ADVANCED ENERGY ECONOMY

ADVANCED ENERGY NOW

2017 Market Report

Global and U.S. Market Revenue 2011-16 and
Key Trends in Advanced Energy Growth

Prepared by Navigant Research

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.

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 2017 Market Report is our fifth annual report on the size, growth, and trends in the advanced energy market, globally and in the United States. It traces the growth of our industry since publication of *Economic Impacts of Advanced Energy* in 2013. Beginning with that report, Navigant Research has been tracking global and U.S. revenue for AEE, with 2011 as the baseline.

This year's edition shows global growth of 7% from 2015 to 2016, nearly twice the rate of the world economy overall. In the United States, advanced energy saw strong growth in power generation and building efficiency technologies, but a big decline in revenue from ethanol, for the second year in a row, resulting in overall growth of 1%. Not counting ethanol, U.S. revenue was up 5% last year – three times the rate of U.S. GDP.

In 2016, 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, equal to 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, equal to pharmaceutical manufacturing, and nearly as big as the wholesale market for consumer electronics.

The advanced energy industry is also a major employer, supporting more than 3 million U.S. jobs. That's equal to the employment provided by retail stores, and twice the jobs in building construction. Meeting energy needs in new and better ways, contributing to a growing economy, and creating jobs – that is what advanced energy means to America.

A transformation is happening 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

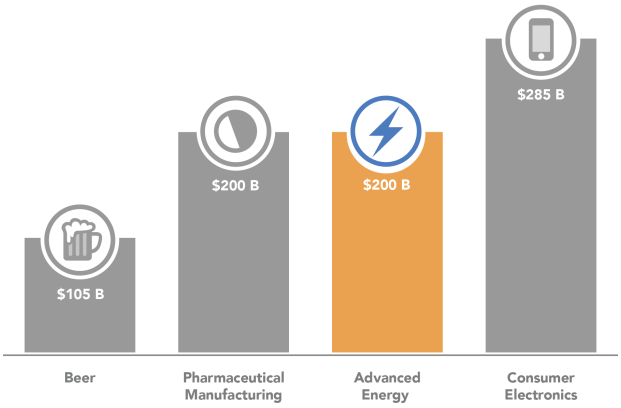
CEO, Advanced Energy Economy

HIGHLIGHTS: ADVANCED ENERGY IS BIGGER THAN EVER

Advanced energy is a $1.4 trillion global industry, almost twice the size of the global airline industry, and nearly equal to worldwide apparel revenue.

The U.S. advanced energy industry generates $200 billion in revenue, nearly double beer sales, equal to pharmaceutical manufacturing, and approaching wholesale consumer electronics.

U.S. Revenue by Industry, 2016



Navigant Research

In the six years that AEE has been tracking, advanced energy in the United States has grown by an average of 5% annually for a total of 28% compared to 2011. Growth last year was 1%, primarily due to the effect of low oil and corn feedstock prices on ethanol revenue. **Without ethanol, U.S. advanced energy grew 5% in 2016, three times faster than U.S. GDP (1.6%).**

WHAT IS ADVANCED ENERGY?

$1.4 TRILLION

global industry revenue

$200 BILLION

U.S. industry revenue

3.3 MILLION

U.S. advanced energy jobs

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. Prepared by Navigant Research, *Advanced Energy Now 2017 Market Report* is the fifth annual report of market size, by revenue, of the advanced energy industry worldwide and in the United States. The industry is broken into seven segments:

- **BUILDING EFFICIENCY**
- **ELECTRICITY DELIVERY & MANAGEMENT**
- **ADVANCED TRANSPORTATION**
- **ADVANCED FUEL PRODUCTION**
- **ADVANCED INDUSTRY**
- **ADVANCED FUEL DELIVERY**
- **ADVANCED ELECTRICITY GENERATION**

2016 U.S. NOTABLE GROWTH

REVENUE GROWTH

$5 BILLION

in building efficiency

$3.9 BILLION

in advanced electricity generation

PERCENTAGE GROWTH

48%

in electric vehicles

54%

in energy storage

30%

in solar PV

21%

in fuel cell generators

U.S. Advanced Electricity Generation was up 8% in revenue, or $3.9 billion, **led by solar PV, which capped off five years of growth with a 30% surge**, to $24.9 billion in 2016. U.S. Wind revenue held relatively steady at $14.1 billion – a welcome change from the boom-and-bust pattern from earlier in the decade. Sales of fuel cells for onsite power jumped 21% to $373 million.

Overall U.S. Building Efficiency products and services grew 8%, or $5 billion, **led by energy efficient lighting and commercial building retrofits, both up 7%** reaching $26.4 billion and $8.4 billion, respectively.

In U.S. Transportation, **Plug-in Electric Vehicle (PEV) revenue has grown tenfold over five years**, from $700 million in 2011 to $7.8 billion in 2016, and 48% over 2015, as all-electric alternatives to gasoline-powered vehicles caught on in the marketplace. Under pressure from low gasoline prices, however, hybrid electric vehicles saw revenue fall for the third straight year, dropping 11% to $8.9 billion. If this trend continues, revenue from PEVs may surge past hybrid vehicles in 2017. **Energy storage** also had another big year, with **revenue jumping 54% to $427 million in the U.S.**

Under price pressure from low prices of both oil and corn stock, revenue from ethanol fuel fell by nearly $7 billion, or 24%, to $20.6 billion despite steady production levels. For the second year in a row, declines in ethanol revenue counter-balanced nearly all the growth in other advanced energy market segments. Revenue from ethanol has dropped by half from its 2012 peak of $40 billion.

TABLE OF CONTENTS

INTRODUCTION

The *Advanced Energy Now 2017 Market Report* is the fifth 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 to the right.

ENERGY SUPPLY

Advanced Electricity Generation

- Hydropower
- Gas turbines
- Solar
- Wind
- Geothermal
- Marine
- Waste
- Biomass
- Nuclear
- Other DG

Electricity Delivery & Management

- Transmission
- Distribution
- AMI
- Microgrids
- EV Charging Infrastructure
- Energy Storage
- Enabling IT

Advanced Fuel Production

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

Advanced 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
- Demand Response

Advanced Transportation

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

Advanced Industry

- Manufacturing Machinery & Process Equipment
- Industrial CHP

METHODOLOGY

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 2017 Market Report* contains final annual revenue from 2011 to 2015 and estimated revenue for 2016 to provide both a snapshot of market size at the present time and growth trends over the past six years.

Advanced Energy Now 2017 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 2017 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 Advanced Electricity Generation segment. Sales of advanced fuels such as ethanol and biodiesel, however, are included in the Advanced Fuel Production segment.
- In some product categories, such as Hydropower, Nuclear, and Gas Turbines, projects can take between two and 10 years to complete, making tracking of annual capital investment difficult. For this analysis, the full total installed plant cost was assigned to the year in which orders were placed for the main components (e.g., turbines, reactor, generator equipment).
- Operations and maintenance revenue is not included, nor is refurbishment revenue, which can be substantial for certain subsegments.
- U.S. market revenue counts only domestic sales of advanced energy products and services and does not include revenue from exports,

understating the economic scope of the U.S. advanced energy industry.

It should also be noted that Navigant Research has utilized strict definitions within product categories, in order to distinguish advanced energy from conventional energy products. For instance, in the Building Efficiency segment, not all HVAC installations are counted, only HVAC installations associated with energy-specific commercial retrofits, new HVAC systems that exceed local code compliance, ground-source heat pumps, and systems deployed in high-efficiency homes. The parameters for advanced water heating are even more restrictive: This category includes only residential water heating as specifically used in high-efficiency homes. For more detailed information on individual subsegments and product categories, see *Economic Impacts of Advanced Energy*. 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 2017 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 2017 edition, so 2014, 2015, and 2016 estimated revenue are directly comparable for all segments and sub-segments.

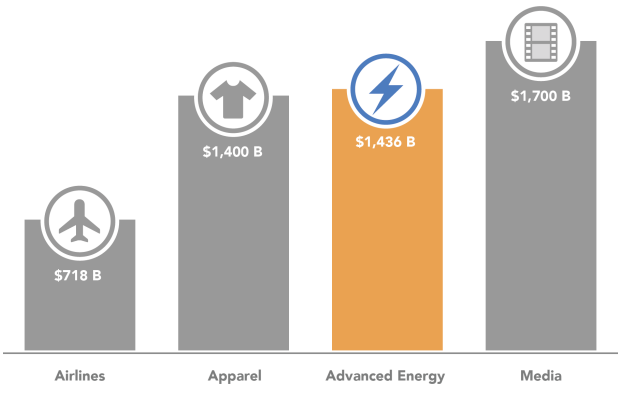
OVERVIEW & SUMMARY FINDINGS

For 2016, the global advanced energy market surpassed $1.4 trillion in 2016, a 7% increase compared to an updated 2015 total of $1.3 trillion. Advanced energy has grown by nearly a quarter (24%) since Navigant Research began tracking for AEE in 2011, adding $257.7 billion in revenue over six years, counting only data complete for the entire period.

Global advanced energy is almost twice the size of the global airline industry, and nearly equal to worldwide apparel revenue.

Almost all of the seven advanced energy market segments experienced year-on-year growth between 2015 and 2016, with only Fuel Production experiencing an annual decline (down 3%), driven by sharp drops in ethanol revenue because of low oil, gasoline, and corn feedstock prices.

Global Revenue by Industry



Navigant Research

GLOBAL ADVANCED ENERGY MARKET

$455.6 BILLION
advanced electricity generation

$447 BILLION
advanced transportation

$271.6 BILLION
building efficiency

$118.1 BILLION
advanced fuel production

$99.1 BILLION
electricity delivery and management

$8.3 BILLION
advanced industry

$953 MILLION
advanced fuel delivery

Electricity Generation remained the largest advanced energy segment globally, with $455.6 billion in revenue (up 5% over 2015). Transportation, the second largest advanced energy segment globally, experienced 8% growth over last year and reached $447 billion. At 15%, Building Efficiency capped a fifth straight year of double-digit growth with a record increase, reaching $271.6 billion in revenue in 2016.

Global Advanced Energy Revenue (million $)

Subsegment	2011	2012	2013	2014	2015	2016 estimate
Advanced Transportation	325,914	315,865	343,577	365,095	413,486	446,989
Advanced Fuel Production	110,667	138,644	141,855	148,062	121,926	118,086
Advanced Fuel Delivery	2,207	1,926	2,606	2,718	900	953
Building Efficiency	118,055	133,839	147,339	208,228	236,494	271,588
Advanced Industry	4,202	5,452	6,733	7,186	7,703	8,283
Advanced Electricity Generation	461,729	408,674	333,882	404,428	432,464	455,582
Electricity Delivery and Management	35,410	65,403	51,151	82,198	97,651	99,113
Total	**1,084,558**	**1,097,676**	**1,058,905**	**1,251,556**	**1,346,324**	**1,436,237**

Navigant Research

In the United States, the advanced energy market grew to $199.2 billion, a 1% increase compared to an updated 2015 total of $197 billion. U.S. advanced energy is nearly double beer sales, equal to pharmaceutical manufacturing, and approaching wholesale consumer electronics.

Growth in the United States was dampened by a sharp drop in Ethanol revenue driven by low oil, gasoline, and corn feedstock prices. At $20.5 billion, Ethanol revenue represents 10% of the U.S. advanced energy total, so the drop creates a noticeable impact on the overall market. **Without ethanol, U.S. advanced energy grew 5% in 2016, three times faster than U.S. GDP (1.6%).**

U.S. advanced energy has grown by over a quarter (28%) since AEE began tracking in 2011, for an average of 5% annually. This represents an addition of $39.6 billion in revenue over six years, counting only segments with data for the entire period, and outpacing the global market growth during that time.

At $68.8 billion, Building Efficiency is the largest advanced energy segment in the United States, in contrast to the global market, which is led by Advanced Electricity Generation. At 8% over 2015, Building Efficiency experienced the second largest year-on-year growth of all the U.S. segments, and was led by the Lighting, HVAC, and Building Envelope categories.

Since Navigant Research began tracking, the Building Efficiency segment has grown steadily at an average of about 10% annually, adding an average $4.5 billion in new revenue each year. Several product categories in this segment have more than doubled in size over the six years covered in this report, including Home Energy Management Systems, Intelligent Lighting Controls, Residential Demand Response, and Building Information Modeling.

Advanced Electricity Generation was the second largest advanced energy segment in the United States, at $52.2 billion in 2016, and experienced 8% year-over-year growth. Led by Solar, Wind, and Gas Turbines, this segment represents over a quarter of the U.S. Advanced Energy market. Despite cost declines, Solar PV revenue in 2016 led all the other product categories with $24.9 billion in revenue – a record high for the six years AEE has been tracking. Solar PV revenue was nearly half of the U.S. Advanced Electricity Generation segment total. Wind, a product category that has seen cyclical swings over the past six years, held roughly steady at $14.1 billion in 2016. Gas Turbines were down to $9.2 billion, a fall of 12% over 2015.

Fuel Production remained the third largest advanced energy segment, with $28.9 billion in revenue, but continued its two-year decline, down nearly 19% in 2016. Ethanol revenue, which makes up most of the Fuel Production segment, is a substantial portion of the U.S. advanced energy total. The price of ethanol is heavily influenced by oil, gasoline, and corn feedstock prices, all of which were low in 2016.

U.S. ADVANCED ENERGY MARKET

$68.8 BILLION
building efficiency

$52.2 BILLION
advanced electricity generation

$28.9 BILLION
advanced fuel production

$21.8 BILLION
advanced transportation

$19 BILLION
electricity delivery & management

$8.3 BILLION
advanced industry

$178 MILLION
advanced fuel delivery

U.S. Advanced Energy Revenue (million $)

Subsegment	2011	2012	2013	2014	2015	2016 estimate
Advanced Transportation	11,709	18,045	25,106	24,848	22,933	21,820
Advanced Fuel Production	43,164	47,337	48,390	49,048	35,708	28,944
Advanced Fuel Delivery	227	378	252	283	186	178
Building Efficiency	35,319	39,314	43,781	57,746	63,736	68,826
Advanced Industry	4,202	5,452	6,733	7,186	7,703	8,283
Advanced Electricity Generation	38,813	43,943	30,404	44,537	48,280	52,187
Electricity Delivery and Management	8,055	14,144	10,599	14,636	18,471	18,982
Total	**141,488**	**168,613**	**165,264**	**198,283**	**197,016**	**199,221**

Navigant Research

While most liquid fuel product categories (led by Ethanol) declined, production of natural gas for transportation fuel continued to grow in 2016.

Advanced Transportation was the fourth largest segment with $21.8 billion in 2016 revenue, down 5% due to the continued reduction in Clean Diesel Vehicle and Hybrid sales. Despite this year's setback, over the six years of tracking the Advanced Transportation, it has nearly doubled from a relatively small starting point of $11.7 billion. Plug-in Electric Vehicles (PEVs) continue to surge at 48% growth compared to 2015. At nearly $7.8 billion in revenue, PEVs are beginning to catch up to Hybrids, at $8.9 billion, and if the trend continues could overtake them this year. Likewise, Fuel Cell Vehicles experienced substantial growth. This category saw the second straight year of triple digit annual growth, from $670,000 in 2015 to $6 million in 2016.

Advanced Industry grew 8% over 2015, below the 15% average annual growth over six years. At $8.2 billion in revenue in 2016, this segment has nearly doubled over the six year period. Industrial Combined Heat and Power (CHP) has exhibited especially strong growth, from just over $1 billion in 2011 to $3.5 billion in 2016.

Electricity Delivery and Management, which includes product categories related to smart grid, microgrid, electric vehicle charging infrastructure, and energy storage, increased 3% to $19 billion in revenue in 2016. Growth in this segment was led by Energy Storage (up 54% to $427 million) and Microgrids (up 16% to $2.2 billion).

Fuel Delivery reached $178 million in 2016 (down 4%), continuing its two-year decline. Low oil prices are a major impediment to natural gas vehicle purchases and, to a lesser extent, investment in fueling infrastructure.

The Future is Already Here

In addition to quantifying the 41 advanced energy subsegments (each with multiple product categories) that make up the advanced energy market, this report features 17 trend stories across the seven market segments. These trends can be rolled up into five over-arching trends, which, among others, are shaping the future of advanced energy.

THE RISE OF BIG DATA

The use of software engines and algorithms to process and analyze large quantities of data and provide insights into how customers behave is changing the way companies do business across the economy, and energy is no exception. The **Big Data Drives Demand Side Management Innovation (p.13)** story shows how, in recent years, utilities and energy efficiency providers have used new data tools (home energy reports, web portals, and mobile apps) to unlock cost and energy savings for customers. **Energy Use? Yes, There's an App for That (p. 16)** profiles energy applications that are targeting the $2.3 billion global Residential Home Energy Management Systems market. Meanwhile, amid the digitalization of energy, which has offered up the Internet of Things (IoT), connected devices, smart grid, and even autonomous vehicles to consumers, new challenges have arisen, including cybersecurity, which we discuss in **As the Grid Goes Digital, Cybersecurity Gains Importance (p. 23).**

HARDWARE COST DECLINES

Advanced energy technology deployment continues to exhibit dramatic growth rates, enabled in large part by cost declines in hardware such as solar PV modules (See **Solar PV Sets New Records Nationally and Globally, p. 63)**), LED lighting, and increasingly battery technology – with gigafactories being built around the globe to produce these items at scale. The extreme pace of these cost and commensurate price declines have restrained market revenue growth as outlined in this report. In response to increasing market maturity and tight margins, advanced energy companies in many sectors are undergoing a shift to services, as discussed in the **Lighting as a Service (p. 15)** story. Market consolidation, vertical integration, scaling of manufacturing, and fierce competition will drive further cost reductions in the future.

NEW BUSINESS MODEL INNOVATION

Evolving energy consumer demands and the increasing ability of customers to exercise choice in a variety of ways are also accelerating a shift toward what Navigant Research calls the Energy Cloud. Customers are increasingly focused on engaging in the generation, purchase, and sale of energy (see **Corporate Procurement of Renewable Energy Gets Creative, p. 22**). If appropriately incentivized, they also can provide other

services such as balancing, voltage support, and voluntary load management, address broad industry goals of greater efficiency and resilience (see **New York REV Demo Projects Point Toward 21st Century Electricity System, p. 27**). Meanwhile, a similar transformation is occurring in transportation as **Car Sharing, Electrification, and Automation are Con-verging into a New Mobility System (p.33)** explains.

