ADVANCED ENERGY ECONOMY

ADVANCED ENERGY NOW

2021 Market Report

Global and U.S. Markets by Revenue 2011-20 and Key Trends in Advanced Energy Growth

Prepared by Guidehouse Insights

Advanced Energy Now 2021 Market Report

ADVANCED ENERGY ECONOMY

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ABOUT ADVANCED ENERGY ECONOMY

Advanced Energy Economy (AEE) is a national association of businesses that are making the energy we use secure, clean, and affordable. AEE is the only industry association in the U.S. that represents the full range of advanced energy technologies and services, both grid-scale and distributed. Advanced energy includes energy efficiency, demand response, energy storage, wind, solar, hydro, nuclear, electric vehicles, and more. AEE's mission is to transform public policy to enable rapid growth of advanced energy businesses. Engaged at the federal level and in more than a dozen states around the country, AEE represents more than 100 companies in the $240 billion U.S. advanced energy industry, which employs 3.6 million U.S. workers. AEE's PowerSuite online platform allows users to track regulatory and legislative issues in state legislatures, U.S. Congress, state PUCs, RTOs/ISOs, and FERC. Sign up for a free trial at powersuite.aee.net. Learn more at www.aee.net and follow the latest industry news at @AEEnet.

ABOUT GUIDEHOUSE INSIGHTS

Guidehouse Insights, the dedicated market intelligence arm of Guidehouse, provides research, data, and benchmarking services for today's rapidly changing and highly regulated industries. Our insights are built on in-depth analysis of global clean technology markets. The team's research methodology combines supply-side industry analysis, end-user primary research, and demand assessment, paired with a deep examination of technology trends, to provide a comprehensive view of emerging resilient infrastructure systems. Additional information about Guidehouse Insights can be found at www.guidehouseinsights.com.

FOREWORD

Welcome to the latest edition of *Advanced Energy Now Market Report*, prepared for Advanced Energy Economy by Guidehouse Insights. In addition to covering the main trends in advanced energy markets we've been tracking since 2011, the 2021 edition contains U.S. and global revenue for 2019 and 2020 – two very different years in the U.S. and world economies.

2019 was a year of strong growth, with U.S. advanced energy revenue up 18% overall – four times the U.S. GDP growth rate of 4% – while global advanced energy revenue grew 8%. In 2020, the COVID-wracked U.S. economy contracted by 2%, and U.S. advanced energy revenue did the same; worldwide, advanced energy revenue rose 2.5% in 2020. The 2% decline in U.S. advanced energy revenue in 2020 was a full seven percentage points off the compound annual rate of 5% since 2011.

What's important to recognize now is the great potential for the advanced energy industry to rebound in 2021 – and lead the return to economic growth in this country.

As the Biden Administration and Congress pivot from COVID relief to post-COVID stimulus, they should look no further than to advanced energy for a place to invest stimulus funds. The same is true for state policymakers. Our analyses in eight states have shown that spending on advanced energy technologies and services generates a return on public investment ranging from four-to-one to 14-to-one. For jumpstarting the U.S. and local economies, advanced energy is a sure bet.

For advanced energy companies, policy enables business growth, and that makes AEE a sure bet. In 2020, we won passage of the Virginia Clean Economy Act, which mandates investments in renewable energy, energy efficiency, and energy storage. We won legislation in Florida to develop an electric vehicle charging plan for the state's highways and regulatory approval in New York for massive investment in EV charging. And we got FERC to allow aggregations of distributed energy resources to participate in wholesale electricity markets. The policies we win help advanced energy companies expand their total addressable market, which is key to equity value creation.

We also help you – businesses as well as advocates for advanced energy, inside government and out – help yourself. Our **PowerSuite** technology platform allows users to manage energy policy risks and opportunities across the country with one, easy-to-use interface.

If your company is in the advanced energy industry, you should be involved with AEE – as a member, or as a subscriber to **PowerSuite**. If you're not already, please come and see us at AEE.net.

Nat Kreamer

CEO, Advanced Energy Economy

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INTRODUCTION

The *Advanced Energy Now 2020 Market Report* is Advanced Energy Economy's seventh report of market size, by revenue, of the advanced energy industry, worldwide and in the United States.

As defined by AEE – a national association of businesses 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, plug-in electric vehicles, natural gas-fueled trucks, high-performance buildings, energy-saving industrial processes, wind turbines, onsite and utility-scale solar power, energy storage, 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 36 subsegments, enumerated in the figure to the right, many of which contain multiple product categories.

ENERGY SUPPLY	
Advanced Electricity Generation	**Electricity Delivery & Management**
Hydropower Solar Wind Geothermal Marine Waste Biomass Nuclear Fuel Cells	Transmission Distribution AMI Microgrids Energy Storage Enabling I&CT
Advanced Fuel Production	**Advanced Fuel Delivery**
Ethanol & Butanol Biodiesel Bio-methane Synthetic Diesel & Gasoline Bio-oil CNG & LNG Hydrogen	Fueling Stations
ENERGY DEMAND	
Building Efficiency	**Advanced Transportation**
Building Design Building Envelope HVAC District Energy, CHP, CCHP Water Heating Lighting Appliances & Electronics Demand Response	Advanced Vehicles Vehicle Design & Materials 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 (later Navigant Research and now Guidehouse Insights) and published in January 2013. *Economic Impacts of Advanced Energy* presented revenue data across what was then 41 subsegments of advanced energy for 2011 and estimates for 2012. Beginning with *Advanced Energy Now 2014 Market Report*, Guidehouse Insights has continued to track global and U.S. advanced energy revenue. *Advanced Energy Now 2020 Market Report* presents final annual revenue from 2018 and 2019 and estimated revenue for 2020 to provide a snapshot of market size at the present time and discover trends over the past nine years.

Advanced Energy Now 2020 Market Report draws on more than 60 previously published Guidehouse Insights studies on specific industry categories for the most comprehensive assessment of advanced energy markets to date. However, the results presented in *Advanced Energy Now 2020 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 Guidehouse Insights 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 fuels such as ethanol and biodiesel, however, are included in the Advanced Fuel Production segment.
- In some product categories, such as Hydropower and Nuclear, 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 Guidehouse Insights 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, air- and 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 technology 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 the data tables. But in all cases, compound annual growth rates (CAGR) are determined using only those product categories for which market data are available for all years being calculated.

In addition, there have been a few changes in methodology in this report. In accordance with AEE's ongoing reconsideration of what constitutes advanced energy, certain subsegments and product categories have been eliminated for this edition. Specifically, Clean Diesel has been eliminated from Advanced Transportation, due to questions raised about emissions associated with these vehicles and the clear industry trend toward vehicle electrification going forward. In Electricity Generation, Gas Turbines and Natural Gas Gensets have been eliminated, on the grounds that natural gas-fired generation is no longer advanced, but rather the status quo. (As a result, the subsegment Fuel Cells and Other DG has been renamed as simply Fuel Cells.) In addition, Electric Vehicle Charging Infrastructure has been moved from Electricity Delivery & Management to Advanced Fuel Delivery, to group all refueling technologies together. Finally, Hydrogen Production Technologies has been added as a product category to Advanced Fuel Production, tracked within the Hydrogen subsegment. In the case of exclusions, prior year revenue data have been adjusted to be comparable.

OVERVIEW & SUMMARY FINDINGS

Advanced energy revenue reached over $1.4 trillion worldwide in 2020, growing by 2.5% over 2019, following 7% growth the year prior. Advanced energy revenue is now greater than pharmaceutical manufacturing globally, and double that of coal mining.[1] Since Guidehouse Insights started tracking for Advanced Energy Economy in 2011, **global advanced energy revenue has risen at a Compound Annual Growth Rate (CAGR) of 6%.**

Global Revenue by Industry

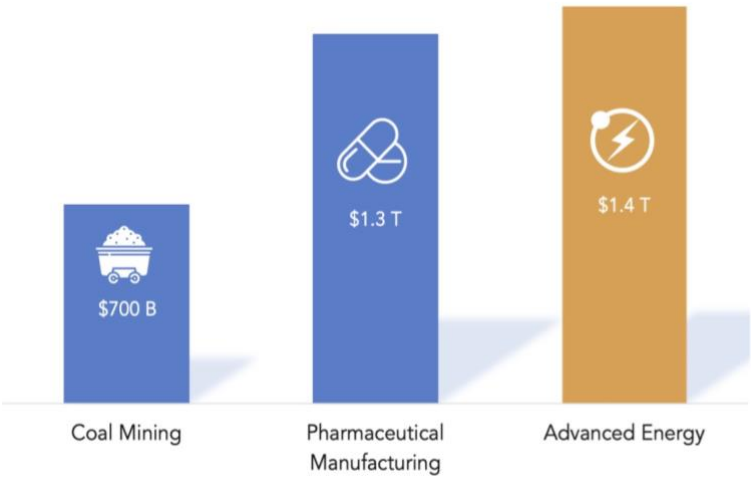

Figure 1

[1] IBISWorld, https://bit.ly/3vkUBHC and https://bit.ly/3rL9BMP.

GLOBAL ADVANCED ENERGY MARKET

$384 Billion
advanced electricity generation

$342 Billion
building efficiency

$319 Billion
advanced transportation

$184 Billion
advanced fuel production

$149 Billion
electricity delivery and management

$64 Billion
advanced industry

$9 billion
advanced fuel delivery

Global Advanced Energy Revenue (Millions $)

Subsegment	2011	2016	2017	2018	2019	2020
Advanced Transportation	64,582	153,532	205,965	256,798	277,502	318,910
Advanced Fuel Production	110,667	118,086	144,635	160,193	221,785	184,260
Advanced Fuel Delivery	2,333	1,817	4,025	3,972	9,357	9,288
Building Efficiency	118,055	249,351	273,278	299,084	325,161	341,749
Advanced Industry	30,576	43,925	48,821	53,261	60,335	64,310
Advanced Electricity Generation	406,248	409,035	410,934	429,672	385,990	384,406
Electricity Delivery & Mgt	50,655	103,204	115,943	120,676	136,088	148,623
Total	783,118	1,078,951	1,203,601	1,323,656	1,416,217	1,451,546

Table 1 (Guidehouse Insights)

Globally, the biggest revenue increase among the seven segments of advanced energy came in Advanced Transportation, up $41 billion (15%) to nearly $319 billion in 2020. This growth was led by Plug-In Electric Vehicles (PEV), up 27% over 2019. PEVs overtook Hybrid Electric Vehicles as the largest revenue segment in 2017 and has only grown its segment share since.

While Advanced Transportation also grew the fastest in 2020 (15%) due to the surge in PEV sales, Electricity Delivery and Management also demonstrated ongoing strength, growing 9% in 2020, to $149 billion. Energy Storage has been one the primary catalysts of this growth, with revenues increasing every year since 2014, including an impressive 35% year-over-year growth in 2020.

Building Efficiency also saw a notable increase in 2020, up $16.6 billion, or 5%, to $342 billion globally. This growth was led by residential energy efficiency and smart appliances, which collectively grew by 10% in 2020. This growth helped to mitigate more severe COVID-related impacts seen in commercial and industrial subsegments. High-efficiency Lighting, the largest category of Building Efficiency, was up 1% in 2020, to $146.5 billion, after 4% growth the year before.

Advanced Fuel Production experienced the sharpest revenue decline, down nearly $38 billion, or 17%, to $184 billion globally. This drop is largely attributed to the impacts of COVID-19, which had dramatic

effects on vehicle travel – and therefore consumption of gasoline, with which ethanol (the largest component of Advanced Fuel Production) is mixed. One new development in this edition is the emergence of hydrogen fuel, which has been growing significantly – though more in Hydrogen Production Technology than in the fuel itself – since 2018, reaching $60 million in 2020.

In the United States, advanced energy revenue had a strong year in 2019, growing a robust 18%, before falling 2% in 2020, in parallel with the decline of U.S. GDP overall. Still, at $240 billion, U.S. advanced energy revenue is close to that of food and beverage stores and twice the revenue of electrical equipment and appliances.[2] **Since 2011, U.S. advanced energy revenue has grown at CAGR of 5%.**

U.S. Revenue by Industry

Figure 2

[2] Bureau of Economic Analysis, https://bit.ly/3th9A3o.

U.S. ADVANCED ENERGY MARKET

$94.5 BILLION
building efficiency

$39.8 BILLION
advanced electricity generation

$37.7 BILLION
advanced transportation

$33.6 BILLION
advanced fuel production

$22.2 BILLION
electricity delivery & management

$11.6 BILLION
advanced industry

$540 MILLION
advanced fuel delivery

The bulk of the $5 billion overall drop in U.S. revenue came from one segment, Advanced Fuel Production, which was down $20.9 billion, largely due to a sharp decline in ethanol revenue from a nine-year peak the year before. But the rest of advanced energy remained strong even in the COVID year, with growth of 8% overall when ethanol alone is excluded from the U.S. total. Driving this resilience has been a surge in revenue across several product categories, including PEVs, Energy Storage, Residential Energy Efficiency, and Wind.

Advanced Transportation saw both the largest revenue increase ($5.1 billion) and the biggest growth year over year (16%). Leading this growth was revenue from PEVs, up 19% from 2019, to $19.7 billion. Indeed, PEV growth has been explosive, with a compound annual growth rate (CAGR) of 45% since 2011. Previously, PEV gains have come at the expense of hybrid vehicles, which peaked at $15 billion in 2013. But after a period of relative stagnation, Hybrid Vehicles have also shown growth over the past two years, with revenue rising 8% in 2020, to $10.9 billion.

U.S. Advanced Energy Revenue (Millions $)

Subsegment	2011	2016	2017	2018	2019	2020
Advanced Transportation	8,715	20,804	23,825	32,428	32,615	37,657
Advanced Fuel Production	43,164	28,944	29,731	33,471	54,514	33,633
Advanced Fuel Delivery	254	360	388	747	680	540
Building Efficiency	35,319	68,245	75,190	82,843	90,271	94,465
Advanced Industry	4,202	8,283	9,082	9,465	10,588	11,633
Advanced Electricity Generation	34,796	40,440	37,569	31,743	36,273	39,797
Electricity Delivery & Mgt	12,179	19,039	19,901	17,709	20,160	22,242
Total	138,628	186,116	195,686	208,407	245,101	239,967

Table 2 (Guidehouse Insights)

Building Efficiency – the largest segment of U.S. advanced energy revenue – saw 5% revenue growth in 2020, reaching $94.5 billion and continuing its unbroken streak of year-over-year increases. There was a notable drop, however, from the 9% growth seen in 2019, as well as the 10% CAGR since 2011, largely due to COVID-19. Impacts from the pandemic were experienced in the commercial and

industrial (C&I) space due to a decline in C&I construction and changing work environments. However, with people spending more time at home and energy load shifting from C&I to residential, residential energy efficiency investments associated with new home construction and renovation drove up Building Efficiency revenues, as did sales of smart appliances.

U.S. Advanced Fuel Production mirrored the global market in a deep decline. Following a record year in 2019, both in total ($54.5 billion) and growth rate (63%), revenues plummeted, dropping $21 billion, or 39%, to $33.6 billion in 2020. This is almost exclusively due to Ethanol sales, which were dramatically impacted in both consumption and price. U.S. Ethanol sales declined 13% by volume in 2020, while the price per gallon dropped even further (33%). This is largely a function of COVID-19, which reduced gasoline consumption globally. As a fuel substitute, the price of ethanol is highly correlated to the price of gasoline, further compounding the demand impact.

