Renewable Energy Committee

2018 EMD Renewable Energy Committee Annual Report

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Version 3 – Executive Summary

Committee Activities

This Executive Summary of the 2018 Annual Report of the Renewable Energy Committee will be followed by the full report when completed and reviewed by the new Committee Vice-Chairs and members of the Advisory Group. Data for 2017 will be added to the report as it becomes available.

Executive Summary

- The objectives of this report are to inform members of the EMD, AAPG and the general public on the development of renewable energy and how the technology developments impacts the oil and gas industry. This report also aims to provide updates to research in the construction, installation, and application of renewables to supply electricity in the U.S. and elsewhere (via wind, solar, hydroelectric (dams and pumped storage), tidal, biofuels, ethanol, and waste-to-energy systems).

- Petroleum use is dominant in the transportation sector, but renewable energy is beginning to occupy the market shares once held by coal and natural gas, especially in electric power generation sector for rural regions.

- Renewable integration into the grid is quickly becoming a setback as renewable sources of power grow and grid operators are seeking new solutions to integration. But there is now a significant amount of wind and solar power being integrated into the electricity market.

- A significant reduction in nuclear capacity may offer an opportunity for renewables to gain the market. Recently, the Indian Point nuclear power plant that now provides about a quarter of the electricity in New York City and nearby counties announced its closure by 2021.Besides, nearly 10.6 GW of long-term nuclear plants retirements move away from markets and create space for renewables to compete, assuming the cost structure is not prohibitive.

- Recently, the U.S. was the second-highest ranked country (only after China) in total amount of new investments in renewable energy and energy-smart technologies. Investments in these two sectors reached $59 billion in 2016 and $507 billion over the past decades.

U.S. Electricity Production and Costs

- In 2016, the U.S. consumed 10,160 Trillion Btu of renewable energy, totaling 10 % of all energy consumption. 55% percent of the renewable consumption was in electric power sector, compared to 23% in industrial sector and 14% in transportation sector.

- U.S. production of renewable energy in the third quarter of 2016 slightly slowed down to 2,416 trillion Btu, an 8% decrease compared with the peak quarter in the same year. But in general, the quarterly production of renewables was relatively steady in 2016.

- In 2015, renewables took up 9.9% of all energy consumptions and accounted for 13.4% of the national electricity production in the U.S..

- Global levelized cost of electricity (LCOE) of solar photovoltaic generation fell from $315 per MWh in 2009 to $100 per MWh in 2016. The cost of onshore wind decreased to $68 per MWh in 2015. Offshore wind notably decreased to around $126 per MWh in 2016.

- The cost of constructing a utility-scale photovoltaic project decreased 57% at a global level, and the cost of wind turbines dropped from $1.34 million per MW to $1.12 million per MW within four years.

- In the United States, 20 states and the District of Columbia have established renewable portfolio standards (RPS) that require utilities in each state to supply a certain portion of electricity from renewable resources.

Employment in Renewable Energy

- States with substantial solar, wind, and fossil fuel resources presented great employments both in conventional fuels and renewable energies, even taking falling fossil fuel prices into account. But states like West Virginia that are highly dependent on coal consumption suffered from declines in employment rates since 2015.

- A total of 112,642 workers are employed in bioenergy electric generation and biofuel sub-technologies. More women are employed in bioenergy/biomass electric generation than in other individual biofuel technologies. The generation sector also hires more Hispanic or Latino and Asian employees, showing more diversity compared with other types of fuels.

Tax Advantages in Renewable Energy

- Despite the uncertainty in U.S. tax policy or attitude towards climate change, large corporations may keep flexing their buying power, especially in corporate renewable procurement. Therefore, the renewable energy sector will likely not slow its rate of development.

- The federal renewable electricity production tax credit (PTC) is a per-kilowatt-hour tax credit for electricity generated by qualified energy and sold by the taxpayer. It applies to wind, closed-loop biomass, and solar systems.

- The Investment Tax Credit (ITC) allows corporations tax credit based on the amount invested rather than electricity produced, which is quite different from the PTC. ITC is a 30% tax credit for the cost of solar system installations both in residential and commercial properties through 2019. It will drop to 26% in 2020 and continue falling to 22% a year later. In 2022, commercial credits are planned to decrease to 10% while the residential credits will expire.

- MACRS stands for the Modified Accelerated Cost Recovery System that currently applies for tax deduction calculations for depreciable assets. All ITC-related technologies as well as large wind projects are eligible for this tax policy.

Hydroelectric Activities

- 2015 was a milestone year for global investment in renewable energy. Excluding large hydro-electric projects, the amount of money invested in renewables rose 5% to $285.9 billion, exceeding the former record of $278.5 billion achieved in 2011. Note that 2015 also witnessed a rapid decline in oil, coal, and gas prices, which protected the competitive position of fossil fuel generation due to the low buying cost.

- In 2015, renewables excluding large hydroelectric projects made up the majority, 55.6%, of the gigawatt capacity of all installations the first time.

- In December 2015, the House of Representatives passed the North American Energy Security and Infrastructure Act, and the Senate passed the Energy Policy Modernization Act of 2015 to facilitate an easier and faster licensing process for hydropower. This is an improvement because currently the licensing process can take up to 10 years, thereby causing delays and setbacks in new and existing hydropower developments.

- Approximately 28 GW of new hydropower capacity was added to the market in 2015, which increased total global capacity to about 1,064 GW. However, continuing droughts in several areas, including the Americas and Southeast Asia had an adverse impact on the hydropower developments. Climate risk and competition from other renewables in the market shares are also driving further improvements of hydropower.

- Existing non-powered dams have become the main target of new hydropower developments. Based on research from the Department of Energy, the largest 100 non-powered dams potentially have as much as 8GW electricity capacity.

Wind and Solar Activities

- Wind and solar power account for nearly two-thirds of the growth in renewable generation with solar being the fastest-growing renewable. Wind has the largest absolute increase in generation and is projected to replace hydropower as the largest source of renewable energy by 2040 replacing hydropower.

Wind Activities

- Wind power is a mainstream power source that supplies 6% of U.S. electricity. In total, the U.S. installed 8,203 MW of wind capacity in 2016, making wind energy the top one source of national renewable energy capacity.

- Oklahoma is a pioneer among other states with 270 MW of wind capacity installed, followed by lowa (154 MW), Utah (62 MW), and New Mexico (32 MW). So far, Oklahoma has invested more than $6 billion in the construction of wind farm and created more than $340 million in labor income to the state.

- Currently, 102,000 workers are employed at wind firms across the nation – a 32% increase since 2015. 37.2% percent of the employment is in construction, compared to 29.0% in manufacturing and14.0% in trade. In fact, job opportunities in wind power have grown more than 25% a year, and there is estimated to be a substantial and growing need in wind turbine technicians.

- GE Renewable, Siemens, and Vestas occupied over 99% of the wind turbines market share in the first quarter of 2016. Alliant Energy also announced a 500 MW Whispering Willow expansion plan in lowa in addition to reported total 1,216 MW in new advanced development in wind power industry.

- The new administration aims to enable private investments in American infrastructure, which may stimulate the construction of electric transmission lines. Expanded transmission would

cross more states with abundant wind resources like Wyoming, Montana, and New Mexico and open more markets for wind power supplies.

- The U.S. issued its historic first offshore 30 MW wind project off the coast of Rhode Island in 2016.

- New York showed support for offshore wind power and held an auction on December 16, 2016 for the rights to a wind farm located in federal waters 12 miles off Long Island. This auction also helped New York state to achieve its goal of generating 50% of its energy from renewables by 2030 to support America's largest population centers.

- In the U.S., offshore wind resources are located in deep waters where conventional foundations such as large steel piles or lattice structures fixed to the seabed are impractical. There are potential needs for developing creative floating offshore wind platforms.

- China owns 31% of the world's installed wind capacity, but China meets less than 3% of its supply need through wind energy and still face the challenges of a lack of transmission infrastructure and the curtailment of wind generation.

- In 2015, the European Union also reached a new record in wind energy, where over 60 Gigawatts of new wind turbine were installed. Wind power takes up 44% of new power capacity installations, which is a greater percentage than any other technology.

Solar Activities

- The U.S. almost doubled the solar PV capacity in 2016, providing 14,762 MWdc of solar PV to over 370,000 individuals. In 2016, a record 22 states each added more than 100 MW of solar PV, and California remained the largest state market for solar energy.

- Policy partially contributed to this boom of solar power in 2016. In 2014 and 2015, developers and utilities anticipated a step-down in the federal investment tax credit in the year of 2016. To capture full tax credits, they submitted a large number of construction plans that have contractual obligations to begin operation at the end of 2016. Despite the official extension of ITC in late 2015, most construction plans remained unchanged.

- Solar cells based on dye-sensitized solar cells, organic compounds, perovskite materials, and inorganic quantum dots have been hugely popular and are garnering R&D efforts. These are gathering interest because they are promising to be less expensive than typical silicon cells and well suited to many more applications.

- The surface of the Moon independently receives 13,000 TWs of solar power. Converting the lunar solar power on the Moon into electric power to beams of around 2.5 GHz microwaves to Earth, feasible way for solar energy applications.