THE NEXT FRONTIER IS ALREADY HERE

A number of industries have reached tipping points or otherwise hit major milestones in 2016. For example, the first offshore wind project in the United States reached completion off the East Coast (see **Rhode Island Lays Foundation for U.S. Offshore Wind, p. 65**). With a 1,000% increase in revenue since 2011, the PEV market is now eating into the traditional hybrid electric vehicle market in the United States and could surpass it in terms of revenue in 2017 as discussed in **Plug-in Vehicle Options Expand, Stimulating Rapid Growth (p. 35)**. Meanwhile, the power of national policy priorities in China, the United States, and Japan continues to stimulate markets for solar PV, biofuels (see **Biofuels Meet Targets, p. 44**), hydrogen vehicles and infrastructure (**Can Toyota, Honda, and Hyundai Make Hydrogen Work?, p. 45)**, and CHP (**CHP provides Onsite Power Generation for Industrial Customers, and Others, p. 49**).

INFRASTRUCTURE FOR THE FUTURE: REPLACING, RETRO-FITTING, AND DIGITALIZTION

The supply – and pricing – of incumbent fuels and technologies will continue to impact advanced energy market growth in the future. For example, low oil prices affect natural gas vehicle (NGV) sales and infrastructure (see **Natural Gas Fueling Stations Continue Slow Buildout, p.57**). On the other hand, Smart Transmission, Distribution Automation Systems, and Advanced Metering Infrastructure (AMI) Systems are now mainstream, as the digitalization of the electric-mechanical infrastructure moves forward. As a result, the grid will increasingly resemble a more sophisticated – but also resilient and distributed – networked system, as we discuss in **Energy Storage Becomes the Glue for Virtual Power Plants (p. 25)**.

Consistent with previous editions of the *Advanced Energy Now Market Report*, the combination of revenue data, trend stories, and forecasts highlight the broad, innovative, and evolving advanced energy marketplace. During the six years that Navigant Research has tracked the advanced energy market for AEE, this report has highlighted the pivotal role played by the United States in developing new technologies, but also in new business models that have enabled overall market growth, despite the changing landscape. Navigant Research expects this trend to accelerate in the coming years as these technologies and solution offerings continue to scale.

BUILDING EFFICIENCY

$68.8 BILLION

U.S. revenue

8%

annual growth

$271.6 BILLION

global revenue

15%

annual growth

Overview

Averaging nearly 14% annual growth over the last five years, global Building Efficiency continued to be a steady growth segment of the advanced energy industry. **This year, revenue reached $271.6 billion – a nearly $35 billion, or 15% increase over last year.** Growth from the first year AEE started tracking data has been impressive as well. Counting only categories in the segment for which we have data for all six years, Global Building Efficiency revenue nearly doubled. Building Efficiency is the third largest advanced energy segment in the global market. Building Efficiency saw growth in every single product category in both the Global and U.S. markets, an achievement no other segment can claim. (Table 1)

In the global market, Lighting remained the largest subsegment with $124.8 billion in revenue in 2016, up 7% from 2015. Commercial Energy-efficient Lighting, the leading product category in this subsegment, reached an estimated $68.7 billion in 2016, up 11% year-on-year. Heating, Ventilation, and Air Conditioning (HVAC) was the second largest subsegment with $65.8 billion in revenue, up 6% over last year.

The two fastest growing subsegments globally were Building Envelope and Appliances and Electronic Equipment, both of which grew more

Global Building Efficiency Revenue (million $)

Subsegment	2011	2012	2013	2014	2015	2016 estimate
Building Design	11,537	13,039	13,932	15,544	17,457	19,021
Building Envelope	13,017	14,006	15,855	18,668	26,187	44,960
HVAC	44,383	49,613	53,923	57,962	62,337	65,820
District Energy and CCHP	2,229	2,787	3,023	2,950	3,458	3,875
Water Heating	1,467	1,612	1,773	2,090	2,237	2,438
Lighting	41,329	47,212	52,770	103,613	116,498	124,782
Appliances and Electronic Equipment	266	613	800	1,200	1,708	3,018
Demand Response & Enabling IT	3,827	4,957	5,262	6,200	6,612	7,675
Total	**118,055**	**133,839**	**147,339**	**208,228**	**236,494**	**271,588**

Table 1(Navigant Research)

than 70% compared to last year. At 77%, Appliances and Electronic Equipment experienced the largest year-on-year growth, surpassing $3 billion in revenue. With an impressive 72% increase in revenue over last year, Building Envelope was the second fastest growing subsegment, reaching $44.6 billion in revenue. This subsegment was led by Zero Energy Buildings, which grew 272% last year and reached $22.7 billion in revenue. At $7.6 billion in 2016, **Demand Response & Enabling IT experienced double-digit growth of 16% and added over $1 billion in revenue.** While demand response has grown consistently every year since 2011, this is the biggest dollar increase in four years. At 12%, growth in District Energy and Combined Cooling, Heating, and Power (CCHP) was also strong last year. In 2014, the subsegment shrank slightly, from just over $3.0 billion to $2.9 billion. Last year's growth brought revenue to a new high of $3.8 billion, surpassing 2015's record peak of $3.4 billion.

U.S. Building Efficiency Revenue (million $)

Subsegment	2011	2012	2013	2014	2015	2016 estimate
Building Design	2,819	3,128	3,351	3,850	4,336	4,711
Building Envelope	8,720	9,645	11,919	12,766	14,127	14,920
HVAC	10,522	11,532	12,306	13,184	14,140	15,233
District Energy and CCHP	814	925	1,189	850	925	1,055
Water Heating	1,133	1,197	1,357	1,490	1,639	1,711
Lighting	9,139	9,992	10,701	22,024	24,666	26,351
Appliances and Electronic Equipment	105	148	208	227	472	887
Demand Response & Enabling IT	2,068	2,748	2,748	3,356	3,431	3,959
Total	**35,319**	**39,314**	**43,781**	**57,746**	**63,736**	**68,826**

Table 2 (Navigant Research

In the United States, Building Efficiency is the largest advanced energy segment, with $68.8 billion in revenue in 2016, over one third of total U.S. advanced energy market revenue. (Table 2) Since AEE began tracking data in this segment, it has grown steadily by an average of 10% per year. Last year, it grew by 8%. HVAC and Building Envelope were the two largest subsegments after Lighting, with $15.2 billion and $14.9 billion in revenue respectively.

As was the case globally, **U.S. Building Efficiency saw growth in every single subsegment and product category.** With $26.4 billion in revenue in 2016, Lighting remains the largest subsegment and accounts for 38% of total U.S. Building Efficiency revenue. The Lighting subsegment grew 7% last year, slightly slower than the Building Efficiency segment as a whole.

It was the rapid growth of other subsegments that pulled the overall segment growth rate higher. The fastest-growing was Appliances and Electronic Equipment, with 88% year-on-year growth – owed to the single product category of Smart Appliances. (Figure 1) Building Design (up 9%) and Demand Response & Enabling IT (up 15%) also experienced strong growth, with $4.7 billion and $4 billion in revenue respectively.

U.S. Smart Appliances Revenue

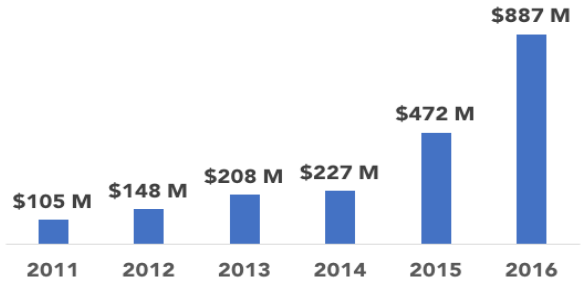


Figure 1(Navigant Research)

Big Data Drives Demand Side Management Innovation

Big data analytics – using software engines and algorithms to process and analyze large quantities of data to provide insights into how customers behave – is changing the way companies do business across the economy, and energy is no exception. For decades, utilities have offered energy efficiency and demand response (DR) programs as means of saving energy for customers and reducing the need for more generating capacity to meet demand. In recent years, utilities and energy efficiency providers have started using big data analytics to provide new insights into how this can be done.

Behavioral demand-side management (DSM) is one application of big data analytics in energy. Using big data analytics, utilities can offer Behavioral DSM platforms to customers through home energy reports, web portals, and mobile apps. Customers receive personalized energy consumption information; social and historical comparisons of energy use; targeted recommendations for decreasing consumption; and notifications or alerts for high bills, outages, or DR events. In this way, behavioral DSM programs encourage customers to reduce their energy consumption through changes in their behavior.

Another method to reduce energy use through big data analytics is called analytical DSM, a method that finds opportunities for savings through equipment monitoring, strategic energy management, operator training, and data analytics. While Behavioral DSM generally serves the residential sector, analytical DSM mostly serves commercial and industrial (C&I) and small and medium businesses.

Not only is big data unlocking opportunities to save energy, it is also changing the way that we monitor and evaluate energy savings more broadly. Utilities must typically demonstrate savings to state regulators through an evaluation, measurement, and verification (EM&V) process. Big data is driving this aspect of energy efficiency programs towards "EM&V 2.0" by allowing utilities to estimate the impact of energy efficiency projects in real time, rather than waiting for after-the-fact measurements. The ability to measure the efficacy of energy efficiency in this way enables utilities to target their programs to specific load pockets and avoid costly system upgrades.

U.S. Demand Response and Enabling IT Revenue

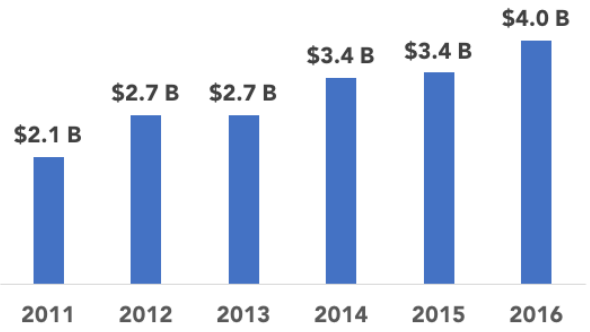


Figure 2 (Navigant Research)

The big data aspect of today's DSM programs is evident in recent acquisitions. The dominant player in behavioral DSM, Opower, was acquired by Oracle in May 2016, where it has become part of the enterprise software and

cloud computing giant's offering to utility customers.

This year, CLEAResult acquired Green Team Energy, an Atlanta-based demand side management software company. Green Team's trademarked DSMTracker, which is a software-as-a-service product, will now be added to CLEAResult's energy efficiency offerings. Retroficiency, one of the leaders in the analytical DSM arena, was acquired by Ecova, in late 2015. This combination brings Retroficiency's analytics into Ecova's broader DSM implementation offering for utilities and businesses.

Although in development for the last decade, behavioral and analytical DSM are relatively new methods for discovering and promoting energy savings. The big data approach they share has the potential to unlock energy savings beyond what traditional utility energy efficiency programs have been able to achieve.

Behind these data-driven DSM offerings are a variety of technical, policy, and economic factors:

- **Higher energy savings targets:** Utility and state-managed DSM programs in the United States have grown rapidly, from $1.1 billion in spending in 2000 to $7.7 billion in 2015. Twenty-four states now have Energy Efficiency Resource Standards (EERS) establishing specific targets that must be met by energy efficiency programs. Many of these states are also ramping up targets, which is driving program administrators to look for ways to identify more and deeper savings through data-driven programs.
- **Cost-effectiveness:** As utilities try to get more savings out of their DSM budgets, behavioral and analytical platforms can be a cost-effective addition to traditional programs. Behavioral platforms can reach more customers for less upfront cost than home-by-home energy audits, and analytical platforms can reduce costs by supplementing onsite energy assessments with analytical audits.
- **Customer engagement and satisfaction:** Communication between utilities and their customers has traditionally been limited to monthly bills and the occasional power outage. Customer surveys have shown that behavioral and analytical DSM services can improve customer satisfaction and engagement.
- **Grid modernization:** Modernizing the grid goes beyond utility infrastructure. It needs to involve a holistic structure for smart grid planning, reliability, and payment. This opens up new opportunities for utilities and third-party vendors to offer innovative customer solutions like behavioral and analytical DSM.

The market for behavioral and analytical DSM has been developing in North America for close to a decade, but it is fairly nascent in the rest of the world. Utilities in Europe and Asia Pacific have shown interest in recent years, and these regions appear poised for growth. Navigant Research estimates that spending on behavioral and analytical DSM will grow

roughly 10 fold over the next eight years reaching an annual market of $2.1 billion globally by 2024. Nevertheless, the majority of spending is expected to take place in North America, primarily in the United States, even as other regions begin to implement data-driven DSM programs of their own.

'Lighting as a Service' Offers New Business Model, Growth Opportunity

The lighting industry is in the midst of two concurrent upheavals. First, light-emitting diode (LED) lighting is gaining market share rapidly over incumbent technologies, and second, lighting controls systems are making it possible to optimize the use of lighting in more sophisticated ways to save energy and money. Everyone from building owners and managers to lighting designers and installers is facing the challenge of this two-pronged transformation. But this transformation is paving the way for a third: the rise of "lighting as a service" (LaaS).

LaaS is defined broadly as the third-party management of lighting systems, which may include additional technical, maintenance, financial, or other services. These offerings can begin with the design and installation of a lighting system, continue through maintenance and management, and even include the recycling or disposal of equipment at the end of its life. Companies have begun to offer combinations of these services as they experiment with how best to meet their customers' needs. These initial efforts represent the beginning of a trend that Navigant Research anticipates will grow rapidly over the next 10 years.

U.S. Energy Efficient and Smart Lighting Revenue

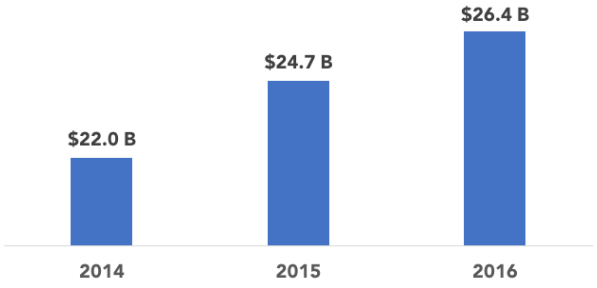


Figure 3 (Navigant Research)

The possibilities for LaaS solutions are wide-ranging, allowing some companies to provide a continuum of offerings, while others simply layer additional services onto the equipment they sell. Current, a start-up within lighting heavyweight GE, is wrapping data and digital solutions around lighting upgrades with optional financing to provide a full suite of LaaS possibilities. Enlighted, a Sunnyvale, California–based startup, has developed a LaaS platform that combines sensors, analytics, and controls. But unlike other LaaS competitors, Enlighted does not use this platform to sell lighting hardware. Rather, the company partners with luminaire manufacturers, facilities management companies, and electrical contractors to create an ecosystem of lighting systems.

Numerous factors are converging to drive the market for LaaS:

- **Looming declines in sales revenue:** LED prices are forecast to continue fall,

while the lifespan of LED lamps will continue to lengthen. Historically, a significant portion of total revenue in the lighting industry is based on the replacement of burned-out lamps. As a growing part of the installed base of lights is replaced with longer-lasting LEDs at falling prices, lighting equipment revenue will begin to decline. Engaging customers in lighting service contracts presents an opportunity for lighting companies to replace repeat sales of bulbs with recurring revenue from LaaS contracts.

- **Technology marching on:** Every aspect of a building's systems has become more complicated, and lighting is no longer an exception. Rather than trying to keep up with the rapid changes in lighting technology themselves, building owners and managers are beginning to turn to third parties to provide these lighting systems for them.
- **Compelling business case:** Advanced lighting controls systems can save significant amounts of energy, but only with optimized operation. Perhaps even more important than direct energy savings, the information gained through a lighting system's sensors can be used to inform space-use decisions and facilities management in a way that can significantly affect a user's bottom line.
- **Building codes:** Updates to California's Title 24, the American Society of Heating, Refrigerating and Air-Conditioning Engineers' (ASHRAE) Standard 90.1 standard, and the International Energy Conservation Code include increasingly strict requirements for lighting control, from occupancy sensing, to daylight usage, to multi-step or continuous dimming. While none of these codes mandate a networked lighting controls system or third-party management, each requires a significant role for lighting controls. Bringing on a third party to provide LaaS and ensure that all building codes are met is an increasingly attractive choice.

Despite these long-term drivers, the LaaS market is currently in its infancy. Global revenue for these services is estimated at just $35.2 million in 2016; most existing projects are pilots and test cases. But as more lighting companies – as well as outside industry players such as IT integrators and facilities management service providers – enter this market, and as companies refine their business models and offerings to entice customers, Navigant Research forecasts that revenue will grow rapidly.

Through 2025, this market is forecast to grow at a compound annual growth rate (CAGR) of 52%, to a total of $1.6 billion in 2025, with North America representing half of that revenue. LaaS is on its way.

Energy Use? Yes, There's an App For That

In a web and mobile application-crazed world, utilities and vendors of energy-related products are finding new ways to engage with customers for energy savings and efficiency.

Customers today want more information, and they want this information at their fingertips. Mobile apps have become the latest means of fulfilling that customer desire, and leading utilities and software vendors have targeted their app development at helping customers manage their energy use.

Global Home Energy Management System Revenue

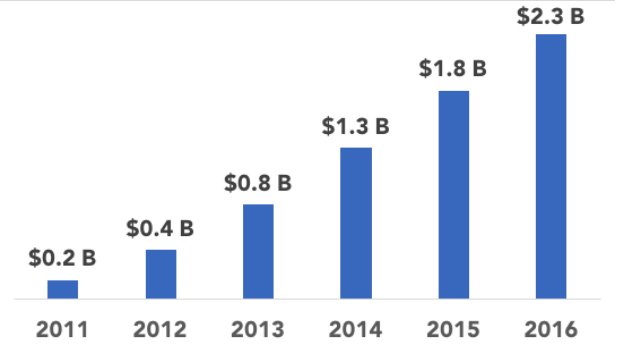


Figure 4 (Navigant Research)

The energy app market is still emerging, but early movers have deployed apps and other related services that provide consumption information and suggest steps that residential customers can take to be more efficient. Some of the apps piggyback on smart home technologies like connected thermostats. The growth of smart meters also plays an important role, generating granular data about consumption that can help customers become more efficient. The effectiveness of these apps varies, with some deployments seeing decreases in consumption of 6% to 8%, while others claim double-digit reductions.