Advanced Electricity Generation revenue showed impressive growth in the face of COVID-19, up 10% in 2020 to $39.8 billion. This segment has fluctuated between roughly $30 billion and $40 billion since 2011, with a low of $24.2 billion in 2013, for a CAGR of 2%. Growth in 2020 was principally a function of Wind, which grew 32% in a record year of deployment, following an 18% increase the year before. Solar growth was strong in 2019, with revenues up 14%. But 2020 saw a 5% drop in revenue, despite a 6% increase in capacity installed that year, primarily in grid-scale projects. Distributed solar fell 10% in capacity installed in 2020.

Electricity Delivery and Management was the second-highest advanced energy growth segment in 2020, increasing by 10% over 2019, to $22.2 billion and adding $2 billion in overall revenues. As with Advanced Electricity Generation, one product category shows disproportionate growth – Energy Storage, with revenue up 139% in 2020, to $1.6 billion. Also buoying this segment is Smart Street Lighting, with 20% growth, to $7.4 billion, adding $1.2 billion to U.S. advanced energy growth in 2020.

BUILDING EFFICIENCY

$94.5 BILLION
U.S. revenue

5%
annual growth

$341.7 BILLION
global revenue

5%
annual growth

Overview

Building Efficiency remains a consistently reliable growth segment for advanced energy globally and in the United States. **Global Building Efficiency revenue reached $341.7 billion in 2020 after growing 5% in 2020 and 9% in 2019**. **In the United States, Building Efficiency revenue grew to $94.5 billion, up 5% in 2020, following an increase of 9% in 2019.** Over the period 2011-2020, **Building Efficiency revenue grew at a compound annual growth rate (CAGR) of 11% globally and 10% in the U.S.**, counting only products for which we have data for all years.

Globally, the combination of regulatory drivers (energy efficiency and electrification policies and targets) and customer interest in building-wide solutions (smart devices, DERs) are driving increased investment in building controls and efficiency technologies.

Lighting remained the largest subsegment globally, with $146.5 billion in revenue in 2020, up 1% from 2019, following 4% growth the year before. Since the commercialization of LED lighting technology, the growth of energy efficient lighting has been extraordinary. Growth has tapered in the past few years due to declining costs and higher saturation of LED lighting; customers are now looking to enhance the value proposition of LED lighting through connected lighting controls (see below).

In other notable categories, revenue from Smart Appliances has taken off with significant growth over the past five years. Up 29% in 2020 and 45% the prior year, this small but growing product category reached $15.3 billion globally in 2020, nearly doubling its revenues since 2018.

Global Building Efficiency Revenue (Millions $)

Subsegment	2011	2016	2017	2018	2019	2020
Building Design	11,537	19,021	21,180	23,605	25,760	27,485
Building Envelope	13,017	22,724	25,676	29,063	32,805	36,345
HVAC	44,383	65,820	71,489	78,592	84,779	87,381
District Energy & CCHP	2,229	3,875	4,291	4,834	5,486	5,792
Water Heating	1,467	2,438	3,182	4,774	7,161	9,925
Lighting	41,329	124,782	133,561	139,473	145,176	146,491
Appliances	266	3,018	4,676	8,133	11,829	15,262
Demand Response & Enabling IT	3,827	7,675	9,224	10,609	12,165	13,069
Total	**118,055**	**249,351**	**273,278**	**299,084**	**325,161**	**341,749**

Table 3 (Guidehouse Insights)

The growing affordability of sensors, smart thermostats, artificial intelligence (AI), and cloud computing has had a profound effect on the building controls market (tracked in the Demand Response and Enabling IT subsegment). Intelligent building solutions that combine hardware, software, and services have been emerging rapidly because of growth in digital technologies to address a multitude of needs in commercial buildings. Many of these solutions evolved from more basic building management systems (BMS) and energy efficiency offerings, spanning into other areas of potential savings and benefits for building managers. Space utilization, improved health and air quality, and demand response (DR) are some of the new and evolving applications being offered in the market because of digitization. **Globally, revenue from Building Energy Management Systems grew 17% from 2018**

to 2019 and 4% in 2020, reaching $5.4 billion. Home Energy Management Systems revenue grew 15% from 2018 to 2019 and 14% in 2020, reaching $4.7 billion.

The COVID-19 pandemic caused disruption within the Building Efficiency segment, with mixed effects. While Global Building Efficiency revenues grew by 5% in 2020, this is a notable drop from the 9% growth in 2019 and 11% CAGR over the 2011-2020 period. Each Building Efficiency subsegment experienced a decline in year-over-year growth between 2019 and 2020. The impact was more heavily felt in commercial and industrial product categories due to shifting work environments and reductions in construction investment. This was somewhat offset by an increase in residential home construction and home improvement spending, which helped to buoy overall Building Efficiency revenues (see "COVID-19 Remote Work Experience Points to Enhanced Residential Customer Engagement," below). **Residential Energy Efficient Homes & Services grew by 15% in 2020 to nearly $34.4 billion.**

U.S. Building Efficiency Revenue (Millions $)

Subsegment	2011	2016	2017	2018	2019	2020
Building Design	2,819	4,711	5,279	5,884	6,555	7,065
Building Envelope	8,720	14,561	16,215	17,950	19,386	20,586
HVAC	10,522	15,233	16,433	17,860	18,845	19,360
District Energy & CCHP	814	832	1,055	1,193	1,338	1,341
Water Heating	1,133	1,711	2,127	2,960	3,766	4,265
Lighting	9,139	26,351	28,338	30,010	31,353	31,683
Appliances	105	887	1,375	2,163	3,718	4,524
Demand Response & Enabling IT	2,068	3,959	4,370	4,822	5,309	5,641
Total	**35,319**	**68,245**	**75,190**	**82,843**	**90,271**	**94,465**

Table 4 (Guidehouse Insights)

The largest segment of U.S. advanced energy revenue, Building Efficiency has grown consistently since AEE began tracking it in 2011, with total revenue nearly tripling over that time. **U.S. Building Efficiency accounted for $94.5 billion of revenue in 2020, growing 5% in 2020 despite disruption of many utility-administered efficiency programs by COVID-19 restrictions.**

Products and services that support building electrification and energy conservation, such as high efficiency HVAC systems (including air-source heat pumps), associated controls, building envelope improvements, and installation and commissioning services, are poised for continued growth in the coming decade. Heat pumps have emerged as a central solution to decarbonizing buildings through electrification. Other forms of electric heat are available to customers, including resistance heating

(such as electric furnaces and baseboard heaters). However, heat pump technology has risen to the top of the list due to lower energy consumption.

Technology innovation adjacent to traditional energy efficiency offerings, such as intelligent building management systems (BMSs), energy storage, and onsite generation, are the primary forces driving change in this market. With new technologies entering the market, vendors and customers are seeing opportunities for building-wide and building-to-grid solutions that address multiple building operational needs beyond energy savings.

Large corporations, primarily, are adopting full-building solutions, with a big gap between market trailblazers and the rest. Corporations with multiple buildings in their portfolios and sustainability commitments to fulfill are primary adopters of new technology. The rest of the market remains largely inhibited by traditional barriers to growth, adopting new building technologies mainly when replacement is necessary.

Controls Drive Lighting as LEDs Transform the Market

Building owners are moving toward improved energy efficient technologies due to changing building codes and standards, corporate sustainability initiatives, utility incentives, and falling technology costs. Nowhere is this more evident than in the Lighting market. These drivers have led to an increased penetration of LEDs across all sectors. The technology for LEDs has improved in quality and price since LEDs first became available, making them more competitive with other lighting technologies. The improved efficacy, efficiency, and lower costs have driven adoption of LEDs in the commercial and residential building market globally. Government regulations for reduced energy use in commercial buildings have also helped propel LED deployment.

The lighting controls market is driven by proliferation of LEDs, increasingly stringent building codes, and pursuit of energy savings; growth of Internet of Things (IoT); and the desire for increased controllability and data collection and insights. Lighting controls are the next frontier in this evolving market. LEDs are more controllable than their legacy lighting counterparts, which provides the foundation for increased adoption of lighting controls and, in turn, connected lighting systems in the commercial market.

Globally, energy efficient lighting has grown from $121.5 billion in 2016 to $141.3 billion in 2020, though the rate of growth has declined in recent years as LEDs have begun to saturate the market. Growth from 2019 to 2020 was just 1% globally and in the U.S.

U.S. Lighting Revenue, 2016-2020 (Billions)

Figure 3 (Guidehouse Insights)

As controls continue to advance in sophistication, the drive toward increased building data will push forward the connected controls market, increasing adoption of all controls, especially within commercial buildings. Lighting systems in commercial buildings have started to shift from manual controls – the basic on-off of a luminaire from a wall switch – to IoT lighting applications. **Revenue from Intelligent Lighting Controls has grown from $3.3 billion globally in 2016 to $5.2 billion in 2020, and from $1.2 billion to 1.9 billion in the U.S.**

Lighting control strategies in commercial buildings are deployed to help reduce energy consumption used by a lighting system, including scheduling, occupancy sensors, daylight harvesting, task tuning, or load shedding (DR), among others. Some strategies, such as personal control and task tuning, can also provide an improved occupant experience. In recent years, there has been a growing trend to focus on the occupant experience, such as improved productivity, and health and well-being. Lighting control strategies are already supporting this trend and are expected to do so in the short and long term.

In addition to managing consumption and control, integration with other building automation systems can help coordinate HVAC systems, security and access, facility scheduling, and maintenance. The ubiquitous and granular nature of a lighting system enables connected lighting to serve as the foundation for IoT value-add applications, such as space utilization, asset tracking, indoor positioning, and others. These additional solutions expand the capabilities of a lighting system to add value beyond illumination.

Although these advanced applications show promise for market growth in the Lighting segment, their adoption is constrained by the tendency of building developers to choose the lowest-cost controls that meet building codes, whereas the benefits of advanced controls generally accrue to the building operator or long-term occupant. Greater attention to building performance by building owners and their commercial tenants would facilitate faster growth.

Working from Home Puts Focus on Residential Energy Use and Customer Engagement

Due to COVID-19 orders and advisories, homeowners have been spending more time at home. More time at home also means an increase in residential electricity consumption. With rising home utility bills and energy load shifting from commercial and industrial sites to the residential segment, engaging residential customers has become increasingly important for utilities and other electricity providers.

Demand side management (DSM) is key to saving money for households and reducing strain on the grid from residential load. can help achieve this stability as energy loads shift towards the residential segment. But during the pandemic, many energy efficiency programs were paused or stopped, forcing utilities and providers to adapt quickly. The industry has attempted to pivot by reducing reliance on onsite visits, embracing digital tools, and finding new ways to help residential customers save money.

Some utilities are turning to enhanced behavioral demand-side management approaches using new technologies. These technologies enable improved prediction, microtargeting, realization, and verification of energy savings. This is also giving utilities added value for customer engagement through app and web portals, as customer engagement via mobile, online, and social network channels has become a top priority. Improved digital interfaces and analytics are enabling utilities to provide timely and relevant information related to saving energy.

The growth of the smart home device market is expanding the energy monitoring and usage control capabilities available to homeowners. For instance, as of 2020, smart thermostats have become common, providing greater control of HVAC systems while facilitating cost savings and tie-ins to utility demand response (DR) and load-shifting programs. U.S. revenue from Home Energy Management Systems has grown from $1.3 billion in 2016 to $2.2 billion in 2020, rising 10% last year alone.

U.S. Home Energy Management System Revenue, 2016-2020 (Billions)

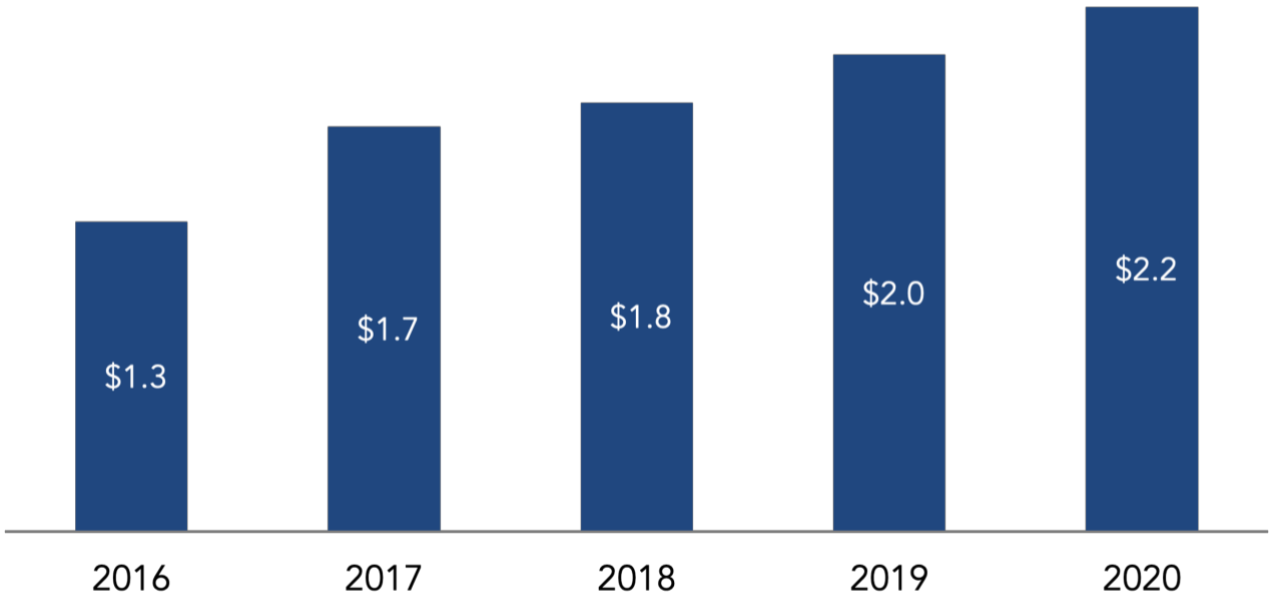

Figure 4 (Guidehouse Insights)

The COVID-19 pandemic has demonstrated the value of engaging with residential customers. As home improvement spending has increased, residential customers have begun to realize the potential for residential energy management solutions to reduce home energy consumption. The coming period should see a proliferation of offerings, by utilities and third-party vendors, especially as states and potentially the federal government establish standards for access to customer data that could be used to develop new products for home energy management.

Smart Appliances Poised for Growth

Smart appliances continue to make inroads as a segment of the growing smart-home market. The effects of COVID-19 did very little to dampen the growth as many consumers, stuck at home but still working during 2020 lockdowns, focused money and energy on upgrading their homes, with smarter products like appliances part of the mix.

Over the past three years, global smart appliance revenue has mushroomed from $8.1 billion in 2018 to $15.3 billion in 2020 at a compound annual growth rate (CAGR) of 37% over two years. In the U.S., revenue attributed to smart appliance sales more than doubled, from $2.2 billion to $4.5 billion over the same two-year period, for a CAGR of 45%.

