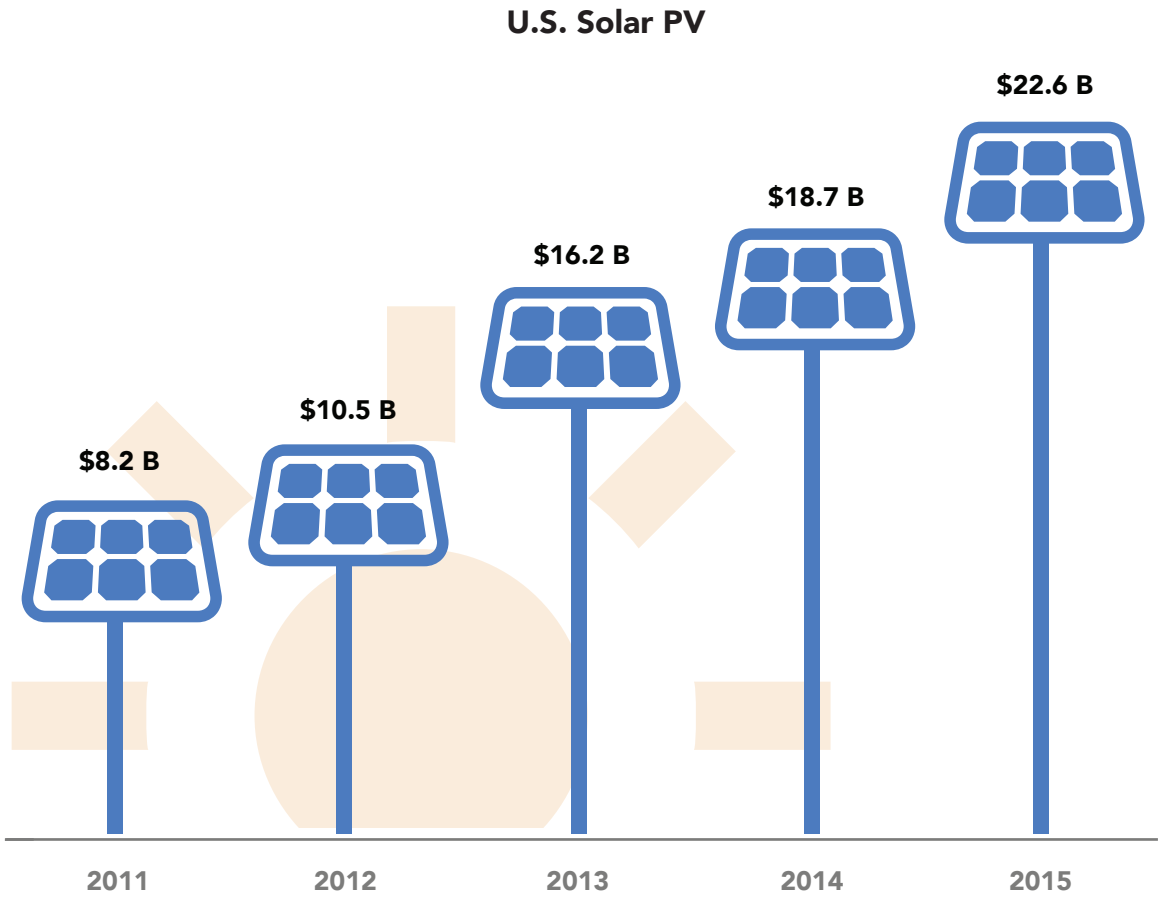


Figure 5.4 (Source: Navigant Research)

With roughly half of the country's installed capacity today, California remains the leading state for solar PV installations. California is also home to rooftop solar companies such as SolarCity, Vivint (acquired by SunEdison), and Sungevity, as well as large-scale developers such as SunPower and Recurrent Energy. Arizona's First Solar completed the 550 MW Desert Sunlight project in California as well – while other states, including Arizona, New Jersey, Massachusetts, and North Carolina, are experiencing strong growth as well.

While residential solar PV installed prices have dropped nearly 50% since 2010, large-scale costs are reaching record lows. Power purchase agreements (PPAs) for solar electricity supplied from a utility-scale solar farm have reached prices below $.05/kWh – competitive with wholesale power in most markets. In solar resource-rich states like Texas, future PPAs could go even lower. Also on the horizon is the growth in "community solar" programs, which offer a potential pathway for utilities and third-party providers to reach the millions of U.S. households that want to purchase solar power, but do not have adequate roof-space.

New global Solar PV installations reached an estimated 58.8 GW in 2015, including those in the United States, reaching approximately $113.9 billion in revenue – a 26% gain over 2014, and up 22% over Solar PV's previous peak year of 2011. China led all markets with more than 17 GW installed last year, as the country's most recent five-year plan calls for 200 GW of solar by 2020. Japan's thriving Solar PV market continued to grow apace in the wake of the Fukushima nuclear disaster and with strong, though declining, financial incentives. The United Kingdom and India continue to be strong markets as well, with an estimated 4 GW and 2 GW installed, respectively, in 2015.

China Drives Nuclear at Home and Abroad

China continues its highly ambitious deployment of electricity generation of all kinds domestically and continues to have a major impact by exporting its technology as well. China's most recent 2020 energy targets call for 200 GW of solar PV, 250 GW of wind, and a steady rollout of nuclear power: 58 GW by 2021, 150 GW by 2030, and 400-500 GW by 2050. According to the World Nuclear Association, China currently is home to 30 nuclear power reactors currently in operation, an additional 24 under construction, and more about to start construction, which means the country is on track to hit its nuclear targets, just as it is with its solar PV and wind targets. By far, China is leading the global nuclear market, which totaled $18.1 billion in 2015, up 13% over 2014 – though still down from a five-year peak of $40.8 billion in 2011. (Table 5.1)

In addition to pursuing staggering domestic targets, the Chinese government is taking a "going global" approach to nuclear, exporting its nuclear technology, including heavy components in the supply chain. Deals to date for China's nuclear exports include the following:

- EDF Energy and China signed a deal to build the 3.2 GW Hinkley Point nuclear power plant in Somerset, England, worth $26.2 billion in late 2015.
- Pakistan struck deals with Chinese vendors for four nuclear power plants at two sites totaling approximately 4 GW at a cost of nearly $12 billion.
- Chinese General Nuclear Power Corp. signed a deal worth $7.8 billion to construct two additional units at the Cernavoda plant in Romania, each with a capacity of at least 720 MW.
- Argentina signed deals with Chinese National Nuclear Corp. (CNNC) worth $5.8 billion for an 800 MW project.

Meanwhile, in the United States, in late 2015, federal regulators approved an operating license for Tennessee Valley Authority's (TVA's) 1,150 MW Watts Bar 2 unit – nearly 43 years following its initial permit to begin

construction was granted. According to World Nuclear News, construction of Watts Bar 2, a pressurized water reactor, began in 1972 but work was suspended in 1985 when the unit was about 55% complete. TVA restarted work on the unit in 2007, and awarded Bechtel the engineering, procurement, and construction contract.

Together, Unit 2 and Watts Bar's already operating Unit 1 will have a rated capacity of 2.3 GW. Other notable developments in the United States include:

- EPA's Clean Power Plan allows new nuclear to be credited as zero-emission generation and at least three states, Tennessee, Georgia, and South Carolina, appear likely to use nuclear as a significant part of their compliance strategies although it remains to be seen whether other states will take this path.
- There is growing interest in the so-called "modular" nuclear reactors being developed by companies such as NuScale, which has attracted investment by Fluor Corp. Nuclear equipment provider Westinghouse has also been conducting its own research on modular nuclear technology.
- Two Massachusetts Institute of Technology-trained scientists are pushing a type of nuclear power generation that is designed to consume its own waste. Nuclear physicists Leslie Dewan and Jacob DeWitte have founded separate but comparable startup companies – Transatomic Power and Upower, respectively – that focus on nuclear generators capable of operating on their own radiated waste, which removes the need for trucking and storing spent radioactive material.
- The Bill Gates-backed nuclear power company TerraPower has signed an agreement with China's CNNC to work together on advanced nuclear technologies that tackle some of nuclear power's toughest issues: waste, safety, and cost.

From financing to ensuring public safety, the role of government is more crucial for nuclear power than for any other power generation technology. As such, the prospect for growth of nuclear in the post-Fukushima world will remain highly dependent on the politics of each country.

U.S. Wind Build-Out Continues; Will Offshore Follow?

With expiration of the production tax credit (PTC), the wind industry in the United States raced to commence construction on projects before the 2014 end-of-year cutoff of eligibility. As a result, more than 8.5 GW of wind power was brought online in 2015, producing revenue of $14.5 billion (up 75% over 2014), with another 9.4 GW now under construction that qualified under the old rules. (Figure 5.5) Now, with the long-term extension and gradual phase-out of the PTC over the next four years, passed by Congress in December, the wind industry boom is expected to continue for the next several years. The momentum should build toward a likely PTC-driven installation peak in 2018 (due to projects that commence construction prior to January 1, 2017, securing the 100% PTC), after which PTC gradually phases out through 2019 (80% of the full PTC for projects that commence construction in 2017, 60% in 2018, and 40% in 2019). At that time, depending on natural gas pricing, the ability to further reduce wind installation costs, and the Clean Power Plan, the wind industry will likely be better able to compete head-to-head with other resources in the marketplace – as it is now already doing successfully in several regions of the country.