Tidal Energy Activities

- Ocean energy capacity, mostly tidal power, remained at about 530 MW in 2015. The dominant ocean energy deployments in 2015 were demonstration projects with most activity focused on tidal energy technology, followed by wave energy conversion devices.

Biofuel Activities

- The federal renewable fuel standard (RFS) is the key driver of the biofuel industry. It mandates transportation fuel sold in the U.S. to contain a minimum volume of renewable fuels. The main application of ethanol and biodiesel is blending them with gasolines to reduce transportation carbon emissions.

- In 2016, the U.S. installed 77MW of biomass and 54MW of biogas.

- With 60.3 million gallons published under RFS2, the U.S. estimates 113 million gallons of annual cellulosic ethanol production capacity. The amount of production was not as large as expected in 2010 due to insufficient capacity. RFS also has also reduced the renewable volume obligations for cellulosic ethanol in transportation fuels since 2010.

- The U.S. and Brazil achieved new records in ethanol production, which contributed to a 4% increase of global ethanol production in 2015. Constrained production in some Asian markets slightly reduced the global production of biodiesel. But 2015 witnessed great progress in the commercialization and deployment of biofuels, with expansions in other applicable biofuels routes such as thermal technology.

Waste-to-Energy Projects

- In February 2017, the Asian Development Bank (ADB) signed agreements with 10 commercial banks to assist Dyna-green Environment Protection Group, the Beijing State-owned assets management company, in clean municipal waste-to-energy (WTE) projects.

- There was no new installation of waste-to-energy plants in the U.S. in 2016. The most recent construction was the 85MW Palm Beach Renewable Energy Facility Unit 2 in 2015.

- Waste-to-energy plants in the U.K. boost more supports from the government. England constructed five new facilities totaling 180 MW in electrical generating capacity and 70 MW of export steam capacity.

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Introduction

The objectives of this report are to inform members of the EMD, AAPG and the general public on the development of renewable energy and how the technology developments impacts the oil and gas industry. This report also aims to provide updates to research in the construction, installation, and application of renewables to supply electricity in the U.S. and elsewhere (via wind, solar, hydroelectric (dams and pumped storage), tidal, biofuels, ethanol, and waste-to-energy systems).

The Brundtland Commission in 1987 came up with the standard definition of sustainable development – meeting the needs of current generation without harming the ability of future generation to meet their own needs. In 2015, The Paris Agreement was established in order to achieve zero net emissions in the second half of the century during the United Nations Framework Convention on Climate Change (Paris Agreement). The world's desire to resolve environmental issues, such as global warming, speeds up the transition from fossil fuels to renewable energy. Currently, we have been in a new era of renewable energy growth that contributes to controlling greenhouse gases emissions and fueling a sustainable future of opportunity and prosperity (Global Trend in Renewable Energy Investment 2016). Renewable energy is a type of energy derived from natural process and naturally replenished at a faster speed in human's lifecycle. There are five typical categories of renewable energy – wind, solar, hydropower, biomass, and geothermal. In this report, we exclude geothermal energy but add another renewable energy source, ocean energy, as a subcategory of hydropower.

International and U.S. renewable energy supply both have been growing over the past decades. We estimated around 147 gigawatts (GW) of added renewable capacity as well as 38 GW of added heat capacity in 2015 on the condition of falling natural gas price (Ren 21). In 2016, the total U.S. renewable energy supply reached around 9 quadrillion Btu, the highest record in the history ever (U.S. Renewable Energy Supply). Top three renewable supplies are hydropower, wind power, and wood mass. U.S. Energy Information Administration predicts that the renewable energy supply will reach to 10 quadrillion Btu in 2018 and the wind power will likely replace hydropower to be the largest renewable energy supply in a near future (U.S. Renewable Energy Supply).

Major consumptions of renewable energy are in electricity, heating, and transportation sectors. In 2015, renewables took up nearly 27.7% of the world's power generating capacity, supporting around 22.8% of the world's electricity (Ren12 2015). Besides, wind, solar photovoltaics (PV), and hydro power are the top three contributors for this market. As for heating system, biomass supports an estimated 8% of global heating consumption(Ren12 2015), and currently there are 227 biomass plants operating in the United States (Renee Cho, 2011). In the transportation sector, the share of renewable energy is relatively small compared to the dominant gasoline consumption, and liquid biofuels are mostly applied to this sector. Recently, vehicles in the United States start to use gaseous biofuels

including biomethane both due to advanced technologies and government policies such as the Federal Renewable Fuel Standard (RFS). Generally speaking, the United States consumed 9.970 quadrillion Btu renewable energy in 2016 while the EU seeks to achieve a 20% share of its overall energy consumption from renewable resources by 2020 (EIA, EU Statistics). Besides, we have witnessed a growing trend in global renewable energy consumption from 15,237 terawatt-hours in 2000 to 21,685 terawatt-hours in 2013 (Renewable Energy 2000-2013).

Nowadays, renewables are one of the cheapest choices for new power generation. Table 1 shows the levelized cost of electricity (LCOE) for different types of power plants. The LCOE of Hydro power is the cheapest among all. Wind, solar PV, and biomass are also cost-competitive compared to a range of $0.07/kWh to $0.14/kWh for natural gas (EIA 2015 Levelized Cost). Besides, installations of wind power, solar PV and concentrating solar power become much more cost-efficient. The cost of constructing a utility-scale photovoltaic project decreased 57% at a global level, and the cost of wind turbines dropped from $1.34 million per MW to $1.12 million per MW within four years (2017 Sustainable Energy in America). However, except for only emphasizing on the falling cost for renewable energy, the world should also value the technical potentials of other relatively expensive renewable resources. Take solar PV for example, even though it was a very costly power generation technology 30 years ago, people still invested in solar technology due to its high technical potentials, which contributes to a great boom of solar technology recently (Alternative Energy). Further research will be discussed in the solar energy section.

Power Plant Type	Cost $/kW- hr
Coal	$0.095-0.15
Natural Gas	$0.07-0.14
Nuclear	$0.095
Wind	$0.07-0.20
Solar PV	$0.125
Solar Thermal	$0.24
Biomass	$0.10
Hydro	$0.08

Table 1 Energy Cost $ per Kw-hr (EIA 2015 Levelized Cost)

$$\text{LCOE} = \frac{lifecycle\ Cost\ (\$)}{Lifetime\ energy\ production\ (kW\ h)}$$

Figure 1: The formula of levelized cost of electricity (formula)

Despite a drastic fall in fossil fuels price, global renewable energy investment achieved a milestone of $285.9 billion excluding large hydro-electric projects in 2015 (Global Trends in

Renewable Energy Investment 2016). The top ten investing developing countries in 2015 were China ($129 billion), India ($10.2 billion), Brazil ($7.1 billion), South Africa ($4.5 billion), Mexico ($4 billion), and Chile ($3.4 billion) (Global Trends in Renewable Energy Investment 2016). Europe invested $17 billion in offshore wind projects, which accounts for 11% of total $48.8 billion investment (Global Trends in Renewable Energy Investment 2016). The United States ($44 billion) ranked the second only after China in renewable investment in 2015 (Rebecca Harrington). Besides, gaining confidence from several large banks and international investment firms, 2015 witnessed that private investors stepped further into renewable energy sector especially solar PV, green bonds, and green vehicles (Ren 21).

The continuing innovations in renewable technologies as well as large-scale utilities deployments contribute to a fast development of renewable energy. Artificial photosynthesis that imitates nature's photosynthesis would be a promising way to increase the production of clean liquid biofuels. In addition, MIT researchers also came up with an innovative solar thermophotovoltaic device that could exceed the highest conventional efficiency limits on record (MIT Technology). Another low-cost solar cell, Perovskite solar cell, obtains a high light-absorbing efficiency. In addition to innovative technologies in the production sector, advanced battery storage expands the renewable energy market and overcomes the disadvantage of inconsistent supplies due to weather changes. Furthermore, the deployments of large-scale utilities such as dams and offshore wind utilities add more generating capacity into global renewable energy sector. For example, the U.S. issued its historic first offshore 30 MW wind project off the coast of Rhode Island in 2016 (North American Wind power).

Even though the job growth rate slows down because of the lagging economic currently, the total number of jobs in renewable energy industry keeps increasing. It is estimated that worldwide around 8.1 million employees are currently working in the renewable energy industry, and additional 1.3 million employees are in hydropower sector (Renewable Energy and Jobs 2016). Furthermore, gender disparity is scarce. Women take up an average 35% of total employees in the renewable energy workplace, compared to a general 20-50% of the workforce in the whole energy industry (Renewable Energy and Jobs 2016).

Major international oil and gas companies also realize the potentials of renewable energy. BP, a leading player in the renewables investment, obtains the largest operated renewable energy business. It holds interests in 14 onshore wind farms located all over the country from the Hawaiian island of Maui to the green hills of northeast Pennsylvania, and generates capacity of 2,259 megawatts in total (BP Wind Energy). In 2015, nearly 3 million tons of carbon dioxide emissions were reduced due to BP's wind investments (BP Wind Energy). Besides, Saudi Aramco, the world's largest oil company, announced $5 billion investment in renewable energy with a purpose of diversifying from crude oil

production in January, 2017 (Saudi Aramco Renewable Investment). Witnessing a drastic fluctuation of the global energy market over the decades, the Middle East started to diversify their portfolios and consider renewable energy as a safety valve for their future developments (Saudi Aramco Renewable Investment).