Smart Appliance Revenue, United States, 2016-2020, (Billions)

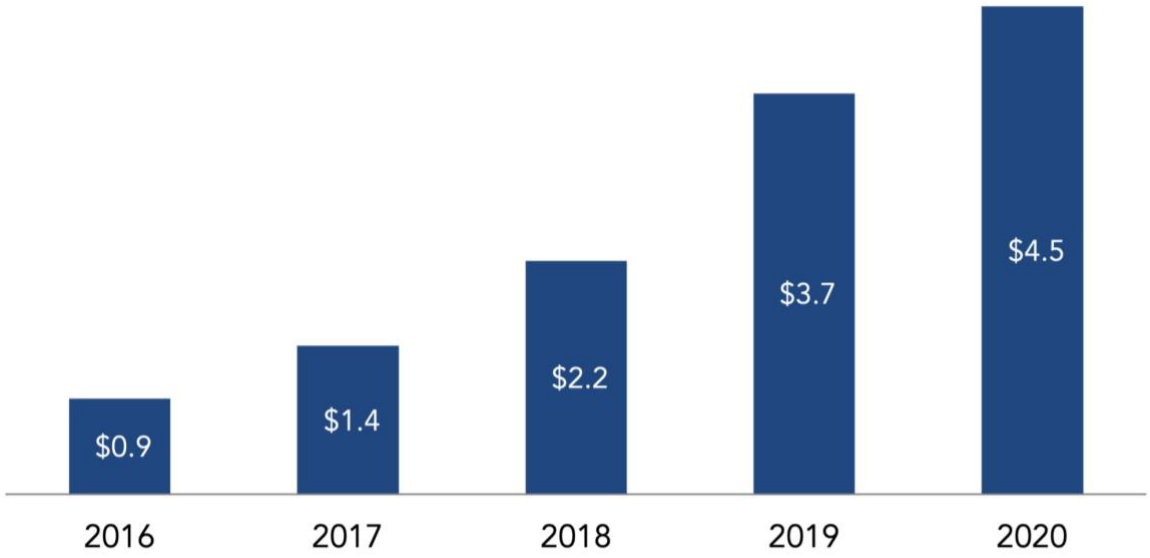

Figure 5 (Guidehouse Insights)

Until recent years, many consumers found the value proposition of a smart appliance to be vague at best, and demand was tepid. But as appliance OEMs have continued to push these smarter products, their marketing efforts have started to resonate. Then, as the pandemic unfolded, the stars started to align for smart appliance.

New appliance features have helped. For instance, LG's line of InstaView refrigerators includes a door that opens via voice command and has a water dispenser that uses UV light to sanitize drinks. Similarly, Sharp is promoting a microwave model that is capable of performing more than 70 voice commands and up to 50 more food presets.

Price remains the biggest barrier to wider adoption of these high-end appliances. Nonetheless, over the coming years, appliances with smarter features are expected to move down market as commodity pricing takes hold and the segment expands.

Growing Role of Heat Pumps for Electrification & Decarbonization

Regulations and pending policies in California, New York, Washington, D.C., and other states and cities are stressing the role of electrification in decarbonizing the built environment. Although multiple options exist to decarbonize heat in commercial buildings, such as integrating renewable natural gas into natural gas supply, electrification is widely considered the most commercially viable pathway to decarbonizing the buildings sector.

Technologies such as electric heat pumps – specifically variable refrigerant flow (VRF) systems – are available to meet heating needs and help meet greenhouse gas (GHG) targets in most climates in the United States. These technologies have already seen sustained growth in adoption over the past five years, with incentives offered through utility energy efficiency programs in some U.S. states. The market is reaching a tipping point, with new climate-related targets spurring added growth and competition among market players in VRF, heat pump, and heat recovery products.

Europe is the most mature market for building decarbonization technologies; VRF systems enjoy widespread adoption in commercial buildings throughout the region. The United States represents the biggest market opportunity for heat pump and VRF OEMs. The market is not yet saturated with VRF and heat pump solutions, customers are getting more familiar with the technology, and local governments across the region are supporting a rapid adoption of decarbonization targets. In Asia Pacific, policy and technology markets primarily focus on energy efficiency targets rather than explicit GHG reduction goals in the buildings sector. Any future electrification in Asia Pacific countries is likely to follow the European scenario and emphasize district systems given their role in heating supply. Latin America and the Middle East & Africa still suffer from limited demand and weak regulatory support for building decarbonization, energy efficient systems, and electrification

As the market matures, significant competition amongst market players is expected, with concentration in several geographic areas:

- Heat pumps still have technical limitations in the northern U.S., although cold-weather models that are more effective at low outdoor temperatures are increasingly available. Utilizing heat pumps for cooling in increasingly warm summers and most heating, with furnace-based heating as back-up is a near-term option. But heat pumps have the biggest market opportunity in regions with moderate temperatures. For instance, California, which has a mild winter season, is headed toward adopting heat pumps. The California Air Resources Board voted to support all-electric building policies in November 2020.
- In Germany, the Renewable Energy Heating Act as part of Energiewende permitted new building constructions from January 2016 only if the space and water heating come from renewable sources, such as solar, solar thermal, biomass, and efficient heat pumps. In addition, the Market Incentive Program by the Federal Ministry for Economic Affairs and Energy supports using solar thermal installations, biomass heating systems, and heat pump.
- In Asia, Japan has supported heat pump water heaters with an incentive program, and China has a guide and policy for electric power substitution. These policies drive electrified heating and cooling market growth.

Guidehouse Insights estimates that U.S. spending on commercial heat pumps will grow at a rate of 13% between 2020 and 2029, slightly higher than the 8% anticipated Global growth rate.

The value proposition for heat pumps in space and water heating improves when coupled with enhanced insulation, which reduces system sizing required. Household decarbonization can be further optimized with EV use and solar power (onsite or community). To contribute to overall decarbonization, electrified water heating, pre-cooling of buildings, and EVs providing flexible charging and discharging could minimize grid purchases of electricity, especially during high demand periods.

ELECTRICITY DELIVERY & MANAGEMENT

$22.2 BILLION
U.S. revenue

10%
annual growth

$148.6 BILLION
global revenue

9%
annual growth

Overview

The market for **Electricity Delivery and Management products and services recorded 10% compound annual growth rate (CAGR) for the period 2011 to 2020 worldwide; in the United States, the CAGR was 2% over that time period.** The year 2019 was one of the biggest for Electricity Delivery and Management, recording 13% growth globally and 14% in the United States; 2020 was strong as well, with global growth at 9% and 10% U.S.

Global Electricity Delivery and Management Revenue (Millions $)

Subsegment	2011	2016	2017	2018	2019	2020
Transmission	25,180	36,110	40,299	40,824	44,005	46,676
Distribution	5,998	7,552	8,552	11,854	13,591	14,571
AMI	6,273	12,666	13,811	13,867	16,055	16,141
Microgrids	3,737	6,835	10,234	7,170	8,139	9,538
Energy Storage	117	1,289	1,850	2,403	2,779	3,757
Enabling ICT	9,351	38,752	41,197	44,559	51,519	57,940
Total	**50,655**	**103,204**	**115,943**	**120,676**	**136,088**	**148,623**

Table 5 (Guidehouse Insights)

Total revenue in the global market is traditionally driven by large-scale transmission infrastructure and the enabling information & communications technology (ICT) that supports grid management. Transmission is a relatively mature market, with moderate growth (7% CAGR 2011-20) expected to continue, with occasional big year-to-year swings resulting from large infrastructure projects. Enabling ICT has grown more consistently over the past 10 years, with a CAGR of 11%, overtaking Transmission revenue in 2016, and now substantially larger, at $57.9 billion in 2020. The fastest-growing subsegment globally has been Energy Storage, with a CAGR of 47% from 2011 to 2020 and 35% growth last year, reaching $3.8 billion.

In the United States, Electricity Delivery and Management revenue has grown at a moderate rate over the past 10 years (CAGR of 2%) but with strong growth in the past two years, along with a pronounced shift among subsegments. Transmission, which comprised nearly half of Electricity Delivery and Management revenue in 2011, has dropped from $6 billion to just over $3.2 billion in revenue since 2016. Though growing modestly in the U.S. over this period, at CAGR of 2% from 2011 to 2020, **Enabling ICT grew 20% from 2018 to 2019 and 11% last year,** reaching $11.2 billion in 2020.

Meanwhile, **Energy Storage has taken off, especially in the past year, jumping 139%, to $1.6 billion, in 2020,** capping a run at 39% CAGR since 2011.

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

Subsegment	2011	2016	2017	2018	2019	2020
Transmission	5,298	6,812	6,000	3,180	3,329	3,216
Distribution	1,064	1,367	1,409	1,614	1,820	1,867
AMI	1,648	1,025	1,332	1,283	1,463	1,265
Microgrids	1,012	2,196	2,817	2,496	2,769	3,093
Energy Storage	81	427	593	701	670	1,599
Enabling ICT	3,075	7,212	7,749	8,435	10,109	11,203
Total	**12,179**	**19,039**	**19,901**	**17,709**	**20,160**	**22,242**

Table 6 (Guidehouse Insights)

Post-COVID, AMI Due to Rebound with Second-Generation Deployments

Global Advanced Metering Infrastructure (AMI) revenue has fluctuated over the past three years, growing slowly in 2018 (0.4%), rapidly in 2019 (16%) and holding, at $16.1 billion, in 2020. China is primarily responsible for the 2018 drop-off, as the country's State Grid Corp. completed its massive first-generation rollout. But the hiccups in AMI deployment in 2020, especially in the United States, came from COVID-19.

COVID had a notable impact on the AMI market last year due to financial constraints and meter installation restrictions. **Smart meter and related revenue barely held steady globally and declined in the U.S. by 14%, at $16.1 billion and $1.3 billion, respectively.** Disruption in the AMI market has additional impacts on the larger Enabling ICT market, as meter data management systems are often tied to AMI deployments. Increased investment in control system platforms and a surge in analytics deployments have helped to offset this impact on Enabling ICT revenue, which grew roughly the same degree globally (13%) and in the U.S. (11%) last year.

The AMI market is expected to recover quickly from its COVID setback, however, as first-generation deployments continue and second-generation replacements and upgrades kick in. From a global perspective, developed and emerging markets will contribute to future market growth in different ways. North America and Western Europe are already advancing second-generation upgrade projects across a number of markets, including Italy and Sweden. Emerging markets will drive investment largely through first-generation deployments; active markets include India, Southeast Asia (Taiwan,

Malaysia), the Middle East (Iran, Saudi Arabia, UAE), and parts of Latin America (Mexico, Brazil, Chile, Colombia).

Early smart meter deployments were largely driven by relatively basic operational benefits and cost reductions (e.g., reduced truck rolls). At the regulatory level, U.S. and European markets were supported through smart grid investment grants funded by the 2009 American Recovery and Reinvestment Act and E.U. Directives, respectively. But now, regulators increasingly expect utilities to justify AMI deployments based on a more comprehensive and sophisticated set of benefits and use cases focused on customer experience, micro-forecasting, connectivity modeling, DER detection, and more. These value-add applications, along with innovations across AMI hardware and communications, are expected to redefine the smart meter market moving forward.

AMI Revenue, United States: 2016-2020 (Billions)

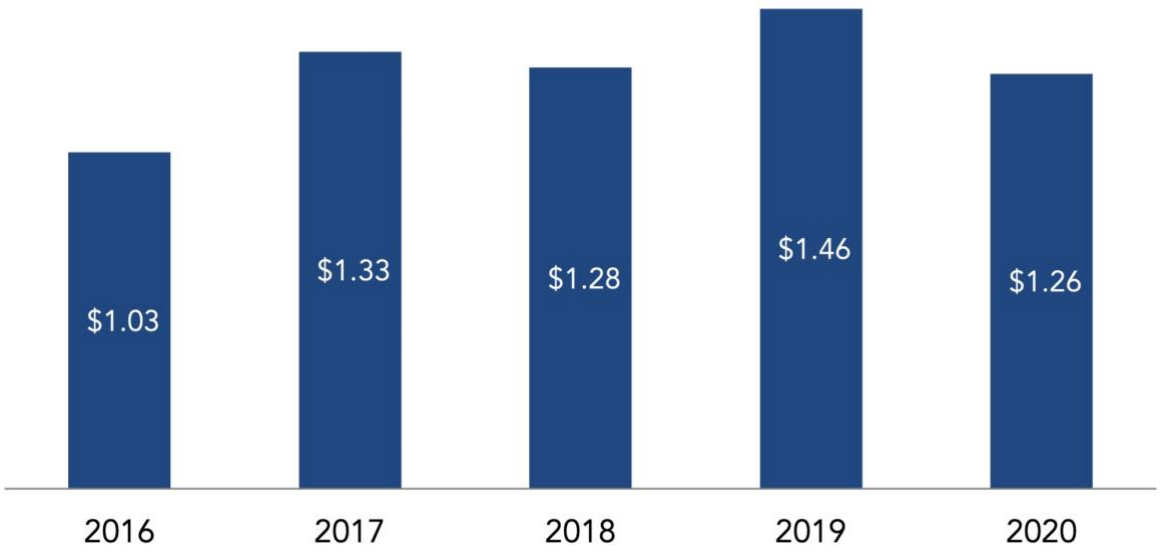

Figure 6 (Guidehouse Insights)

Control Systems & Analytics Drive Growth in Utility Software Market

The combination of increased AMI deployment and higher expectations for value-added applications from AMI, along with the ongoing digitization of the grid, is also leading to greater interest in making the data more readily available to third party providers of DERs and other energy products and services. This is seen as another way to help unlock the value of both customer and system data, along with the utility investments in the enabling platforms.

Enabling ICT is now the largest subsegment within Electricity Delivery and Management, having shown impressive year-over-year growth since 2015. This subsegment includes utility software systems & analytics, smart grid communications, and smart street lighting.

Digital Transformation sits at the heart of this recent growth story. Beginning with the proliferation of smart metering in the early 2000s, utilities have increasingly turned to data as a new source of value. This has led to the expansion of low-cost sensors throughout T&D networks and unprecedented levels of data generation. Yet, without advanced IT and OT systems to process this data, true situational awareness and operational insights cannot be achieved. The rapid growth in DER is leading utilities to invest in smart grid IT/OT solutions—including advanced distribution management systems (ADMSs), distributed energy resource management systems (DERMSs), and a number of analytics solutions.

Global Smart Grid IT/OT Software and Service spending has grown by 12% annually from 2011, reaching $9 billion in 2020. The large market size is primarily due to expensive billing and stand-alone control systems, while recent growth has been driven by asset management systems, modular ADMS and DERMS platforms, and data analytics. Utilities in the United States are advancing many of these same macrotrends.

The United States experienced two strong years in Smart Grid IT/OT, reaching $1.2 billion in 2019 on 12% growth, before seeing a decline to just over $1 billion in 2020. COVID-19 was certainly a factor in the 2020 decline, as IT and OT system deployments faced challenging delays and deferments. Also at play was the shift away from monolithic software platforms, which are typically very expensive and suffer from long deployment times, and towards modular systems/architectures. Utilities in Western Europe and the United States have already established these systems, such as ADMS, as best practice. This has caused stagnant or declining growth rates for stand-alone systems that have always led the market in spending. With ADMS, utilities can take a more flexible spending approach, deploying modules as needed. Utilities in emerging markets have moved slower in this area, and still largely opt for the "systems of yesterday." This has shielded global revenue from some of the short-term impacts seen in the United States for several reasons: high CAPEX costs of stand-alone systems, expensive customizations and bolt-ons, annual maintenance fees for multiple systems, long deployment times (i.e., expenditures already committed to future years), and more.