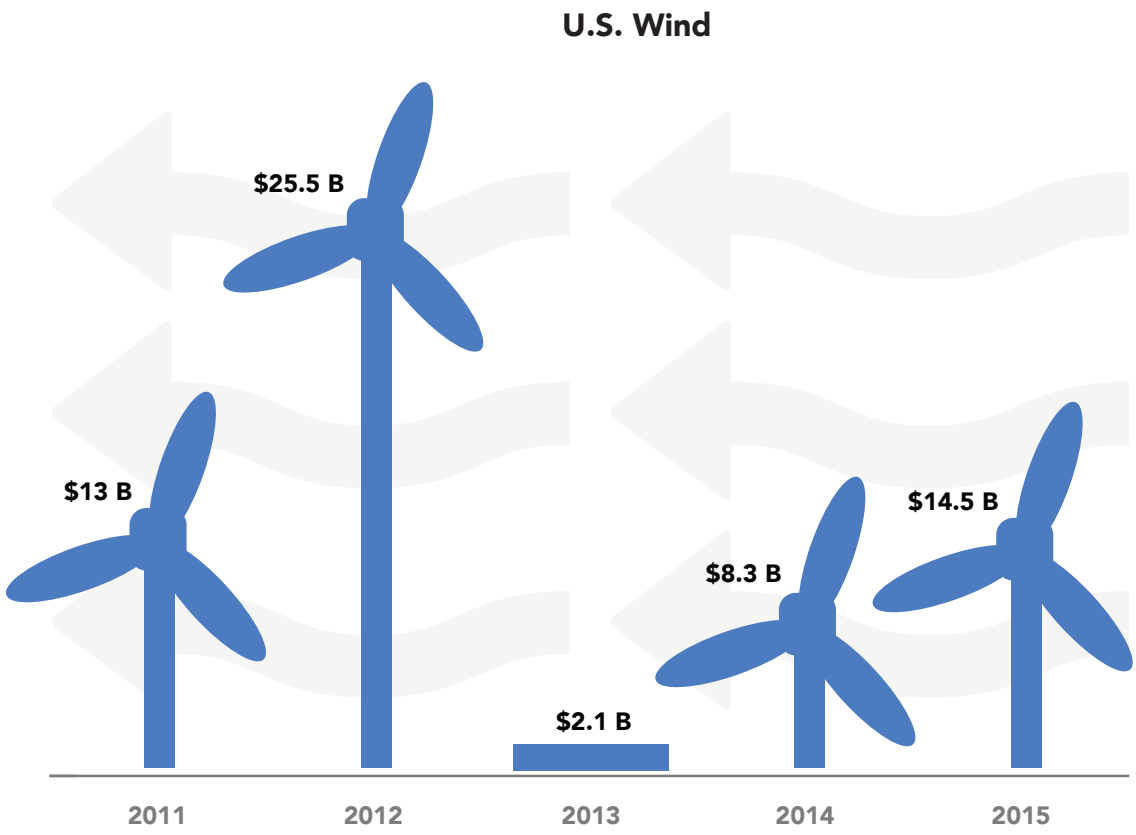


Figure 5.5 (Source: Navigant Research)

Texas stands to be one of the biggest winners of the PTC extension with over half of the expected capacity in the pipeline being built in the Lone Star State alone. This is largely due to the robust transmission system now in place in Texas – specifically, the Competitive Renewable Energy Zone (CREZ) transmission system, which was completed in early 2014. With development of large amounts of wind generation in remote locations, a strong transmission system is needed to connect this power to population centers over the grid. CREZ leads the way, with the capability of transmitting up 18.5 GW of wind power alone and as much as 6 GW of solar that is expected to be online by 2017.

Companies such as Vestas, General Electric (GE), and Siemens are among those that are well positioned to capitalize on U.S. market growth – and beyond. Recent deals between major actors in the wind market point to consolidation and other alliances to make the most of new market opportunities. The Gamesa/Siemens merger, expected to be finalized in early 2016, will give the company a combined market share of 15% globally, which would surpass GE and Vestas. For its part, Vestas teamed up with Mitsubishi Heavy Industries in 2013 for a joint venture specializing in offshore wind turbines. Nordex also acquired Acciona wind power in late 2015 in a deal worth $880 million.

With the onshore wind industry expected to continue its boom, the question comes whether offshore wind will finally take off in the United States as well. Though rich with offshore potential along the northeast, gulf coast, and even in the Great Lakes, the United States still remains devoid of any operating offshore wind capacity. Currently, the 30 MW Block Island wind farm off the coast of Rhode Island, developed by Deepwater Wind, is the only project under construction in the United States. DONG Energy, one of the largest offshore wind developers in the world, has secured leases nearby, off the coast of Rhode Island and near Martha's Vineyard in Massachusetts. Other projects, such as the Fishermen's Energy Atlantic City wind farm or the massive Cape Wind project have made it far in the permitting process but have run into significant roadblocks – Cape Wind

losing its utility contracts in the face of unrelenting legal challenges and Fishermen's Energy failing to get approval from New Jersey utility regulators.

Globally, offshore wind had a record year, adding 3.7 GW of capacity (up from 995 MW in 2014) and bringing cumulative installations worldwide to approximately 12 GW by the end of 2015. Over 65% of the 2015 capacity additions was installed in Germany. Other key markets, such as the United Kingdom, the Netherlands, and China, added capacity as well.

INDUSTRY

In 2015, the advanced energy Industry segment, the sixth largest globally, reached a five-year high of $43.4 billion, representing 6% growth over 2014, and 42% since 2011. Industry is made up of only two subsegments – Manufacturing Machinery and Process Equipment ($13.5 billion, up 9% over 2014) and Industrial CHP ($29.9 billion, up 5% over 2014). Both have seen steady annual growth since 2011 – 38% and 44%, respectively. (Table 6.1)

Global Industry Revenue by Segment (millions)

Industry	2011	2012	2013	2014	2015 (estimate)
Manufacturing Machinery and Process Equipment	$9,773	$10,513	$11,340	$12,315	$13,465
Combined Heat and Power	$20,803	$22,812	$27,155	$28,513	$29,938
Industry Subtotal	**$30,576**	**$33,325**	**$38,495**	**$40,828**	**$43,403**

Table 6.1 (Source: Navigant Research)

In the United States, Industry also remained the sixth largest advanced energy segment, with $7.7 billion in revenue, a 7% annual increase, and up 83% since 2011 – making it the third fastest growing U.S. advanced energy segment during that time. Following the global trend, Manufacturing Machinery and Process Equipment continued its steady growth, reaching $4.3 billion in 2015, up 9% year-on-year, and 36% since 2011. Industrial CHP reached nearly $3.4 billion in 2015, up 5% from 2014 and 232% since 2011. (Table 6.2)

U.S. Industry Revenue by Segment (millions)

Industry	2011	2012	2013	2014	2015 (estimate)
Manufacturing Machinery and Process Equipment	$3,184	$3,414	$3,669	$3,969	$4,325
Combined Heat and Power	$1,018	$2,038	$3,064	$3,217	$3,378
Industry Subtotal	**$4,202**	**$5,452**	**$6,733**	**$7,186**	**$7,703**

Table 6.2 (Source: Navigant Research)

CHP Holds Appeal for Commercial and Institutional Buildings

The use of CHP in large buildings has increased recently in the United States, Europe, and Asia-Pacific. This is due largely to technical improvements and cost reductions in smaller-scale (often pre-packaged) systems that match thermal and electrical requirements of buildings. Nevertheless, many owners of commercial properties, especially those of smaller facilities, are not aware of opportunities to install CHP, as they do not consider energy to be part of their core businesses. This educational gap presents a potential limitation on the continued growth in the number of CHP installations that are ultimately pursued.

The commercial CHP market is a bright spot for CHP. It consists of a loose collection of building types ranging from hospitals and college campuses to high rises, prisons, and other categories within the built environment. In 2015, continued growth brought total installations to just over 33 GW of capacity, with an average capacity of approximately 3 MW per installation. Today, installations are mostly confined to developed markets in Northern Europe, South Korea, Japan, and the United States. Hospitals, universities, and other applications with nearly 24/7 heat load requirements represent the greatest share of the global installations.

Industrial CHP is still a bigger market, with $29.9 billion in revenue globally in 2015, $3.4 billion of that in the United States, with growth of 5% over last year in both. But commercial CHP is growing faster: up 17% globally, to $3.5 billion, and up 9%, to $925 million, in the United States Although hospitals and institutional buildings such as universities represent the largest installed base among application groups, small and large commercial buildings are expected to gain an increasing share of the market over the next decade.