Relevant policies in the United States

Energy is a policy- and technology-driven market. Detailed technology developments will be discussed within sectors of different types of renewable sources. As for policies, currently there are federal and state level policies to fund renewables.

Federal levels

The Investment Tax Credit (ITC) allows corporations tax credit based on the amount invested rather than electricity produced, which is quite different from the PTC (NREL U.S. renewable energy policy and industry). ITC is a 30% tax credit for the cost of solar system installations both in residential and commercial properties through 2019 (NREL U.S. renewable energy policy and industry). It will drop to 26% in 2020 and continue falling to 22% a year later (EIA 2016). In 2022, commercial credits are planned to decrease to 10% while the residential credits will expire (EIA 2016).

The Federal Renewable Electricity Production Tax Credit (PTC) is a per-kilowatt-hour tax credit for electricity generated by qualified energy and sold by the taxpayer (NREL U.S. renewable energy policy and industry). It applies to wind, closed-loop biomass, and solar systems.

The Clean Power Plan sets state-by-state goals for carbon emissions cuts, and offers adjustable plans for states depending on their situations (U.S. EPA). With a purpose of moving away from coal-fired power plants, states could cut down their emissions by investing in renewable energy, natural gas, and nuclear energy plants. After former president Obama signed the final Clean Power Plan in 2015, the final policy sets limits on natural gas (EDF).

The Modified Accelerated Cost Recovery System (MACRS) currently applies for tax deduction calculations for depreciable assets (NREL U.S. renewable energy policy and industry). All ITC-related technologies as well as large wind projects are eligible for this tax policy.

U.S Department of Energy loan program issues loans guarantees for projects under certain conditions. If the projects could “avoid, reduce or sequester air pollutants or anthropogenic emissions of greenhouse gases; and employ new or significantly improved technologies as compared to commercial technologies in service in the United States at the time the guarantee is issued”, though some of them are associated with high technology risks, they are still eligible to apply for this program (U.S. DOE).

State levels

The Renewable Portfolio Standards (RPS), also known as Renewable Electricity Standards (RES), require utilities in each state to supply a certain portion of electricity from renewable resources. Currently, 29 states and the District of Columbia have established such policy for their electricity supplies (AWEA state).

Renewable Energy Certificates (REC) are issued if one megawatt-hour of electricity is produced and transported to the electricity grid from any renewable energy resource (EPA REC). Each REC lists the type of generated renewable resources, location of generation, and year of generation, which contributes to tracking and accounting renewable electricity generation and usage (Mirsad Hasic 2011). It is like carbon emissions trading except for measuring by kilowatt hours. 29 states in the U.S. and the District of Columbia and Puerto Rico mandate renewable energy certificates (Mirsad Hasic 2011).

Feed-In Tariffs (FIT), also known as Clean Energy Cashback, support the deployments of renewable energy resources and pay renewable energy developers due to their efforts in sustainable electricity generation (NREL Feed-In Tariffs). Currently, California, Hawaii, Maine, Oregon, Vermont, and Washington require FIT related programs (NREL Feed-In Tariffs).

Net Metering is a state level policy specifically for solar energy. It is a billing mechanism that issues credits to solar energy system owners for the electricity they add to the grid (SEIA net metering).

Cap and trade program in California applies market-based theories to lower greenhouse emissions. This program determines maximum, statewide greenhouse gas (GHG) emissions for all covered entities each year, and allows them to trade extra allowances (California Carbon dashboard). Covered entities include the power and industrial sectors, and expanded to natural gas and transportation fuels in 2015 (California Carbon dashboard).

The Property Assessed Clean Energy (PACE) Programs aim to increase energy efficiency and finance private renewable energy installations (Energy.gov). Local governments will fund the up-front cost of qualified energy improvements, and a home or business owner will pay back based on an assessment on property tax over time(Property-assessed clean energy).

Subsidies for the oil and gas industry

Most governments over the world subsidize energy including fossil fuels. In the U.S., energy subsidies consist of research funds, tax incentives, and tax breaks, which cut production and development costs. Based on the calculation from an EIA report in 2014, the oil and gas industry in the U.S. received approximately $2.3 billion subsidies from government (EIA 2013). Figure x indicates the amounts of three subsidies among different energy sources. The U.S. subsidizes the oil and gas industry with nearly zero tax incentives, but the largest amount of tax breaks (IE inside energy).

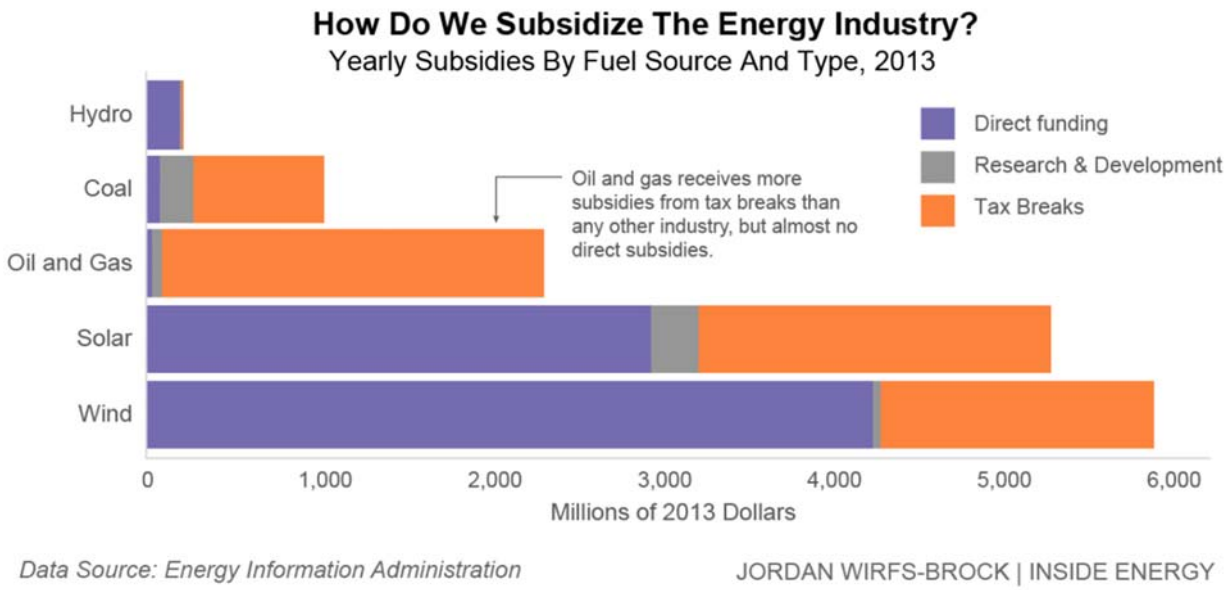

Figure x Subsidies in the energy industry (IE inside energy)

A tax break doesn't count for getting a reduction in taxes. Instead, it means claiming deductions or excluding income from tax return (Tax year 2016). The two most important tax breaks for oil and gas industry are expensing of intangible drilling costs ($1,495 million annually) , and percentage depletion for oil and natural gas wells ($1,343 million annually) (U.S. treasury 2015). The expensing of intangible drilling costs supports companies to reduce most of the costs of drilling new wells in the United States. The percentage depletion for oil and natural gas wells grants a deduction of fixed percentage –15 percent – of the revenue from each drill site under certain conditions (U.S. treasury 2015). Fossil fuels, a mature and developed industry, has enjoyed national supports totaling around $72 billion over the decades (ELI 2009). However, when it comes to renewables, a young and developing industry, only receives total $29 billion subsidies (ELI 2009).

Energy subsidies for the oil and gas industry are inconsistent with the global agreements on climate changes, a cleaner energy economy, and carbon pollution reductions. On the other hand, the public commonly believe that subsidies mostly contribute to the fast developments of renewables without knowing that the oil and gas industry has already been receiving subsidies nearly over a century. In fact, as is seen from figure x, renewable energy is also cost- competitive to natural gas even without subsidies.

Figure x Unsubsidized renewable vs conventional power costs (Joel Hruska 2014)

Wind

Onshore wind developments in the U.S.

The United States is a naturally windy country that obtains abundant wind energy resources. The windiest places in the United States are off the coasts, in the mountains, and through the Great Plains. The American Wind Energy Association lists 10 states that have the most abundant wind energy resources in a descending order(excluding offshore wind resources): North Dakota, Texas, Kansas, South Dakota, Montana, Nebraska, Wyoming, Oklahoma, Minnesota, and Iowa (The best states for wind power). Even though small-scale wind projects have few geographical restrictions, large utility- scale ones will require locations with good wind power resources.