Underlying the more traditional grid-based drivers has also been a revaluation of the customer. Customers expect higher levels of service from their utilities. Utilities are responding with increased investment in customer-centric solutions, including customer information systems (CISs) and customer analytics, which can be embedded in CISs or offered as stand-alone solutions. **Globally, Advanced CIS grew by 4% in 2020 to $4.6 billion, and has shown 8% growth over the nine-year period. In the United States, 2020 experienced a decline of 4% to $662 million.**

From a global perspective, strong growth is expected across the ADMS space and DERMS (typically offered as an ADMS module or integration). Data analytics have also surged in the past four years, with a premium around asset performance management and predictive analytics. These tools present a viable alternative to costly and complex hosted software platforms that some utilities cannot or are unwilling to deploy. **Between 2011 and 2020, Smart Grid Data Analytics revenue has increased by 19% on an annual basis globally and 20% in the U.S. In 2020, these markets showed impressive resilience to the impacts of COVID-19, growing by 12% globally and 10% in the U.S.**

The combination of increased AMI deployment and higher expectations for value-added applications from AMI, along with the ongoing digitization of the grid, is also leading to greater interest in making the data more readily available to third party providers of DERs and other energy products and services. This is seen as another way to help unlock the value of both customer and system data, along with the utility investments in the enabling platforms.

Grid-Scale Energy Storage Is Hitting Its Stride

Both globally and in the United States, grid-scale energy storage continues to gain traction in the marketplace. **Global revenue for Energy Storage has grown from $117 million in 2011 to $3.8 billion in 2020. In the United States, Energy Storage revenue has climbed from $81 million to $1.6 billion over the same period.** While energy storage has behind-the-meter applications as well, helping customers reduce costly demand charges from times of peak consumption, and new opportunities will emerge for owners of distributed energy storage to participate in wholesale markets under FERC Order 2222 (see below), much of the growth to date has come in managing the bulk-power system, and it shows no sign of slowing down.

Around the world, the increasing use of solar and wind generation drives interest in energy storage to maintain grid stability, increase grid flexibility and increase efficiency by allowing fossil fuel power plants that operate infrequently to close. Many countries, as well as U.S. states, have aggressively pursued the buildout of renewable energy with supportive policies, which has led to rapidly falling costs for solar and wind generation. Energy storage is following the same pattern, with countries that have the highest penetration of solar and wind generation building energy storage markets as well.

Today, energy storage has become a key component of power system planning in countries around the world, representing a major shift from 2018, when the technology was still largely considered too

expensive or complex for integration into energy markets. Falling battery prices have made energy storage projects cost-competitive with fossil fuel generation and other technologies for numerous applications, including peak generating capacity and frequency regulation. However, the most substantial shift has been the improving economics of combined solar-plus-storage projects, which are now cheaper than natural gas generation in many locations and account for a large, growing portion of the global energy storage market.

Notably, in 2019, the Los Angeles Department of Power and Water entered into a contract for a 400 MW solar+storage project with a price for solar of 1.997¢/kWh — half the estimated cost of power from a new natural gas plant — and battery power for 1.3¢/kWh. In 2020, Southern California Edison announced it would buy 770 MW of cost-effective energy storage, most of it co-located with solar farms, to help the utility replace four gas power plants along the Southern California coast.

Energy Storage Revenue, Global: 2016-2020 (Billions)

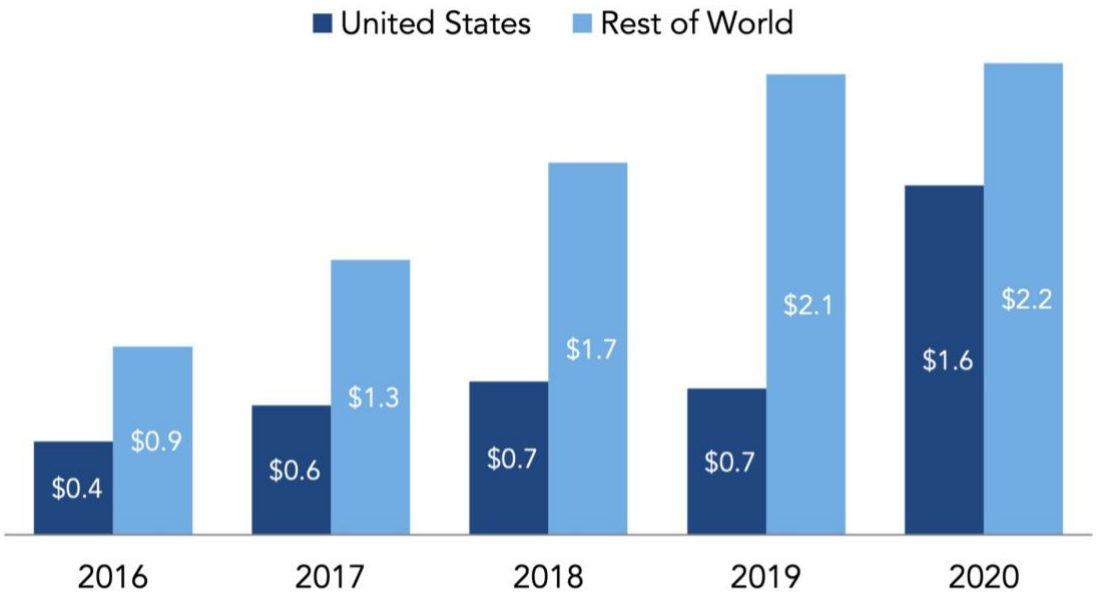

Figure 7 (Guidehouse Insights)

C&I is Now the Fastest Growing Microgrid Market

Ten years ago, when Guidehouse Insights first started tracking the microgrid market, the C&I segment was the smallest. Today, this segment is now forecasted to be the fastest growing in North America. The reason is simple. These customers know the cost of power outages. During last year's Public Safety Power Shutoff (PSPS) events in California, businesses realized they needed better solutions than back-up diesel generators that faced emission limits on run times. Globally, a similar value proposition is

being made, especially in off-grid environments where the cost of diesel fuel is expensive, and integration of renewables reduces ongoing O&M costs.

There are four reasons Guidehouse Insights forecasts that C&I will be the fastest growing microgrid market over the next decade, with an especially attractive market in the U.S.:

- Steep drops in the cost of distributed solar photovoltaics and energy storage devices. While this trend benefits all microgrid developments, it is particularly pertinent to the C&I segment. C&I customers place a premium on reliability but also do not want to pay a premium for energy services. The lower the cost of key microgrid enabling technologies, the more attractive the microgrid value proposition becomes.
- Major advances in software controls. This translates into the ability of microgrids to maximize the value of legacy assets – such as back-up diesel generators – and new technologies like solar and battery storage. One of the primary sticking points in the past is confidence in the ability of smart inverters and software overlays to manage diverse distributed energy resources. Multiple commercial projects around the world validate that this is now possible.
- Business model innovation. Vendors offering no-money-down Energy as a Service (EaaS) contracts limit upfront capital expense and allow a microgrid to be viewed as an O&M expense. This places the risk for project performance on the solution provider, now a commercially viable pathway given advances in the digital control platforms that optimize microgrids.
- The emergence of modular microgrid solutions. In the past, microgrids were customized to meet the precise goals of specific customers. This is still the case for larger systems, which require custom engineering solutions. There is a growing movement within microgrid ranks to make microgrids modular and scalable – which is particularly relevant to C&I customers, which may own or manage portfolios of similarly sized commercial buildings. This approach is also attractive to financiers, as it creates portfolios of similar assets.

These microgrid trends prompted the creation of GreenStruxure, the new venture by Schneider Electric and Huck Capital to move the microgrid market in California (as well as the Northeast.) Schneider has already launched its AlphaStruxure joint venture with The Carlyle Group for larger, custom-tailored projects. GreenStruxure is focused on modular, standardized microgrids for medium-sized facilities in the half-megawatt to 5 MW range that spend at least as $30,000/month on electricity. Like other vendors offering modular solutions targeting C&I customers – which include Bloom Energy, with its fuel cell microgrids, or Scale Microgrid Solutions, with its standardized packages combining dispatchable natural gas generators, solar PV, and batteries that can be pre-configured to fit any site's needs – California is now a focal point due to wildfires and PSPS events.

All told, the 2020 Microgrid market represented an $9.5 billion market globally; General Microgrids, which include C&I customers, accounted for $3.6 billion, or ~38% of this global market. The largest market globally in 2020 was Remote Microgrids at $4.1 billion. This reflects the

fact that, outside of the U.S., the majority of microgrids deployed historically have been in emerging economies that lack traditional grid infrastructure. **Total spending on Microgrids in the U.S. in 2020 was over $3.1 billion, growing 13% annually since 2011.**

Microgrid Business Model Market Share, Global, Q3 2020

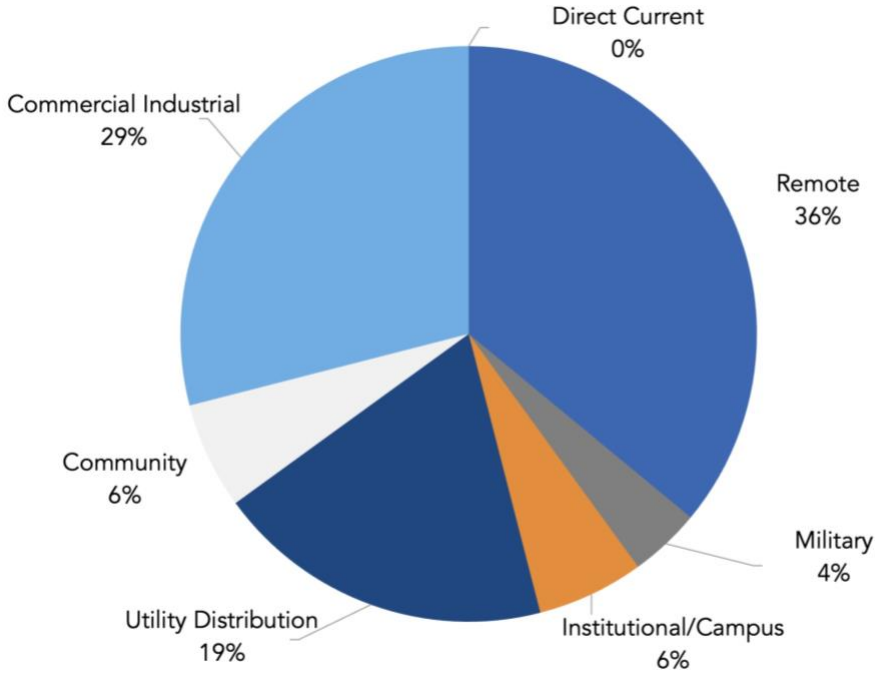

Figure 8 (Guidehouse Insights)

Distributed Solar and Storage Combine for Microgrid, Wholesale Market Opportunities

The driving force behind microgrid deployments is the growth in a wide variety of distributed energy resources (DER)s. As one of many options to aggregate and optimize DER, the microgrid platform allows for new levels of resilience and reliability – and now, as a result of Order No. 2222 in the United States, a future opportunity to participate in organized wholesale markets.

This order from the Federal Energy Regulatory Commission (FERC) requires that barriers to the participation of DERs in organized markets for electric energy, capacity, and ancillary services operated by regional transmission organizations (RTOs) and independent system operators be removed. Order No. 2222 builds on reforms previously undertaken by the FERC to enable participation by energy storage and, once fully implemented, should be a significant step toward opening up RTO markets to competition, facilitating the new entry of resources and fostering business model innovation.

Although Order 2222 is not limited to microgrids, it signals an important shift by recognizing the inherent value of mixed DER asset portfolios to the grid. The ruling will accelerate the ability of microgrids to become virtual power plants (VPPs), providing grid services upstream to wholesale markets. By bundling DER assets into a single bidding entity, synergies between generation, load, and energy storage can be captured and rewarded financially. Globally, similar market reforms are taking place and will likely build on this important policy precedent.

For the larger wholesale electricity market, two major counterbalancing trends affect the DER market mix. Government support for renewables in the form of subsidies is generally reducing as costs for hardware devices decline. Solar PV, for example, is at grid parity in a growing number of retail energy markets. As traditional supports for distributed renewables (e.g., net metering credits) get reassessed, asset owners increasingly look at markets to capture more value. In many cases, that means adding energy storage devices to help optimize variable renewable power generation. Over time, however, these supports for energy storage will also decline as commodity price pressure works its magic on costs.

The evolving mix of DERs at the microgrid level mirrors what is happening on the larger grid: an overall shift away from fossil fuels and toward renewable energy resources. Furthermore, the transition to modular technologies, such as solar PV and storage, positions these technologies as the two leading choices for microgrid designs and wholesale market opportunity today and into the future.

ADVANCED TRANSPORTATION

$37.7 BILLION
U.S. revenue

16%
annual growth

$318.9 BILLION
global revenue

15%
annual growth

Overview

Advanced Transportation was the third largest advanced energy segment worldwide in 2020, with an estimated $318.9 billion in revenue. Advanced Transportation growth from 2019 to 2020 ranked the highest among all segments at 15%.

Globally, Advanced Transportation revenue has grown at an 18% CAGR since 2011. Driving much of this growth is the recent boom in plug-in electric vehicle (PEV) sales. At the end of 2020, nearly 23 million PEVs were on the roads worldwide. PEV sales are in a period of strong growth, driven by lower battery prices, supportive regulations and incentives, and a proliferation of new models. By the end of 2030, Guidehouse Insights expects there to be more than seven times as many PEVs on the road. **Global PEV revenue has grown at a staggering CAGR of 59% since 2011, reaching $120 billion in 2020.** Outside of one down year in 2018, PEV revenues have grown by at least 25% every year, with most years registering over 60% annual growth.

Since 2011, **U.S. Advanced Transportation revenue has grown at a compound annual rate of 17%. As with global markets, surging PEV sales have driven overall Advanced Transportation revenue upwards, reaching nearly $37.7 billion in 2020.**

Hybrid electric vehicles (HEVs) continue to grow globally, with revenue from hybrid sales up 1% over 2020, to $66.8 billion. **But the growth story over 2020 is in PEVs, with annual revenue growing 27% globally, to $120.4 billion, and 19%, to $19.7 billion, in the United States.**

In this edition, for the first time, we do not include Clean Diesel in global or U.S. revenue for Advanced Transportation (see Methodology). While in past years Clean Diesel had been considered a legitimate contender for high-efficiency, low-emissions mobility, questions arising from the "dieselgate" emissions scandal paired with rapid improvements in price and performance of EV technology have shifted industry focus toward electrification, in the form of hybrids, PEVs, and fuel cell vehicles.

It is also worth noting that the 2011-2020 Advanced Transportation growth rates do not include electric bicycles or smart parking systems. AEE began tracking these subsegments revenues beginning in 2013; since that time, global revenues from electric bicycles and smart parking systems have grown at CAGRs of 19% and 6%, respectively.

Global Advanced Transportation Revenue (Millions $)

Subsegment	2011	2016	2017	2018	2019	2020
Vehicles	63,759	142,186	185,004	220,569	237,044	266,355
Vehicle Design and Materials	824	11,302	20,908	36,161	40,376	52,464
Enabling IT	0	44	53	68	81	91
Total	**64,582**	**153,532**	**205,965**	**256,798**	**277,502**	**318,910**

Table 7 (Guidehouse Insights)

Global sales of light-duty PEVs grew by nearly 1 million vehicles from 2018 to 2019, for sales growth of nearly 25%. The continued success of the Tesla Model 3, as it was introduced into new markets such as Europe and China, aided in advancing overall EV sales growth. This success coupled with strong HEV sales led to positive traction in the Advanced Transportation market in 2019, albeit with some areas of the market, such as PEV sales in the United States, having a slow year.