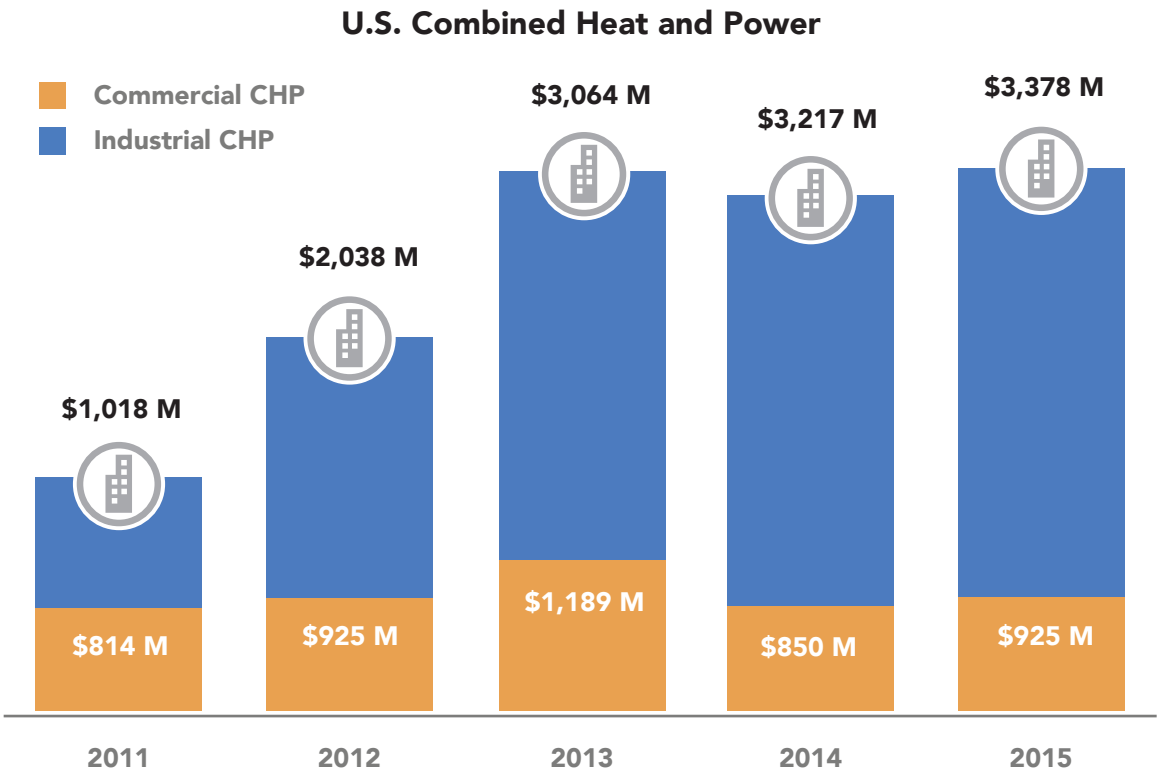


Figure 6.1 (Source: Navigant Research)

The upfront capital cost associated with CHP systems is the primary barrier to continued market growth. In addition, a range of factors impact the prospects for CHP:

- High or volatile "spark spreads," or the difference between electricity and natural gas prices on a $/MMBtu basis;
- Significant, year-round thermal requirements;
- Match between customer needs for thermal and electrical output;
- Favorable regulatory framework with utilities (i.e., interconnection standards, net metering or feed-in tariffs, demand charges, standby charges, etc.).

The relative importance of these factors depends on geographic location, building size, building function, and other site-specific factors. End users – from hospitals to schools to business parks – have installed CHP systems as a means of reducing operating expenses, improving power reliability, and capturing sustainability benefits monetized through credits, rebates, and increased sales or tenant occupancy based on market differentiation. The two primary motivations, though, are energy savings potential and guaranteed power supply to mission-critical operations (e.g., research institutions, hospitals, and data centers). CHP received an additional boost in 2012 when President Barack Obama signed an executive order to accelerate investments in industrial energy efficiency, including CHP. The executive order sets a national goal of 40 GW of new CHP installations over the next decade.

Among equipment suppliers, GE designs and manufactures a variety of components used in CHP systems including Waukesha gas engines, designed for isolated, mission-critical applications. 2G-CENERGY, an American subsidiary of German company 2G Energy AG, focuses on mass-manufactured systems, which reduce the cost and complexity of installation, as these systems can be manufactured, delivered, and installed in 15 to 21 weeks. Capstone Turbines' microturbine systems are designed to work individually or in a series, on- or off- grid, and as prime power or backup units. Germany-based MWM, acquired by Caterpillar in 2010, produces turnkey CHP container systems that are designed to enable quick availability at low cost, maximize control over the entire system, encourage flexibility, require low maintenance, and provide high run-times. Using pre-manufactured components and a modular design, installation costs are kept to a minimum. To overcome the need for regular oil changes, Tecogen typically installs one extra module that allows customers to avoid exorbitant charges when they must rely on the grid for short periods of downtime.

Companies involved in developing, operating, and managing CHP institutional and district energy systems in the United States and around the world include Veolia, GE, Blue Delta Energy, and Invenergy.

Industrial Energy Management Systems Deliver – and Expand – Worldwide

The industrial sector accounts for roughly 50% of U.S. electricity consumption, and more than 30% in Europe. This presents a major opportunity for energy and financial savings are a major opportunity for the companies operating in this sector. Industrial Energy Management Systems (IEMS) analyze and manage energy consumption and operations data within an industrial facility, delivering actionable information to managers of industrial facilities.

These analytics-based tools help industrial customers make strategic investments and equipment improvements as well as monitor the impacts of energy efficiency measures, from capital-intensive system replacement to

no-cost operational changes. IEMS revenue reached $13.5 billion worldwide in 2015, up 9% from 2014 – a 38% increase over 2011, as a result of steady annual growth. The United States market reached $4.3 billion in 2015, up 9% over 2014, and 36% over 2011. (Figure 6.2)

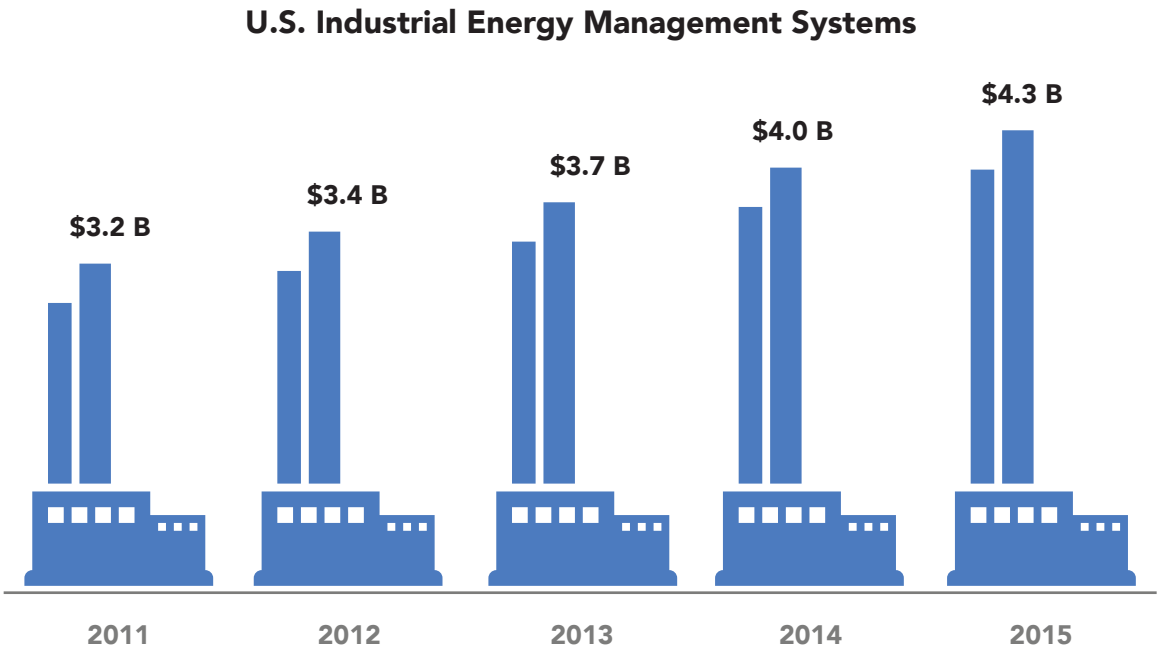


Figure 6.2 (Source: Navigant Research)

Major IEMS customers include manufacturers, food, textiles, transportation equipment, and many other sectors. IEMS are deployed on industrial processes including pumps, air compressors, fans, materials handling and processing, and refrigeration making up the majority of an industrial facility's load profile.

Companies are increasingly realizing the financial business case for IEMS investment, as these systems increase budget certainty by providing tools for predicting potential maintenance, energy, and capital costs. The software and services provide insight into energy-related financial underperformance by analyzing operations against energy costs, including utility rates, demand charges, and wholesale prices.