The market for these applications has grown as customers have become increasingly aware of what data can do for them. The global market for Residential Home Energy Management Systems has grown nearly 1300% since 2011, up to $2.3 billion in 2016. (Figure 4) There are several key drivers for broader energy app development and use:

- **Data:** Because smart meters generate data hourly or even more frequently, there is a growing amount of information that can be shared with customers. This granular data can be used to help customers better understand their usage, even predict their monthly bill. The flow of data also helps keep customers engaged, boosting satisfaction.
- **Motivation:** Apps provide motivation to help customers change their behavior. For example, a rewards program offered through an app can spur customers to reduce their usage as part of a utility's energy efficiency efforts. Similar to mail- or web-based behavioral efficiency programs, some apps compare usage with neighbors or with similar-sized homes.
- **Ease:** Apps can make it easy for customers to operate their HVAC systems or take part in efficiency programs that save them money. Energy applications generally fall into four main categories:
- **Billing:** Apps allow customers to view and pay bills electronically, either online or through mobile devices. They also can be designed for sending alerts about potential high bills or prepayment for service.
- **Thermostat control:** The most prevalent smart home apps with web-

connected thermostats that let customers set or adjust temperatures for heating or cooling systems. Other smart home apps, such as lighting and appliance control, do exist, but are not as common.

- **Energy efficiency and demand response (DR):** Apps can provide links to EE programs or alerts about DR events and let customers know how they can save energy and money.
- **Customer engagement:** Apps are used for communicating information about current or projected energy use, tips to reduce consumption and lower bills, and as a tool to collect feedback from customers to improve operations. Apps are useful for two-way communication with customers during outages, both for collecting data on how customers are experiencing the outage and for sending customers timely updates on restoration efforts.

Direct Energy, an energy retailer with about 5 million customers in the United States and Canada, partnered with Grid4C, a software vendor specializing in predictive analytics, to deploy an innovative set of applications to approximately 300,000 customers in Texas. Through these online apps, the energy retailer presents interval meter data all the way down to major appliances, sending alerts when there might be an issue, and offering predictive energy consumption information for the coming week. Deployed in the spring of 2015, early results have been encouraging, as company officials say they have received three times the customer feedback they were expecting and, overall, the response has been positive.

Startups are also getting involved in the energy app space. Eyedro, a software and electronics design company based in Ontario, Canada, offers an electricity monitor that provides real-time data via a web portal and mobile app called MyEyedro. Toronto-based Wattsly, a personalized "energy butler" mobile app, offers a tagging feature that allows users to tap a point on their energy usage Smart Graph and tag activities (e.g. laundry), which helps the app generate advice for further savings, as well as allowing homeowners to challenge themselves to be more efficient to capture further savings. People Power, based in Redwood City, California, created Fabrux & Influx, a cloud server and customizable app framework for weaving together incompatible platforms and protocols to make managing appliances easier – the energy equivalent of a universal remote.

Much of the discussion about the energy future for residential customers focuses on hardware like smart meters and smart thermostats as well as distributed energy resources like solar PV panels. But the next step will be using software and applications to bind these pieces together to create an efficient, easy to use, and automated home energy management system. With the coming app revolution, customers will have greater choice and control over their electricity usage and spending than ever before.

ELECTRICITY DELIVERY & MANAGEMENT

$19 BILLION

U.S. revenue

3%

annual growth

$99.1 BILLION

global revenue

1%

annual growth

Overview

Electricity Delivery and Management was the fifth largest advanced energy segment in 2016 with $99.1 billion in global revenue. (Table 3) This total represents modest (1%) growth over last year but a nearly 11% compound annual growth rate (CAGR) compared to 2012, when Navigant added smart street lighting to its market tracking for AEE. The growth in this segment reflects a move towards power grids becoming cleaner, smarter, and more flexible.

Enabling Information and Communication Technology (ICT) was the largest subsegment, at $36.4 billion (up 11% over 2015). Enabling ICT barely edged out Transmission, which had revenue of $36.1 billion (down 12%) in 2016.

Global Electricity Delivery and Management Revenue (million $)

Subsegment	2011	2012	2013	2014	2015	2016 estimate
Transmission	9,808	17,894	6,110	29,288	41,242	36,110
Distribution	5,998	7,383	3,404	8,459	9,186	7,552
AMI	6,273	6,514	5,805	5,835	7,654	10,054
Microgrids	3,737	4,400	5,479	7,087	5,284	6,835
Charging Infrastructure	127	355	417	480	511	864
Energy Storage	117	791	646	462	889	1,289
Enabling ICT	9,351	28,066	29,289	30,588	32,884	36,410
Total	**35,410**	**65,403**	**51,151**	**82,198**	**97,651**	**99,113**

Table 3 (Navigant Research)

Whereas Transmission revenue tends to be cyclical, due to a relatively small number of big projects, **Enabling ICT has consistently grown by 4% or more since 2011.** The integration of these technologies into the operation of the power grid is a trend that is not likely to go away.

AMI, another subsegment that has seen cyclical growth over the last five years, **grew 31% to a new peak of $10.1 billion globally in 2016**, making it the third largest subsegment. (Figure 5) Meanwhile, Distribution fell 18% to $7.6 billion. With strong growth in Remote Microgrids and General Microgrids, the Microgrids sub-segment improved 29% year-on-year with $6.8 billion in revenue. The largest regional market for microgrids today is Asia Pacific, followed by North America, which Navigant Research expects to be the leading markets through 2024.

The most impressive growth in this segment came from two technology subsegments: Energy Storage and Charging Infrastructure. **Energy Storage grew 45% over 2015 to reach $1.3 billion in revenue**, continuing a big growth trajectory after a dip in global revenue that ended in 2014. Charging Infrastructure for PEVs meanwhile grew 69% over 2015, continuing five years of significant growth to reach $864 million, a sevenfold increase compared to 2011.

Global AMI Revenue

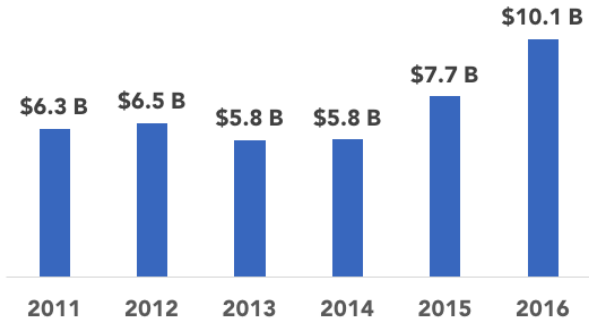


Figure 5 (Navigant Research)

U.S. Electricity Delivery and Management revenue comprises one fifth of the global total, with an estimated $19 billion in 2016, up 3% year-over-year. (Table 4) The two biggest subsegments are Transmission, with $6.8 billion (down 6% compared to last year), and Enabling ICT, with $7.2 billion (up 13%). Though Transmission revenue was down from 2015, it was still nearly double 2014 ($3.6 billion) and five times 2011 ($1.1 billion). Transmission revenues are likely to stay high going forward given that many transmission assets in the United States are approaching the end of their useful lives and in need of upgrade. Additionally, the massive deployment of utility-scale renewables has led to continued investment in transmission infrastructure in high-penetration wind regions such as Texas, California, and the Midwest.

U.S. Electricity Delivery and Management Revenue (million $)

Subsegment	2011	2012	2013	2014	2015	2016 estimate
Transmission	1,147	2,133	576	3,357	7,219	6,812
Distribution	1,064	1,322	250	1,621	1,481	1,295
AMI	1,648	1,681	1,387	1,193	1,051	861
Microgrids	1,012	1,265	1,623	1,957	1,893	2,196
Charging Infrastructure	27	92	154	157	164	182
Energy Storage	81	360	519	58	277	427
Enabling ICT	3,075	7,291	6,089	6,293	6,386	7,209
Total	**8,055**	**14,144**	**10,599**	**14,636**	**18,471**	**18,982**

Table 4 (Navigant Research)

Distribution, which tends to experience cyclical growth, declined 13% to $1.3 billion in 2016. AMI continued a four-year downward trend from a peak of $1.7 billion in 2012, declining 18% to $861 million. Electric Vehicle Charging Infrastructure also has experienced booming growth over the period, recording the largest increase compared to 2011 (576%) of any subsegment with $182 million in 2016 revenue, following the rapid pace of PEV deployment. (Figure 6)

U.S. Electric Vehicle Charging Infrastructure Revenue

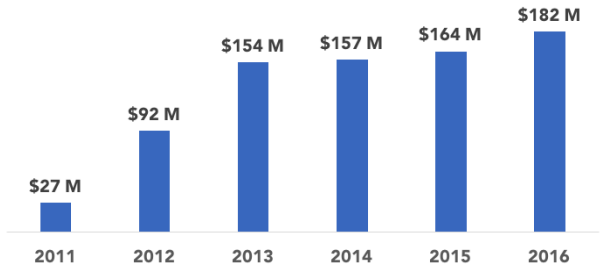


Figure 6 (Navigant Research)

Energy Storage revenue surged by 54% to reach $427 million in 2016. This is a category rapidly transitioning from a large infrastructure market of pumped hydro and underground compressed air projects to a technology-driven market as battery storage grows to scale. With battery price reductions following a similar curve as solar PV modules, energy storage in the U.S. is expected to continue to boom.

Corporate Procurement of Renewable Energy Gets Creative

As a growing number of companies turn to advanced energy to meet their electricity needs, corporate procurement has emerged as a significant driver of deployment. After a record year in 2015, when corporate purchasers and other non-utility buyers signed contracts for more than 3.7 GW of solar and wind power – surpassing utility purchases – corporate pro-curement maintained a steady clip in 2016, reaching 2.5 GW by the end of the year. These numbers do not count onsite generation, another important market segment led by companies like Walmart, Apple, and Coca-Cola.

The growth of corporate advanced energy procurement can be traced back to several underlying trends, most notably the falling price of wind and solar and the rise in corporate renewable energy and sustainability com-mitments. Once the sole domain of leading companies like Google, Microsoft, Amazon, and Walmart, today a variety of energy-intensive industries such as data center users like Salesforce, and manufacturers like Procter & Gamble, as well as government facilities, are setting renewable energy procurement goals. As of 2016, 71 Fortune 100 companies had set sustainability or renewable energy targets, up from 60 two years earlier.

As companies set targets, they are also using new types of transactions to meet them. These range from Renewable Energy Certificate (REC) purchases, participation in utility green pricing programs or renewable energy tariffs, and an assortment of so-called financial, or "virtual," power purchase agreement (PPA) structures. Increasingly, companies are reaching innovative deals with their local utilities. For example, in Virginia, Amazon Web Services (AWS) and Dominion Virginia Power signed a renewable energy delivery deal that allows Dominion to manage and integrate the energy produced from various Amazon wind and solar farm projects onto the grid that serves AWS datacenters. In Wyoming, Microsoft agreed to allow the local utility, Black Hills Energy, to reach behind its meter to make use of its new, onsite backup natural gas generators to meet grid needs. At the same time, Microsoft agreed to purchase RECs from a wind project adjacent to its Cheyenne data center.

Some companies have shown they will go to great lengths to get their energy of choice. MGM Resorts and Wynn Resorts announced they will pay exit fees to NV Energy to allow them to purchase wholesale power on their own, cutting themselves off from the state's largest utility in order to control their energy costs and contract for renewable energy. The

companies expect payback in six or seven years, despite paying fees totaling $100 million to offset the impact of their exit on other ratepayers, as well as $80 million in additional fees to be paid over six years.

Looking ahead, leading companies are doubling down on their commitments. When announcing it had met its goal to source 100% of its electricity from renewable energy, Google set a new, more ambitious target: achieving 100% renewable energy on a real-time basis, not just over the course of the year. At the same time, smaller companies are entering the equation, creating demand for ways to make small purchases at scale.

One recently formed company offering a turnkey solution for corporate customers pursuing sustainability targets is Edison Energy, an unregulated arm of Edison International. Edison Energy assembled several acquisitions to offer a combination of renewable energy procurement, energy efficiency services, and distributed renewable generation paired with battery energy storage. In a similar move, Schneider Electric picked up advisory firm Renewable Choice Energy to add renewable procurement to its energy service offerings. We will watch closely as new turnkey offerings and business models emerge from other big players, including GE Current and Duke Energy Renewables.

As the Grid Goes Digital, Cybersecurity Gains Importance

Nearly $3 trillion has been invested globally in grid modernization since 2000. According to the International Energy Agency, another $8 trillion will be required over the next 25 years to accommodate emerging areas like distributed intelligence and data analytics. These investments will help boost reliability and resilience while reducing operating costs. Amid the digitalization of energy, offering up the IoT, connected devices, smart grid, and even autonomous vehicles to consumers, new challenges, such as cybersecurity, arise.

The U.S. Department of Energy's (DOE) second Quadrennial Energy Review, published in January, describes the economic and resiliency benefits of a modern electrical system – supporting a two-way flow of electrons and information – but also points to the vulnerabilities:

"The range of goods and services that involve grid communications and two-way electricity flows, including the IoT, represents significant value creation and greatly supports and enhances our economy and global competitiveness. At the same time, these goods and services place new demands on the electric grid for high levels of reliability, smarter components, visibility, analytics, and system-wide planning. These features and services also introduce new vulnerabilities to our electricity system (e.g., accelerated time scales sufficient to require significant automation and cybersecurity) that rise to the level of national security concerns."

While the new technologies introduce new vulnerabilities, they also help to reduce old vulnerabilities.

U.S. Smart Grid Revenue

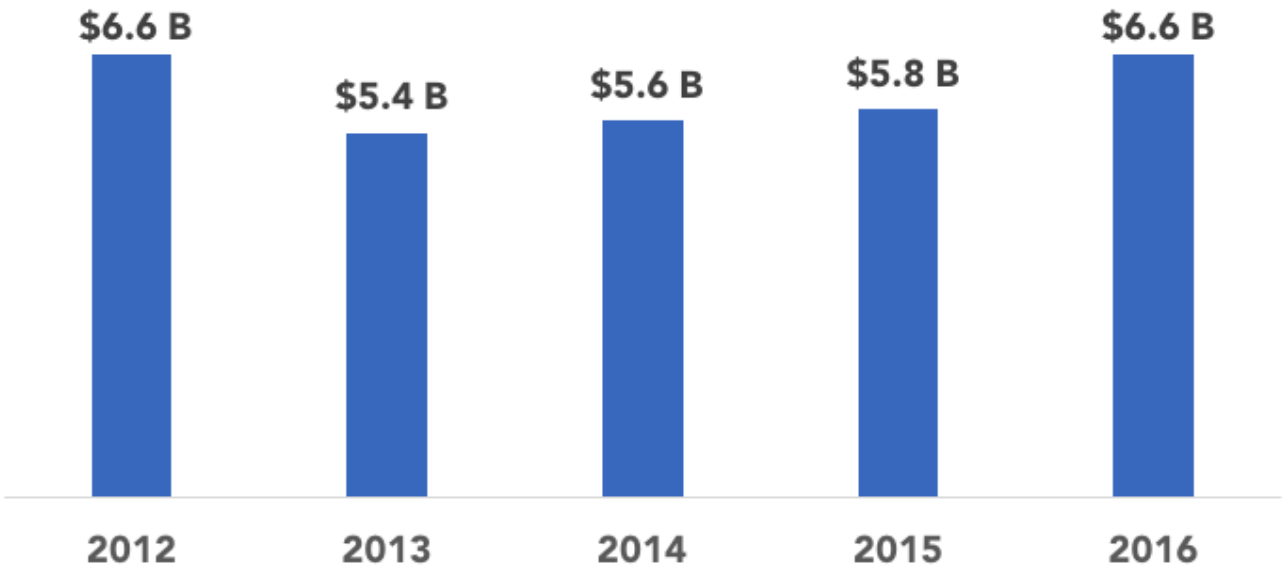


Figure 7 (Navigant Research)

The physical grid faces a host of potential, unanticipated threats to reliability. Weather events ranging from high winds to wildfires to blizzards can all damage the physical infrastructure of the grid. Human beings can also cause damage – inadvertently, through vehicle collisions with poles, or intentionally, through attacks on critical energy infrastructure. Even wildlife like squirrels, lizards, and birds can cause major disruptions in the delivery of power across the transmission or distribution network. Power plants themselves can experience unplanned outages due to fuel shortages or equipment failure. A more distributed, connected grid can significantly improve grid operators' ability to monitor and respond to unanticipated power fluctuations, and reduce operating costs while improving reliability. Utilities used to rely on customers to call in and report power outages. Now, utilities increasingly utilize smart grid technology to notify them instantaneously when an outage occurs. Using the same connected hardware, utilities can anticipate power fluctuations and sometimes even respond by reducing load or re-routing power flows.

That said, it is a growing challenge to protect hardware, software, and data from bad actors looking to do harm. Reports of cyberattacks have ranged from the low level (baby monitors) to smart refrigerators and thermostats (as demonstrated by researchers) to Stuxnet, the malicious 2009-10 cyberattack on an Iranian nuclear facility. A 2015 hack of Ukrainian substations, which left more than 230,000 people without power for hours, is a potent reminder of the risks. Vulnerabilities further expand to the transportation sector, as

modern vehicles are equipped with dozens of networked electronic control units running tens of millions of lines of code.

Over the long-term, the grid of the future holds the promise to use the distribution of assets, intelligence, and redundancy to contain these vulnerabilities by rapidly – even instantaneously - identifying and isolating problems. But in the here and now, the need for stepped-up security measures is apparent to managers at energy companies and utilities around the globe. A Vodafone survey of executives, which gathered responses from people in 17 countries from all the major regions, shows that six in 10 (59%) energy and utility companies are working on IoT security guidelines. Still, that leaves 40% neglecting the digital backdoor into energy facilities.

Protecting modern technology systems from harm is nothing new. Despite disturbing hacks early on, online and mobile banking have become sufficiently secure to protect their customers' accounts and identities. Much the same thing is to be expected in the energy world as it gets connected to an ever-widening range of intelligent devices.

Separate from appliances, the proliferation of distributed energy resources (DERs) has led to a growing effort to standardize security protocols. For instance, the North American Electric Reliability Corp. (NERC) has set mandatory Critical Infrastructure Protection standards for utility assets, including specific standards related to cyber security. Grid operators in places with high penetration of distributed generation also are beginning to address cyber security issues. The California Public Utility Commission, for example, is evaluating cybersecurity functionalities for inverter-based technologies.

The digitalization of the electrical grid is essential for improving safety, recovering from power outages, incorporating distributed energy technologies, and reducing unnecessary energy consumption. Given that absolute security is not possible, some in the industry now suggest that cyber-resilience – much like resilience against threats from storms and other sources of disruption in the physical world – is the appropriate goal.

Energy Storage Becomes the Glue for Virtual Power Plants

Energy markets are evolving toward a greater reliance upon DERs, whether those resources generate, store, or manage the use of electricity. Strategies to harvest more value from smaller, cleaner, and smarter energy resources are being deployed today. One such strategy is a virtual power plant (VPP), which through intelligent aggregation and optimization of DER can provide the same essential services as a traditional 24/7 centralized power plant.