However, states with the most abundant natural wind resources don't mean that they are the most developed wind energy generation states. Based on the calculated installed wind capacity from each state, the top ten wind energy generation states in a descending order are Texas, Oklahoma, Kansas, Iowa, California, Illinois, Minnesota, Oregon, Washington, and Colorado (The top ten states for wind energy 2015). We could clearly see the distinct differences between the two lists. One reason is that the first list doesn't include offshore wind resources. In general, offshore wind resources are more abundant, stronger, and blow more constantly. Further discussions on offshore wind energy will be in chapter Offshore wind developments in the U.S.. In fact, abundant wind resources is not the only factor that influences wind energy generation. Note that California is the fifth largest wind generation state, but is not listed in the top ten natural wind resources states. It is because that California offers more stipends on wind projects and has established a series of renewable-friendly policies such as existing renewables facilities program (ERFP). Further discussions on wind policies will be in chapter Relevant policies in the United States .

Installed wind capacity indicates the amount of potential output that could be obtained from wind projects at their maximum operating rates (Potential Wind Capacity, Installed Wind Capacity). Most renewable energy reports currently adopt installed wind capacity in their databases, and the U.S. Department of Energy records installed wind capacity as wind energy's market share. Figure 1 presents the accumulated installed wind power capacity in each state till the first quarter of 2017. So far, the United States has already achieved 84,143 MW installed wind capacity (American Wind Energy Association). However, the drawback of using installed wind capacity as a metric is that wind projects cannot always operate at their maximum rates mostly due to wind speed changes.

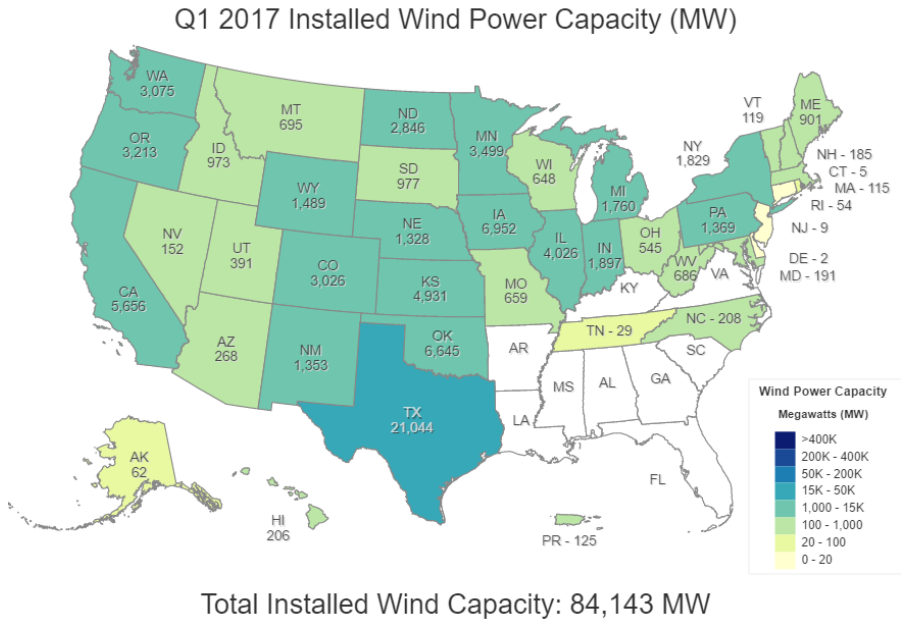

Figure 1 Installed Wind Capacity in each state (American Wind Energy Association)

Potential wind capacity is another term that shows the maximum amount of wind resources that could be utilized in a certain region. It could give a sense of the physical limits of the wind technology in that area. Figure 2 presents the potential wind capacity in each state and a total amount of 10,640,080 MW potential wind capacity all over the country (AWS True power, NREL).

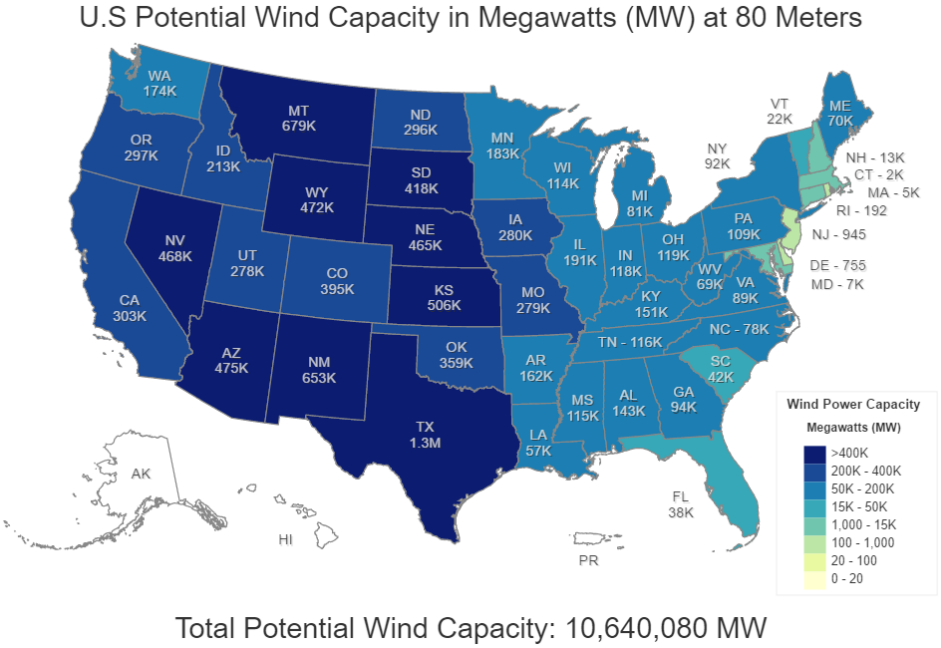

Figure 2 Potential Wind Capacity (AWS True power, NREL)

The United States has made significant achievements in onshore wind energy generation over the decades. Only in 2016, 8,203 MW of wind capacity was added into the market, and wind power now takes up 6 % of U.S. electricity supplies (AWEA U.S. wind industry annual market report 2016). In another saying, wind generated 226 million MWh and supported 17.5 million typical U.S. homes in 2016 (Wind energy factsheet). Iowa, one of the shining star states in wind power generation, achieved

great progresses last year that wind power supplied over 31 percent of in-state electricity (Wind energy factsheet). It is the first time ever that more than 30 percent of a state's annual electricity is provided by wind power (Wind energy factsheet).

Wind power brings jobs and economic benefits to the United States. The wind industry has invested over $143 billion (U.S. wind energy industry white paper), and states such as Oklahoma has invested more than $6 billion in the construction of wind farms (The statewide economic impact). Currently, 102,000 workers are employed at wind firms across the nation – a 32% increase since 2015 (U.S. energy and employment report 2017). 37.2% percent of the employment is in construction, compared to 29.0% in manufacturing and14.0% in trade (U.S. energy and employment report 2017). In fact, job opportunities in wind power have grown more than 25% a year, and there is estimated to be a substantial and growing need in wind turbine technicians (U.S. energy and employment report 2017).

Wind energy contributes to cutting down carbon dioxide emissions and other air pollutants. As mentioned before, wind energy generated 226 million MWh in 2016, which significantly reduced nearly 159 million metric tons of CO_2 that equals to the emissions of 33.7 million cars (Carbon dioxide savings). Figure 4 also shows the low greenhouse gas emissions of both onshore and offshore wind farms compared with fossil fuels. In addition to carbon dioxide emissions, wind energy also reduces a great amount of air pollutants such as sulfur dioxide (SO_2) and nitrogen oxides (NO_2). Based on a study from Harvard School of Public Health, the reduced amounts of SO_2 and NO_2 contribute to saving more than $5.5 billion and $1.9 billion for public health (Carbon dioxide savings).

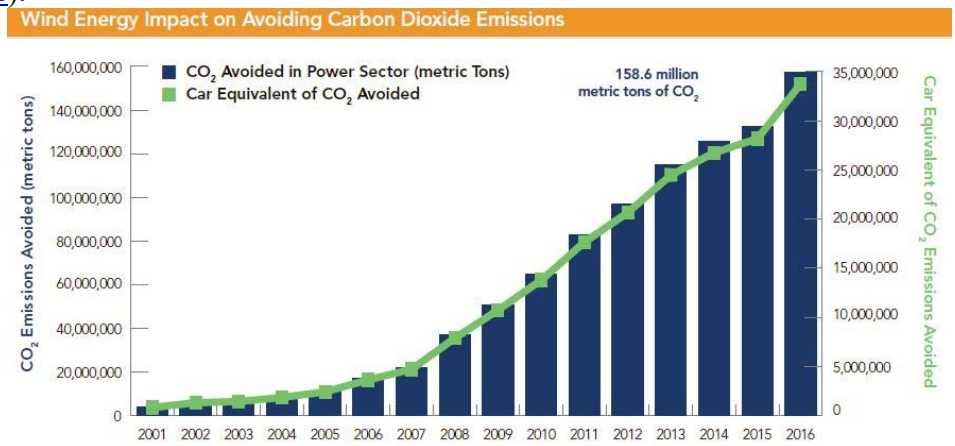

Figure 3 Wind energy impact on avoiding carbon dioxide emissions (Carbon dioxide savings)