In 2020, the introduction of several new SUV and crossover PEV models in the United States, as well as additional 48-volt mild-hybrid vehicles coming to market in Europe, is expected to propel growth. The 48 V electrical system provides several functional benefits at a comparatively modest cost

premium. Current 12 V systems are limited to approximately 2 kW-2.5 kW electrical output; by contrast, a 48 V system can generate a 10 kW-12 kW enabling functionality like regenerative braking, stop-start at speeds up to about 5 mph, and electric launch, electrification of ancillary components, and new functionality such as active suspensions and driving automation. The electric pickup truck market is expected to continue to support increasing PEV sales in the United States as these models come to market in 2021 and beyond.

Deployment of charging stations is the key element of the EV market other than vehicles, and there the United States is playing catch-up. (See Fuel Delivery.)

U.S. Advanced Transportation Revenue (Millions $)

Subsegment	2011	2016	2017	2018	2019	2020
Vehicles	8,444	18,528	20,667	27,112	27,640	31,719
Vehicle Design and Materials	271	2,261	3,143	5,297	4,956	5,919
Enabling IT	0	14	15	19	18	19
Total	**8,715**	**20,804**	**23,825**	**32,428**	**32,615**	**37,657**

Table 8 (Guidehouse Insights)

In the United States, PEV sales revenue decreased 7% in 2019, but rebounded sharply in 2020 with 19% growth, reaching $19.7 billion in revenue. In 2017, PEV sales in the U.S. eclipsed that of hybrid electric vehicles as hybrid sales flatlined amid a surge in PEV adoption. This gap has grown wider since 2017, with 2020 PEV revenue nearly doubling that of hybrid EVs. However, hybrid EV sales have begun showing growth after a period of relative stagnation from 2015 and 2018; 2019 and 2020 revenues grew by 18% and 8%, respectively.

Plug-In Electric Vehicles Revenue, United States, 2016-2020 (Billions)

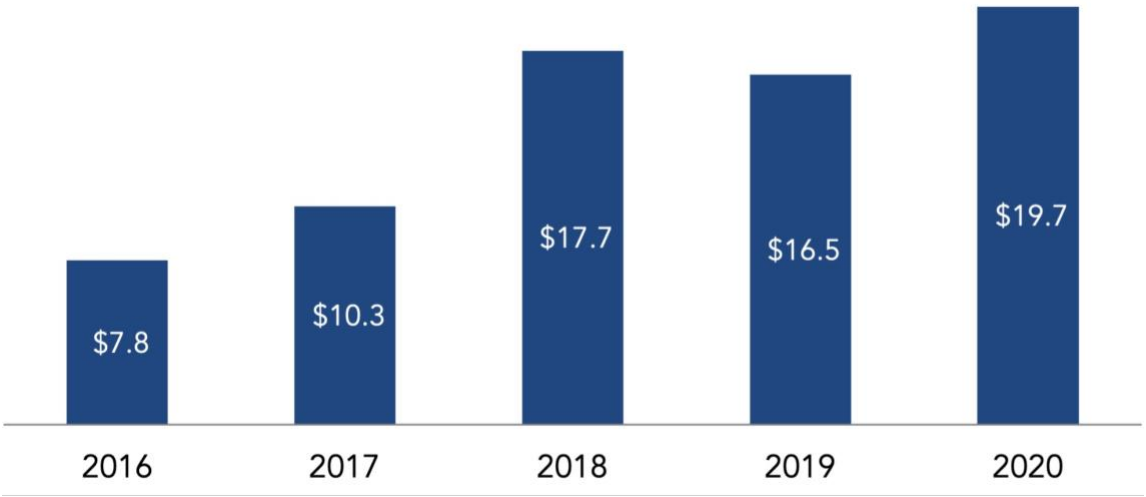

Figure 9 (Guidehouse Insights)

PEVs Surge Through COVID

In a year that spelled catastrophe for many industries around the world, the global PEV market reached record sales. **Since 2011, global PEV sales revenues have grown at a 59% CAGR. Meanwhile, PEV sales in the US have grown by nearly 45% annually since 2011, while still only accounting for ~16% of the global market in 2020.** This highlights the massive size and growth trajectory of international markets.

Europe saw over 500,000 battery EV (BEV) sales in 2020 and nearly 1 million sales of plug-in hybrid (PHEV) and standard hybrid EVs (HEVs), which is a 50% increase in total sales from 2019. While the total light-duty automotive market in the United States saw sales drop 15% in 2020, PEV sales remained relatively steady from 2019 levels. In China, the world's leading PEV sales region, sales rose 18% despite significant economic impacts of COVID-19 in the early part of the year.

Plug-In Electric Vehicles Revenue, Global, 2016-2020 (Billions)

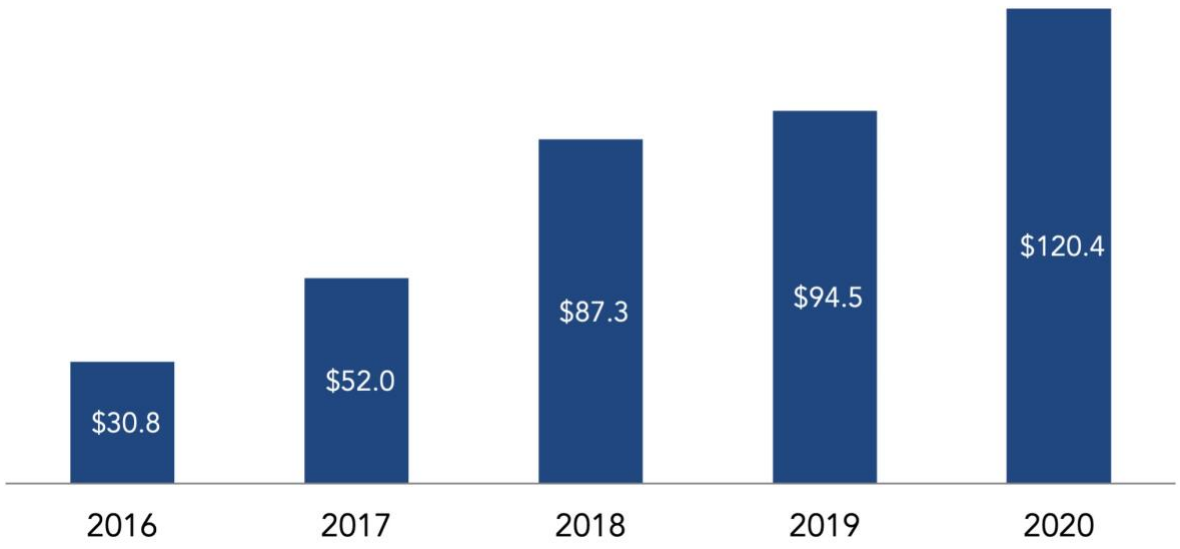

Figure 10 (Guidehouse Insights)

In China, fleets of taxis and buses (largely state-owned) are electrifying rapidly; two-thirds of new buses in 2017 were PEVs. According to Guidehouse Insights analysis, electric buses (including hybrid, battery electric, plug-in hybrid, and fuel cell) have already reached 16% of sales for public transit systems in the United States, as of late 2018. Fleet operators are more sensitive to vehicle economics than are individual consumers, but they are also more focused than consumers on total cost of ownership, which is more favorable for PEVs. Fleets can utilize company-owned charging depots, reducing reliance on publicly available charging stations. Over time, pairing vehicle grid integration (VGI) infrastructure technologies with fleet-owned PEVs will increase PEV payback. Companies such as UPS, FedEx, and Penske, are already actively exploring PEVs for fleet purposes.

Guidehouse Insights estimates that PEVs made up less than 1% of the fleet vehicle market in 2018 but will rise to 12% of fleet vehicles by 2030. The light duty segment will continue to make up the majority of PEV fleet sales, but medium- and heavy-duty PEV adoption rates are expected to increase throughout the forecast period.

Trucks Start to be Electrified

The market for electric trucks and buses is still young, but rapid developments in the industry and increasing market interest are setting a strong foundation for electrification to become the new norm.

Although the electric-drive medium- and heavy-duty vehicle market is gaining increased attention, the vehicles currently make up a small portion of global PEV sales outside of China. The rise of these vehicles is driven by several factors: regional fuel efficiency and emissions regulations, growing adoption of urban low- to zero-emission zone regulations, increasing demand from corporate customers for low- to zero-emissions logistics services, and lower fuel and maintenance costs for fleet owners.

Pathways to overcome challenges with range, infrastructure, and capital costs are becoming more clear, with encouraging developments in solid-state batteries, innovations in charging infrastructure technologies and deployment architectures, and new financing models. A development of note is the upcoming debut of megawatt charging systems, expected in 2021, which will eventually enable electrification of long-haul trucking. Also of note, the roll-out of leased vehicle-to-grid (V2G) capable electric school buses by U.S. utility Dominion Power, to school districts in its service territory, as well as the Montgomery County, MD, school district's contract for EV school-buses-as-a-service from Highland Electric Transportation. These leasing arrangements set the stage for the transformation of North America's 500,000-strong school bus fleet, a campaign goal enunciated by President Biden.

Beyond technical developments, major customers are showing increased willingness for electrification of truck fleets. This is evidenced by major investments from parcel distributors like UPS, FedEx, Amazon, and DHL in electric trucks from Arrival, Chanje, Rivian, and BYD respectively.

Guidehouse Insights estimates that the electric truck and bus market will grow to over 900,000 unit sales globally by 2030, roughly 15% of the market that year.

E-Bike Sales Surge During COVID-19

The rise of traditional bicycle and e-bike sales in 2020 is well-documented, as COVID-19 has driven an increase in demand for physically distanced transport options. What has been less discussed is the trend over the past six to eight years of e-bikes cannibalizing bicycle sales. Countries such as the Netherlands are far along in the transition from analog bikes to e-bikes, and many other European countries are showing similar patterns, including major e-bike markets such as Germany, Belgium, Austria, and France.

While 2020 has been a banner year for e-bike sales in the U.S., this market has generally lagged far behind Europe. This is largely due to the lack of priority given to bicycle promotion and infrastructure at a national level, resulting in bicycles being treated as more of a recreational apparatus than a viable transportation option. Consider, by comparison, the following national-level efforts to promote bicycling, and so e-bikes, across Europe:

- The Netherlands built a network of 20 bicycle highways between 2000 and 2010 that it continues to extend. The country also introduced an e-bike leasing program in 2020 through

which residents can "get interest-free loans to purchase e-bikes, lease bikes from their employer, and get reimbursed for kilometers ridden" according to Jack Sexty, editor at eBikeTips.

- Germany is building bicycle highways that will span over 62 miles, 10 cities, and four universities once completed. These highways are anticipated to remove 50,000 cars from the road per day.
- France offers e-bike subsidies as high as €500 ($580).
- Ireland uses 20% of its annual transport budget for cycling and walking, which is approximately 10 times the U.S. share. Britain's government recently committed £2 billion ($2.6 billion) for cycling and walking infrastructure.

Despite the lack of national action, e-bike sales in the U.S. grew at a 37% CAGR from 2013 to 2020, though accounting for just 2% of total bike sales in 2019. With the impact of COVID, however, **U.S. electric bicycle sales grew by nearly 25% in 2020, reaching $734 million in revenue.**

Consumer awareness of the benefits of e-bike technology has significantly increased, and unprecedented levels of interest are being shown at the city level regarding bicycle lane expansion (with potential national efforts to come). Meanwhile, new e-bike products are being released by an increasing variety of manufacturers, and continued cost and performance improvements in lithium-ion battery technology are expected to continue.

Guidehouse Insights projects that e-bike sales in the U.S. will reach between 15% and 20% of the total bike market by 2030.

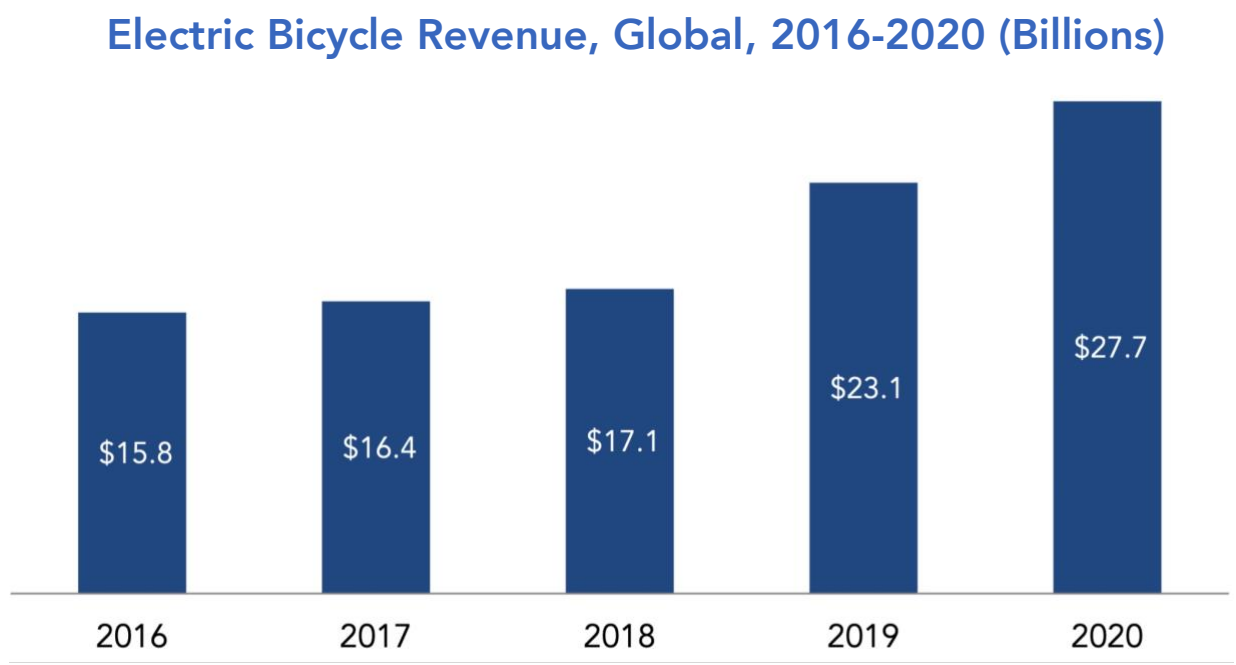

Figure 11 (Guidehouse Insights)

ADVANCED FUEL PRODUCTION

$33.6 BILLION

U.S. revenue

-38%

annual growth

$184.3 BILLION

global revenue

-17%

annual growth

Overview

Global Advanced Fuel Production revenue dropped to $184.3 billion in 2020, following its highest year on record in 2019 at $221.8 billion. The United States experienced even steeper revenue declines, down 38% in 2020 to $33.6 billion. This is largely due to volatility in Ethanol and Butanol revenue, which in the United States dropped sharply in 2020 (47%) following 101% growth in 2019. Hard hit by COVID-19, U.S. ethanol consumption fell from 15.8 billion gallons in 2019 to 13.7 billion gallons in 2020. **The Compound Annual Growth Rate (CAGR) for Global Advanced Fuel Production revenue over the 2011-2018 period was 6%, while in the United States CAGR was -3%.**

Globally, CNG/LNG revenue grew 4% in 2020; annual growth rates have remained in the single digits following a 27% jump in 2017. Biodiesel sales have picked up since 2017, prior to which revenues had largely stagnated, at around the $20 billion mark. While declining slightly in 2020 – down 2%, to $43.4 billion – revenues grew globally by at least 20% in 2017, 2018, and 2019, for CAGR of 10% since 2011.