Leading companies providing IEMS include Emerson Process Management, AECOM, and Schneider Electric. These solution providers serve a variety of industrial sectors, including chemical, oil and gas, refining, pulp and paper, power, water, mining and metals, food and beverage, and life sciences. As an example, Emerson Process Management offers Energy Advisor, a real-time energy management information system that automatically monitors and manages energy consumption across plants, mills, and refineries. Schneider's StruxureWare is a platform of applications that gives clients visibility into energy consumption and other resource utilization across the organization, including electrical management, automation, building management, critical power and cooling, and electrical distribution services.

IEMS is also a viable solution to help energy service companies better manage and monitor industrial projects. Companies like Ecova, CLEAResult, and others partner with a utility to enact energy savings across the utility's industrial client base. IEMS can support these partnerships with the tools for measuring and monitoring the impact of efficient measures and ensuring persistent savings. Because the industrial sector is such a large consumer of electricity, even minor improvements, enabled by real-time data and process improvements, can result in significant financial savings.

Navigant Research forecasts the global IEMS market will grow from $13.5 billion in 2015 to $35.6 billion in 2024, increasing at an 11.4% CAGR.

In North America, regulatory drivers are expected to have a less direct impact on the market. That said, the mid- and long-term impacts of EPA's Clean Power Plan could accelerate interest and financial support of energy efficiency investment in the U.S. industrial segment. IEMS vendors can take advantage of this growing opportunity to engage customers with software and services to meet their energy management objectives. The North American market is expected to grow at a 10.9% CAGR through 2024.

Meanwhile, the European Union (EU) will continue to pressure industrial customers to improve energy efficiency and reduce greenhouse gas emissions under the regulatory framework of the EU Emissions Trading Scheme (ETS) and Energy Efficiency Directive (EED). Corporate commitments to sustainability and climate change mitigation are also expected to bolster opportunities for IEMS vendors in the region. Navigant Research forecasts an 11.5% CAGR for the region through 2024.

But the fastest growing market will be Asia-Pacific, projected to grow at a 13.4% CAGR during this time.

BUILDING EFFICIENCY

In 2015, worldwide revenue in the advanced energy Building Efficiency segment reached $236.3 billion, up nearly 14% over 2014 and 60% over 2011, counting only products for which we have five years of data. (Table 7.1) Building Efficiency is the third largest segment of the advanced energy market globally. All subsegments experienced growth in 2015, with Lighting as the top revenue source at $116.5 billion due to strong growth in both residential and commercial energy efficient lighting.

Global Building Efficiency Revenue by Segment (millions)

Segment	2011	2012	2013	2014	2015 (estimate)
Building Design	$11,537	$13,039	$13,932	$15,544	$17,457
Building Envelope	$13,017	$14,006	$15,855	$18,668	$26,187
Heating, Ventilation, and Air Conditioning (HVAC)	$44,383	$49,613	$53,923	$57,962	$62,337
District Energy and Combined Cooling, Heating, and Power (CCHP)	$2,229	$2,787	$3,023	$2,950	$3,458
Water Heating	$1,467	$1,612	$1,773	$2,090	$2,237
Lighting	$41,329	$47,212	$52,770	$103,613	$116,498
Appliances and Electronic Equipment	$266	$613	$800	$1,200	$1,708
Demand Response & Enabling Information Technology	$3,752	$4,829	$5,023	$5,719	$6,378
Building Efficiency Subtotal	**$117,981**	**$133,710**	**$147,100**	**$207,746**	**$236,260**

Table 7.1 (Source: Navigant Research)

Heating, Ventilation, and Air Conditioning (HVAC) was the second largest subsegment, with $62.3 billion (8% growth over 2014) worldwide, with increasing sales of both equipment and services from energy service companies. Building Envelope and Building Design were the next two leading subsegments, with $26.2 billion (up 40%) and $17.5 billion (up 12%) in revenue, respectively. (Table 7.1) Counting only products for which all five years of data is available, Building Envelope experienced impressive five-year growth, over 60% since 2011.

The fastest-growing subsegment globally, Appliances and Electronic Equipment, saw revenue reach $1.7 billion in 2015, up 42% from 2014 and 542% since 2011, showing that smart appliances and connected devices in the home and workplace are being deployed and saving money for residents and building owners.

Demand Response & Enabling Information Technology has seen steady annual growth, reaching $6.4 billion in 2015, up 12% from 2014 and 70% from 2011. Demand response (DR) is increasingly being integrated into utility resource planning – a mutually beneficial arrangement for building owners and utilities looking to meet peak demand cost-effectively.

District Energy and Combined Cooling, Heating, and Power (CCHP) reached $3.5 billion in revenue worldwide in 2015, up 17% from 2014 and 55% from 2011, as lower natural gas prices, expanded use of biomass, and increased awareness among cities contributed to market growth. Europe continues to be the leading market for these technologies. Water Heating also increased 7% in 2015 to reach $2.2 billion in revenue, a 52% increase from 2011.

In the United States, Building Efficiency was the largest advanced energy segment, with $63.6 billion in revenue, an increase of nearly 11% since 2014, and 50% since 2011, counting only products for which we have five years of data. U.S. Building Efficiency followed the global trend, with all subsegments increasing year-over-year, led by three subsegments each reaching $14 billion in revenue when counting only products for which we have all five years of data, including HVAC ($14.1 billion, up 7%), Building Envelope ($14 billion, up 11%), and Lighting ($14 billion, up 14%). (Table 7.2) Counting only products for which we have five years of data, both Building Envelope and Lighting have experienced five-year growth rates of over 50%, and HVAC experienced growth of over 30%.

U.S. Building Efficiency Revenue by Segment (millions)

Segment	2011	2012	2013	2014	2015 (estimate)
Building Design	$2,819	$3,128	$3,351	$3,850	$4,336
Building Envelope	$8,720	$9,645	$11,919	$12,766	$14,127
Heating, Ventilation, and Air Conditioning (HVAC)	$10,522	$11,532	$12,306	$13,184	$14,140
District Energy and Combined Cooling, Heating, and Power (CCHP)	$814	$925	$1,189	$850	$925
Water Heating	$1,133	$1,197	$1,357	$1,490	$1,639
Lighting	$9,139	$9,992	$10,701	$22,024	$24,666
Appliances and Electronic Equipment	$105	$148	$208	$227	$472
Demand Response & Enabling Information Technology	$2,020	$2,663	$2,572	$2,996	$3,245
Building Efficiency Subtotal	**$35,271**	**$39,229**	**$43,604**	**$57,386**	**$63,550**

Table 7.2 (Source: Navigant Research)

Water Heating in the United States increased to $1.6 billion in 2015 (up 10% over 2014), and District Energy and Combined Cooling, Heating, and Power gained 9% year-on-year, with revenue of $925 million. Meanwhile, connected buildings, Internet of Things (IoT), and other smart technologies are starting to have a major impact in the residential and commercial sectors. Appliances and Electronic Equipment had the biggest year-on-year growth, at 108%, with U.S. revenue of $472 million, as well as five-year growth of 350%.

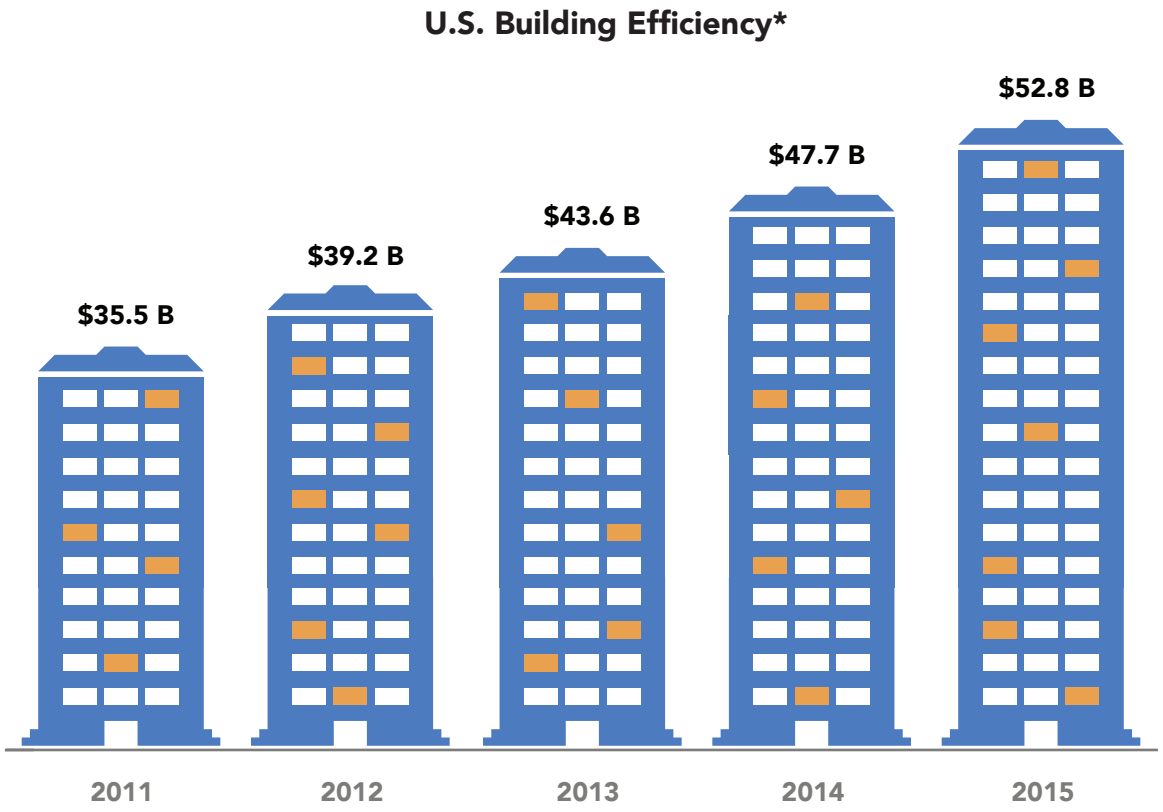


Figure 7.1 (Source: Navigant Research) - *Revenue shown only for product categories with revenue data for all years 2011-2015.