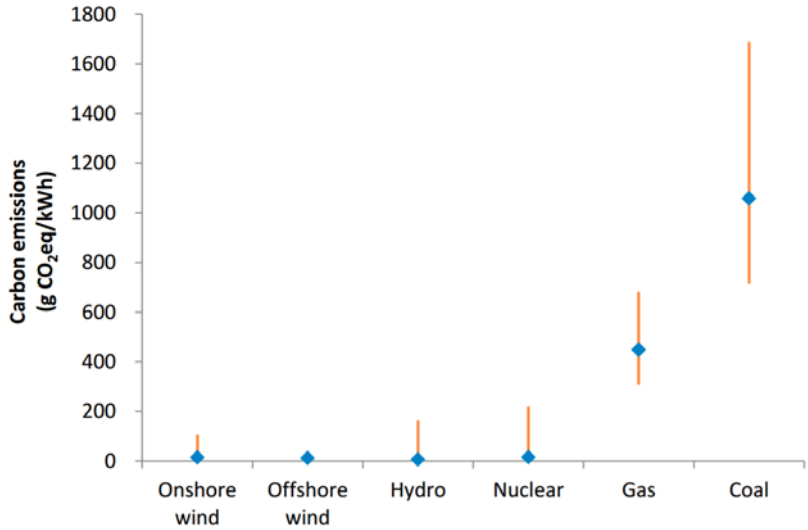

Figure 4 Comparison of carbon emissions of wind with other types of generation (Climateexchange)

However, wind power still has its drawbacks. Variable weather conditions, grid systems, battery storage, transmission lines, and environmental impacts are all controversial issues for wind. Wind energy supply is not as reliable and consistent as fossil fuels due to variable weather conditions. It is naturally inevitable, and this report is not going to focus too much on it. In the following paragraphs, this report will discuss the rest issues in detail.

Nowadays, many utilities worry about wind power's negative potential impacts on electric power system operations due to changes in electricity demand. Wind speeds are not constant, which leads to the variations in the energy conversion from wind to electricity. Once the electricity demand exceeds or drops beyond a safe load range, there will be damages to electricity power system operations. Therefore, as the United States increasingly deploys wind power to support its electricity, these concerns shouldn't be future barriers for wind developments, and therefore should be adequately addressed.

Grid systems and battery storages are developed to solve such problems. When there is no wind power, the power stored in the grid-tie inverter will be utilized to support the system. When there is more wind power than required, the wind farm owner could gain tax credits based on production tax credit (PTC) by selling the extra power to the power companies. When the wind blows out of control, the system will solely use the power from a backup from the inverter, or the inverter will automatically turn off the system until proper power comes back. Off-grid system is a second type of system for wind power, and is mostly applied to self-consumption of wind power generation in residential areas. It is more self-reliant and the wind power generated by the off-grid system will be stored in batteries. The biggest advantages of the off-grid system are low maintenance costs and independent of the power companies. Besides, battery storage could immediately and precisely respond to changes in loads, which enhances turbine flexibility (GE renewable energy). Nevertheless, lithium-ion battery packs, the brightest type of large-scale energy storage system, cost around $1,000

-3,000 per kWh (EnergyPost). The break-even price for storage is only nearly $1000 per kWh, indicating that battery storage has not been a cost-effective way for wind power yet (EnergyPost).

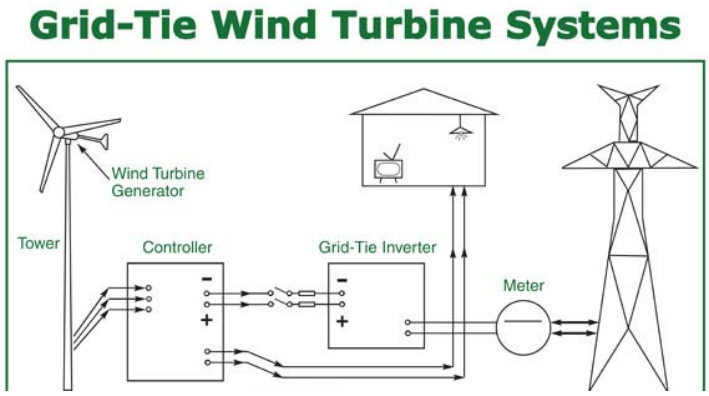

Figure x On-grid wind turbine system (WindEnergy)

A backup in the inverter means that other plants will provide energy when the wind power is not accessible. Before discussing the backup, we need to understand the three metrics to determine the reliability of a grid system – energy, capacity, and flexibility (AWEA). Energy is the amount of electricity produced by a certain type of power plant; Capacity is the ability to generate electricity to a certain level in time or MW; Flexibility means the ability to adapt changes to accommodate the fluctuations of energy supply and demand (AWEA). No single type of energy could perfectly obtain all good metrics. Therefore, having a mix of energy sources is a cost-effective way to achieve the power system reliability. Table 2 describes the levels of three metrics in different types of power plants. As is seen from the table 2, wind, nuclear, and coal power plants all obtain low flexibility while natural gas-related and hydroelectric power plants are prominent in flexibility. In order to meet all three metrics requirements at the same time, the trend for the reliable power system is to integrate renewable energy and natural gas. In another saying, natural gas is the backup power for wind energy on the conditions of emergencies.

In a word, there still exists room for reducing more carbon emissions from natural gas, and further technology developments are needed to achieve both reliable and 100% renewable supplied power system.

	Energy	Capacity	Flexibility
Wind	X+	Some	Can, but is costly
Nuclear	X	X	None
Coal	X	X	Little
Natural gas comb. cycle	X-	X	X
Natural gas turbine	Too costly	X+	X+
Hydroelectric	Some	X	X

Table 2 three metrics for different power plants (AWEA)

Large scale wind utilities are usually located in remote and rural areas where there are small energy consumptions. 54 percent of the world's population lives in urban cities, areas that have

considerable daily energy demands (United Nation). The role of Transmission lines is to transport electricity from where it is produced – remote and rural areas, to the consumption areas – urban cities. However, the constructions of transmission lines require relatively huge land occupations and would cross various types of habitats and several states, unavoidably having potential adverse impacts upon our environments. Therefore, under the National Environmental Policy Act (NEPA), construction companies need to provide an Environmental Assessment (EA) or Environmental Impact Statement (EIS) report to get approved by governments. Based on a staff from Clean Line energy LLC, the preparation of relevant documents and permitting process together will take around 3 years for wind transmission lines. The original purpose of NEPA is to protect our environment. However, unexpectedly, it prolongs the duration of the construction to a certain extent. Currently, approximately 300,000 MW that take up 20 percent of our electricity needs, is still waiting for connecting to transmission lines (Greenpower superhighways). The U.S. Department of Energy also points out that inadequate transmission lines are the greatest restriction to realize green electricity supplies and economic benefits.

Although wind power plants are more environmental-friendly than fossil fuels ones, there are still concerns about bird and bat fatalities, and accumulative habitat-based impacts. As for birds, higher-risk sites are shorelines, small islands, wetlands, migratory bird flyways, mountain ridge-tops, wooded areas, and native grasslands. Lower-risk sites are most agricultural lands, deserts, and ranches. In 2013, researchers estimated an annual bird mortality range from 140,000 to 573,000 due to wind turbines (Biological Conservation). Involved bird species ranges from small warblers to large eagles, and many of them are protected under federal law of the Migratory Bird Treaty Act (1918) (Impacts of wind on wildlife). Besides, small passerines that include over 90% land birds account for nearly 60% of fatalities in the wind turbine collisions (AWWI wildlife 2016). Bats also suffer a lot from wind turbines. Researchers estimate that more than 600,000 bats fatalities are caused by wind turbines in 2012 (Wind Energy and Wildlife Conservation). In fact, migratory bats tend to fly at lower heights than birds, and they usually chase after insects that are attracted by turbine lighting or turbines, which both leads to a higher number of fatalities (Impacts of wind on wildlife).

Good news is that people now are realizing the negative impacts of wind energy to birds and bats, and starting developing birds or bats- friendly wind turbines. Recently, Ogin Inc was allowed to install 40 of its “shrouded” wind turbines that are less mortal to birds and bats than conventional turbines near San Francisco (Kent Harrington, 2014). This unprecedented wind turbine shape is expected to have “the two concentric cowls around the blades” that make them less accessible to birds and bats (Kent Harrington, 2014). However, note that it is a trial experiment at an early data collection stage. Further studies are needed.