Navigant Research defines a VPP as "a system that relies upon software and a smart grid to remotely and automatically dispatch retail DER services to a distribution or wholesale market via an aggregation and optimization platform." Europe has experience with supply-side VPPs where a portfolio of diverse resources are orchestrated through smart grid technology to provide balancing services that would be provided by a conventional, steel-in-

the ground, 24/7 coal, gas, or nuclear plant. Most of these VPPs are focused on variable renewable sources, though there are supply-side VPPs that aggregate and optimize diesel generation and other fossil assets. While in North America demand response (DR) can be considered a form of VPP, as reduction in demand is substituted for additional generation when called upon by grid operators. But the growing commercialization of energy storage – global revenue grew 45% globally in 2016, to $1.3 billion, and 54% in the United States, to $427 million – increasingly allows for combinations of supply- and demand-side resources working together, with energy storage bridging the gaps between them. (Figure 8) These multi-dimensional VPPs promise the maximum benefit of their component advanced energy technologies – and have become realities in places like California, Hawaii, New York, Austria, Australia, and Ontario.

U.S. Energy Storage Revenue

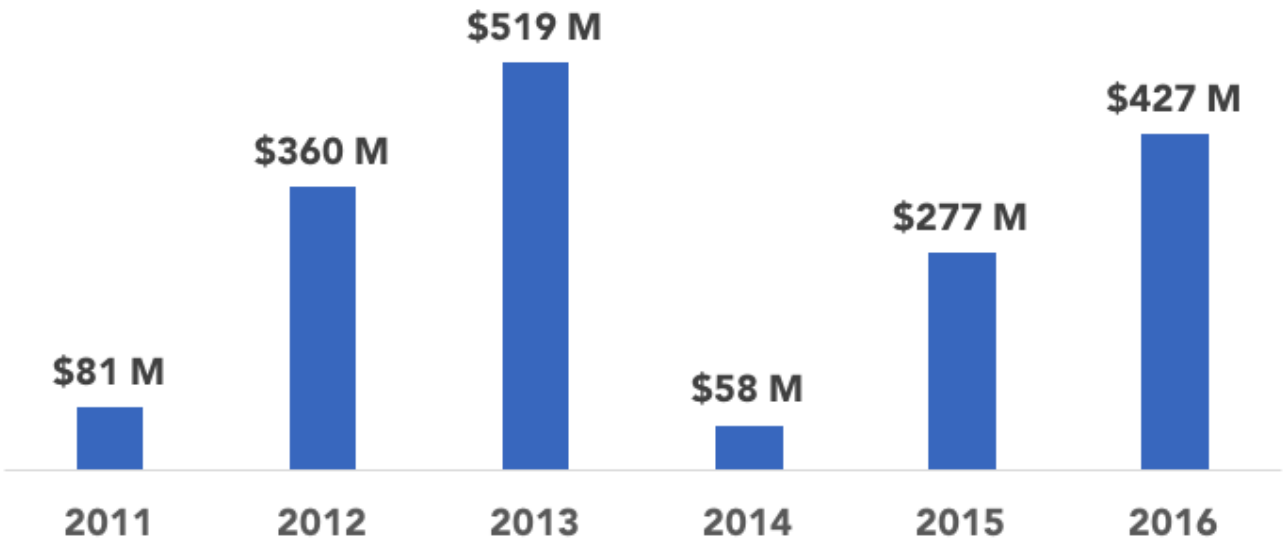


Figure 8 (Navigant Research)

Energy storage is not a prerequisite to the creation of a VPP, but it acts like the glue that enhances the flexibility and the underlying value of other generation and load assets assembled in the VPP portfolio. The reason storage is so critical to flexibility is the speed of response time on shifting load up and down. Rather than merely providing a buffer to optimize DER, storage becomes a critical component of service delivery by providing, for example, bulk storage and load leveling services designed to reduce transmission and distribution losses.

Stem, an energy storage vendor with a portfolio of 580 sites representing 100 MWh of capacity and 70 MWhs of stored energy, is

involved in two projects with Hawaiian Electric that combine to act as a VPP. The company delivered a 1 MW mixed-asset VPP designed to demonstrate the reliability and scaling potential of software-driven storage to provide grid stability and efficiency that will help Hawaii reach its goal of 100% renewable energy by 2045. Working in partnership with Hawaiian Electric, 29 commercial and institutional customers across the island of Oahu will rely on Stem's behind-the-meter energy storage software and power monitors to manage their energy use against predictive load needs and utility tariff data to boost efficiency and control loads. Stem aggregates these storage devices and makes excess capacity available to Hawaiian Electric grid operators, with responses in real times. Stem collects and transmits that cloud-based data along with the data from 300 other locations with data-only capability to Hawaiian Electric to integrate into their renewable energy monitoring forecasting.

Ultimately, energy storage-enabled VPPs let a utility add the capacity of a power plant to its system without investing in a new physical plant. The capital costs are shared with end users and the benefits are accrued by both the end customer and the utility. VPPs can stretch supplies from existing generators and utility demand reduction programs (and other forms of DER). According to Navigant Research, global spending on energy storage devices for VPPs will reach $12 billion annually by 2025.

Currently, the most prevalent storage technologies for VPP-based ancillary services are lithium-ion batteries and flywheels. The most versatile of storage technologies utilized in VPPs today are Li-ion batteries, which are capable of delivering support services at the centralized grid, substation, and generation levels. Li-ion batteries can also be deployed for community energy storage – a new application directly affecting both VPPs and microgrids – and be installed to firm up large-scale and distributed variable renewable resources. Flywheels are less versatile, but have extremely long lifespans (i.e., the number of times they can be charged and discharged before the unit breaks down) and can provide grid regulation services instantaneously.

Manufacture of storage-sized Li-ion batteries has long been dominated by Asian companies, but the United States made its mark in late 2016 with the arrival of one of the world's largest factories. Tesla Motors, which added powerful energy storage systems to its suite of energy solutions in 2015, recently started production in a Nevada-based Gigafactory. The massive production facility, located just outside of Reno, makes batteries for Tesla's energy storage arm in addition to batteries for the company's much-anticipated Model 3 electric car. At this facility, Tesla expects to double the world's production of Li-ion batteries, according to Bloomberg News – providing a lot "glue" for the world's VPPs.

Energy storage-enabled VPPs pose significant potential for integrating supply and demand side resources, while still enhancing grid service capabilities – without needing to invest in new physical power plants. Indeed, VPPs provide another tool for utilities as the grid becomes more flexible, resilient, and cleaner.

New York REV, Demo Projects Point Toward 21st Century Electricity System

Utilities and electricity regulators in the United States and Europe are facing new electricity market realities: flat load growth, rapid adoption of DERs, emission reduction requirements, and ambitious goals for renewable energy deployment. In Q2 2016 alone, regulators across 42 states took more than 100 different regulatory actions addressing DER adoption, positively or negatively including measures on fixed charges, net metering, solar valuation, third-party ownership, and community solar. New York's Reforming the Energy Vision proceeding (REV), launched in 2014, stands out as an example of a regulatory strategy that promotes more efficient energy use, better integration of renewables and onsite power, and more customer choice.

Specifically, REV is part of a broader push to achieve the following energy goals for New York's electricity system by 2030:

- 40% reduction in energy sector greenhouse gas (GHG) emissions from 1990 levels, ultimately decreasing total carbon emissions 80% by 2050;
- 50% of all electricity generated by renewable energy sources;
- 23% decrease in energy consumption in buildings from 2012 levels.

REV looks to fundamentally reorient the way electric utilities operate and make money. Under REV, regulated utilities will become operators of a Distributed System Platform (DSP), not just delivering power to customers from central power plants but also facilitating transactions between customers and third-party providers of DER products and services. Through this platform, customers large and small will be able to actively participate in electricity markets and connect with a range of service providers that can help them manage their electricity use and generate power themselves.

Under this construct a new valuation framework would allow DERs to compete in the marketplace based on the value of the benefits that they provide. In November 2016, the New York Department of Public Service (DPS) described the process this way:

> The modernization of New York's electric system will involve a variety of products and services that will be developed and transacted through market initiatives. Products, rules, and entrants will develop in the market over time, and markets will value the attributes and capabilities of all types of technologies. As Distributed System Platform capabilities evolve, procurement of DER attributes will develop as well, from a near-term approach based on requests for proposals and load modifying tariffs, toward a more sophisticated auction approach.

The value flowing from the participation of these DERs would be shared by all the participants in the system. As a result, REV is attempting to transform DER from a growing threat to utilities' bottom line to a central

element of the electricity system transformation that aligns interests of utilities, third party service providers, and customers. If successful, New York would set an important precedent for other states.

Although much of the REV vision is still to be realized, 12 demonstration projects have been approved, with the purpose of testing new business models; creating new relationships between utilities, customers, and third-party

NY REV Demonstration Projects

Demo Project	Partners	Objective
CenHub Marketplace	Simple Energy	To build an online marketplace bringing together residential customers with third-party DER providers
Building Efficiency Marketplace	Retroficiency	To build a clean energy marketplace for small commercial customers and identify energy efficiency opportunities
Clean Virtual Power Plant	SunPower and Sunverge	To provide bundled residential solar with storage offerings that can be aggregated and dispatched as a virtual power plant to meet local distribution energy needs
CONnectED Homes Platform	Bridgevine and Opower	To create an online marketplace for residential customers to buy energy efficiency services and products
Buffalo Niagara Medical Campus Distributed System Platform (DSP)	Buffalo Niagara Medical Campus and others	To optimize DERs throughout Buffalo Niagara Medical Campus and test the benefits of a distributed system platform
Fruit Belt Neighborhood Solar	Buffalo Niagara Medical Campus and NYSERDA	To help low-to-moderate-income customers access clean energy and reduce arrears by creating a community rooftop solar program and pairing communications to deliver benefits to electricity system
Resiliency Demonstration in Potsdam	Clarkson University, SUNY Potsdam, and NYSERDA	To work with local customers and DER providers to fund a microgrid to test demand for premium resiliency services
Community Energy Coordination	Taitem Engineering	To aggregate and coordinate local demand for clean energy technologies, provide the greatest system benefits, and lower costs and increase benefits to customer
Flexible Interconnect Capacity Solution	Smarter Grid Solutions	To test a less costly and faster way for customers and third parties to connect large DER to the grid by providing an infrastructure-as-a-service
Residential Customer Marketplace	Simple Energy	To analyze data on an online marketplace engagement platform that helps find energy products and services to meet customers' needs
Energy Marketplace	Simple Energy	To launch an online marketplace to help customers better understand and manage their energy use

Table 5 (Navigant Research)

service providers; and promoting innovation within utilities. These projects are intended to show how new products and services might capture latent value on the grid, and how new business models can monetize and distribute that value across third parties, utilities, and customers. As the demonstration projects roll out, and the DSP begins to take shape, others are expected to follow suit. Table 5 shows approved pilots and what they are testing.

There is a long way to go in REV's remaking of the utility business model for facilitating new customer options, many of which have not yet been imagined. REV has caught the attention of many other utilities facing similar challenges, and as a first-mover in many ways, will undoubtedly face years of refinement. But these dozen demonstration projects signal the start of experimentation about what a truly modern 21st century electricity system can offer. Advanced Transportation.

ADVANCED TRANSPORTATION

$21.8 BILLION

U.S. revenue

-5%

annual growth

$447 BILLION

global revenue

8%

annual growth

Overview

Advanced Transportation remained the second largest advanced energy segment worldwide in 2016, with an estimated $447 billion in revenue, an increase of 8% over 2015. Clean Diesel Vehicles are the largest source of revenue globally, with $305.8 billion in revenue, or about two-thirds of the global Transportation total. With 6% growth over last year, the global market for Clean Diesel Vehicles appeared largely undeterred by the Volkswagen emission scandal. Hybrids are the second biggest category in this segment, with $57.1 billion in revenue, followed by Light Duty Natural Gas Vehicles (NGVs) with $32 billion.

The most notable shift taking place in this segment is **the rapid growth of PEVs, which reached $30.8 billion in 2016. With 50% year-on-year revenue growth,** PEV sales

appear to be eating into Hybrid sales, which were flat compared to 2015. When Navigant first began tracking data for AEE in 2011, PEV revenue was just over $1.8 billion. Since then, **revenue from PEVs has grown by more than 15 times** and continues to attract new market entrants and new product offerings.

Fuel Cell Vehicles are undergoing similarly rapid growth, albeit from a smaller base, compared to five years ago. In 2016, revenue in this product category was $19.7 million compared to a 2011 starting point of less than $1 million. Electric Bicycles, meanwhile, grew 54% over last year, driven primarily by demand in Asia. Natural Gas Trucks and Buses saw steady growth at 9%, reaching $6.4 billion in 2016, with the United States accounting for roughly 10% of the global market.

In the United States, the shift toward PEVs is even more notable than in the global market. The Hybrid and PEV product categories account for more than three-quarters of the Advanced Transportation segment total, with $8.9 billion and $7.8 billion in 2016 revenue, respectively. PEV revenue grew 48% over last year, while revenue from Hybrids declined by 11%. (Figure 9) **If revenue from PEV sales continues to grow at the same rate, it will eclipse Hybrids by the end of 2017.**

U.S. Hybrid and Plug-in Electric Vehicle Revenue

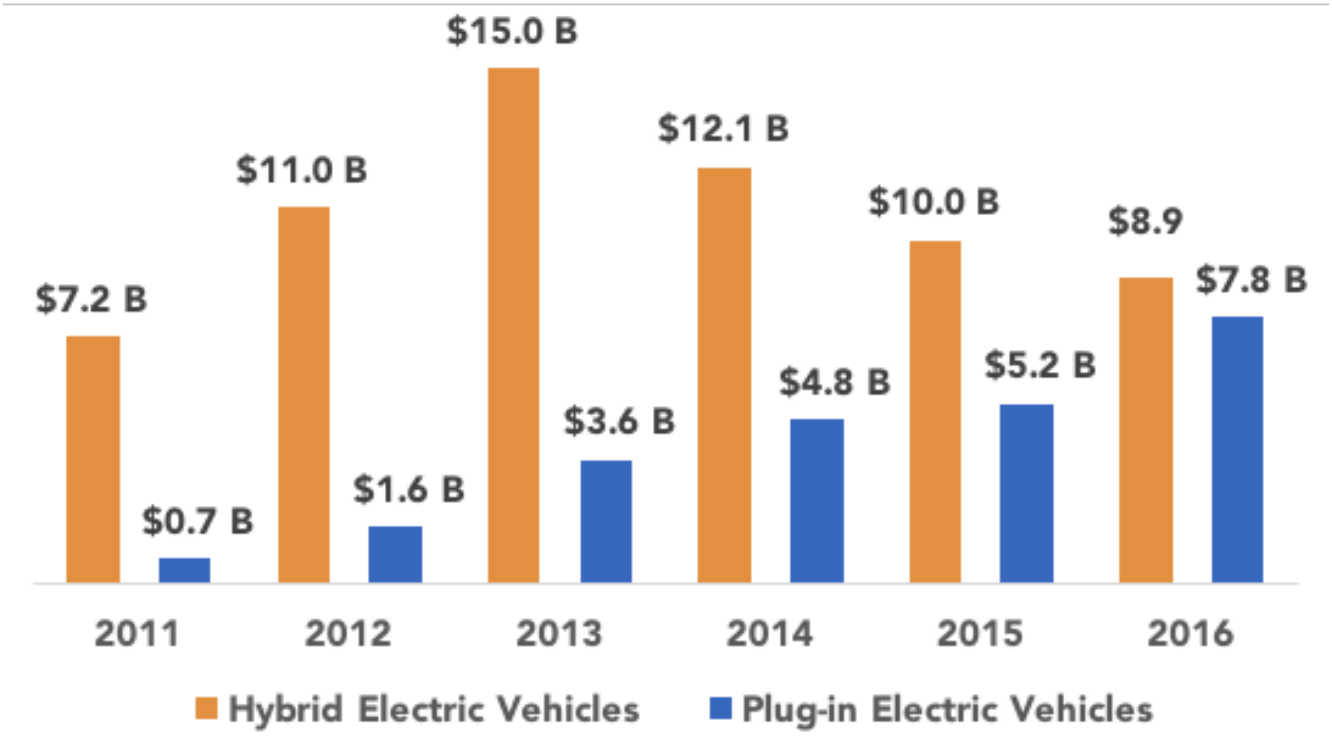


Figure 9 (Navigant Research)

As opposed to the global market, the VW emission scandal appears to have hit the U.S. Clean Diesel market severely. Revenue in this product category suffered a 45% decrease in 2016, returning to 2011 levels of $3.3 billion.

The enormous revenue decline ($2.7 billion from 2015-2016) in Clean Diesels, combined with the decline in Hybrid revenue, brought the overall U.S. Transportation segment total down to $21.8 billion, a decrease of 5%, despite hefty gains in PEV sales.

NGVs saw growth of 2% (to $934 million) in the Light Duty category and 1% (to $631 million) in the Trucks and Buses category. These relatively modest total revenue figures are nonetheless notable considering the combined revenue of these two product categories has nearly doubled in the past five years. Following the global trend, the Fuel Cell Vehicle product category experienced rapid growth (859%) from a small base, reaching an estimated $6 million in 2016. (Figure 10)

U.S. Fuel Cell Vehicle Revenue

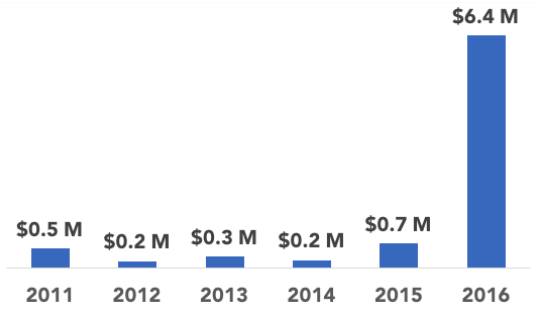


Figure 10 (Navigant Research)

Car sharing, Electrification, and Automation are Converging into a New Mobility System

The personal transportation market is evolving in new ways. In the near future, it is reasonable to expect that car-sharing and ride-hailing will combine with autonomous vehicle technology and connectivity to remake personal transportation. Cars may not fly, but riding from here to there will be on-demand, cleaner, and safer.