From Energy Management to Connected, Comfortable Buildings

The intelligent building is a facility that leverages information technology to improve system performance for energy savings and operational improvements. The market launched about a decade ago with new software, building energy management systems (BEMS), designed to deliver energy efficiency improvements by translating more data into better information and explicit action. BEMS combat the challenge of using and maintaining complex and proprietary control and automation systems. These new software solutions utilize a wider array of data including utility bills, smart meter interval data, weather, and sensor signals to identify opportunities for energy efficiency and operational improvements. BEMS are technology agnostic, so regardless of any existing control and automation infrastructure, the software applications can direct energy cost savings. For example, BEMS can detect anomalies in heating system operations and then direct a reset of setpoints or schedules. The result is better use of heating systems, which drives down utility bills. The energy efficiency story is straightforward and quantifiable. Customers see declining utility bills aligned with the performance improvements in their building systems.

A growing number of intelligent building applications are designed to maximize worker efficiency and satisfaction by improving responsiveness to heating and cooling complaints, easing the process of finding collaboration space, fine-tuning lighting to meet specific worker preferences, and showcasing energy, waste,

and water conservation improvements that support corporate sustainability commitments. The line between building algorithms and business algorithms is blurring as connected, comfortable buildings come to define the modern workplace.

BEMS are central mechanisms for making buildings more intelligent, comfortable, and efficient. They are data-driven decision support tools for facilities and operations management. BEMS enable the strategic improvements in operations and maintenance, help guide investment in building system upgrades, and improve resource utilization within a facility or across a portfolio. This wide array of benefits helps drive investment in BEMS worldwide.

Revenue from BEMS was flat in 2015, at $2.8 billion globally and $1.1 billion in the United States, as the market continues to mature. But growth since 2011 has been substantial, up 50%, from $1.8 billion, in global revenue and 45% higher than 2011's $737 million in U.S. revenue. (Figure 7.2) Navigant Research forecasts that global BEMS revenue will reach $10.8 billion in 2024.

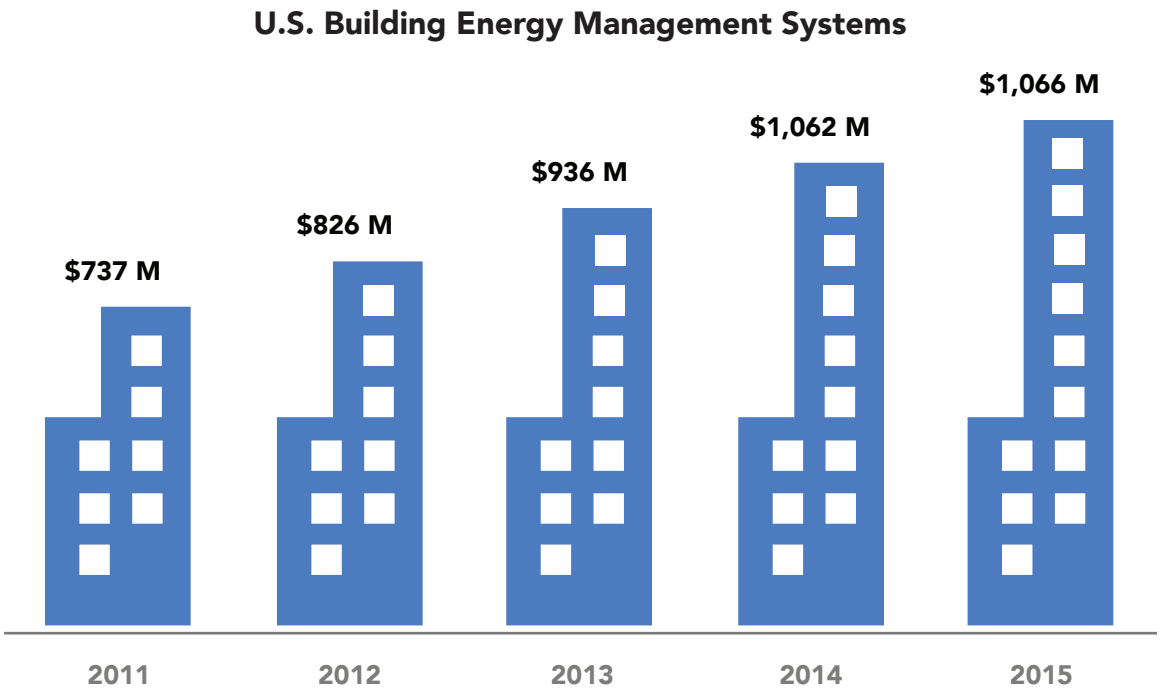


Figure 7.2 (Source: Navigant Research)

An evolution in building technologies is reshaping how owners can leverage buildings as valuable assets. A couple of corporate moves that occurred in 2015 illustrate the kinds of changes that are happening in the building management business as BEMS and other technologies provide new capabilities in energy management and comfort:

- CBRE made two significant investments to deepen capabilities in energy management, engineering, and supply chain management with the acquisitions of Johnson Controls' Global Workforce Solutions business (for a purchase price of $1.5 billion), and Environmental Systems Inc. CBRE and other major real estate management and outsourcing firms continue to broaden their capabilities around intelligent building technologies and energy management to meet the shifting demands of both tenants and investors.
- Energy and services provider Direct Energy completed the acquisition of Panoramic Power for $60 million. This transaction will enable Direct Energy to introduce device-level energy management to their customers.

The move reflects the opportunity for energy providers to deepen engagements with their commercial customers beyond specific demand side management programs and putting them into new positions as trusted energy advisors.

- The growing penetration of BEMS in commercial buildings provides greater insight and actionable information to stakeholders across the value chain including building owners, operators, and service providers. It is a win-win situation: BEMS drive energy savings that improve the bottom line, and at the same time make workspaces more comfortable and convenient.

Integrated Data Center Management is the Next Frontier

Intelligent buildings integrate software and services to maximize energy and operational efficiency across building systems—from HVAC to lighting and plug loads. Integrated data center energy management is the implementation of a unified intelligent building strategy to optimize both IT and facility resources. As building owners invest in intelligent building solutions to deliver comprehensive energy management, they have begun to look at on-site and enterprise data centers as key candidates for optimization because of data centers' high levels of energy consumption.

By coordinating investment in energy conservation measures, equipment upgrades, and the use of software and services, integrated data center energy management promises to deliver greater energy and operational efficiency improvements to the facility or campus that hosts the data center. The idea is to leverage resources that can meet the needs of both the data center and the larger facility.

The deployment of intelligent building solutions and approaches across facility and IT systems will only increase over time, making the integrated data center the next frontier for the intelligent buildings market. A few examples of solutions that help customers manage their on-site data center resources framework include:

- BEMS
- Advanced cooling solutions and strategies
- Intelligent lighting controls
- Integrated monitoring and control hardware, such as electric submeters, occupancy sensors, and smart thermostats
- Building-integrated renewables

Integrated Data Center Category	Intelligent Building Offering	Capabilities Benefits	Representative Vendors
Software & Services	BEMS	Visualization and reporting, fault detection and diagnostics, predictive maintenance and continuous improvement, optimization	BuildingIQ, Daintree Networks, Honeywell*, Johnson Controls*, Pacific Controls*, Schneider Electric*, Siemens*
	DCIM	Capacity planning, asset management, adds and changes, resource management, operations management, alarms and reporting	1E, CA Technologies, iTRACS, Modius, NetApp, Raritan
	Energy Efficiency Services	Project design, implementation, and management for energy efficiency measures	Ameresco, CBRE/ESI*, EnerNOC*, JLL, McKinstry, Trane,* Johns Manville, Opower, CLEAResult
	Data Center Energy Efficiency	Electrical system efficiency, virtualization	Eaton*, Emerson*, Viligent
Equipment & Systems	Building Controls	Building automation for scheduling, equipment settings, load management	Aircuity, Delta Controls, Distech Controls, Entic, KMC Controls
	Cooling	Cooling redundancy, controls, dynamic cooling	Carrier, Daikin, Lennox International
	Lighting	Intelligent lighting controls, software analytics	Acuity, Bridgelux, Cree, Digital Lumens*, Enlighted*, GE Lighting, Philips
	Renewables	Integrated solar PV	Leidos, RGS Energy, SunPower

Table 7.3 (Source: Navigant Research) – * Vendors with offerings that cross categories

Navigant Research tracks the development of specific intelligent building technologies and solutions, many of which are gaining significant traction in the market. (Table 7.3) The promise of the intelligent building is centered on fully integrated energy management enabled by software, services, and advanced automation and control technologies. The evolution of a traditional facility into this intelligent building framework also relies on collaboration across customer teams. This is important context for the integrated data center, as the IT assets represent not only an additional set of energy end uses but also business decision-makers.