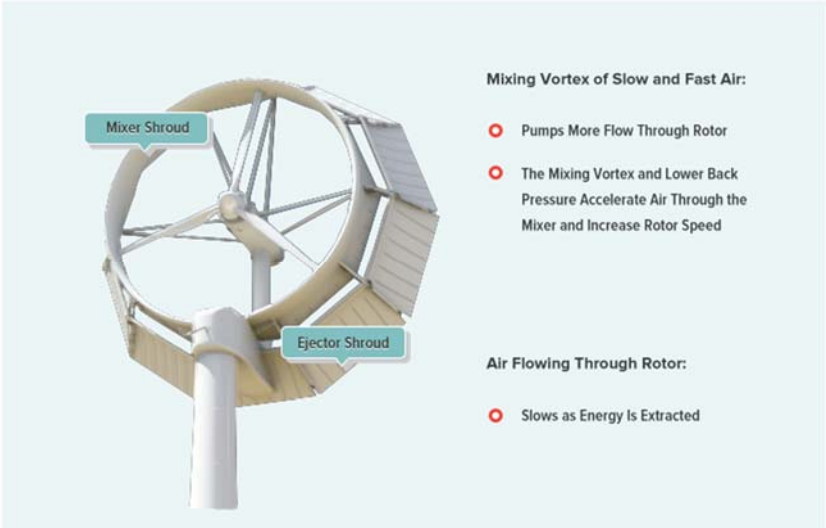

Figure x Ogin Inc computer simulation (Ogin Technology)

Project constructions and operation noises would be another issue for birds and bats. The transportation of large component parts of turbines, the tower, nacelle, hub, and blades needs extra road construction (Alternative Energy Tutorials, 2016). What's more, large concrete foundations and trenches for grid connection cables can lead to the occupation of existing habitats for birds and bats. Operation noises produced by the gearbox will indirectly keep the two species away from this site.

Offshore wind developments in the U.S.

Figure x describes the estimated average wind speeds annually at 90-m height at a spatial resolution of 200 m (NREL). Basically, if an area has mean wind speed of 7 meters per second and is above 90 m height, we could consider it as a potential place for future offshore wind developments (NREL).

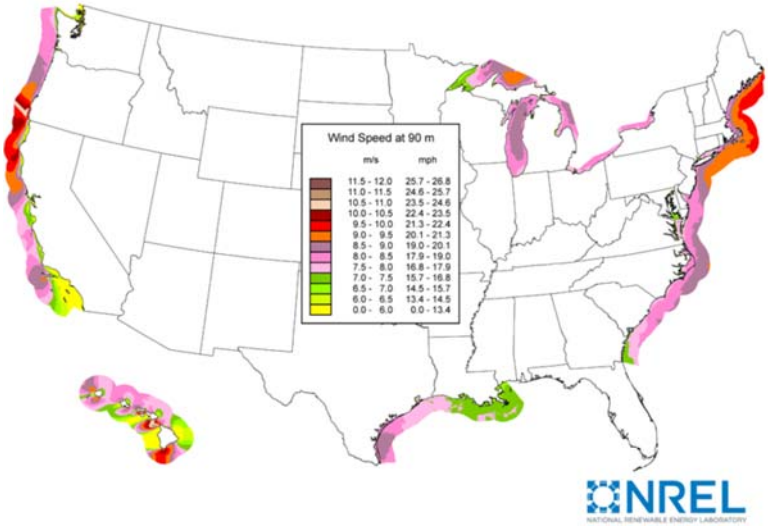

Figure x Offshore wind map in the United States (Map)

In fact, three-quarters of the world's mega-cities are near the coast (Greg Laden, 2011). Those cities indicate large electricity demand but have limitations of accessing to a high-quality onshore wind resource and connecting to transmission lines. Many coastal areas in the United State also face the same problem. In 2008, the U.S. Department of Energy (DOE) set up a goal of achieving 20% of

its electricity supply from wind energy (NREL offshore). Offshore wind promises to be a great potential resource for coastal electricity loads and the national goal. The United States continues to grow the offshore wind energy as a domestic renewable energy supply, and it issued the historic first offshore 30 MW wind project off the coast of Rhode Island in 2016 (Wind technologies market report). New York also showed support for offshore wind power and held an auction on December 16, 2016 for the rights to a wind farm located in federal waters 12 miles off Long Island (BOEM). This auction also helped New York state to achieve its goal of generating 50% of its energy from renewables by 2030 to support America's largest population centers (DOE national offshore wind strategy).

Taking the benefits of offshore wind resource will require to conquer three obstacles: lowering the cost of offshore and technical risks affiliated with offshore wind projects, establishing comprehensive environmental regulations and mitigations, and educating the public about the benefits and costs of offshore wind energy (DOE national offshore wind strategy). The cost of onshore wind decreased to $68 per MWh in 2015 while offshore wind notably decreased to around $126 per MWh in 2016, indicating the future possibilities of implementing offshore wind power projects (Bloomberg new energy finance 2015). In the U.S., 90% of areas with offshore wind resources are in deep waters where conventional foundations such as large steel piles or lattice structures fixed to the seabed are impractical (BOEM offshore wind energy). There are potential needs for developing creative floating offshore wind platforms. Besides, even though offshore wind power doesn't require on-land large-scale utilities that may bring concerns to human communities especially in cities with dense population, it still may bring issues to ocean ecosystem such as noises. At last, it is very costly and inefficient to development offshore wind in most states due to lacking sufficient policy support to offshore wind power like tax credits. Good news is that PTC and ITC extensions in 2016 helped offshore wind projects to get relevant policy benefits (Wind technology market report 2016).

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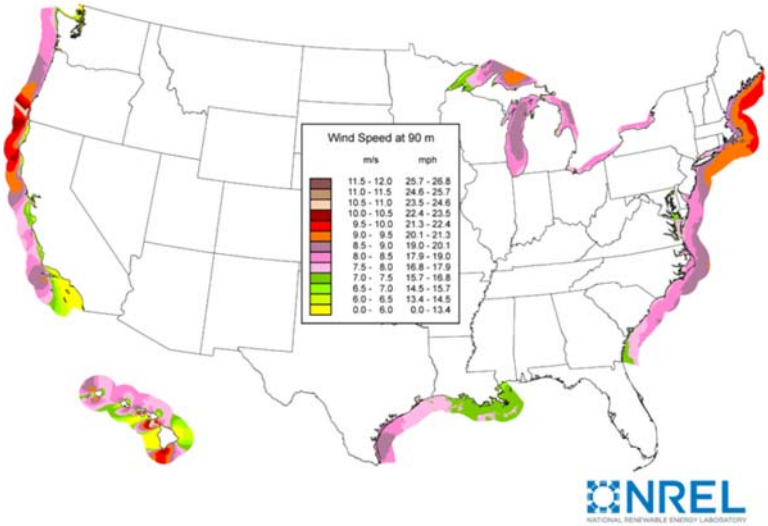

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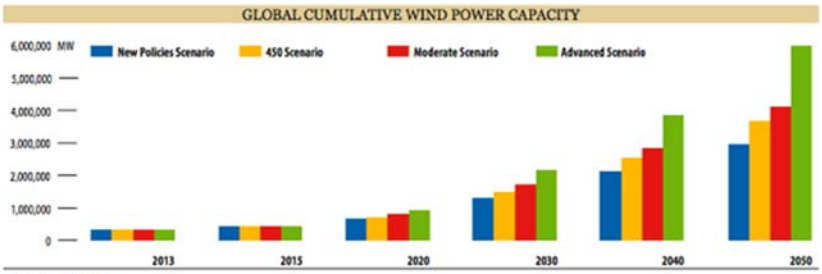
International onshore and offshore wind developments

Wind power has been developing rapidly over the decades. New and emerging markets appear across Africa, Asia and Latin America. Wind power grows steadily in the U.S. due to its policies. At the same time, China and India also make a strong commitment to global developments. In 2016, more than 54 GW of renewable wind power was added into the global market, and 9 countries have achieved more than 10,000 MW installed capacity while now 29 countries have crossed the 1,000 MW line (GWEC global statistics). Besides, Denmark increased its wind power penetration level to 40% of its power from wind, followed by Uruguay, Portugal and Ireland (over 20%), Germany (16%), the U.S. (5.5%), and China (4%) (Global wind energy outlook 2016).

Figure x indicates four scenarios – New policies scenario, 450 scenario, moderate scenario, and advanced scenario – to forecast the future potential for wind energy developments. In summary, wind power capacity is expected to continue its quick growth in both developed and developing markets. However, emerging markets such as Latin America and Africa, will play a more important role in the future.



	2013	2015	2020	2030	2040	2050
New Policies Scenario						
MW	318,354	432,656	639,478	1,259,974	2,052,583	2,869,611
TWh/a	714	868	1,569	3,311	5,394	7,541
450 Scenario						
MW	318,354	432,656	658,009	1,454,395	2,458,757	3,545,595
TWh/a	714	868	1,614	3,822	6,462	9,318
Moderate Scenario						
MW	318,354	432,656	797,028	1,675,624	2,767,351	3,983,995
TWh/a	714	868	1,955	4,404	7,273	10,470
Advanced Scenario						
MW	318,354	432,656	879,446	2,110,161	3,720,919	5,805,882
TWh/a	714	868	2,157	5,546	9,779	15,258

Figure x Global Cumulative wind power capacity forecast (Insights from GWEC 2016 outlook)

The global offshore wind industry has witnessed great achievements over the past decades. With over 3.4 GW new capacity added in 2015, total offshore wind capacity reached 12 GW. In addition, eleven European countries installed accumulatively more than 11,034 MW offshore wind capacity in coastal areas at the end of 2015 (Insights from GWEC 2016 outlook).

Solar Energy in the U.S.