Though it still accounts for only a fraction of the total Advanced Fuels market, Bio-methane grew by 11% globally in 2020 as landfill gas continued to be captured and is increasingly consumed by waste hauling trucks.

Global Fuel Production Revenue (Millions $)

Subsegment	2011	2016	2017	2018	2019	2020
CNG and LNG	23,018	57,420	72,924	77,299	79,850	82,725
Ethanol and Butanol	68,140	36,964	43,248	46,275	89,063	49,227
Biodiesel	17,882	19,998	23,998	30,477	44,196	43,364
Synthetic Diesel and Gasoline	1,580	3,207	3,849	5,350	7,758	7,889
Bio-oil	1	0	0	0	0	0
Bio-methane	47	496	615	656	713	788
Hydrogen	-	-	-	134	204	268
Total	**110,667**	**118,086**	**144,635**	**160,193**	**221,785**	**184,260**

Table 9 (Guidehouse Insights)

The biofuels market in the U.S. is regulated by the Renewable Fuel Standard (RFS). Congress set the original targets in 2007 but the U.S. Environmental Protection Agency (EPA) sets the final mandate each year in a final ruling before the year starts to adjust the RFS to the market conditions. Most recently, EPA released the final annual percent standards for 2019 and for the 2020 biodiesel volume in December 2018.

For 2019, EPA increased the mandate to 19.92 billion gallons, up from 19.29 billion gallons in 2018. The EPA's "Advanced Biofuel" category includes a carve-out for biomass-based diesel (biodiesel or renewable diesel produced from vegetable oils or animal fats) of 2.1 billion gallons, another one for cellulosic fuels, which includes biogas, of 418 million gallons, and a general pool that can be fulfilled with any biofuel with a greenhouse gas (GHG) emissions reduction of at least 50%, which captures sugarcane-based ethanol. Conventional biofuels, which the EPA defines as starch-based (primarily corn) ethanol with a 20% GHG emission reduction, remained at the final congressionally mandated target of 15 billion gallons for the first time.

U.S. Advanced Fuel Production Revenue (Millions $)

Subsegment	2011	2016	2017	2018	2019	2020
CNG and LNG	504	1,288	1,674	1,556	1,502	1,475
Ethanol and Butanol	39,140	20,580	20,190	22,386	45,030	23,962
Biodiesel	3,135	4,567	5,074	7,256	5,986	6,141
Synthetic Diesel and Gasoline	372	2,100	2,352	1,717	1,416	1,453
Bio-oil	1	-	-	-	-	-
Bio-methane	12	410	441	491	502	516
Hydrogen	-	-	-	65	78	86
Total	**43,164**	**28,944**	**29,731**	**33,471**	**54,514**	**33,633**

Table 10 (Guidehouse Insights)

Hydrogen Gets Renewed Interest as a No-Carbon Fuel

Currently, pure hydrogen is produced and used mostly for oil refining and ammonia production. The most common method of hydrogen production is steam-methane reforming (SMR), where hydrogen is produced by reacting steam at high temperature and pressure with methane (mostly from natural gas). But alternative methods of hydrogen production are gaining traction in the market. Specifically, there is growing interest in producing hydrogen using renewable energy so it can be a carbon-free fuel. The main pathway currently being pursued to make this "green hydrogen" is to use renewable electricity in an electrolyzer to split water into pure hydrogen and oxygen. Applications in fuel cell vehicles (FCVs) or as storage for excess renewable energy are expected to further increase demand. Globally, revenue from Hydrogen Production Technology grew from $108.8 million in 2018 to nearly $207.4 million in 2020, while revenue from Hydrogen fuel itself – much lower – rose from $25 million to $60.4 million.

Guidehouse Insights sees the most opportunities for green hydrogen in a select number of applications over the coming five to 10 years. Cost is perhaps the most important factor determining potential, but scalability and pressure to decarbonize are other key drivers. Level of government support is also important in these relatively early days. Specific opportunities include high-temperature industrial uses, certain transportation uses, and renewables integration, where electrification or other low-carbon options may be less technically viable.

Refueling of FCVs is among the fastest-growing use cases for hydrogen, with policies favoring the green variety. In California, at least 33% of hydrogen fuel is required to be generated from renewable

resources. Though green hydrogen is more expensive at the pump thanks to compression and distribution costs, it is approaching cost parity with gasoline on a per-mile basis, at least in some subsidized markets. While plug-in electric vehicles have had more commercial success to date, given sufficient hydrogen infrastructure, there is significant potential for FCVs in some classes, especially long-distance trucking.

Hydrogen can also serve as long-term storage for renewable energy, even providing an alternative to additional transmission. Heavy renewables areas such as the North Sea may benefit from hydrogen storage and shipping instead of high-voltage transmission. Transport of hydrogen by pipeline could also be compared with the high costs of transmission permitting and construction for moving renewable energy over long distances.

Europe is expected to be a world leader in emerging hydrogen production technology. The EU has allocated funds; multiple countries such as France, Germany, and the UK have published hydrogen roadmaps. In October 2018, projects for 100 MW plants were announced for Amsterdam (Nouryon and Tata Steel) and Germany (Gasunie, TenneT, Thyssengas). The primary use cases for those two plants are industrial processes and renewables integration, respectively, with vehicle fueling another likely use case.

The Asia Pacific region has also been aggressive in driving hydrogen production and use. Japan and South Korea have explored hydrogen to ameliorate energy concerns, Australia has explored the potential of exporting hydrogen due to the sheer volume of its potential renewable electricity, and China is aiming to strongly adopt FCVs and integrate hydrogen into its energy strategy.

North America has been less ambitious on developing a hydrogen economy than Europe and Asia Pacific. In June 2020, the U.S. Department of Energy announced an investment of up to $100 million over five years in research and development for hydrogen and fuel cell technologies. Nevertheless, interest in green hydrogen among U.S. utilities is on the rise, especially those with decarbonization goals, whether these are voluntary utility targets or in states with decarbonization policies. States such as California and those in the northeast region of the U.S. have already shown inklings of a shift toward higher levels of hydrogen investment. In New York and Massachusetts, National Grid is engaged in multiple hydrogen blending research projects aimed at residential heating. Also in New York, Plug Power recently announced the construction of what will be the largest green hydrogen production facility in North America, supported by hydropower and capable of producing 45 metric tons of green hydrogen daily.

Hydrogen is also being evaluated for use as long-duration energy storage, as a fuel to use in power plants to provide flexible low- and zero-carbon capacity to achieve 100% clean grid targets, and by natural gas utilities looking for ways to decarbonize. While many technical issues remain to be addressed, we expect interest to grow in a variety of applications.

Ethanol was Hit by COVID Travel Slump – but not Biodiesel

Ethanol and Butanol was one of the hardest-hit subsegments of the advanced energy industry in 2020. **Global Ethanol and Butanol revenue dropped by 45% in 2020, and by 47% in the United States.** During 2020, wholesale ethanol in the U.S. sold, on average, at $1.91 per gallon, while in 2019, the price averaged $2.85 per gallon. This drop was driven by the global lockdowns caused by COVID-19, which affected gasoline consumption globally. As a fuel substitute, the price of ethanol is highly correlated to the price of gasoline and hence with crude oil, which faced a worldwide glut in 2020. In years when ethanol production exceeded the RFS mandate, ethanol has typically traded at around 70% of the price of gasoline, due to its lower energy content.

The other factor affecting ethanol margins is the price of feedstocks (corn, sugar beet, and sugar cane). When the price of these feedstocks is high relative to the price of ethanol, some plants shut down as they become unprofitable, which then pushes the price of ethanol up until the mandate is fulfilled. In 2019, high corn prices caused by lower than expected crop sizes in South America drove up the price of ethanol, with revenues surging as a result.

Ethanol and Butanol Revenue, United States, 2016-2020 (Billions)

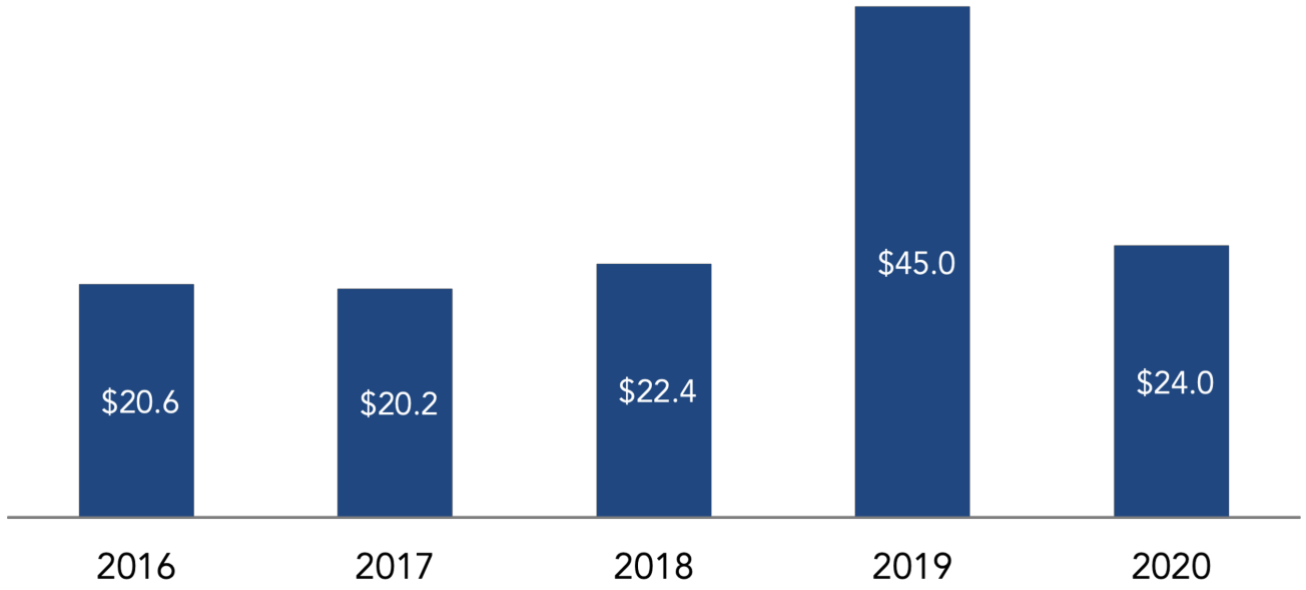

Figure 12 (Guidehouse Insights)

The picture for biodiesel in 2020 was much better. The new annual standard for biomass-based diesel is high enough to absorb the current capacity. Diesel consumption overall was not affected dramatically by COVID-19, as a decline in the early days of lockdowns was offset by a subsequent

increase attributable to delivery operations. In the U.S., 1.78 billion gallons of biodiesel were consumed in 2020, slightly above the 1.72 billion consumed in 2019.

U.S. Biodiesel revenue grew 3% in 2020, to $6.1 billion, despite a small decrease in price to $3.45 per gallon, from $3.48 per gallon in 2019. This revenue total is still well below the 10-year peak of $7.3 billion in 2018. That year, U.S biodiesel revenue grew by 43%, buoyed by the $1 per gallon biodiesel tax credit retroactively extended for 2017 by Congress in February 2018, with revenue realized in 2018. Biodiesel production increased 16% in 2018 with average retail price up 11%, contributing to record revenue for the 2011-2020 period, for which CAGR was 8% overall.

ADVANCED INDUSTRY

$11.6 BILLION
U.S. revenue

10%
annual growth

$64.3 BILLION
global revenue

7%
annual growth

Overview

Advanced Industry, the sixth largest advanced energy segment both globally, contains two subsegments: Manufacturing Machinery and Process Equipment and Industrial Combined Heat and Power (CHP). (For non-industrial applications of CHP, see Building Efficiency). Manufacturing Machinery and Process Equipment tracks sales of industrial energy management systems, which are software and services for energy management within an industrial facility or across an enterprise to meet efficiency, cost savings, and sustainability targets while maintaining optimal operation of production processes.

Global Advanced Industry revenue reached $64.3 billion in 2020, growing by 7% over 2019. This continues an elevated growth trend that began in 2017, when revenues jumped 11% after a multi-year period of single-digit growth. This uptick in spending is a function of multiple market drivers, including digital transformation initiatives, cost reductions (operational, data management), shifts toward automated and predictive maintenance strategies, and worker safety considerations. While cost reductions and worker safety have always been market drivers, the proliferation of digital transformation initiatives has galvanized both the U.S. and global markets into higher levels of expenditure. Nevertheless, Industrial CHP remains the larger of the two subsegments globally, by revenue, but growing more slowly, at 7% CAGR, versus 11% CAGR for Manufacturing Machinery and Process Equipment, from 2011 to 2020. CHP revenue grew 4% in 2020, while Manufacturing Machinery and Process Equipment revenue rose 11% year over year.

Global Advanced Industry Revenue (Millions $)

Subsegment	2011	2016	2017	2018	2019	2020
Manufacturing Machinery & Process Equipment	9,773	14,809	18,219	20,402	22,919	25,399
Combined Heat & Power	20,803	29,116	30,603	32,859	37,416	38,912
Total	**30,576**	**43,925**	**48,821**	**53,261**	**60,335**	**64,310**

Table 11 (Guidehouse Insights)

In the United States, Advanced Industry revenue grew 10% overall from 2019 to 2020, to $11.6 billion. Since 2011, U.S. Advanced Industry revenue has more than doubled, growing at a CAGR of 12%. U.S. Manufacturing Machinery and Process Equipment revenue increased 10%, to $7.0 billion, in 2020, based on sales of industrial energy management systems. CHP revenue increased by 9% year-over-year, to $4.6 billion, following 13% growth in 2019. Though smaller in the United States than Manufacturing Machinery and Process Equipment, Industrial CHP has grown faster over the 2011-2020 time period, at 18% CAGR versus 9% for Manufacturing Machinery and Process Equipment.

U.S. Advanced Industry Revenue (Millions $)

Subsegment	2011	2016	2017	2018	2019	2020
Manufacturing Machinery & Process Equipment	3,184	4,744	5,162	5,730	6,381	7,048
Combined Heat & Power	1,018	3,540	3,920	3,735	4,207	4,585
Total	**4,202**	**8,283**	**9,082**	**9,465**	**10,588**	**11,633**

Table 12 (Guidehouse Insights)

Energy Savings and Sustainability Goals Drive Industrial CHP

Following the birth of initiatives such as Renewable Energy 100 (RE100), the Science-Based Targets initiative, and the Paris Agreement on greenhouse gas emissions, corporate sustainability efforts are permeating Fortune 500 and other large multinational companies across industry verticals with a new level of vigor. Manufacturing may not conjure images of clean energy and sustainable production. However, as a result of the energy and sometimes emissions-intensive nature of production, supply chain and public pressures are causing manufacturers across industries to explore a variety of mechanisms by which to decrease their energy consumption and GHG emissions.

CHP, also known as cogeneration, is particularly well suited for industrial manufacturers with high energy demand. Typically run on fossil fuels or biomass, a CHP unit is significantly more efficient than deriving electric load and thermal load from separate sources; CHP can operate at 65% to 85% efficiency, compared with 45% to 55% overall when these needs are met separately.

Industrial manufacturers have increasingly turned to CHP for onsite energy management as a means to achieve sustainability targets. **Since 2011, Global CHP spending has grown by an average of 7% annually, reaching $38.9 billion in 2020. In the United States, CHP spending has grown even faster, at 18% CAGR, since 2011, with 9% growth in the past year, compared with global growth of 4%.**

CHP is likely to remain the leading onsite generation technology deployed by industrial manufacturers. According to the Energy Information Administration's *Annual Energy Outlook 2019*, natural gas-fired CHP capacity is expected to grow at the fastest rate for commercial distributed generation through 2050.