Furthermore, these assets will continue to demand energy, capital, and business resources. The integrated data center energy management approach can ensure that data centers are optimized for savings and efficiency, and allow data center operators to leverage innovations already underway. A Microsoft natural gas fuel cell pilot

project reported a 30% efficiency gain by installing fuel cells directly onto server racks, bypassing the need to convert from direct to alternating current and thereby reducing conversion losses. Fuel cells play a small but growing role at data centers, with installations such as Apple's 10 MW system at its North Carolina facility and Ebay's 6 MW system in Utah.

The North American integrated data center energy management market is expected to grow from $46.9 million in 2015 to $119.7 million in 2024, representing a 43% CAGR. This aggressive outlook reflects the early beginnings today, but also the bullish expectations for broad adoption of intelligent building strategies including integrated data center energy management. As commercial facility owners become more comprehensive in their approach to energy management, on-site information technology resources such as servers and small data centers are essential assets to incorporate into their approach.

Internet of Things Comes to Life at Home

The IoT concept, though much hyped for its future potential, is not just coming. It is already well on its way – into the home. Smart thermostats allow a user to remotely control household temperatures via a smartphone. Smart meters can connect to thermostats for DR. Some LED lights have embedded radios that allow the user to remotely control them from mobile devices. Smart appliances and security systems are able to connect via wireless or wired technologies and share status or other data for home automation, safety, and convenience. These devices enable customers to input data into behavioral efficiency software which can generate recommendations to lower energy use. Though still early, this trend is accelerating as device manufacturers add connectivity to more devices.

Navigant Research defines residential IoT as connected devices in the home that provide human or unaided control of functional systems that benefit residents in terms of comfort, security, energy efficiency, maintenance, and automation. This is carried out with intelligent devices and sensors that provide control, with or without human intervention, and relay data via wired or wireless connections and with intelligence from the Internet. The key drivers of the residential IoT include:

- Home security: Consumers get integrated home security systems that not only connect door locks and cameras, but also provide access via the Internet or mobile device to a smart thermostat and lighting and energy management tools.
- Energy management: A growing perception among consumers is that connected devices, like thermostats, LED lighting, and smart meters, coupled with services, can help them more efficiently manage energy consumption.
- Mobile devices and applications: The proliferation of smartphone applications has created the expectation among consumers that in-home devices embedded with a wireless radio interface can be monitored or controlled.
- In-home networks: Along with mobile devices, a home Wi-Fi network has enabled static devices like smart thermostats to connect to the Internet, share data, and be monitored or controlled remotely.

In related product categories followed for the *Advanced Energy Now 2016 Market Report*, revenue from Home Energy Management Systems (HEMS) has grown globally from $93 million in 2011 to $1.1 billion in 2015, and in the United States from $44 million to $495 million. (Figure 7.3) Smart appliance revenue has climbed from $266 million to $1.7 billion globally, and from $105 million to $472 million in the United States.

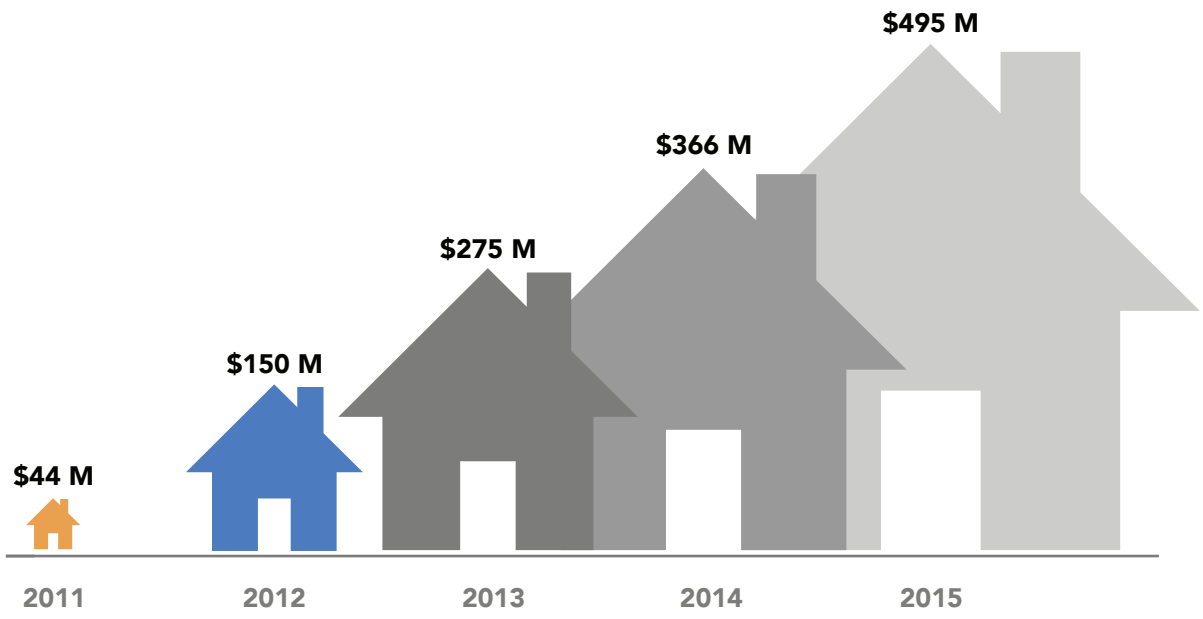


Figure 7.3 (Source: Navigant Research)

Already a wide array of companies is providing products and services to drive the residential IoT trend. These companies foresee a thriving market well into the next decade, and they include some well-known brands:

- Nest, a division of Alphabet, sells smart thermostats, connected smoke and carbon monoxide alarms, and connected cameras.
- Comcast's Xfinity service can connect smart thermostats, smart locks, lighting, and sprinkler systems, among other things.
- Samsung's SmartThings Hub connects an assortment of devices, including locks, thermostats, lighting, and cameras.
- Belkin's WeMo offers a collection of Wi-Fi-connected devices such as light bulbs, switches, and small appliances that can be controlled from smartphones or tablets.
- Lowe's offers the Iris platform, which enables users to connect thermostats, locks, cameras, and other sensors in a home.
- Apple's HomeKit is a framework for controlling devices like smart thermostats, lighting, cameras, switches, and sensors through iPhones and iPads.

Despite the many drivers for the residential IoT, some significant obstacles stand in the way of a flourishing market:

- Protocols and standards: Multiple protocols and standards create an interoperability issue, confusing consumers and stalling adoption.
- Price of devices: Even with component prices dropping, the newest IoT gear is still more costly than traditional alternatives, and will be for the immediate future.
- Battery life: Some IoT devices like sensors or door locks will need to function reliably for a long time on batteries; there is still uncertainty about how long those batteries need to last.

Navigant Research expects global revenue attributed to residential IoT devices to grow from $7.3 billion in 2015 to $67.7 billion in 2025, which represents a CAGR of 25%. The North American market is expected to see revenue grow from nearly $2.5 billion in 2015 to $17.7 billion in 2025, with a CAGR of 22%. Shipments of smart meters, smart appliances, smart thermostats, and security and management systems are expected to be among the main revenue drivers.

As tempting as it may be to ignore the hype of "internet of… whatever," in the residential and consumer markets, the Internet of Things is already here.

ELECTRICITY DELIVERY AND MANAGEMENT

In 2015, Electricity Delivery and Management was the fourth largest advanced energy segment worldwide with $94.3 billion in revenue, an increase of 19% over 2015 – and the fastest growing segment during the past five years – with 111% growth over 2011 counting only products for which we have five years of revenue. (Table 8.1) With increasing penetration of renewable energy worldwide, and stimulated by billions in government infrastructure spending in response to the financial crisis, global investment in the electric grid has grown substantially, especially in the past two years, with Transmission increasing 45% to $42.6 billion in 2015 (up 334% since 2011). Closer to end-users, Distribution, Advanced Metering Infrastructure (AMI), and Enabling Information and Communication Technology subsegments increased 9% to 15% in 2015, with revenue of $9.2 billion, $6.7 billion, and $13.1 billion respectively.

Technology cost reductions, new business models, and market opportunities have enabled Energy Storage to reach a five-year high of $2.1 billion worldwide for installations at the residential-, commercial-, and utility-scale, a 356% increase globally over 2014, and an 18-fold increase from 2011. New investment in Electric Vehicle Charging Infrastructure increased 7% in 2015, to $511 million, capping 300% growth over the past five years.