Solar energy is the most abundant and cleanest renewable energy resource on earth. Approximately 173,000 terawatts of solar energy arrive to earth surface constantly, which is more than 10,000 times the global total energy consumption (Energy.gov solar energy). It is easy to use a

fluid passing through a heat sink to collect thermal radiation from the sun. The circulated fluid then could be applied as a source to heat water, or to generate electricity by driving a wheel or turbine. Photovoltaic (PV) cells are sophisticated semiconductors cells that convert photons into electrons to form electrical currents (Institute for energy research). Currently, PV panels and concentrating solar power (CSP) facilities are mainstreams in solar energy applications.

Solar PV

Rooftop PV panels and large-scale PV projects both adopt photovoltaic panels to convert sunlight directly into electricity. In the mid of 2015, the United States had already installed nearly 800,000 rooftop PV panels nationally (SEIA 2014). Besides, a five-kilowatt residential PV panel is able to produce an average range of 7,000 to 8,000 kilowatt-hours per year, which equals to a typical U.S. household annual electricity consumption (Union of concerned scientists the solar resource). California obtains the greatest potentials to compensate electricity usage, approximately 74% of the electricity generated by its rooftop PV in 2013 (NREL rooftop solar PV). Even Washington, the lowest population-weighted solar resource state, still occupies 27% of the total electricity generation (NREL rooftop solar PV). Large-scale PV projects usually involve millions of PV panels installed in a large area of land. In addition, those projects could adjust their optimal angles to follow the sun, significantly increasing the conversion efficiency.

Currently there are three main PV technologies – crystalline silicon, thin film such as CdTe and CIGS, and multi-junction. Silicon is still the most common and efficient material used in solar cells, occupying nearly 90% modules sales in the market (Solar photovoltaic cell basics). Crystalline silicon solar cells are also called the first-generation cells that silicon atoms attract to each other to form a crystal lattice to better convert light into electricity. Besides, the life cycle of crystalline silicon solar cells is expected to be around 25 years or more without losing too much productivity (Solar photovoltaic cell basics). Second-generation solar cells are named thin-film solar cells due to its amorphous silicon or non-silicon materials. Such materials have a relatively high absorption coefficient in the most portion of the visible spectrum, making the production of extremely thin-film cells possible (Thin film solar cells). Due to this flexibility, thin-film solar cells can be applied to rooftop shingles and tiles unlike crystalline silicon type. The materials for third-generation solar cells are various, ranging from solar inks to conductive plastics. In fact, some solar cells use plastic lenses or mirrors to reflect sunlight onto relatively small but highly efficient PV cells. However, requirement that lenses must be pointed at the sun sets a geological limit for a wider use of such PV arrays. For example, concentrating PV arrays are mainly installed in the desert southwest in the United States.

The cost of solar PV cells has dropped by more than 60 percent since 2006, making solar more affordable than ever (Solar industry data). Figure x indicates that solar PV prices have already dropped drastically and fell to less than $2 per watt in 2016, contributing to a boom of solar PV installations (SEIA 2016). Besides, policy also partially contributed to this boom of solar power in 2016. Early in 2014 and 2015, developers and utilities anticipated a step-down in the federal investment tax credit in the year of 2016. To capture full tax credits, they submitted a great amount of

construction plans that have contractual obligations to begin operation at the end of 2016. Despite the official extension of ITC in late 2015, most construction plans remained unchanged.

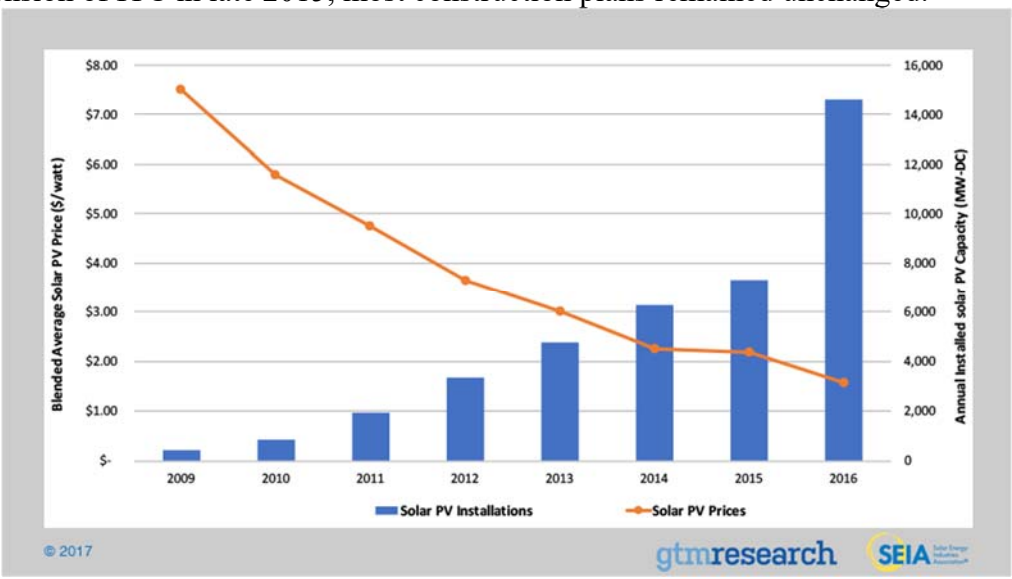


Figure x Growth in solar is led by falling price (SEIA 2016)

Concentrating solar power (CSP) facilities

Concentrating solar power (CSP) facilities capture the sun's radiations to heat a liquid and produce steam to turn a turbine or wheel to create electricity. CSP projects are mainly located in deserts where the solar power is more steady and abundant. Three large-scale projects installed in the California desert areas – Mojave solar one, Ivanpah Solar Electric Generating System, and Genesis Solar – generate 892 MW of solar capacity to supply the grid system, equaling to the electricity consumptions of 220,000 American typical households (U.S. DOE the year of concentrating solar power 2014). In total, the United States operates over 1,800 MW of CSP plants nowadays (SEIA concentrating solar power).

Due to a combination of technological advancements and favorable government incentives, solar power is at the growth stage through a life cycle analysis. Solar PV installations were nearly doubled in 2016, providing 14,762 MW of solar PV to over 370,000 individuals (SEIA solar market insight report 2016). In 2016, a record 22 states each contributed more than 100 MW of solar PV, and California remained the largest state market (35%) for solar energy (SEIA solar market insight report 2016). In the future, it is estimated to grow at an annual rate of 38.8% over the 10 years till 2021 (IBIS world solar energy 2016). Though recently the new administration moved away from Paris agreement, the public still aware the importance of clean energy and decide to diversify their energy portfolio. For example, Apple, Amazon, Google and other big technology companies launched a campaign named "We Are Still In" to adhere to the Paris climate agreement.

The solar power industry is also an industry with a high level of revenue volatility, capital intensity and entering barriers. A higher level of revenue volatility implies a greater industry risk. Despite the stable market demand, fast expanding installations of solar-generating capacity, quick growth rate, government subsidies in a limited time range, and declining costs attract more operators

but also involve more uncertainty in. Revenue volatility will influence corporates' long-term strategies such as capital investments. Besides, the level of capital intensity is also high for solar power, meaning that solar power needs a significant investment in assets at the first beginning to get back a certain amount of sales revenue (Mallory Otis 2011). In another saying, it means that compared to every one dollar spent on labor in each of the past five years, solar power capital cost such as plant, machinery and equipment is $2.70 in average (IBIS world capital intensity). However, long life cycle of PV cells and CSP facilities lower down the overall costs for relevant projects. In fact, high capital costs also bring barriers to enter in the solar power industry. Higher production costs compared to fossil fuels, risks of buying or leasing remote lands for solar power facilities, transmission costs are inevitable factors that make the entering costs expensive.

The solar power industry obtains a high level of industry assistance. Even though neither tariffs nor non-tariff barriers includes solar power, the American Recovery and Reinvestment Act of 2009 and the Energy Policy Act of 2005 both offer subsidies for energy efficiency and renewable energy programs. ITC, PTC, RPS and several state-level programs also provide incentives or tax credits to lower down large capital spending associated with the constructions of solar power facilities and encourage to generate electricity from solar energy.

The concentration level of solar power considers to be low, with less than 12.0% market share occupied by the three main industry participants (IBIS world concentration level). More companies are willing to enter in this industry because of high growth rates and greater profits. Residential solar power facilities are also getting larger, lowering down market share concentration.

Life cycle stage	Growth	Regulation level	Heavy
Revenue volatility	Very high	Technology change	Medium
Capital intensity	High	Barriers to entry	High
Industry assistance	High	Industry globalization	Medium
Concentration level	Low	Competition level	Medium

Table x Solar power industry analysis (IBIS world concentration level)

However, the same as wind power, solar power is also an intermittent energy influenced by weather patterns and seasonal fluctuations. Firstly, solar projects confine themselves to regions with plenty sunlight and fine weather. Besides, major technological barrier for solar energy is to meet demand by properly switching on and off. Solar power is generated in remote areas such as deserts and transmitted through grid systems. Grid is a transmission network of synchronized power providers and consumers, delivering electricity from supply areas to demand areas. However, grid is not able to store electricity, which means that once there is a specific demand, instantaneously the power needs to be supplied by the interconnected generators through grids (Sean Leavey, 2012). Therefore, having a balance of supply and demand is significantly essential. As a result, solar farms and stations are switched off when oversupply, and are fueled by natural gas, oil, or coal to assist in powering up when the sunlight is too little to generate electricity. From figure x, we could clearly see that solar power is less abundant and fluctuated than wind power in Minnesota probably due to its

geological location. After sunset, demand still exists and needs to be backed up either by other energy resources or battery storage. Hydro/Biomass are steadier when generating electricity, and further research will be discussed in specific chapters.