Since Uber was founded in 2009, adoption of the company's mobile app-based transportation service has exploded, also inspiring car sharing competitors like Lyft. Now, people in 56 countries and more than 200 cities worldwide are able to "grab an Uber" by tapping the screen on their phones. This year, CNBC reported that there are more Uber cars than yellow cabs on the streets of New York City. With $8.7 billion in equity funding, Uber is accelerating its efforts on EVs and autonomous vehicles, which it sees as central to its business plan. And incumbent vehicle manufacturers are taking notice.

In early 2016, General Motors (GM) invested $500 million in Lyft and offered a program called Lyft Express Drive to rent relatively new cars to drivers on that platform (for $0 to $239/week based on number of rides, plus mileage fees). GM has also teamed up with Uber to offer a similar pilot program for its drivers. In that program, Uber drivers will get vehicles through GM's existing car-sharing

company, Maven, which launched in Germany and the United States in early 2016.

Car-sharing operations are also starting to feature EVs as emissions-free options for riders. Uber has partnered with China-based auto and bus manufacturer BYD to provide electric e6 taxis in Chicago and London. Uber drivers in Chicago have the option to rent the e6 taxis from the Green Wheels USA dealership for $200 a week, and Uber customers will be able to choose an EV through the smartphone app when booking a vehicle. In London, Uber has also partnered with Nissan and BYD to give drivers the option to rent all-electric vehicles, and may expand to hundreds more in anticipation of stricter emission laws in the capital's urban center.

Then there is the dawning of vehicle automation, which is now on the horizon. Traditional auto manufacturers like BMW, GM, and Audi; Tier 1 suppliers such as Delphi, Continental, and Autoliv; new entrants like Tesla; and technology companies such as Google, Baidu, and NVIDIA all want a place in the autonomous driving age. Ride-hailing companies Uber, Lyft, Israel's Gett, and China's Didi Chuxing are similarly interested in automation as a hedge against the cost of human drivers in their network. Long-haul trucking companies are showing interest, for the same reason.

Uber announced that the company would be testing a self-driving pilot program in Pittsburgh last fall, though, according to the company's website, the cars still have a "safety driver" behind the wheel to "make sure the ride goes smoothly." Otto, a company that specializes in self-driving 18-wheelers that was acquired by Uber, helped Anheuser-Busch deliver a 120-mile beer shipment last spring. Meanwhile, in Europe, the European Truck Platooning Challenge saw six companies organize to test long-haul equipment in a robotic caravan following a single human driver.

Fully self-driving cars and trucks won't happen overnight. Indeed, vehicle automation can be broken down into five distinct levels, adopted by the National Highway Traffic Safety Administration (NHTSA):

- Level 0: the human driver does everything;
- Level 1: an automated system on the vehicle can sometimes assist the human driver conduct some parts of the driving task;
- Level 2: an automated system on the vehicle can actually conduct some parts of the driving task, while the human continues to monitor the driving environment and performs the rest of the driving task;
- Level 3: an automated system can both actually conduct some parts of the driving task and monitor the driving environment in some instances, but the human driver must be ready to take back control when the automated system requests;
- Level 4: an automated system can conduct the driving task and monitor the driving environment, and the human need not take back control, but the automated system can operate

only in certain environments and under certain conditions; and

- Level 5: the automated system can perform all driving tasks, under all conditions that a human driver could perform them.

Navigant Research estimates that between 20% and 25% of vehicles in use in the key markets of North America, Western Europe, and Asia Pacific will have full automation (NHTSA Level 4) by 2035.

Vehicle automation promises one other potential benefit: safety. There were more than 32,000 fatal crashes in the United States in 2015, resulting in more than 35,000 deaths. A NHTSA study estimated that the economic cost of vehicle crashes in the United States in 2010 was $242 billion when taking fatalities, injuries, and property damage into account. Adding in quality-of-life values, the total societal cost from auto accidents in 2010 ballooned to $836 billion. While no comprehensive study has yet been performed, The National Highway Safety Administration will increasingly be evaluating the potential for automation to reduce these costs – and save lives.

Point-to-point transportation available on-demand could slash wasted time and improve quality of life in cities and suburbs, while car-sharing and automation would ease congestion, increase efficiency, and reduce the number of personally owned vehicles making one-person trips. Indeed, Navigant Research expects global vehicles in use will likely begin a steady decline in the 2030s, eventually dropping by half or more by mid-century. Just as the mass-produced automobile changed the way people work, live, and play in the 20th century, the new shared mobility system enabled by automation, connectivity, and electrification will change society in the 21st century.

Plug-In Vehicle Options Expand, Stimulating Rapid Growth

The PEV market is now well-established in North America, Europe, and developed Asia Pacific markets. This has largely been a function of strong government support for PEV technologies through fuel efficiency regulations, which stimulate the supply of PEVs, as well as incentives for PEV purchases, which stimulate demand. As a result of the two-pronged approach to PEV market development, the PEV market has grown from around 30,000 vehicles in 2011 to over 500,000 in 2015, and now an estimated 684,000 in 2016. This translates to a six-year compound annual growth rate (CAGR) in unit volume of 87%, and nearly $7.8 billion vehicle sales revenue in 2016.

With the market on a steady foundation, automakers are beginning to develop offerings and technologies that will likely accelerate market acceptance, including improvements in all-electric range, cost, and charging time. Most notably, General Motors (GM), Nissan, and Tesla will soon offer PEVs with ranges of 150 to 250 miles, at cost points below $40,000, which will make them competitive with traditional internal combustion engine vehicles. In line with these

plans, many automakers are strategizing on the development of fast-charging networks for both inter- and intra-city travel.

U.S. Plug-in Electric Vehicle Revenue

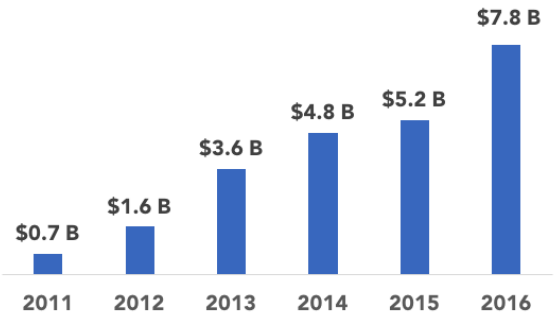


Figure 11 (Navigant Research)

As of the end of 2016, light duty PEVs accounted for about 26% of the global light duty EV market; hybrid electric vehicles, which are included as EVs, account for the remainder. PEVs, which are more expensive than hybrids, generated a larger share of the EV market's near $90 billion 2016 estimation at over 35%. Navigant forecasts that in 2025, light duty PEVs are expected to capture between 70% and 75% of the EV market. The growth of PEV market share will be aided in part by the number and variety of PEV offerings coming to the market over the next several years. It will also be due to the continued drive to reduce carbon emissions and improve vehicle fuel economy in the major developed vehicle markets.

Following a slowdown in 2015, Navigant Research estimates that the North American market grew 38% in 2016 from 2015 levels, nearing 160,000 sales. Last year's sales were buoyed by deployment of the next-generation Chevrolet Volt and Tesla Model X, both of which had their first full year of sales. More automotive giants introduced new PEV models near the end of the year, including the Toyota Prius Prime and the much-anticipated 200+ mile Chevrolet Bolt. Navigant Research expects the introduction of the Tesla Model 3 in late 2017, along with full year sales of the Bolt and Prius Prime, to boost the market between 47% and 60% in 2017. This is a growth pattern Navigant Research sees lasting into 2018: With a full year of Tesla Model 3 sales in 2018, growth is likely to be between 45% and 54%.

After 2018, strong but stable growth is expected, with a CAGR from 2018 to 2025 of nearly 21%. By 2025, Navigant Research anticipates that PEVs in certain small car segments with low ranges will have achieved cost parity with conventional counterparts without subsidies. Achieving this threshold, combined with a growing field of cost competitive long-range PEVs and expansion of public and workplace electric vehicle charging options, provides an indication that market growth is likely to accelerate after 2025.

The PEV market in the United States has been concentrated on the West Coast, with PEV market share in California exceeding 5% in 2016. Hawaii and Washington are likely to maintain the significant market growth both states witnessed over the last five years. Outside of the West Coast, a group of eight states in the Northeast (Maine, Vermont, Massachusetts, Connecticut, Rhode Island, New York, New Jersey, and Maryland) is likely to see sales increase considerably as

automakers respond to state policies, including the adoption of the Zero Emission Vehicle mandate, by encouraging electric vehicle adoption with focused sales and marketing efforts. The deployment of PEVs with 200 miles of range or more and expansion of PEVs outside of small passenger car body type segments are also likely to bring Colorado and Utah, which have favorable demographics and government incentives, to the fore of PEV adoption.

Though Toyota deployed a PEV SUV in California in 2012 and 2013, PEV models have until recently been limited to passenger car body styles. At the end of 2015, new PEV introductions broke out of the passenger car segment with SUVs and crossovers from Tesla, Porsche, BMW, and Volvo. Despite success in European and Asian markets, Mitsubishi delayed the launch of the Outlander PHEV in North America, but the second-generation version of the vehicle may be made available to the U.S. market in 2017, making it the first non-premium SUV PEV. Fiat Chrysler's introduction of the first mass-market plug-in hybrid minivan anticipated for February 2017 is another breakthrough in model type; 2017 is likely to see increased variety of electric vehicles, but market attention will be focused on sales performance of the Chevy Bolt and Tesla's initial fulfillment of over 370,000 pre-orders, with deposit, for the Model 3.

Future of Clean Diesel is Uncertain in the Face of Electric Vehicles

Because diesel engines are more fuel efficient than gasoline engines, diesel has become a popular automotive alternative, especially in markets where gasoline prices are higher than or equal to diesel prices, most notably in Europe and India. The traditional challenge with diesel engines is that they are more polluting than gasoline engines, but auto (and truck) makers have made great strides toward reducing the emissions of these fuel-efficient vehicles, giving rise to the term "clean diesel." Navigant Research considers diesel vehicles that meet or exceed the EU's Euro 5 standards or the U.S. Tier 2 standards to be clean diesel vehicles. Clean diesels have been heavily adopted in the European market, where they are credited with dampening the initial sales of gasoline-powered hybrids. It looked like North America, the second largest automotive global market, was primed to follow Europe's lead. Then came "Dieselgate."

U.S. sales of clean diesels grew steadily, from $3.3 billion in 2011 to $6.1 billion in 2014, mostly on the back of German automaker deployments. Then, in Sep-tember 2015, EPA issued a notice that Volkswagen (VW), the leading diesel car provider in North America, was cheating on the tests for nitrogen oxide (NOx) emissions. VW had fitted some 600,000 vehicles sold in the United States since 2009 with a so-called "defeat device" to comply with NOx emissions standards, something the com-pany was having trouble achieving.

Revelations of the scandal continue to play out worldwide. In the United States alone, Volkswagen has settled a number of claims that add up to around $20 billion; the latest estimate on total settlements since the scandal

broke tops $24 billion. Meanwhile, 13 VW managers have been indicted, with one manager receiving a sentence in South Korea of 18 months. With VW under fire, U.S. automakers like Fiat Chrysler, GM, and Ford, introduced a number of new diesel models, mainly in light truck classes. Recently, however, EPA accused Fiat Chrysler of using similar methods to sidestep NOx emission regulations. EPA is, however, still investigating whether the method constitutes a defeat device and the automaker has made no admission of guilt. With heightened scrutiny from regulators, the future of diesel might appear uncertain but the global market continues to suggest otherwise. Worldwide, the Clean Diesel Vehicles market grew again in 2016, to $306.6 billion, up an estimated 6% from 2015. (Figure 12)

Global and U.S. Clean Diesel

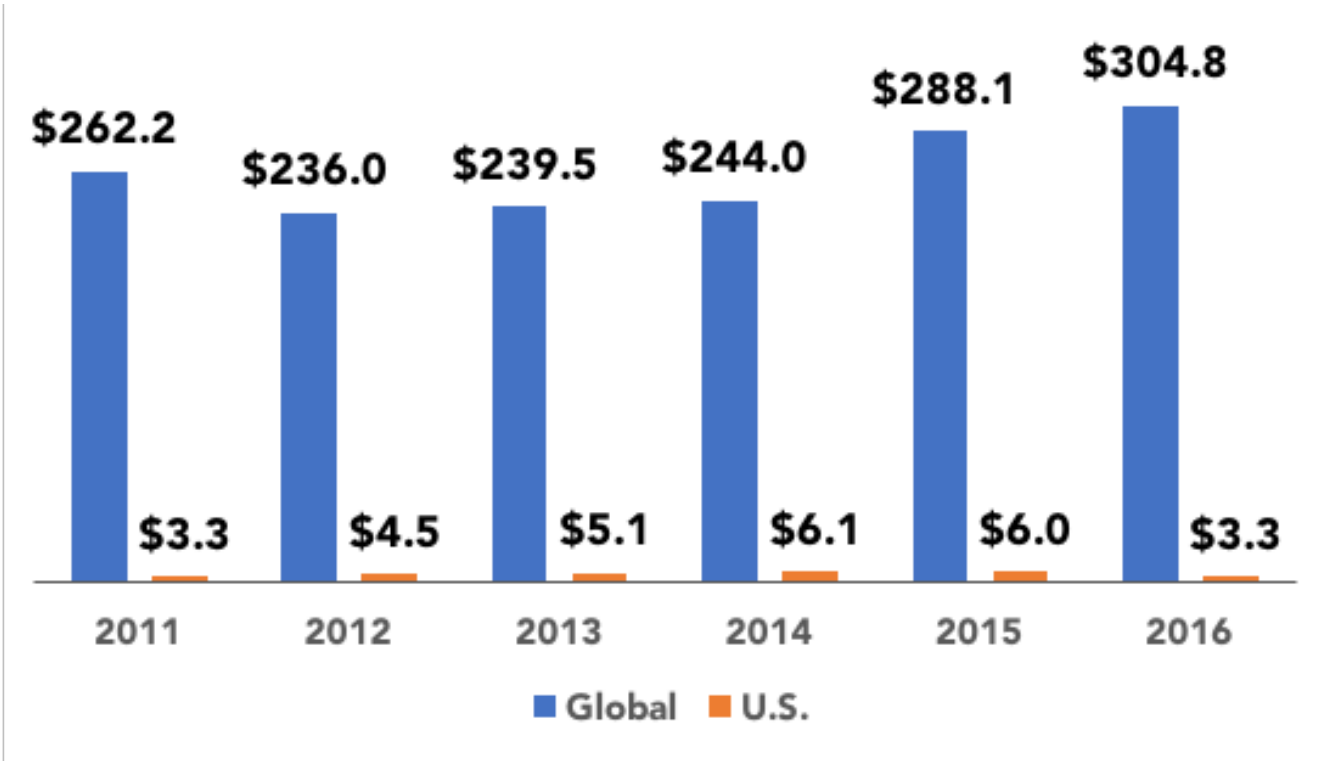


Figure 12 (Navigant Research)

At the same time, regional markets do show the impacts of the scandal. In Europe, although diesel's share of new vehicle sales has fallen slightly, a buoyant automotive market in the region has lifted diesel vehicle in total sales volume. **But in the United States, clean diesel sales took a sizeable hit, down 45%, to an estimated $3.3 billion in 2016.**

While global diesel vehicle sales figures appear to show initial resilience, this may not last. Hybrids and plug-in electrics carry less skepticism and are becoming increasingly competitive and a number of additional companies, including VW, are entering the market. In the United States, at least, clean diesel's future is likely limited to utility vehicle classes: light trucks, SUVs, and vans, as well as heavy-duty trucks. Of the German automakers that produced diesel passenger cars for the U.S. market, only BMW seems interested in returning and BMW is simultaneously making a big electrification play.

Unlike North America, Europe's automotive markets are dominated by passenger cars, limiting the extent to which diesel's competitive advantage for larger vehicles can mitigate losses in smaller vehicle segments. The result in Europe is a belated surge toward hybrids, and rapid ac-ceptance of PEVs.

Upon its introduction in the late 1990s, the hybrid powertrain caught on in Japan and North America, but had trouble in Europe, where clean diesel dominated. That changed in 2015. Navigant Research estimates sales grew 21% that year and then 23% in 2016. The main beneficiary of this growth, Toyota, saw hybrid sales increase 40% in the region last year. PEVs have also caught on quickly in Europe, with some countries considering moves to ban internal combustion engines by 2025. Growth of this segment will also pull from diesel market share, and will likely do the same with hybrids within a few years.

ADVANCED FUEL PRODUCTION

$28.9 BILLION

U.S. revenue

-19%

annual growth

$118 BILLION

global revenue

-3%

annual growth

Overview

Fuel Production remained the fourth largest advanced energy segment in 2016, with an estimated $118.1 billion in revenue worldwide. (Table 6) Between 2014 and 2015, Fuel Production experienced an 18% decline, due primarily to a sharp drop in revenue from Ethanol, whose price tracks closely to gasoline, oil, and corn prices. This year, **as the price of oil and corn remained low, Ethanol continued to decline.** Total Fuel Production revenue leveled off slightly with a 3% decline overall over last year.

Despite declines in most liquid fuel product categories, gas fuel production continued to grow in 2016. Global Compressed Natural Gas (CNG) / Liquefied Natural Gas (LNG) for

Transportation maintained its lead as the largest product category, after supplanting Ethanol last year. **With an estimated $57.4 billion in revenue in 2016, CNG/LNG** accounts for nearly half of the Fuel Production segment total. This product category **has consistently experienced growth in revenue over the past six years and grew 9% over the last year.** Biogas and Biogas Capture Equipment also saw revenue increases, 13% and 109%, respectively, over last year, for combined revenue of $496 million in 2016. The non-ethanol liquid fuels, Biodiesel Fuels and Synthetic Diesel and Gasoline, both saw 5% increases over last year.

In contrast, global Ethanol and Butanol Fuels dropped 19% to $37 billion in revenue, down from its 2012 peak of $77.5 billion, contributing to the second straight year of revenue reductions in the Fuel Production segment. Also contributing to the revenue decline, Navigant Research found no new investments in refinery infrastructure for ethanol, biodiesel, synthetic gasoline or bio-oil in global or U.S. markets.

Global Fuel Production Revenue (million $)

Subsegment	2011	2012	2013	2014	2015	2016 estimate
CNG and LNG	23,018	31,486	37,654	43,302	52,439	57,420
Ethanol and Butanol	68,140	84,240	76,645	77,956	46,218	36,964
Biodiesel	17,882	20,432	21,993	21,342	19,692	19,998
Synthetic Diesel and Gasoline	1,580	1,938	4,693	5,394	3,142	3,207
Bio-oil	1	500	805	16	19	0
Hydrogen	-	-	-	-	-	-
Bio-methane	47	48	65	51	416	496
Total	**110,667**	**138,644**	**141,855**	**148,062**	**121,926**	**118,086**

Table 6 (Navigant Research)

The United States followed global trends with a second straight year of Fuel Production revenue declines, with $29 billion in annual revenue, down 19% from 2015 and 41% from a 2012 peak of $40.6 billion. (Table 7) Revenue from Ethanol Fuels in 2016 accounted for most of the decline, with sales revenue dropping 24% to $20.6 billion. Synthetic Diesel and Gasoline also experienced a significant decline, down 41% to $2.1 billion in estimated revenue in 2016.