Global Electricity Delivery and Management Revenue by Segment (millions)

Electricity Delivery and Management	2011	2012	2013	2014	2015 (estimate)
Transmission	$9,808	$17,894	$6,110	$29,288	$42,564
Distribution	$5,998	$7,383	$3,404	$8,459	$9,186
Advanced Metering Infrastructure (AMI)	$6,273	$6,514	$5,805	$5,835	$6,684
Microgrids	$3,737	$4,400	$5,479	$4,416	$422
Charging Infrastructure	$127	$355	$417	$480	$511
Energy Storage	$117	$791	$646	$462	$2,104
Enabling Information and Communication Technology	$9,351	$28,066	$29,289	$30,588	$32,884
Electricity Delivery and Management Subtotal	**$35,410**	**$65,403**	**$51,151**	**$79,527**	**$94,354**

Table 8.1 (Source: Navigant Research)

In the United States, Electricity Delivery and Management was the fifth largest advanced energy segment, with $18.2 billion in revenue, a 24% increase from 2014, and 72% increase from 2011 counting only products for

which we have five years of data. Similar to the global trend, Transmission was the largest subsegment, with $7.6 billion in revenue – a 125% increase over 2014, and 560% increase over 2011, with growth led by smart transmission system upgrades and high-voltage projects. Critical to integrating larger amounts of wind to the electric grid, and building on the success of Texas' CREZ transmission build out that was completed in 2014, a number of additional high-voltage projects moved forward in 2015 such as the potentially 400 mile Illinois Rivers Project. Enabling Information and Communication Technology increased 4% in 2015, to $6.5 billion, led by a variety of smart-grid IT, software, and data analytics products and services, in addition to smart street lighting. The U.S. Distribution and AMI categories each showed a decline in 2015, with revenue down 9%, to $1.5 billion, and 5%, to $1.1 billion, respectively.

U.S. Electricity Delivery and Management Revenue by Segment (millions)

Electricity Delivery and Management	2011	2012	2013	2014	2015 (estimate)
Transmission	$1,147	$2,133	$576	$3,357	$7,567
Distribution	$1,064	$1,322	$250	$1,621	$1,481
Advanced Metering Infrastructure (AMI)	$1,648	$1,681	$1,387	$1,193	$1,134
Microgrids	$1,012	$1,265	$1,623	$1,957	$548
Charging Infrastructure	$27	$92	$154	$157	$164
Energy Storage	$81	$360	$519	$58	$734
Enabling Information and Communication Technology	$3,075	$7,291	$6,089	$6,293	$6,537
Electricity Delivery and Management Subtotal	**$8,055**	**$14,144**	**$10,599**	**$14,636**	**$18,165**

Table 8.2 (Source: Navigant Research)

A number of energy storage projects came online in 2015 in the United States, with an estimated $734 million in revenue, a nearly 13-fold increase from 2014, and more than 800% growth since 2011 – a major milestone for this fast-evolving technology. (Figure 8.2) Electric Vehicle Charging Infrastructure grew a healthy 5%, with revenue reaching a five-year high of $164 million in 2015, up 510% over 2011.

Drones & Robotics for Utility Transmission & Distribution Offer Improved Safety and Cost-Effectiveness

While popular media highlights the controversy around unmanned aerial vehicles (UAVs, or drones) in public airspace, the drive toward commercial uses for drone technology is proceeding at a rapid pace. Private companies, grid operators, and public utilities across the globe are beginning to look toward drones to reduce costs, improve safety, increase reliability, and decrease response times across their systems.

Companies like Amazon are seeking airspace regulations that establish corridors for commercial drone-based delivery applications. Transmission and distribution (T&D) system operators and utilities in all regions of the world have been performing line inspections and maintenance, storm damage assessments, and vegetation management using traditional line crews for decades. They have also used helicopters to perform T&D line inspections in remote areas and inaccessible right of ways.

No matter how it's done, working on high- and medium-voltage T&D systems is difficult, expensive, and dangerous. Indeed, the lineworker's job is considered one of the 10 most dangerous occupations in the United States.

New UAV and robotics-based utility solutions can address major operations such as overhead visual transmission line maintenance inspections, storm damage assessments and outage management/response, and substation inspection. These solutions also assist with asset management and condition monitoring, as well as vegetation management.

Today, the drone and robotics technologies market for T&D is still at an early stage, with new developments and product releases occurring almost on a daily basis. The value proposition for T&D utilities to perform at least a portion of their inspection, maintenance, and damage assessment utilizing these solutions is strong. With more than 50 companies now in the market, consolidation and large-scale growth are expected as the technologies mature and the practice gains acceptance among utilities.

Navigant Research expects cumulative global UAV and robotics revenue for technologies, integration/analytics, and inspection services to reach $16.2 billion by 2024. The annual revenue opportunity is expected to grow from $132 million in 2015 to $4.1 billion in 2024, with accelerating growth in all technology categories.

Forecast: Global Annual Revenue

Technology	2015	2024
UAV & Robotics for Utility T&D	$132 M	$4,100 M

Table 8.3 (Source: Navigant Research)

T&D system operators across the world are conducting research and development (R&D) and limited demonstration projects with UAV and robotics. A number of U.S. utilities have provisional Federal Aviation Administration (FAA) licenses, including Florida Power & Light (FPL), San Diego Gas & Electric (SDG&E), Xcel Energy, Duke, and Commonwealth Edison (ComEd). These utilities are currently testing either transmission line inspections or storm damage assessments using multi-rotor drones in limited geographic areas. In Italy, Enel is currently using drone technologies for inspection services.

Many utilities may ultimately opt out of maintaining their own fleets of drones, instead contracting with third-party inspection and maintenance services companies under a drones as a service (DaaS) license. These companies may supply drones, pilots, and cloud-based streaming data for the utility operations center.

Navigant Research expects Europe and Asia-Pacific to present the largest regional revenue opportunities, representing 44% and 28% of the current global market, respectively. As the market matures and airspace regulations become both well-defined and streamlined, the North American market will begin to grow. As new generations of UAVs, robotics, and analytics are introduced, the cost of UAV and robotics data analytics and integration can be expected to drop, while adoption and replacement rates accelerate. Notably, new UAV and robotics technologies may be introduced, updated, and replaced on an almost annual basis. Advanced analytics applications will likely be packaged into productized software and integrated with major utility systems, rather than being deployed on a custom basis. Drones will become part of the utility routine.

New Era of Demand Response

The amount of demand response (DR) capability in North America has grown considerably in the past five years, both at utilities and in competitive markets such as the PJM Interconnection (PJM) in the U.S. Northeast. However, DR has generally been relegated to a role as a last-called resource, deployed only at times of maximum stress on the grid. However, that is changing.

The use of DR in grid planning and operations has solidified as utilities increasingly rely on DR to meet installed capacity requirements and sometimes even operating reserve requirements. Furthermore, independent system operators led by PJM have incorporated DR into procurement mechanisms for capacity, energy, and ancillary services. Industry acceptance of DR as an integral part of the future grid continues to grow, with states like California and New York rolling out major regulatory initiatives that enable a larger role for DR.

Hawaiian Electric (HECO), an investor-owned utility, has issued a request for proposals to DR aggregators for the provision of grid services, including ancillary services, from demand-side resources. As with other regulatory initiatives in the island state, Hawaii's innovative uses for DR to help manage the grid in real time come in response to massive customer investment in behind-the-meter solar PV. This could be the future for many utilities that are only now seeing the first effects of customer investment in on-site renewables, storage, and other distributed energy resources.

DR is also expanding from big commercial electric customers to residences. Opower recently announced results from its behavioral DR (BDR) program. The company reported that it sent over 12 million personalized communications to customers during 29 DR events last summer, delivering 3% average peak reduction and over 5% savings under peak time rebate pricing plans. Utilities involved included Baltimore Gas and Electric (BGE), ComEd, DTE Energy, Consumers Energy, Pacific Gas and Electric (PG&E), and Hydro Ottawa. BGE is able to bid its BDR resource into PJM's capacity market to meet system reliability needs.

Even as its value to customers and grid operators was growing, DR has until recently had its fate in the hands of the courts. Power generators sued FERC over its Order 745, on DR compensation in the wholesale energy markets like PJM's, and the U.S. Court of Appeals for the D.C. Circuit ruled that the Order was an interference in retail electricity markets, over which state regulators have jurisdiction. But on January 25, the Supreme Court reversed the DC Circuit's decision on both parts of the case, meaning that DR does fall under FERC's jurisdiction, and the payment of full Locational Marginal Price (LMP) in the wholesale energy markets is just and reasonable. It was a full victory for DR providers like EnerNOC, Comverge, and Johnson Controls, and generators will have to learn to live with competition from real-time demand reduction.

The global market for DR services surpassed $2 billion in 2015, up 17% from 2014, with the United States representing two-thirds of that total.

Indeed, utilities will be entering a new era as DR technology further blurs the line between generation and demand-side resources, and not just in Hawaii. Looking ahead, emerging state policies and evolving market rules could drive DR to heights that would have been difficult to envision just five years ago.