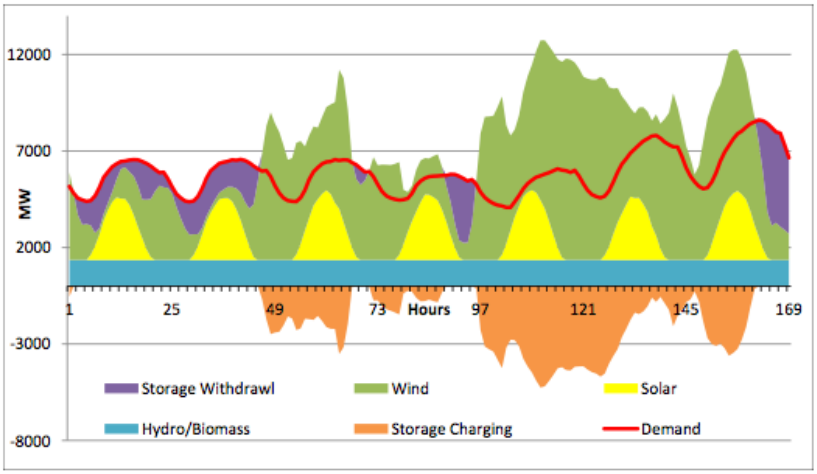


Figure III-7: Hourly supply and demand, with storage. July 11-17, 2007. *Source: IEER.*

Figure x Hourly supply and demand with storage in Minnesota, July 11-17, 2007 (IEER)

The solar industry is a fast-growing industry in the United States, with currently 373,807 employees working in manufacturing, installation, and distribution sectors (U.S. energy and employment report 2017). New solar jobs represented 2% of total added jobs in the United States, and has enjoyed at least 20 percent per year increase over the past four years (National solar jobs census). In a near future, solar-related companies expect to increase employment mostly in PV technologies by seven percent. Besides, a small portion—approximately nine percent—of total employment is in CSP facilities. Female takes up roughly a third of the workforce. Approximately two in ten workers are Hispanic or Latino while one in ten are Asian, Black or African American. Apart from job opportunities, the solar industry contributed to $84 billion to the U.S. GDP in 2016 (Economic impacts report 2016).

Recycling solar panels

PV cell is considered as a clean technology with minimal wastes. In general, the life cycle of solar modules is nearly 30 years, therefore most modules in today's market haven't reached to their end lives (IRENA 2016). During their operation periods, there almost is no hazardous waste generated. However, solar modules still contain some hazardous materials such as silicon tetrachloride, cadmium, and sulfur hexafluoride (Solar power 2010).When the time comes, the wastes from the decommissioning of the solar modules cannot be avoided. With the growing adoption of solar modules both in residential and commercial areas, there is a significant need of solar recycling. Based on industry trends statistics, the size of solar panel recycling management market grew over $20 million in 2015 and is expected to achieve 35% increase from 2016 to 2024 (Global Market Insights). For example, the overall amounts of decommissioned panels in Germany quickly crossed 75,000 tons in 2015 compared to 50,000 tons in 2010 (Global Market Insights). At the same time,

more solar farms signed in effective waste disposal and recycling projects in Germany, which also encourages the growth of such market.

From a technical point of view, the PV recycling industry "treats end-of-life PV panels through separate batch runs within existing general recycling plants", making material recovery of major components possible (IRENA 2016). So far, there are two different methods, thermal and mechanical, to recycle solar panels. If no silicon exists, panels could be thermally dissolved in chemical baths. Unlike thermal approach, mechanical process firstly detaches the module from the upper glass, and then separates the plastic material that protected the whole cell before (Greenmatch 2016). Therefore, the final products of mechanical process are copper, silicon powder, and plastic materials. In fact, the recycling efficiencies of two approaches can be as high as 98%, meaning that a 20-kg-weight PV module is able to produce 19.6 kg usable materials (Greenmatch 2016). Those materials can be reused to support new construction of PV panels or other productions. Despite that silicon powder cannot be used in constructing new PV cells due to impurity, it is still useful in other fields such as casting iron foundries. Besides, the plastic materials could be recycled to make vessels and containers. In 2016, IRENA predicted that the recyclable materials could contribute to $15 billion values by 2050, and such recycling projects could create significant green job opportunities (Sarah Lozanova, 2017).

International solar energy developments

solar energy

"The solar PV market was up 25% over 2014 to a record 50 GW, lifting the global total to 227 GW. The annual market in 2015 was nearly 10 times the world's cumulative solar PV capacity of a decade earlier. China, Japan, and the United States again accounted for the majority of capacity added, but emerging markets on all continents contributed significantly to global growth, driven largely by the increasing cost-competitiveness of solar PV."

"An estimated 22 countries had enough capacity at end-2015 to meet more than 1% of their electricity demand, with far higher shares in some countries. China achieved 100% electrification, in part because of significant off-grid solar PV installed since 2012; On grid, however, curtailment of solar generation started to become a serious challenge for China's solar PV sector."

"Morocco (160 MW), South Africa (150 MW) and the United States (110 MW) all brought new CSP facilities online in 2015, raising total global capacity by about 10% to nearly 4.8 GW. The new facilities represent a mix of parabolic trough and tower technologies, and all incorporate thermal energy storage (TES). – Concentrating solar thermal power (CSP): marked shift to developing regions, increasing importance of thermal energy storage"

"Solar thermal heating and cooling: continued slowdown in China and Europe, but increased deployment of large-scale projects."

"Global capacity of glazed and unglazed solar thermal collectors rose by more than 6% in 2015, despite a market slowdown due primarily to the continued contraction of markets in China and

Europe. China accounted for about 77% of newly installed solar water heater capacity, followed by Turkey, Brazil, India, and the United States."
http://www.ren21.net/wp-content/uploads/2016/10/REN21_GSR2016_FullReport_en_11.pdf

Why China is a big player in the solar industry?

The fact data:

"China is the world's largest market for both photovoltaics and solar thermal energy. Since 2013 China has been the world's leading installer of solar photovoltaics. Solar PV in China is a growing industry with over 400 companies. In 2015, China became the world's largest producer of photovoltaic power, narrowly surpassing Germany. By the end of 2016, total PV capacity had increased to over 77.4 GW."
https://en.wikipedia.org/wiki/Solar_power_in_China
"On January 5, Reuters reported that China's National Energy Administration (NEA) has announced in the next three years that China will invest $361 billion in renewable power generation. The spending comes as the cost of building large-scale solar plants has dropped by as much as 40 percent since 2010."
"China's investment is poised to generate over 13 million jobs in the clean energy sector."
https://www.forbes.com/sites/edfenergyexchange/2017/01/06/china-is-going-all-in-on-clean-energy-as-the-u-s-waffles-how-is-that-making-america-great-again/#15181ab61c18
"China's dependency on fossil fuels has long been decried as a heavy contributor to global carbon emissions. In 2016, estimates suggested that China was responsible for a third of the world's total carbon emissions - having previously fueled its economic growth through heavy coal usage in industrial sectors."
"2016 also saw a dramatic increase in China's investment in renewable energy production – making it the biggest producer of solar power in the world."
"The 13th five-year plan for Chinese development aims to add more than 110 gigawatts of solar energy capacity by 2020. While solar power currently only represents 1 percent of China's total energy output, this increase in investment is set to boost output from renewable energy from 11 percent to 20 percent by 2020."
http://www.wired.co.uk/article/china-climate-change-policy-solar-production
Why China is dominating the solar industry?
https://www.scientificamerican.com/article/why-china-is-dominating-the-solar-industry/
China: solar energy
Why does China invest in solar energy?
"Coal is the source of an estimated 40 percent of the most dangerous pollution particles in the country's air, finding alternatives to it has become a crucial priority. Air pollution was a big part of what put President Xi Jinping in a position to announce, in a landmark 2014 deal with President Obama, that China's emissions of planet-warming carbon dioxide would peak around 2030, a pledge that became the centerpiece of its commitments under the Paris climate agreement."
"It's not just pollution that's driving the determined focus on renewable power. Leaders have made clear that they view clean energy as a powerful engine for job creation."

Troubles in China's solar energy also in renewable:
"They set up these huge wind farms and they don't have connections to the grid. Leaders are now starting to reckon with those issues, installing new power lines and focusing on building smaller wind and solar farms in populated areas."
http://news.nationalgeographic.com/2017/05/china-renewables-energy-climate-change-pollution-environment/
Biofuels in the United States
With new administration, the policy changes, construction good news, but not good for overall
Hydropower
Add geothermal as summaries
http://www.aapg.org/about/aapg/overview/committees/emd/articleid/26351/committee-emd-geothermal-energy#141872236-activity--reports