Biodiesel production, however, **was a bright spot, with a 43% increase in revenue, to $4.6 billion.** CNG/LNG for Transportation product category increased 1% year-on-year to $1.3 billion, representing 155% growth since 2011.

Bio-methane Fuels (up 15%) and Biogas Capture Equipment/Upgrades (up 168%) reached a combined total of $409 million in revenue, maintaining annual revenue in the triple digits for the second year in a row. This is a notable expansion given that revenue for these two categories in 2011 barely surpassed $12 million.

U.S. Biofuels Take Revenue Hit But Get New Target Less Constrained by 'Blend Wall'

The biofuels market in the United States is primarily driven by the Renewable Fuel Standard (RFS). While Congress set the original targets in 2007, the U.S. Environmental Protection Agency (EPA) sets the final mandate for each calendar year to adjust for market conditions. In 2016, the EPA expanded the biofuels market by nearly 1.2 billion gallons for 2016, and another 1.17 billion gallons for 2017 across the four major renewable fuel categories: advanced biofuels; biomass-based diesel; cellulosic biofuel, made from cellulose or lignin; and "renewable fuel," primarily corn-based ethanol, the largest category.

Conventional biofuels have seen their target steadily increased by 3% per year since 2015, reaching the initial Congressional requirement target of 15 billion gallons for the first time in 2017. Advanced biofuels are set to increase 18.5% in 2017 compared to 2016, reaching

U.S. Fuel Production Revenue (million $)

Subsegment	2011	2012	2013	2014	2015	2016 estimate
CNG and LNG	504	581	883	1,016	1,271	1,288
Ethanol and Butanol	39,140	41,730	40,371	40,932	27,331	20,580
Biodiesel	3,135	4,231	4,751	3,859	3,200	4,567
Synthetic Diesel and Gasoline	372	438	2,368	3,206	3,564	2,100
Bio-oil	1	345	2	16	0	0
Hydrogen	-	-	-	-	-	-
Bio-methane	12	12	16	19	341	410
Total	**43,164**	**47,337**	**48,390**	**49,048**	**35,708**	**28,944**

Table 7 (Navigant Research)

4.28 billion gallons. The carve-out for biomass-based diesel (biodiesel and renewable diesel produced from vegetable oils or animal fats) was increased from 1.73 billion gallons in 2015 to 1.9 billion gallons in 2016 and now to 2 billion gallons in 2017.

The 2017 cellulosic biofuel requirement was set at 311 million gallons, up from 230 million gallons in 2016. The United States used 159 million gallons of ethanol-equivalent cellulosic biofuels in 2016, 32 million gallons above 2015, but falling far short of the 2016 mandate. Biogas from anaerobic digestion is supplying the bulk of all cellulosic biofuels – 157 million gallons of ethanol equivalent – as only 3.3 million gallons of cellulosic ethanol was blended in 2016.

The higher 2017 target for ethanol is supported by U.S. DOE data, which shows that gasoline consumed in 25 states and the District of Columbia contained more than 10% ethanol on average in 2015. Prior to this, the market had run up against the "E10 Blend Wall," a technical limitation for cars produced prior to 2001 that had set a limit on RFS volumes as gasoline consumption declined amid fuel economy increases.

EPA Renewable Fuel Volumes (billion gallons)

Fuel Type	2014	2015	2016	2017
Cellulosic biofuel	0.33	0.12	0.23	0.31
Biomass-based diesel	1.63	1.73	1.90	2.00
Advanced biofuel	2.67	2.88	3.61	4.28
Conventional biofuel	13.61	14.05	14.50	15.0
Total Renewable fuels	**16.28**	**16.93**	**18.11**	**19.28**

Table 8 Units for all volumes are ethanol-equivalent, except for biomass-based diesel volumes, which are expressed as physical gallons. Source: EPA.

The ethanol industry had pushed for E15 to become the new standard, but automakers claimed that earlier models could be harmed by the higher ethanol content. As cars produced prior to 2001 become more rare on U.S. roads, the E10 Blend Wall will be less of an obstacle to ethanol use. According to the Renewable Fuel Association (RFA), fueling station companies such as Sheetz, MAPCO Express, Protec Fuel, Murphy USA, and others now offer E15 to 2001 and new vehicles at several stations today. Over the next 12 months, nearly two thousand stations are expected to come online thanks to USDA grants and ethanol and agricultural subsidies. But U.S. revenue from corn-based ethanol continues its decline, falling from $39 billion in 2014 to $27 billion in 2015, and then to an

estimated $20 billion in 2016. Global wholesale ethanol prices were down 20% in 2016, reaching an average of $1.50 per gallon, and U.S. prices dropping to an average of $1.40 per gallon in 2016. The price of ethanol is tied to the price of two other resources: oil and crop feedstocks. As a fuel substitute, the price of ethanol is highly correlated to the price of gasoline and hence crude oil. The RFA reported in late 2016 that operating capacity of the industry was 15.4 billion gallons per year, meaning the mandate will cover 97% of the capacity in 2017 – high enough to support all of the plants currently operating. This should allow the industry to operate with a healthy margin during 2017 overall, though seasonal swings will occur.

Biofuels Meet Targets

Global biofuel markets are driven by a unique elixir of national annually adjusted production targets, oil prices, and desire for energy independence. Biofuels have endured more than a decade of scrutiny for everything ranging from subsidies to environmentalist concerns to possible impacts on food prices. Despite all of this, biofuels have proven a resilient global market led by the United States and Brazil. Revenue from ethanol production dropped dramatically in 2016 – down to $37 billion globally, and to $20.6 billion in the United States – as ethanol prices have fallen in competition with low-priced oil. (Figure 14) In both worldwide and U.S. markets, ethanol revenue hit its lowest point in the six years Navigant Research has been tracking the industry. In addition to the low oil prices, and resulting low gasoline prices, low corn prices contributed to the decline in ethanol pricing. Corn prices also fell to the lowest in a decade in October 2016, right after the U.S. corn harvest ended.

Generally, during years in which ethanol production exceeded the RFS mandate, ethanol has traded at approximately 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, some plants shut down as they become unprofitable. Conversely, as supply decreases, the price of ethanol rises until the mandate is fulfilled. 2016 was kinder to biodiesel: The U.S. produced 1.5 billion gallons of biomass-based diesel in 2016, 20% more than in 2015. U.S. revenue from biodiesel surged from $3.2 billion in 2015 to $4.5 billion in 2016 due to a jump in the price of the fuel to $2.96 per gallon. (Figure 13)

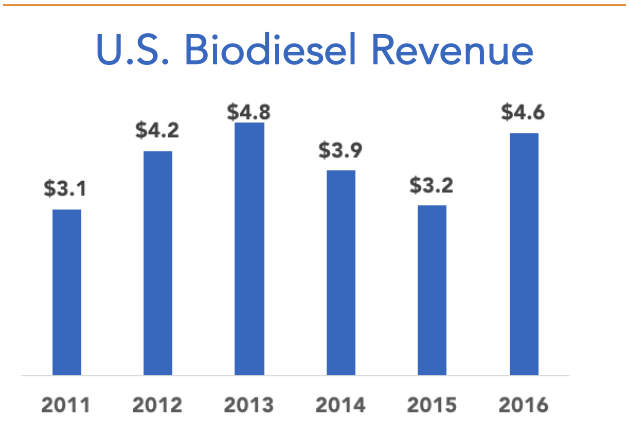


Figure 13 (Navigant Research)

This surge was due to higher local diesel prices and a significant increase in the price of vegetable oils, but was also in line with global

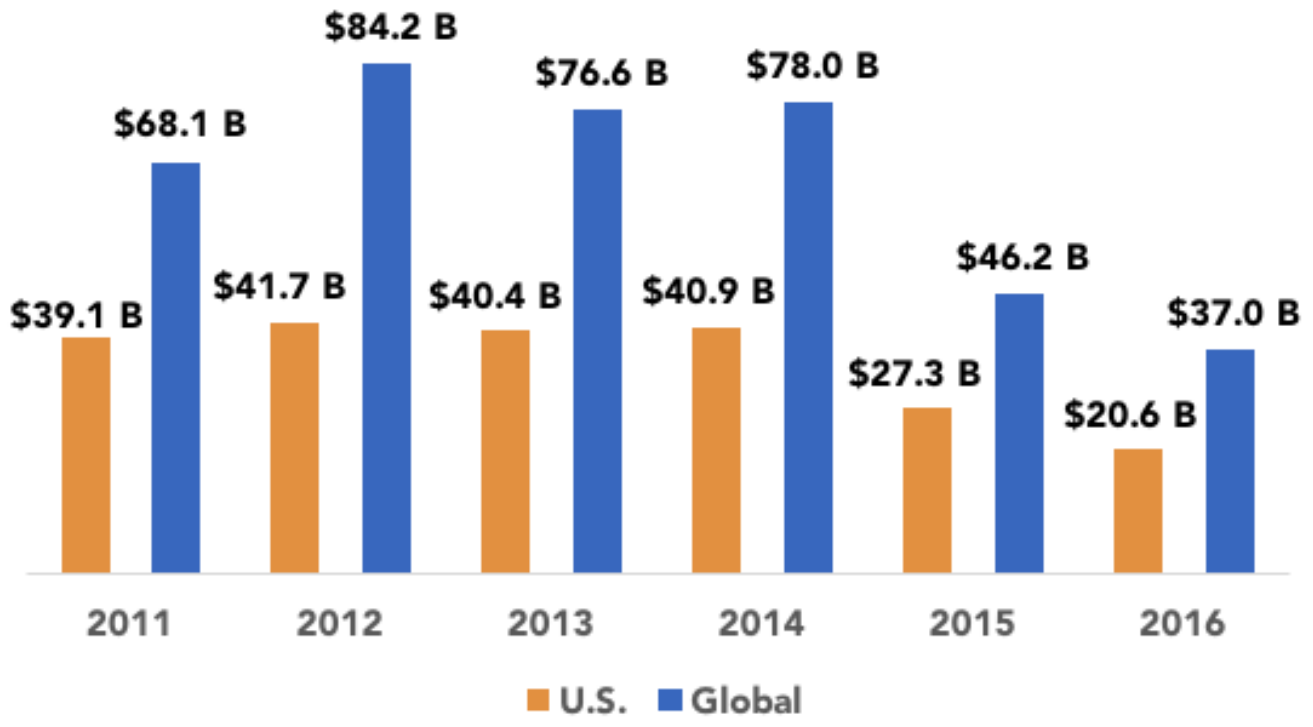


Figure 14 (Navigant Research)

pricing for biodiesel. Global revenues only increased slightly, 5%, to $20 billion.

Can Toyota, Honda, and Hyundai Make Hydrogen Work?

Growth in hydrogen fueling transportation infrastructure and fuel cell vehicle (FCV) sales is advancing the concept of a true "hydrogen highway" – and ultimately the potential for more rapid growth in retail hydrogen fuel sales. Commercial sales for hydrogen transportation fuel are not included in the market sizing estimate as this data is just beginning to become available, for two reasons. First, there are relatively few commercial sales of hydrogen fuel. The infrastructure is mostly limited to pilot sites or regionally concentrated in countries like Germany, the United States, Japan, Korea, and Denmark. Though retail networks are growing, both pilot and retail sites remain intrinsically linked to automaker deployment plans. Hence, steady station growth is necessary before more FCVs hit the roads.

Second, new FCV owners typically receive pre-paid fuel cards and are not individually paying for fuel directly. For example, Toyota and Honda both provide three years of fuel (capped at $15,000) and Hyundai offers free fuel as part of its lease arrangement for the Tucson ix35. Today's new stations are mostly

being built at existing gasoline stations, and in California required to be open 24/7 with point of sale (credit card) payment.

California and Japan hold the most near-term prospect for hydrogen fuel sales. In California, there are now 25 retail hydrogen stations (compared to non-retail stations, which charge for fuel via business-to-business arrangements). True Zero Network, the company operating at least 16 of the retail stations, mostly located in Northern and Southern California, claims that by late 2016 more than 12,000 charges totaling 33,800 kilograms of hydrogen were conducted at its facilities. The State of California has committed funding for 100 stations, expected by 2020 to support the growing vehicle sales.

As with solar in China and biofuels in the United States, Japan is driving domestic fuel cell markets for both stationary and transportation applications as a policy priority. In 2016, the Japanese Ministry of Economy, Trade, and Industry (METI) revised its Strategic Roadmap for Hydrogen and Fuel Cells, providing a major boost to Honda and Toyota's domestic market. The new Roadmap calls for 40,000 FCVs on the road by 2020, 200,000 by 2025, and 800,000 vehicles by 2030. This corresponds with similarly scaled targets for infrastructure – 60 hydrogen stations by 2020, and about 320 stations by 2025.

Toyota, the company largely credited with launching the hybrid-electric vehicle market 20 years ago with the Prius, is doubling down on its commitment to hydrogen. Toyota released what it calls the first "mass produced" zero-emission FCV, the Mirai, offering a 312-mile range and mileage equivalent to 67 miles per gallon. The four-door sedan debuted at €66,000 in Europe and $57,500 in the United States, before incentives. In late 2016, the Mirai's lease price dropped from $499 to $349 per month, though it maintains the same Manufacturers Suggested Retail Price (MSRP). Nearly 700 Mirai were sold or leased as of September 2016. Honda, is also expanding its FCV offerings. The Japanese automaker released the next generation of the Clarity Fuel Cell in Japan and the American market last year, which has a slightly higher horsepower, extended driving range (366 miles), and extra seating (5 passengers) compared to the Mirai for a similar selling price. Honda Clarity Fuel Cell launched December 2016 in the U.S. market and to date has delivered over 60 vehicles. This vehicle is "lease only" in California and is offered at $369 per month with the offer of a Hydrogen Fuel Card with up to $15,000 of fuel over the three-year lease. Honda is also poised to release a PEV and HPEV variant by the end of this year.

U.S. Fuel Cell Vehicle Revenue

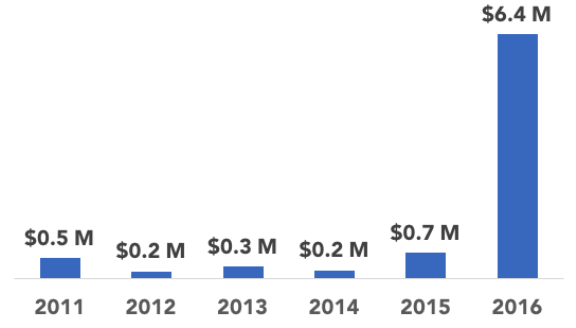


Figure 15 (Navigant Research)

Not to be outdone by its neighbor across the Sea of Japan, South Korea is also positioning itself to go big on hydrogen. It now offers an incentive for FCVs of over $23,000, with the aim to place as many as 630,000 on the road by 2030.

The country also aims to increase the number of refueling stations to 520 by 2030. Currently, only the domestic brand Hyundai sells an FCV in this market, while Kia (which is also part of the Hyundai Motor Group) is aiming to release one by 2020.

Unlike many other major vehicle markets, Japan and South Korea are heavily dominated by domestic automakers. Additionally, PEVs have had a slower start in both these markets relative to other developed markets. Under these conditions, government support of FCVs may secure a path for the domestic automakers to bring FCVs, infrastructure, and fuel costs down through economies of scale, eventually making FCVs more competitive internationally with PEVs, hybrids, and conventional vehicles. Both PEV and FCV manufacturers are targeting a sub-$30,000 price point for consumers. While PEVs such as the Ford Focus Electric, Chevrolet Volt, and Nissan Leaf are all at or near this target, FCV models are still pricier.

Hydrogen fuel has advantages and disadvantages, and vehicles that run on it will face fierce competition with electric vehicles, which are growing fast. Cost is key: FCVs, infrastructure, and fuel are now too expensive on their own, relative to conventional or alternative fuels, to consider growth potential without significant continued government support. While Japan and South Korea offer incubation for these technologies, other markets are steadily moving forward with PEVs, which have clear paths to achieving competitive cost advantages over conventional vehicles in the foreseeable future. If FCVs can capitalize on hydrogen's fast refueling capabilities and longer range, and an infrastructure network can be established to solve hydrogen fueling station paucity, and if the cost of both vehicles and fuel come down, hydrogen could have role to play in an advanced transportation system, even if only in regional markets.

ADVANCED INDUSTRY

$8.3 BILLION

U.S. revenue

8%

annual growth

$43.9 BILLION

global revenue

1%

annual growth

Overview

Industry is the sixth largest advanced energy segment, both globally and domestically. It contains only two subsegments: Manufacturing Machinery and Process Equipment, and CHP. The global Industry segment reached $43.9 billion in 2016, a modest 1% increase over 2015, but the fifth straight year of successive growth. (Table 9) Since 2011, the segment has grown at a compound annual growth rate (CAGR) of 8%. At $29.1 billion in revenue, CHP makes up two-thirds of the global Industry total.

Global Advanced Industry Revenue (million $)

Subsegment	2011	2012	2013	2014	2015	2016 estimate
Manufacturing Machinery and Process Equipment	9,773	10,513	11,340	12,315	13,465	14,809
CHP	20,803	22,812	27,155	28,513	29,938	29,116
Total	30,576	33,325	38,495	40,828	43,403	43,925

Table 9 (Navigant Research)

In 2016, CHP saw a slight (3%) decline after experiencing four years of successive growth. Since 2011, however, CHP revenue in 2016 still shows a 7% CAGR. Manufacturing Machinery and Process Equipment revenue rose to $14.8 billion, a 10% increase over 2015.

In the United States, the Industry segment faired better than it did globally. Reaching an estimated $8.3 billion – an 8% increase over last year – the U.S. Industry segment accounts for one fifth of the global total. (Table 10) Since 2011, revenue in this segment has nearly doubled, growing at a CAGR of 28%. While CHP is the dominant subsegment globally, Manufacturing Machinery and Process Equipment is actually larger in the United States. In 2016, U.S. Manufacturing Machinery and Process Equipment increased 10% to $4.7 billion due to strong growth in sales of industrial energy management systems. CHP revenue increased 5% year-over-year to $3.5 billion.