Renewables, Grid Services Drive Energy Storage Growth

High penetration of renewables in markets such as Hawaii, California, Denmark, Germany, and China is one aspect of the ongoing changes in the electricity system that points toward rising opportunity for energy storage at the residential, commercial, and utility levels. Solar and wind, in particular, as rapidly scaling forms of variable

generation, could benefit from storing excess electricity generation – whether on the grid or in the home – until it is needed. At the same time, energy storage is emerging as an alternative to traditional sources of ancillary services, for voltage regulation and other grid supports. Ultimately, large-scale storage could replace peaking power plants that are needed to run only a few hours a year to meet peak demand, while also being used to provide other valuable grid services year-round.

As noted in last year's Market Report, energy storage is transitioning from a large infrastructure market of pumped hydro and underground compressed air projects – which it still is, in much of the world – to a technology-driven market, with rising scale and falling prices. And it is taking off: global revenue from Energy Storage multiplied five-fold, from $462 million in 2014 to $2.1 billion in 2015, and in the U.S. more than ten-fold, from $58 million to $734 million. (Figure 8.1)

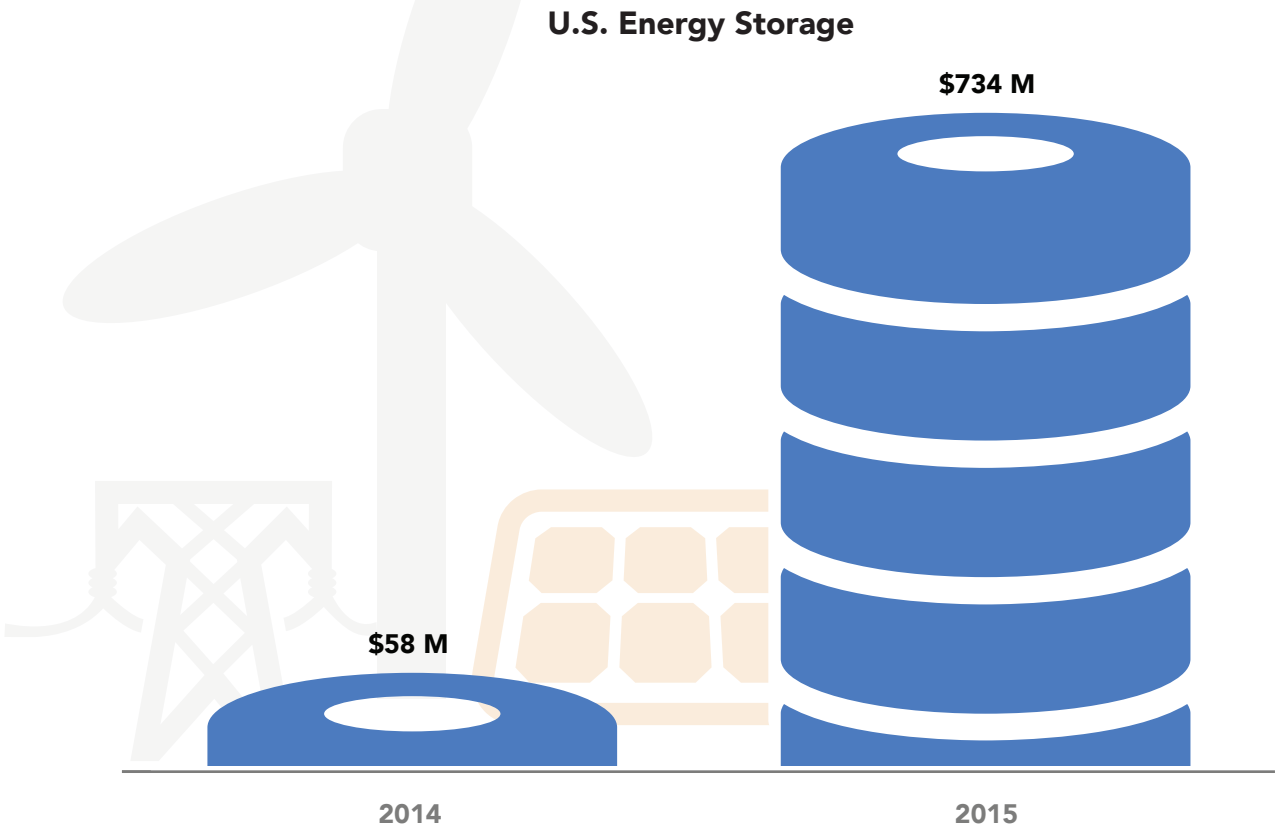


Figure 8.1 (Source: Navigant Research)

Lower prices for advanced batteries and a flood of new systems integrators are opening up new use cases and geographic markets for energy storage systems situated on the distribution grid or behind the meter. Tesla's Powerwall, a home battery storage system announced in May, is being marketed as a companion to PV systems as well as a back-up power source. It is being sold to customers by companies including SolarCity, and Vermont utility Green Mountain Power. Tesla claims to have taken enough reservations to account for the entire first years' worth of estimated production. Sungevity, another distributed solar provider, is also offering a solar-plus-storage package in the United States, in partnership with Sonnen, one of Europe's leading home energy storage firms.

According to Navigant Research, new installed energy storage systems for renewable energy integration are expected to grow from 196 MW globally in 2015 to 12.7 GW in 2025.

Several countries are forecast to see substantial growth in energy storage deployments in the coming decade. The two leading countries, the United States and China, are expected to have a balanced mix of utility-scale and distributed storage installations. Annual deployments of utility-scale energy storage in the United States are expected to increase from 184 MW in 2015 to 4.2 GW in 2025, and from 89 MW in 2015 to 2.6 GW of distributed systems. Even larger growth rates are expected for China, where annual utility-scale deployments are forecast to grow from 97 MW in 2015 to 5.5 GW in 2025, and from 60 MW in 2015 to 3.6 GW of distributed systems.

Growth in the U.S. to date has been led by California where market trends and legislative actions have combined to create a rapidly growing market for both distributed and utility-scale energy storage. In 2010, the state passed AB 2514 – the country's first energy storage mandate – requiring utilities to procure 1.3 GW of energy storage by 2020, of which 875 MW must be distribution grid-connected or customer-sited storage. Southern California Edison (SCE) was the first utility to procure energy storage under these requirements and announced contracts for 261 MW of new energy storage capacity, five times the amount required under the new state law. SCE's contracts for energy storage included a 100 MW battery system from AES Energy Storage and a 26 MW thermal energy storage system from Ice Energy.

Many of the energy storage projects procured to meet California's energy storage requirements will be installed over the next five years, and additional procurements from utilities will continue. In 2015 the state passed SB 350, modifying the state's RPS to require utilities to generate 50% of their electricity from renewable sources by 2030. More energy storage projects are expected to come online in order to help integrate variable renewable generation.

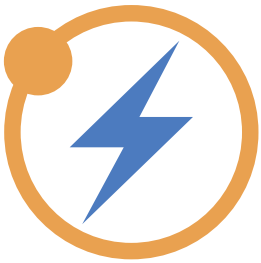
The majority of the market for advanced energy storage comes from battery technologies, which have seen significant reductions in price along with improvements in capabilities and functionality in the last two years. An average utility-scale Li-ion energy storage system, which could be installed for around $1,500/kWh in 2014 are now being built for under $1,000/kWh. Li-ion batteries have undergone technological advancements in recent years. But cost and operational life continue to present an obstacle to deploying Li-ion storage at utility-scale. New advancements in liquid metal batteries, pioneered by Ambri, are designed to help solve the problem of cost-effective, utility-scale battery storage. Ambri's liquid metal battery is made from abundant materials, is designed to handle high voltage, and made to last for significantly longer than most Li-ion batteries. If successfully commercialized, Ambri's batteries could also be made at a fraction of the cost of Li-ion batteries.

But batteries aren't everything that's hot in energy storage. Other interesting developments include advances in modular thermal energy storage from companies such as Ice Energy and Calmac. Their technologies are used to reduce the energy demand from air conditioners by freezing water at night to provide cooling during daytime peaks. Significant advances have been made in flywheel technology in recent years by companies including Amber Kinetics, Temporal Power, and Beacon Power. New flywheel systems now allow energy to be stored for up to four hours. This technology has the advantage of a longer lifecycle with potentially lower operating costs compared to batteries.

While battery and other hardware improvements will continue, much of the industry's focus is now on innovation in software and energy management controls. Many leading storage system integrators such as, Greensmith, Invenergy, RES Americas, AES Energy Storage, Stem, and Younicos offer proprietary software and controls that are designed to maximize the value of a system by providing multiple services to the grid or end-users, thereby capturing the maximum possible revenue.

Energy storage enabling technology – including power conversion (primarily focused on inverters), system-level software and controls, and systems integration services – is a portion of the energy storage value chain getting

intensive attention. While battery prices have fallen 40% to 60% in the past 18 months, thanks to manufacturing innovations and volumes, energy storage systems overall still vary wildly in terms of price. Now that battery prices have started to come down, the balance of plant—or the enabling technology portion of overall cost—needs to deliver on pricing. Once this happens, the industry will scale further and faster.



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