Industrial CHP Revenue, United States, 2016-2020 (Billions)

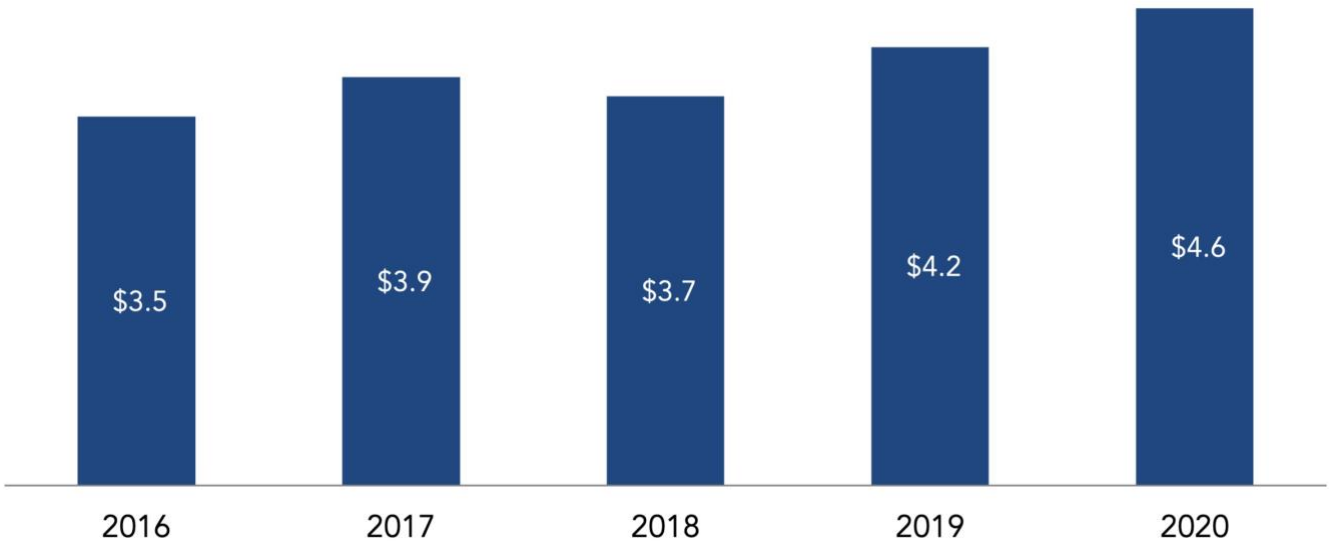

Figure 13 (Guidehouse Insights)

As an example, ArcelorMittal is the world's largest integrated steelmaker, with vertical business operations extending from mining to iron and steel manufacturing and finishing facilities that produce an array of end products. Approximately 15% of the cost of turning raw materials into steel relate to energy. To secure savings and improve sustainability, ArcelorMittal obtains 62% of the electrical energy used in steel production from capturing and reusing coke oven gas (a production byproduct) and utilizing blast-furnace gas to fuel large CHP plants.

Industrial IoT Moves from Buzzword to Mainstream

The Industrial Internet of Things (IIoT) is transforming the way industries operate, creating more efficient, safe, and profitable operations. The proliferation of sensors in industrial environments provides a vast amount of valuable data. Advances in cloud computing make it possible to integrate machine learning, artificial intelligence, and advanced analytics to quickly respond to the changing dynamics at industrial sites. In simple terms, Industrial IoT is the use of digital and internet technologies and tools – e.g., hardware, software, and analytics – for the benefit of business processes.

Industrial IoT enables more efficient use of energy as equipment makes intelligent adjustments to energy consumption and lowers operational costs through enhanced predictive and preventive

maintenance. Industrial IoT follows the rise of Industrial Energy Management Systems (IEMS), software and services that support holistic energy management within an industrial facility or across an enterprise to achieve efficiency, cost savings, sustainability, and climate change targets while maintaining the optimal operational parameters for the production processes. **Global IEMS revenue has grown from $9.8 billion in 2011 to nearly $25.4 billion in 2020, at a CAGR of 11%. The United States has shown a similar growth trajectory, growing 9% over the same period to exceed $7.0 billion in 2020.**

However, this emerging trend differs from traditional energy management systems in that its focus is far broader than energy. IIoT systems are becoming the go-to solution for leveraging data to deliver economic and business benefits.

The coronavirus pandemic in 2020 has had a marked impact on industrial work environments. Industrial production in the European Union fell by more than 5% from February to September 2020, despite strong gains over the summer. With the global spike in new cases as of October, the outlook for production activity worsened through the end of 2020. Nonetheless, Guidehouse Insights believes that the trend toward digitalization and IIoT will overcome these constraints and continue to spark demand for industrial software platforms that can enable advanced asset performance management, predictive/prescriptive maintenance, and enhanced worker safety.

Most entities that set out to modernize their industrial operations have one or more objectives in common:

- Bringing the agile software delivery and development mindset of IT into the operational technology (OT) world, which involves introducing traditional IT technologies and processes into OT
- Reducing downtime of equipment with predictive maintenance and automated software updates
- Enabling centralized command and control to visualize overall operations in one location or across multiple sites
- Implementing a consistent and flexible software architecture that eliminates barriers and connects processes into a unified whole

The IIoT, with its sensor, software, and networking technology foundations, is spreading rapidly throughout the industrial world. Looking ahead, enterprise and industrial site managers must understand the competitive advantages that these solutions provide and make long-term investments to remain relevant and competitive.

IIoT Device, Software, and Service Revenue for Manufacturing, Global, 2020-2025 (Trillions)

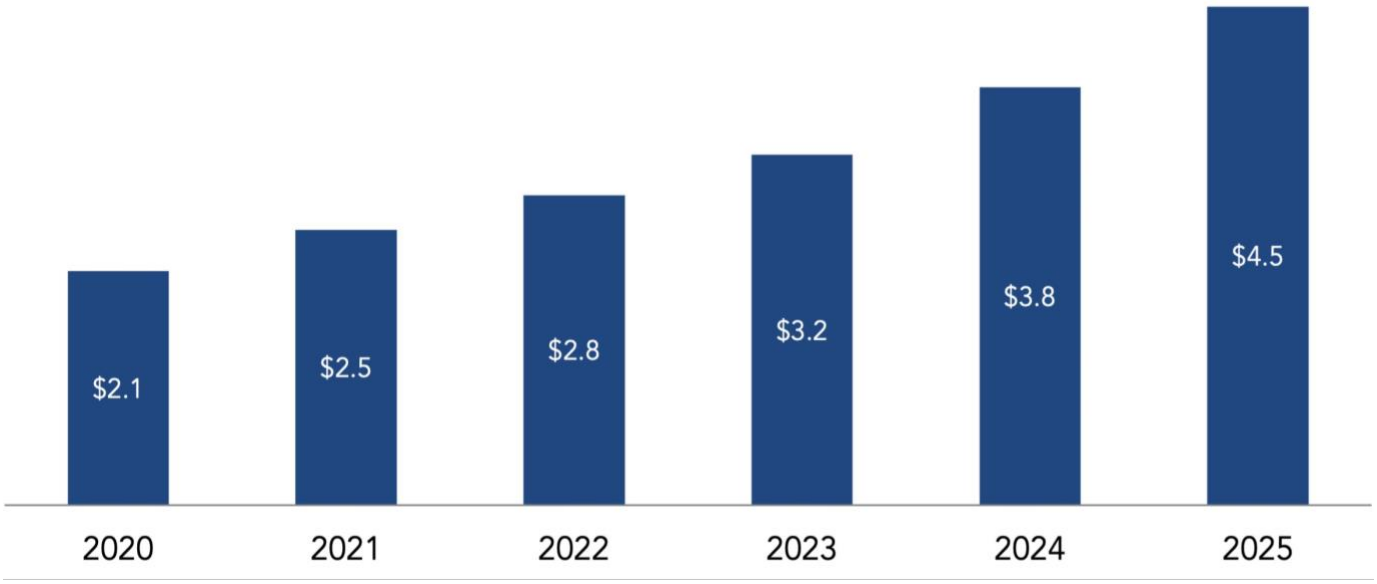

Figure 14 (Guidehouse Insights)

ADVANCED FUEL DELIVERY

$540.1 MILLION
U.S. revenue

-21%
annual growth

$9.3 BILLION
global revenue

-1%
annual growth

Overview

Global Advanced Fuel Delivery revenue – here quantified as Fueling Stations serving electric, natural gas, and hydrogen vehicles – dropped slightly in 2020, by 0.7% to $9.3 billion. This followed a monumental year of 136% growth in 2019. In the United States, the market for Advanced Fuel Delivery saw declines in 2019 (9%) and 2020 (21%), following three consecutive years of growth.

This report includes Electric Vehicle (EV) Charging Infrastructure in Advanced Fuel Delivery for the first time; in previous editions, EV Charging Infrastructure revenue was presented in Electricity Delivery and

Management. Grouping together fueling stations for all three advanced vehicle technologies – electric, natural gas, and hydrogen – reveals a dramatic shift in spending over the course of the period 2011 to 2020. In 2011, natural gas fueling stations accounted for 92% of Advanced Fuel Delivery revenue. By 2016, electric vehicle charging infrastructure had overtaken natural gas, and has since grown to 90% of total revenue in 2020. Spending on natural gas fueling stations has shrunk by more than half worldwide since 2011, and by over one-third in the United States.

The Compound Annual Growth Rate (CAGR) for Advanced Fuel Delivery revenue was 17% from 2011 to 2020 globally and 9% in the United States, with most of that growth attributable to EV Charging Infrastructure.

EV Charging Infrastructure more than doubled its market size from 2018 to 2019 (179%), an increase driven almost entirely by a surge of charging station deployments (estimated at nearly 800,000 stations in China). This growth trajectory flattened in 2020 at 1% globally; as the balance of supply and demand in China corrects, growth is expected to remain slow.

Hydrogen Fueling Station investment surged in 2019 after a period of relative stagnation, growing 76% and 31% in 2019 and 2020, respectively, reaching $76.3 million globally. Investment in hydrogen refueling has been expected to increase, especially across Europe and the Asia Pacific region. In the U.S., where California remains the only state with a significant commitment to fuel-cell vehicles, revenue from hydrogen fueling stations peaked in 2012, at $27 million, and has not exceeded $10 million since 2017.

Investments in natural gas refueling equipment for larger vehicles dropped 28% last year worldwide, while infrastructure for light duty vehicles, which accounts for the bulk of segment revenue outside of EV Charging, decreased 18%, to $788 million. This decline is likely influenced by increasing interest in the electrification of medium- and heavy-duty trucks.

Global Fuel Delivery Revenue (Millions $)

Subsegment	2011	2016	2017	2018	2019	2020
Commercial NG Vehicle Fueling Stations	19	91	59	38	41	30
Electric Vehicle Charging Infrastructure	127	864	3,032	2,981	8,302	8,394
Hydrogen Fueling Stations	49	42	32	33	58	76
Natural Gas Vehicle Fueling Stations	2,139	820	902	920	955	788
Total	**2,333**	**1,817**	**4,025**	**3,972**	**9,357**	**9,288**

Table 13 (Guidehouse Insights)

In the United States, Fuel Delivery revenue dropped 21% in 2020, to $540 million. Natural gas fueling station revenue for both light-duty and commercial vehicles fell to its lowest point in the 10-year period, $141 million. EV Charging Infrastructure revenue also fell from its 2018 peak of $579 million in each of the subsequent years, reaching $394 million in 2020. Given the generally upward trajectory of plug-in EV sales since 2016, with a small decline in 2019 but resurgence to $19.7 billion in 2020 sales (see Advanced Transportation), declining investment in charging infrastructure could result in an increasing lag between available charging capacity and a growing mass market of EV owners. But regulatory approval of large-scale EV charging programs in California and New York in 2020, as well as pilots in several other states, should spur growth in 2021 and beyond.

U.S. Fuel Delivery Revenue (Millions $)

Subsegment	2011	2016	2017	2018	2019	2020
Commercial NG Vehicle Fueling Stations	11	56	39	27	30	28
Electric Vehicle Charging Infrastructure	27	182	228	579	496	394
Hydrogen Fueling Stations	24	12	8	5	7	5
Natural Gas Vehicle Fueling Stations	192	110	113	136	147	113
Total	**254**	**360**	**388**	**747**	**680**	**540**

Table 14 (Guidehouse Insights)

EV Charging Infrastructure Boom Spurs Innovation

EV Charging Infrastructure has witnessed a global boom, as the market grew by nearly 180% in a single year. The marked growth is primarily attributed to the roll-out of ultra-fast charging networks, heavily supported by automaker investments in major regions of the world. These investments are not expected to abate any time soon with PEV technologies spreading into new vehicle segments such as light trucks and heavy commercial vehicles. The latter requires specific charging infrastructure with capacities well over those used for light duty vehicles. The development of this infrastructure is expected to grow dramatically in the second half of the 2020s as electrification looks to take on long-haul trucking.

In China, market development is taking a unique turn, with potential ramifications for developed markets. Battery swapping, scoffed at after the failure of A Better Place in the early 2010s, has re-emerged, with multiple light-duty and heavy-duty commercial automakers introducing the technology and deploying it for commercial network services. The technology competes with conventional retail fuel pumps on speed, and poses opportunities for grid services, PEV financing, optimization of battery health, and battery supply for second life uses.

One second life use for batteries may be to support the development of charging infrastructure itself. Batteries deployed at charging sites help speed expansion of charging capacity, they buffer PEV charger demand allowing operators to optimize electricity prices, and they can help maintain charging station reliability. Many charging station manufacturers are even integrating batteries directly into electric vehicle service equipment (EVSE) enabling highly mobile and temporary EVSE deployments. Currently, this market is mostly supplied by new batteries, but that could shift to second-life PEV batteries as evidenced by Volkswagen's development of a 360 kWh battery-integrated charger using batteries designed for its PEV platform, M.E.B.

Beyond these developments in charging hardware, significant developments are also being made in networking. Access and authorization interoperability of EVSE for PEV drivers has been a complication in many markets. To date, this has been overcome through the use of e-roaming agreements between charging networks or through the establishment of interoperability platforms that act as clearinghouses for transactions made by PEV drivers out of network. The latter has been popular in Europe and has only recently made headway in China. In North America, interoperability is primarily achieved through e-roaming agreements. A separate technology standard, known as Plug&Charge, is now coming to market with Ford, Porsche, and new PEV maker Lucid introducing it on 2021 model year vehicles. This standard provides a seamless experience for PEV drivers in that all access, authorization, and payment processes are automated when the physical connection between vehicle and EVSE is made.

Networking is also progressing for vehicle-grid integration. This type of network sends data streams on grid conditions to PEVs to modulate the rate at which PEVs are consuming power. PEVs sending power back to the grid, via vehicle-to-grid (V2G) technology, is also gaining traction in Europe and

North America, with major commercialized deployments for residential PEV owners and fleets underway.