U.S. Advanced Industry Revenue (million $)

Subsegment	2011	2012	2013	2014	2015	2016 estimate
Manufacturing Machinery and Process Equipment	3,184	3,414	3,669	3,969	4,325	4,744
CHP	1,018	2,038	3,064	3,217	3,378	3,540
Total	4,202	5,452	6,733	7,186	7,703	8,283

Table 10 (Navigant Research)

CHP Provides Onsite Power for Industrial Customers, and Others

For roughly a century, CHP systems have been reliable, cost-effective sources of power and thermal energy in both industrial and commercial building applications. Representing as much as 8% of U.S. electricity generation, CHP systems are used widely in manufacturing, hospitals, district heating, commercial buildings, and even residential applications.

Global CHP Revenue

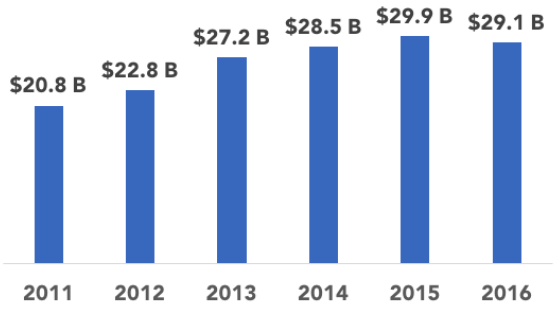


Figure 16 (Navigant Research)

Producing power and heat (separately) typically results in a combined efficiency of 45%. By contrast, CHP systems (also known as cogeneration) generate electricity and thermal energy in a single system, resulting in a combined efficiency as high as 80%. Gas turbines make up the largest share of CHP systems, often exporting power to the electrical grid, but it is not the only way for CHP to work.

Following five years of growth, from $20.8 billion in 2011 to $30 billion in 2015, global industrial CHP revenue slipped 3% in 2016, but still represented a $29.1 billion market. (Figure 16) With more than 80 GW installed to date in the U.S alone – equal to the cumulative base of wind and nearly double that of solar PV – U.S. industrial CHP revenue continued its upward trajectory, increasing 5% to $3.5 billion in 2016, up steadily from $1 billion in 2011. (Figure 17) In the U.S. many projects were hurriedly completed before the CHP investment tax credit (ITC) expired on December 31, 2016. This credit, worth up to 10% of the system cost, has been an important driver of installations so ongoing efforts in Congress to reestablish the credit for 2017 are an important pivot point for the industry.

The lower natural gas prices afforded by the shale gas boom are an important driver of CHP installations, though the relationship is complex. Natural gas prices in North America approached historic lows in 2012-2016, which improved the spark spread, or the difference in cost per MWh of natural gas and electricity. This typically is good for natural gas, though caveats exist. First, grid electricity has gotten cheaper as more centralized natural gas generation comes online in response to low gas prices, eroding some of the business case for CHP. Paradoxically, the high efficiency of CHP can also be a hindrance with cheap natural gas: if CHP utilizes twice the energy per unit natural gas, the value of that efficiency is directly proportional to gas prices. Finally, volatility in natural gas prices can introduce financial risks that some facility owners don't want to undertake. Still, many industrial customers see the value in CHP over the longer term and are willing to invest. For example, while US industrial customers saw

electricity prices steadily rise by 49% from 2000 to 2015, natural gas prices were down by 12% (albeit with more volatility). Customers that can realize multiple value streams from CHP are thus willing to invest.

A growing business model in CHP is that of utility-owned deployments. While the legal issues vary by jurisdiction, many utilities see CHP as a way to cooperatively use customer facilities to meet their responsibilities related to capacity, energy efficiency, or flexible power generation. For example, in an effort to stabilize rising electricity prices, Florida Public Utilities Co. (FPU) worked with its industrial customer Rayonier to install a 20MW CHP turbine system in 2016. The system, called Eight Flags, is projected to produce electricity at $84.30/MWh, or 12% below the average local cost of wholesale energy.

U.S. CHP Revenue

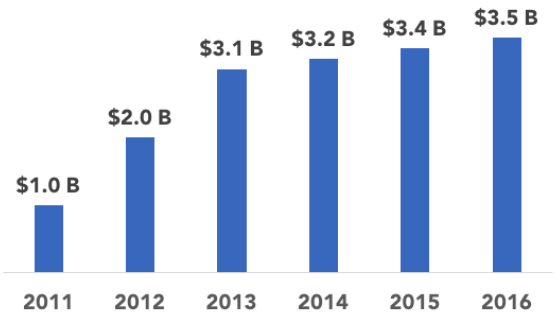


Figure 17 (Navigant Research)

In addition, the combustion turbine will be equipped with inlet air cooling to increase electric output during summer months – adding flexibility that will become ever more important for utilities and grid operators with the growth of intermittent renewables like solar PV. Other utilities are incentivizing CHP toward meeting their energy efficiency goals, which is not always the cheapest option, but can be attractive as low-hanging fruit like lighting and HVAC upgrades become saturated. One such utility is Baltimore Gas and Electric, which anticipates that 19.5% of its total Commercial and Industrial (C&I) electricity savings will come from CHP projects.

Industrial facilities account for more than 80% of existing CHP capacity in the United States – with more than 1,200 installations. Industrial sites are a strong match for CHP systems (of 20 MW in nameplate capacity) due to the presence of both high thermal and electric loads. There is also some potential in CHP using biomass, particularly in rural areas, where natural gas is too costly or not available, and in paper mills, where waste stock provides a source of fuel.

While large turbines over 20 MW dominate CHP in the U.S. (accounting for 90% capacity), there are three technologies that each are well suited as prime movers in CHP applications on a smaller scale:

- Natural Gas generator sets are the most mature of the three and are seeing renewed interest, thanks to in part to growing interest in energy resiliency in smaller sites including commercial sites. Compared to turbines, reciprocating engines ramp to full power faster and are readily available in much smaller sizes, including below 100 kW. For these reasons generator sets represent more

than half of all installed CHP capacity under 5 MW, for a total of 1.5 GW.

- Microturbines are emerging as a low maintenance solution for a range of applications, including oil & gas (O&G) fields, where fuel would be otherwise wasted. Gas that has traditionally been flared, often of poor quality, is being piped into flexible microturbines and generates heat and power for production processes. Microturbines represent just 0.1% of installed CHP capacity, though that share is growing thanks to growing demand for low-maintenance flexible generation.
- Stationary fuel cells are being adopted at four times the rate of transportation fuel cells (by annual capacity additions) and will continue to lead fuel cell deployment. Fuel cells account for just 0.1% of installed CHP capacity, though that share is growing thanks to cost declines and growing demand for ultra-low-emission onsite generation.

Gas turbines will continue to make up the majority of large CHP applications, but there is a growing opportunity for stationary fuel cell applications in larger systems. One application is prime power, where the fuel cell is used for electricity or power and heat, ranging from 5 kW to several MW (though usually at a scale of 200 kW and higher).

Large CHP fuel cell applications are found mostly in South Korea and the United States. CHP fuel cell units are used in the utility and C&I sectors. Hospitals and universities, with their campus configuration and high thermal demands, install CHP in growing quantities with fuel cells accounting for a growing share. Multi-family residential structures also represent a large opportunity in this segment. For example, Doosan Fuel Cell America is working with the local utility to install a large CHP fuel cell at a multifamily residential development in Busan, South Korea. Sized at more than 30MW, it is projected to be one of the largest fuel cell installations in the world.

Using waste heat can result in efficiencies above 85%, potentially opening new markets. GE's new fuel cell combined-cycle will combine its Solid Oxide Fuel Cell (SOFC) with its Jenbacher generator set at a megawatt scale, representing a compelling value proposition as costs come down.

Navigant Research forecasts fuel cell capacity for CHP will grow fastest in Asia Pacific, with Japan (and to a lesser extent, China and India) joining South Korea as the next most attractive markets. As a relatively mature market, the United States is expected to continue growing at close to historical trends.

ADVANCED FUEL DELIVERY

$178 MILLION

U.S. revenue

-4%

annual growth

$953 MILLION

global revenue

6%

annual growth

Overview

At an estimated $953 million globally in 2016, Fuel Delivery is the smallest advanced energy segment. After experiencing a decline from 2014 to 2015 due to shrinking Natural Gas Vehicle (NGV) Fueling Station revenue, this segment bounced back with 6% growth last year. The segment is still well down from its 2013 high of $2.6 billion, however. NGV Fueling Stations for light-duty vehicles represents the majority of revenue (86%) in this segment and increased 5% to $820 million. The second largest product category was Commercial NGV Fueling Stations for larger vehicles (up 5%) with $91 million in revenue. Hydrogen Fueling Stations generated the lowest total revenue, $42 million, but the

biggest year-over-year growth (up 40%). In the United States, Fuel Delivery saw a 4% decline in 2016, dropping to an estimated $178 million in revenue, continuing a downward trend from its 2012 peak of $378 million. NGV Fueling Stations and Commercial NGV Fueling Stations, which together comprise 93% of revenue in the Fuel Delivery segment, rose a modest 2% in 2016, to $171 million. While growth in each of these categories has been cyclical, the former has increased at a remarkable 38% compound annual growth rate (CAGR) since 2011.

Global Fuel Delivery Revenue (million $)

Subsegment	2011	2012	2013	2014	2015	2016 estimated
Fueling Stations	2,207	1,926	2,606	2,718	900	953
Fuel Transportation Infrastructure	-	-	-	-	-	-
Total	**2,207**	**1,926**	**2,606**	**2,718**	**900**	**953**

Table 11 (Navigant Research)

Growth in these two product categories was offset by a drop of $10 million in Hydrogen Fueling Stations, which saw a 47% year-on-year reduction in 2016, to just $12 million. Low oil prices are a major driver in NGV purchases and, to a lesser extent, investment in fueling infrastructure. It is worth noting, however, that the **U.S. electric vehicle charging infrastructure product category (in the Electricity Delivery and Management segment) eclipsed the entire U.S. Fuel Delivery segment for the first time in 2016.**

The rapid rise in natural gas production has fundamentally altered the energy landscape worldwide. In the United States, 60 GW of coal-fired power plants have been or are slated to be retired, due to a combination of low natural gas prices, increased environmental regulation, and expanding renewable energy.

Globally, low-cost natural gas to date has primarily entered markets with existing pipeline infrastructure, but with estimates of increased natural gas supply (some estimates expect as high as a 40% increase in next few decades), some analysts are pointing to potential regional imbalances in supply and demand if infrastructure growth does not keep pace.

According to Pipeline & Gas Journal, 94,799 miles of pipelines are planned or under construction worldwide. Of these, 44,951 miles are in various stages of construction; nearly 50,000 miles of pipeline projects are in the engineering and design phase.

U.S. Fuel Delivery Revenue (million $)

Subsegment	2011	2012	2013	2014	2015	2016 estimated
Fueling Stations	227	378	252	283	186	178
Fuel Transportation Infrastructure	-	-	-	-	-	-
Total	**227**	**378**	**252**	**283**	**186**	**178**

Table 12 (Navigant Research)

Asia Pacific is among one of the least developed regions of the world when it comes to natural gas pipeline infrastructure so it is not surprising that the region is second in projects planned or under construction, following North America:

- North America 34,191 miles
- South/Central America and Caribbean 5,085 miles
- Africa 6,528 miles
- Asia Pacific 29,759 miles
- Former Soviet Union and Eastern Europe 11,191 miles
- Middle East 4,929 miles
- Western Europe and European Union 3,116 miles

US Gas Market Disrupts Coal, Plays Increasing Role in Global Markets

Historically, the United States has imported large quantities of natural gas, mostly from Canada. In 2005 alone, the United States imported 4 trillion cubic feet of this fuel. But hydraulic fracturing has resulted in an abundance of domestic natural gas supply. The U.S. Energy Information Administration (EIA) expects the country to become a net exporter of natural gas in 2017 for the first time since 1958, citing declining pipeline imports from Canada, increased pipeline exports to Mexico, and greater LNG exports elsewhere. By 2026, EIA projects U.S. exports at 4 trillion cubic feet even if oil prices remain at current lows.

When it comes to electricity markets, natural gas will continue to displace coal power generation in the United States as well as globally. Producing power with U.S. natural gas is cleaner and cheaper than burning than coal, and it provides fast-ramping generation that pairs well with variable renewable sources. Continued low prices will drive both more utilization in the United States as well as more exports, both via pipeline to Mexico and via tanker to other destinations. Cheniere's Sabine Pass LNG facility has begun LNG deliveries to foreign markets, and four other large LNG export terminals are currently under construction.

How much it will grow depends, in part, on pipeline capacity. Existing infrastructure and pipeline projects already underway provide

room for some growth, but difficulties in siting, permitting, and constructing pipelines, as well as the distance between supply and demand, pose a potential limit to natural gas growth. The sudden abundance of natural gas as a low-priced resource has inspired a rush of proposals for new or expanded pipelines to get the resource to consumers. Some large projects appear to be moving forward:

- Fluor Corp. DTE Energy Co. and Spectra Energy Partners, LP, are lead developers of the 250-mile NEXUS gas pipeline project, which is expected to cost $2 billion and deliver gas from the Utica and Marcellus shale plays to meet growing demand for gas in Ohio and Michigan.
- The Federal Energy Regulatory Commission (FERC) is reviewing an application for the 711-mile Energy Transfer Partners' Rover Pipeline to move 3.25 Bcf/d of Utica/Marcellus gas to the upper Midwest.
- Tennessee Gas Pipeline Co., a Kinder Morgan company, has filed an application with FERC for its proposed Northeast Energy Direct Project (NED). The anticipated in-service date is Nov. 1, 2018.
- Four U.S. companies – Dominion, Piedmont Natural Gas, Duke Energy, and AGL Resources – formed Atlantic Coast Pipeline, LLC, to build and own the proposed 564-mile Atlantic Coast Pipeline. The interstate gas transmission pipeline is expected to begin service in late 2018.

Concerns for pipeline pathways in these regions, based on sensitive environmental and cultural areas, safety risks, and other factors, have resulted in lengthy and contentious reviews by FERC, which regulates pipeline development. Numerous gas pipeline projects have been denied permits, while others are facing concerted opposition from local grassroots groups and their elected officials, resulting in delays – or cancellations. Examples include the Pacific Connector Gas Pipeline (Oregon), the PennEast Pipeline (Pennsylvania, New Jersey), the Atlantic Coast Pipeline (West Virginia, Virginia, North Carolina), the Northeast Energy Direct gas pipeline (Massachusetts and New Hampshire), and the Constitution Pipeline (Pennsylvania, New York), among others.

Furthermore, while the abundance of shale gas supply may provide a business rationale for more pipelines, the difficulty pipeline developers are facing in getting their projects sited and built does not necessarily constitute a crisis in meeting natural gas demand. A US Department of Energy study, *Natural Gas Infrastructure Implications of Increased Demand from the Electric Power Sector*, has recently found relatively less demand for pipeline compared to previous periods of domestic natural gas consumption. According to the report:

- Diverse sources of natural gas supply and demand will reduce the need for additional interstate natural gas pipeline infrastructure. The rate of expansion from 1998-2013 was three times the capacity additions that is forecasted for 2015-2030.

- Higher utilization of existing interstate natural gas pipeline infrastructure will reduce need for new pipelines. According to the study, the U.S. pipeline system is not fully utilized because flow patterns have evolved with changes in supply and demand, and that it is more cost effective to find alternative routes that utilize available existing pipeline capacity versus building new infrastructure.

Nevertheless, new capacity infrastructure development is coming to a head in regions such as in the US Northeast – home to the most prolific gas shale play in the world right now producing over 27% of total gas supply in the country and by 2040 producing over 60% of US lower 48 supply. As North America becomes integrated into the global gas market for the first time with the LNG deliveries from Sabine Pass, the role of the US will have increasing dynamics on the global energy market.

Natural Gas Fueling Stations Continue Slow Buildout

In the early part of this decade, the deployment of non-traditional methods of natural gas extraction, especially hydraulic fracturing, both dramatically increased the availability of this fuel and drove down the price, making it a possible alternative to other fuels not only for power generation but also for transportation. The prospect of lower operating cost made it seem that NGVs could be a good solution for larger vehicle types (and vehicle fleets), despite higher purchase prices.

Since then, the growth of NGV has been hindered by the collapse of world oil prices in late 2014, which reduced the cost differential with gasoline and diesel. Still, other market drivers continue to make NGVs appealing in the coming decade, especially for larger trucks and buses. Tightening emissions regulations, particularly for diesel engines, could push fleets further toward natural gas conversions – and refueling infrastructure will follow.

U.S. Natural Gas Fuel Station Revenue

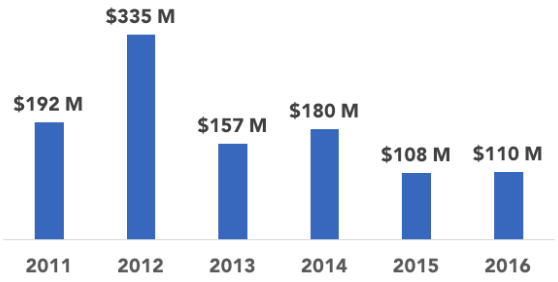


Figure 18 (Navigant Research)

While NGVs and refueling infrastructure for them have gained a significant foothold in several markets around the world, including parts of Western Europe and China, other markets like North America have lagged behind. Global natural gas fueling station revenue has been on a downward curve since 2011, when it was $2.1 billion, reaching $820 million in 2016. U.S. revenue for this fueling infrastructure peaked at $335 million in 2012 and had dropped to $110 million in 2016.

Two technical and economic challenges are central to the growth of NGVs: on-vehicle fuel storage and refueling infrastructure. Both CNG and LNG storage systems are more bulky and

expensive than a gas tank. Although CNG has a significant cost advantage and is generally easier to handle during fueling, LNG has approximately 2.4 times the energy density and a corresponding advantage in driving range, making it more desirable for high-mileage applications such as long-haul trucking.

Refueling stations also face issues in cost, local regulatory approval, and ready access to gas supply. The cost of refueling stations ranges from as low as $50,000 for a station that can fuel four to eight vehicles a day to several million dollars for a high-capacity station. New examples of high-capacity stations include those installed in 2015 by Honda of America at its Marysville, Ohio, factory and Fiat Chrysler Automobiles (FCA) at its Detroit Truck Terminal. The Honda station was constructed and is operated by Trillium CNG, while TruStar Energy was responsible for the FCA facility.

The main regulatory driver for the use of natural gas as a transport fuel is emissions regulations. These include mandates to reduce emissions of greenhouse gases (GHGs), particulate matter (PM), and nitrogen oxides (NOx) in regions with more stringent regulations including the European Union, Japan, Canada, and the United States. In the United States, next-generation emissions standards being phased in during 2017 will begin to affect medium- and heavy-duty vehicles such as trucks and buses, while even light-duty vehicles (LDVs) will face tighter limits on PM and NOx, in addition to tighter fuel economy standards. According to the U.S. Department of Energy's Argonne National Laboratory, light-duty NGVs emit 6% to 11% fewer full-lifecycle GHG emissions than comparable gasoline-fueled vehicles. The gap is wider when comparing diesel vehicles to CNG. The PM and NOx emissions from diesel-powered medium- and heavy-duty vehicles running in dense urban areas have a bigger impact on air quality, giving a significant advantage to natural gas alternatives. The cleaner emissions from NGVs also negate the need for expensive diesel exhaust after-treatment systems, which add to maintenance costs on these vehicles.

U.S. Natural Gas Vehicles Revenue

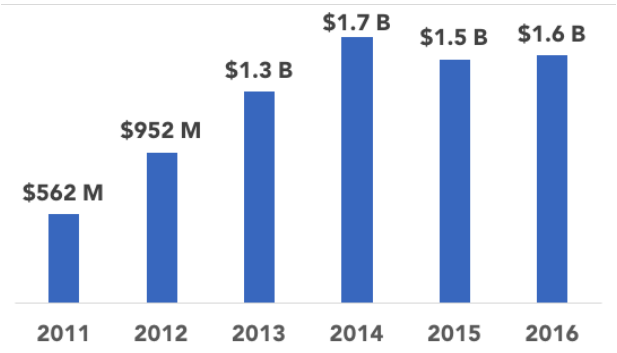
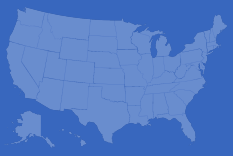


Figure 19 (Navigant Research)

The market for NGVs and corresponding refueling infrastructure remains a mixed bag, and is highly dependent on vehicle segment and region. As with other alternatives to traditional liquid fuels, natural gas does not represent a universally viable competitor to gasoline and diesel for vehicles, though Navigant Research expects the market to grow. The global light-duty vehicle market is projected to grow to more than 105 million vehicles annually by 2026, along with another 6.2 million medium- and heavy-duty vehicles.

NGVs are expected to account for more than 4.5 million light-duty and nearly 456,000 heavier-duty vehicles. As a result, the natural gas refueling infrastructure market is projected to grow at a 4.4% compound annual growth rate globally to a total of 39,300 locations by 2026.

ADVANCED ELECTRICITY GENERATION



$52.2 BILLION

U.S. revenue

8%

annual growth

$455.6 BILLION

global revenue

5%

annual growth

Overview

For the third year in a row, **Advanced Electricity Generation is the largest advanced energy segment globally**. With $455.6 billion in revenue, this segment represents nearly a third of the overall global advanced energy market in 2016. Up 5% from 2015, Electricity Generation experienced the third straight year of growth.

Global Solar PV led all product categories and generated a record high $131.8 billion in revenue in 2016. With more than 77 GW installed worldwide last year, **Solar PV also set a record growth rate of 35% over the previous year, topping off a third straight year of growth.**

Global Advanced Electricity Generation Revenue (million $)

Subsegment	2011	2012	2013	2014	2015	2016 estimated
Solar	96,193	87,672	96,828	94,800	99,057	132,084
Wind	67,069	82,111	67,685	94,575	103,273	86,368
Geothermal	666	1,730	1,470	1,500	1,700	2,148
Hydro	185,260	149,098	84,328	133,871	143,650	97,311
Marine	300	140	-	-	-	-
Waste	4,700	2,750	5,910	2,954	3,223	1,497
Biomass	10,500	7,200	14,700	13,500	5,900	8,500
Nuclear	40,805	34,210	14,300	15,950	18,068	79,844
Gas Turbines	55,481	42,755	42,043	40,199	46,667	37,534
Fuel Cells and Other DG	755	1,009	6,618	7,079	10,927	10,297
Total	**461,729**	**408,674**	**333,882**	**404,428**	**432,464**	**455,582**

Table 13 (Navigant Research)

Meanwhile, estimates for Concentrated Solar Thermal dropped to an all-time low of $300 million.

Growth in Wind revenue, the second largest product category in this segment, has been cyclical globally. Driven by a relative drop in installations in China, Wind revenue fell 16% to $86.4 billion. Hydro was the third largest subsegment, with an estimated $97.3 billion in new orders, a decrease of 32% compared to 2015.

Nuclear saw the largest year for new orders globally since Navigant has been tracking for AEE: $79.8 billion (up 342% over 2015). Most of this growth occurred in Asia, led by China. Gas Turbines, including simple cycle and combined cycle varieties, declined 20% to $27.5 billion in revenue in 2016, the lowest total for new orders in the six-year period covered in this report.

Global Nuclear Generation Revenue

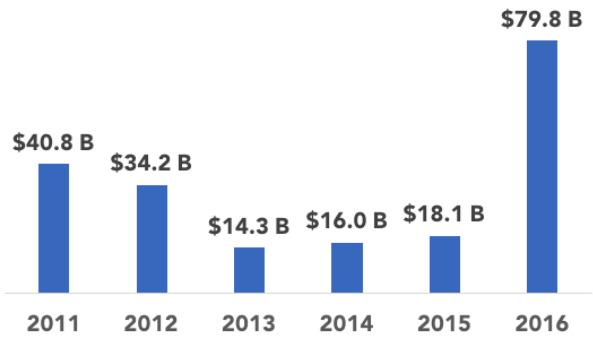


Figure 20 (Navigant Research)

U.S. Advanced Electricity Generation Revenue (million $)

Subsegment	2011	2012	2013	2014	2015	2016 estimated
Solar	8,246	11,850	19,519	22,110	19,188	24,945
Wind	12,993	25,461	2,060	8,252	14,450	14,064
Geothermal	118	723	833	450	450	629
Hydro	-	386	-	897	488	179
Marine	30	-	-	-	-	-
Waste	640	290	550	348	524	227
Biomass	300	600	900	882	-	22
Nuclear	12,287	-	-	-	-	-
Gas Turbines	4,017	4,542	4,376	9,204	10,455	9,208
Fuel Cells and Other DG	182	91	2,165	2,394	2,725	2,913
Total	**38,813**	**43,943**	**30,404**	**44,537**	**48,280**	**52,187**

Table 14 (Navigant Research)

Biomass (up 44%) and Geothermal (up 26%) each experienced strong year-on-year growth globally with $8.5 billion and $2.1 billion in revenue, respectively. Meanwhile, Fuel Cells and Other Distributed Generation (down 6%) and Waste (down 54%) declined to $10.3 billion and $1.5 billion.

In the United States, Electricity Generation remained the second largest advanced energy segment. With $52.2 billion in estimated revenue, this segment represents more than a quarter of the total U.S. advanced energy market in 2016. Growth in this segment compared to 2015 was 8%, slightly lower than the five-year average of 9% since 2011.

For the third straight year, renewables accounted for most annual utility-scale capacity additions – with nearly 9 GW installed in Q4 2016 alone. Solar PV was by far the largest product category, led by a massive surge in utility-scale installations, resulting in a 30% increase in revenue, despite declining costs. Solar PV revenue in 2016 was $24.9 billion – nearly half of the U.S. segment total. Wind was the second largest subsegment with $14 billion in revenue, down slightly (3%), but showing relative stability compared with the boom-and-bust of previous years. U.S. revenue for

Gas Turbines was $9.2 billion, down 12% from 2015. According to the EIA, gas is expected to provide 34% of U.S. electricity generation in 2017, as coal falls to an estimated 30% due in large part to lower gas prices. Despite relatively larger market sizes in 2011-14, Biomass has seen limited activity in recent years, with an estimated $22 million in 2016,

well below the 2014 peak of $882 million in 2014.

Geothermal (up 40%) reached $629 million in revenue in 2016, while Fuel Cells and Other Distributed Generation shrugged off the global contraction, growing 7% to an estimated $2.9 billion.

U.S. Geothermal Revenue

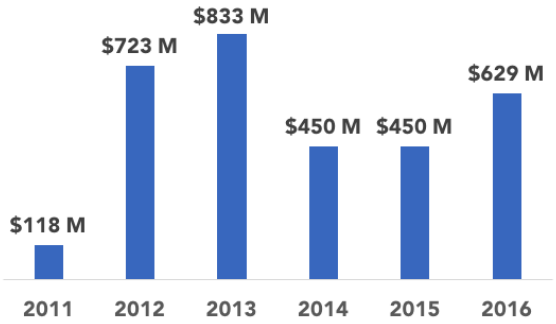


Figure 21 (Navigant Research)

Solar PV Sets New Records Nationally and Globally

In 2016, the solar PV industry set a record with an estimated 77.2 GW of new capacity installed around the world – 52% above 2015's installation figure of 51 GW.[1] That does not mean the year was an easy one for the industry. Pricing pressure on manufacturers and developers alike kept revenue growth from matching the rate of deployment. Still, the global market grew 35% in 2016, to $131.8 billion.

[1] Official estimates range from 50-58 GW for 2015 due to different reporting methodologies. For the purpose of this report, Navigant Research used a conservative estimate.

Solar PV module prices continued their dramatic price drops in 2016 – by as much as 30%. Expansion of PV manufacturing capacity between 2015 and early 2016 caused a slight overcapacity, stimulating price competition between manufacturers. Also, countries around the world changed from Feed-in Tariffs (FiTs) to competitive auctions, which forced developers to cut margins to win deals. These factors led to record deployment – and lower costs for solar power. 2016 marked the lowest Power Purchase Agreement (PPA) price for solar PV, with Dubai Electricity and Water Authority signing a $0.029/kWh PPA in the United Arab Emirates for phase three of the 800 MW Mohammed bin Rashid Al Maktoum Solar Park. The 350 MW project will be built by a consortium led by the Masdar Group and will be commissioned by 2020.

U.S. installations also set an all-time high, with an estimated 14.6 GW of capacity added in 2016 – a 90% increase over 2015. Utility-scale installations accounted for more

U.S. Solar PV Revenue

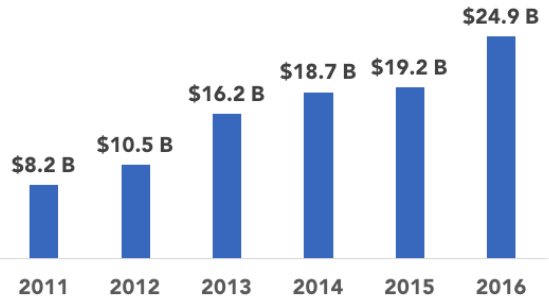


Figure 22 (Navigant Research)

than two-thirds of the total. The U.S. market surged in anticipation of the scheduled

reduction of the federal Investment Tax Credit (ITC) at the end of 2016. Instead, the ITC was extended late in the year through 2019 at the 30% level. Some projects that would have been fast-tracked to catch a vanishing ITC have now been spaced out, carrying the utility-scale boom into 2017 and beyond.

Commercial and residential capacity additions also increased in 2016, but at a slower rate. There were an estimated 2.7 GW of new residential additions and 1.6 GW of commercial installations in the U.S. market in 2016. These two segments have accounted for between 40% and 60% of the total market the last five years, but dropped below 30% in 2016 as utility-scale installations took off. (It is important to note that a significant portion of corporate PPA-driven expansion is off-site and therefore counted under the utility-scale total.) California, North Carolina, Arizona, New Jersey, and Nevada continue to lead the market, but growth in Georgia, Utah, Texas and even South Carolina, among others had strong showings in 2016, contributing to the new record. California, the largest market for residential solar, saw a decline in new additions in 2016 compared to prior years.

Globally, solar PV growth in 2016 was led by China. The country doubled its capacity additions to around 30 GW – 22 GW in the first six months of 2016 as developers rushed to benefit from the 2015 FiT. The Japanese market fell an estimated 14% compared to 2015, but still added 8.7 GW, making it the third-largest market worldwide, after the United States.

One of the countries that showed strongest growth was India, which more than tripled new capacity additions from 2 GW in 2015 to over 6 GW in 2016. (The total of 2016 installations was approximately 8 GW near the end of the year, but a number of projects then in the commissioning stage officially came online in 2017.) The country must further increase growth in order to achieve its ambitious target of 100 GW of solar capacity by 2022. The Ministry of New and Renewable Energy is therefore focusing on large utility-scale installations and recently doubled its new generation target for this category from 20 GW to 40 GW by 2020. The target calls for a total of 60 GW of combined "Large- and Medium- Scale" systems to compliment 40 GW of rooftop systems.

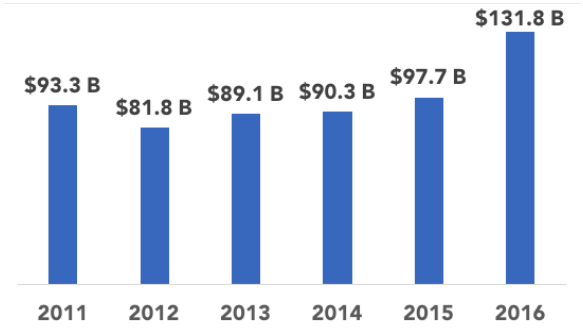


Figure 23 (Navigant Research)

Meanwhile, at an estimated 7.1 GW of installations, Europe had its worst year since 2007 – a 17% decline from 2015. Despite the relatively high retail cost of electricity on the continent, the solar industry in Europe is going through a transition period. The industry is expected to further decline in 2017 as incentives expire in the UK, the largest market

during the past two years. But not all is gloomy. Italy, which recently adopted net metering, increased solar installations in 2016. In Spain, the government is rethinking the so-called "sun tax" that amounted to a retroactive tax for onsite consumption. If the tax is reversed, it could help to revive development in the country with the best solar resources on the continent.

Rhode Island Lays Foundation for U.S. Offshore Wind

The United States installed its first offshore wind facility in 2016. The 30 MW Block Island project off Rhode Island, developed by Deepwater Wind, now raises the broader question to industry followers and the American public alike: Does Block Island herald the beginning of an offshore wind market in the United States?

If it does, there is a lot of catching up to do, compared to the rest of the world. At the end of 2015, total global offshore wind capacity reached nearly 12,000 MW. A remarkable 3,755 MW of that total came online in 2015, driven largely by Germany.

The Production Tax Credit (PTC) and the Investment Tax Credit (ITC), tax policies that support wind projects, were reinstated in late 2015, and critical new timeline flexibility announced in mid-2016 allows wind projects that began construction or achieve "safe harbor" through a 5% spending on equipment by the end of 2016 to have four years to complete construction and receive 100% tax credit value.

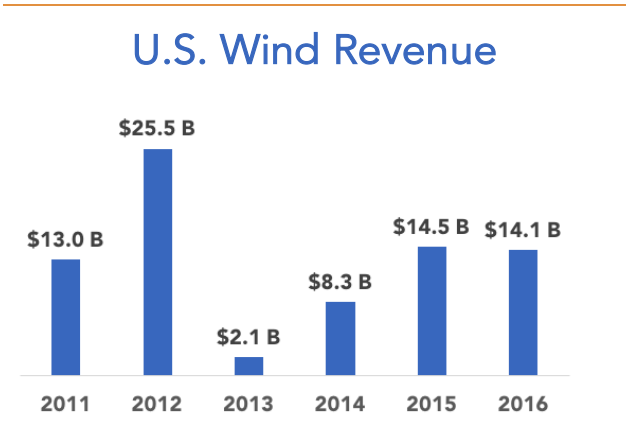


Figure 24 (Navigant Research)

The following three years provide declining tax credit values (80%, 60%, and 40%) if projects begin construction in years 2017, 2018, and 2019, providing a window of policy certainty that will affect the installation of wind projects through 2023. Navigant Research estimates 8.2 GW of wind was installed in the U.S. in 2016, bringing the cumulative total to approximately 84 GW – enough capacity to generate electricity for 20 million homes.

Despite the late start, Navigant Research projects that the United States will develop a modest U.S. offshore wind market by the early 2020s, with multiple projects in the 300 MW or above range. The following are developments driving the U.S. offshore wind industry in the coming years:

- **Federal Ocean Leases:** More than 16,000 MW in the offshore wind project development pipeline is advancing thanks to 11 offshore wind-site lease auctions offered by the federal Bureau of Ocean Energy Management (BOEM).

- **Massachusetts:** First-in-the-nation legislation was passed in July 2016 requiring utilities to contract for 1,600 MW of offshore wind by 2027. Deepwater, DONG Energy, and OffshoreMW each hold federal leases for tracts off the Massachusetts coast and are expected to compete for these power contracts. DONG has already entered into a partnership with Eversource Energy, with the utility taking a 50% stake in the Bay State Wind project off of Martha's Vineyard.
- **New York:** In his 2017 State of the State Address, Governor Andrew Cuomo committed the state to building 2.4 GW of offshore wind by 2030. Long Island Power Authority has contracted with Deepwater for a 15-turbine, 90 MW project at a cost of $740 million. Statoil outbid NYSERDA in a BOEM auction, securing an offshore lease for another project at the record price of $42 million.
- **Carper-Collins ITC Bill:** This bill in the U.S. Senate would extend the 30% investment tax credit (ITC) to up to 3 GW of offshore wind. Due to falling prices, estimates have reduced the cost of the bill from $3.5 billion to $535 million, making it more attractive to lawmakers.
- **U.S. DOE Demonstration Projects:** The DOE has awarded two Advanced Technology Demonstration Projects in Ohio and Maine for the Lake Erie Energy Development Corporation's Icebreaker and the University of Maine's New England Aqua Ventus I projects, respectively. Both are eligible for up to $40 million each, contingent on reaching milestones and congressional appropriations.

U.S. offshore wind can expect costs to fall over the next decade, making it easier to capture the abundant potential in the United States. A new cost analysis by the National Renewable Energy Laboratory shows scenarios for cost reductions below $100/MWh by 2025, making this resource competitive in some regions of the country, including the Northeast, where retail electricity prices are high. Results in recent European contract auctions support this assessment. DONG won a contract for 700 MW at €72.70/MWh (~$80.52/MWh) and Vattenfall captured a Danish near-shore tender at €63.8/MWh (~$71.15/MWh).

With a technical potential of 2,058 GW accessible in U.S. waters, the scale of offshore wind development is potentially massive. That potential is nearly double the total electric generation capacity of the United States in 2015. A DOE analysis expects the United States to could develop as much as 86 GW of offshore wind by 2050. While it's a small fraction of the potential, it means offshore wind could be a U.S. reality before long.