Global EV Charging Infrastructure Revenue, 2016-2020 (Billions)

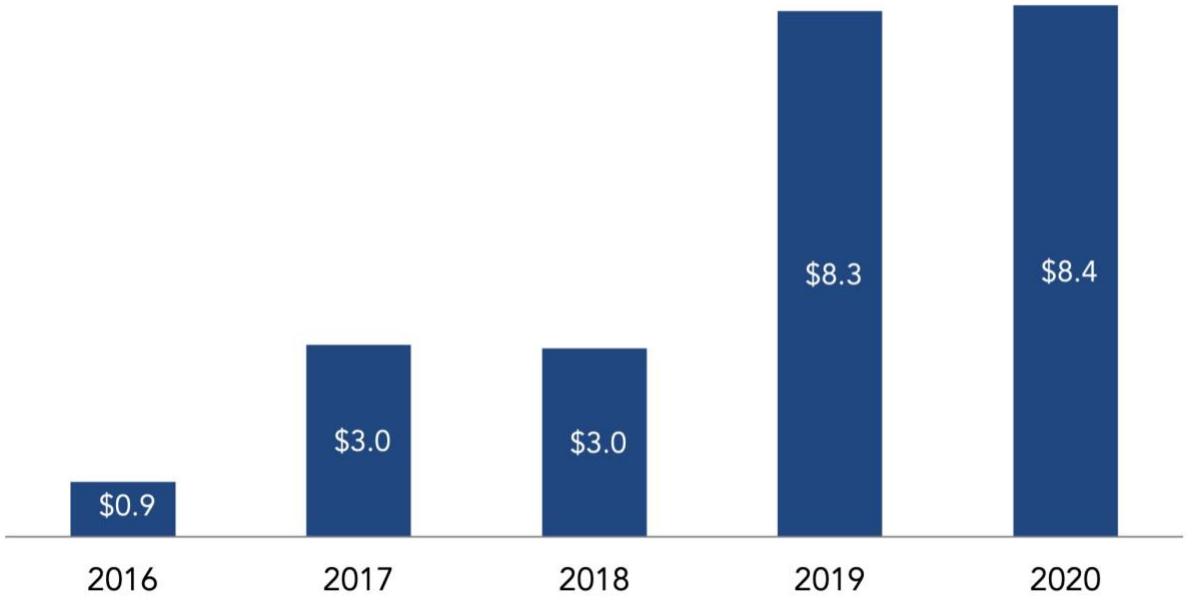

Figure 15 (Guidehouse Insights)

Potential of Hydrogen for Trucking Spurs Growth in Fueling Infrastructure

With automotive and transportation companies divided over hydrogen fuel cells versus batteries for long-range electrified driving, Hydrogen Fueling Stations have accounted for a relatively small but varying portion of Advanced Fuel Delivery throughout the past decade. While some hydrogen fueling infrastructure has existed for many years, growth has been much slower than for EV charging. At $33 million, global Hydrogen Fueling Infrastructure revenue was 32% lower in 2018 than it was in 2011. **However, a resurgence of interest in hydrogen, particularly for trucking, and in commercializing "green" hydrogen produced by electrolysis powered by renewable energy, led to positive growth the past three years. Most notably, revenue grew by 76% in 2019 and 31% in 2020, reaching $76.3 million globally**.

There are a growing number of global efforts aimed at expanding hydrogen infrastructure to help further refine the production process and narrow the cost gap between hydrogen and other transportation fuels:

- China is currently developing its first national fuel-cell vehicle (FCV) policy. Beijing would provide financial rewards to chosen demonstration regions, which are required to achieve a set of FCV market development targets. The policy would be China's first subsidy design on a national level for hydrogen energy and FCVs.
- Germany launched its National Innovation Program Hydrogen and Fuel Cell technology initiative in 2006 and has set FCV targets through 2030.
- California has published a plan to have 1 million FCVs on the road by 2030.

Hydrogen faces the challenges of ensuring adequate infrastructure, namely pipelines and refueling stations. Solving this problem requires coordinated efforts from both emerging hydrogen production technology manufacturers, consumers, and government agencies involved with infrastructure development.

ADVANCED ELECTRICITY GENERATION

$39.8 BILLION
U.S. revenue

10%
annual growth

$384.4 BILLION
global revenue

0%
annual growth

Overview

Advanced Electricity Generation – a category that, in this edition, no longer includes natural gas generation technologies (see Methodology) – is now the largest advanced energy segment globally. **At $384.4 billion, Advanced Electricity Generation was down less than 1% in 2020.** Global revenue has been in decline since 2018, dropping by $45 billion from the peak (driven by Nuclear) that year. This overall decline masks significant growth in solar in 2019 and wind in 2020.

In the United States, Advanced Electricity Generation continues to be the second largest segment of the advanced energy market and is still growing strongly, up 10% in 2020, with revenue growth in

wind, while solar declined 5%. **Over the 2011-20 period, the CAGR for Advanced Electricity Generation revenue was -1% globally, while for U.S. revenue compound annual growth was 2%.**

Advanced Electricity Generation in 2020 globally was boosted by investment in wind and hydro generation. According to IEA, multiple flagship hydropower projects in China drove increased spending in 2020. Supplemented by pockets of activity in Latin America and Africa, the market is expected to remain fairly stable over the next five years.

Solar led all generation categories with $130 billion in global revenue, even with decline of 11% in 2020. The gap between Solar and Wind spending is quickly closing though, as global wind revenue increased by 13% in 2020 to $119.2 billion. Solar overtook Hydro and Wind as the segment leader in 2016 following 33% growth over 2015. Since 2016, solar revenues have shown more modest and variable growth due to declining prices, while Wind has grown steadily.

Global Advanced Electricity Generation Revenue (Millions $)

Subsegment	2011	2016	2017	2018	2019	2020
Solar	96,193	132,084	142,297	140,375	146,667	130,029
Wind	67,069	86,368	93,781	91,309	105,260	119,228
Geothermal	666	2,148	1,033	1,073	1,132	1,157
Hydro	185,260	97,311	140,780	122,587	84,830	102,003
Marine	300	-	-	-	-	-
Waste	4,700	1,497	2,815	3,030	3,345	3,223
Biomass	10,500	8,500	9,214	9,218	9,223	8,724
Nuclear	40,804	79,844	19,648	60,582	33,786	18,175
Fuel Cells	755	1,283	1,366	1,498	1,747	1,868
Total	**406,248**	**409,035**	**410,934**	**429,672**	**385,990**	**384,406**

Table 15 (Guidehouse Insights)

There is now more than 719 GW of installed wind capacity worldwide (99% grid-scale), with 59.7 GW installed in 2019 alone. This growth comes despite a wind market that has faced challenges in recent years. Many mature country markets have eliminated or reduced subsidies or shifted to competitive power contract auctions, tenders, and other wind procurement mechanisms that squeeze profit margins throughout the supply chain. Meanwhile, solar PV is an increasingly capable competitor due to rapid cost reductions.

Despite these challenges, the wind market is holding steady and adjusting to a new normal of intense price competition. Some markets, such as the United States and China in the short term, are experiencing rapid near-term increases of capacity additions as supportive policies change or phase out. Wind power is being developed not only in a greater variety of countries but also offshore as well as onshore. China, Taiwan, and Europe are the leading markets, with the U.S. soon to join when the first large-scale offshore wind plants are commissioned in coming years along the northeast seaboard.

In the United States, Advanced Electricity Generation is the second largest advanced energy segment, with $39.8 billion in revenue in 2020. Growth in this segment over 2019 was 10%, outperforming the compound annual growth of 2% from 2011 to 2020.

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

Subsegment	2011	2016	2017	2018	2019	2020
Solar	8,246	24,945	23,969	17,150	19,514	18,458
Wind	12,993	14,064	11,417	12,268	14,430	19,062
Geothermal	118	629	489	910	882	883
Hydro	-	179	739	531	533	536
Marine	30	-	-	-	-	-
Waste	640	227	142	54	57	54
Biomass	300	22	424	423	425	361
Nuclear	12,287	-	-	-	-	-
Fuel Cells	182	374	388	408	433	443
Total	**34,796**	**40,440**	**37,569**	**31,743**	**36,273**	**39,797**

Table 16 (Guidehouse Insights)

Wind was the largest subsegment of Advanced Electricity Generation in the U.S., with $19.1 billion in 2020 revenue. Looking over the past three years, U.S. wind revenue has grown gradually after a period of relative stagnation. This is in contrast to the boom-and-bust cycles of previous years when the fate of the production tax credit (PTC), a key federal financial incentive, was regularly in question.

Despite stable revenues from 2017 to 2019, U.S. biomass revenues declined in 2020 to $361 million. Geothermal revenue has been flat the past two years, reaching $883 million in 2020. Meanwhile, revenues from Fuel Cells were up 3% to $443 million, while Waste was down 5% to $54 million.

U.S. Solar, Wind Revenue, United States, 2015-2020 (Billions)

Figure 16 (Guidehouse Insights)

Despite COVID-19, Solar and Wind Show Strong Year

In 2020, global solar and wind installations remained resilient despite challenges brought on by the COVID-19 pandemic. **Global wind revenue has increased every year since 2017, growing 13% in 2020 to exceed $119.2 billion.** The growth of wind revenue in 2020 was largely driven by the European Union plan for renewables and will be bolstered in 2021 by the latest extension of the wind production tax credit (PTC) in the United States.

The COVID-19 pandemic has caused short-term disruptions, but wind markets, and offshore wind in particular, have proven extremely resilient globally. The supply chain disruptions caused by COVID-19 were less intensive across offshore wind installations due to longer project timelines compared to onshore wind. Europe currently leads developed markets in offshore wind capacity and has benefitted from this resilience, especially the U.K., Germany, Belgium, Denmark, and the Netherlands. In the long term, annual installations of offshore wind are expected to increase from 6.4 GW in 2020 to 20.7 GW in 2030. While COVID-19 has caused some 2020 capacity additions to be rescheduled for 2021, overall levels remain strong, and the global wind market is expected to continue its growth in 2021.

The COVID-19 pandemic has created significant challenges for the solar industry, disrupting supply chains and creating permitting challenges for new solar installations. **In 2020, Solar revenue decreased 11% globally, while the U.S. solar market recorded a 5% decline.** Despite the challenges brought on by COVID-19, the U.S. market added 13.4 GW of capacity in 2020, a 6% increase in

installations compared to 2019, despite lower revenue. Grid-scale installations proved more resilient than distributed solar, increasing 20% over 2019. The distributed solar market, on the other hand, saw a nearly 10% reduction in added capacity.

Across solar and wind markets the primary impact of the COVID-19 pandemic has been in delays caused by supply chain and worksite disruptions. Lockdown measures significantly slowed manufacturing and construction at times in 2020, as projects were temporarily shut down or delayed. Despite these challenges, solar and wind were relatively resilient. In 2020, the wind market saw nearly $19.8 billion global investment in offshore wind alone.

Renewable energy is seen as a key component of the economic recovery strategy in many countries. As such, solar and wind markets are expected to be strong in 2021.

U.S. Wind Revenue, 2016-2020 (Billions)

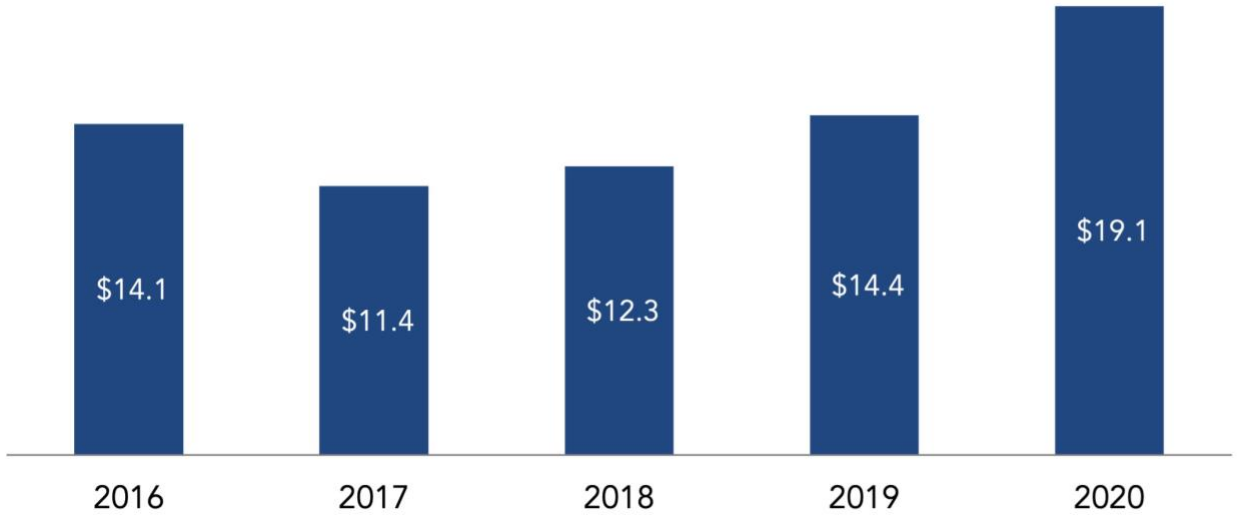

Figure 17 (Guidehouse Insights)

Fuel Cells Benefit from Green Hydrogen Push

Despite new attention over recent years, fuel cells have been under development for more than 100 years, with applications from space travel to residential micro-CHP. Historically, the fuel cell market has been constrained by the high cost of materials used in production. This cost is expected to decrease as fuel cell efficiency improves and less costly materials are used in production.

Some of the recent attention on fuel cells may be attributed to the rising hype around the hydrogen economy. Although most of the capacity of stationary fuel cells to date has been fueled by natural gas with internal reforming, pure hydrogen-powered fuel cells are gaining interest as the hydrogen feedstock can be produced from renewable energy sources through electrolysis.

Fuel cell incentives across the globe are often linked to fuel cell vehicles (see Advanced Transportation), but there is funding for stationary power generation applications as well. The South Korean government subsidizes as much as 80% of the purchase price of fuel cells with potential local subsidies to stack on top of that. As a result, South Korea is the world leader in fuel cell power generation, boasting a fleet of nearly 300 MW. Japan also directly supports fuel cells, as does the U.S. with the Investment Tax Credit.

The global market for fuel cells has grown steadily over the past three years, increasing 10% in 2018, 17% in 2019, and 7% in 2020. Investment in green hydrogen and fuel cell technology across Europe and Asia Pacific indicates that this growth will continue.

Global Fuel Cell Revenue, 2016-2020 (Billions)

Figure 18 (Guidehouse Insights)

Hybrid Power Plants Quickly Emerging as Electric Power Leader

The emergence of solar-plus-storage has been the most important trend in the electric power industry in the past two years. These hybrid power plants account for a large percentage of newly announced energy storage capacity, including some of the largest energy storage systems built around the world.

The U.S. has emerged as the hottest market for these new projects and is driving much of the innovation. In U.S. interconnection queues there are 102 GW of solar PV projects and 11 GW of wind projects being proposed with energy storage attached. Precipitated in large part by a dramatic decline in battery costs, nearly one-third of all proposed solar projects in the U.S. now include energy storage. Hybrid projects are also being planned and built in Australia, Japan, Europe, and the Middle East.

These projects are becoming more standardized in their technical and business model designs. Combining solar PV and battery uses at a single site through standardized configurations can provide significant cost savings relative to building the two technologies separately. Savings are derived from shared hardware such as inverters and transformers, along with more streamlined installation, project design, and interconnection. Projects are also being standardized in their business and financial models, although there is still variation in terms of managing the co-located solar and storage assets separately or as a single grid resource. PPA is the preferred structure for these new projects, offering utilities and other customers the ability to procure dispatchable solar PV generation at a set rate.