When renewable energy met sustainable growth

Regulation, cost reduction, and the rise of renewable energy in the United States

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Historically and famously fossil-fuel dependent, the U.S. energy and electricity mixes are evolving quickly as costs fall for renewables, regulations mandate their implementation, and fiscal policy incentivizes their installation.

The investment and production tax credits (ITC and PTC) as well as power purchase agreements (PPAs) are well-known for their contributions to the development of solar and wind capacity, and the recent extensions of these credits has led to a positive outlook for continued growth in installations and generation. In addition, the green power market is experiencing record participation, as tracking the positive environmental externalities of renewable power has become important to meet renewable portfolio standards, which mandate implementation of renewable energy by state.

Cost reduction is further taking place globally due to technological advances and economies of scale, which serves as another key driver for development. Of course, challenges are still present, particularly due to a plentiful and inexpensive domestic fossil fuel supply, uneven application of regulation and incentives state-by-state, and the uncertainty of continued political support.

Even so, a progressive lowering of traditional barriers is leading to the potential for widespread deployment of renewables across the American landscape.

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Environmental and energy security concerns mean that renewables are being implemented more and more, even in regions with large fossil resources.

Recent years have seen enormous energy policy changes throughout the world due to economic, environmental, security, and social concerns, many of which influence renewables. Given the United States' responsibility for 16% of global CO_2 emissions in 2014, rapid deployment of low-carbon, renewable energy sources is essential for reducing the global increase in temperature and alleviating the multifaceted threats posed by climate change. While climate issues do remain a point of contention in the United States, all agree on the need for greater energy security. So, despite regional complexities like divided politics, limited federal regulatory power, and plentiful fossil resources, renewable capacity additions and their share in the energy mix have been increasing rapidly.

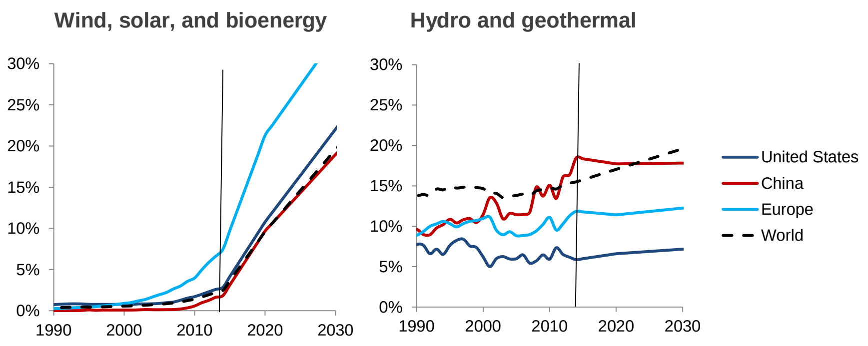
Wind and solar: disrupting the U.S. energy mix?

The growing role of renewables

Until the early 2000s, the global implementation of renewable energy was highly dependent on cost; only hydropower and geothermal energy sources could compete on a cost basis with fossil fuels for electricity generation while for transportation, residential, commercial, and industrial use there was almost no cost-competitive alternative. As a result, only countries with high hydro and geothermal power availability, such as Brazil, Norway, and Iceland, had a significant share of renewables in their electricity mix. In all other countries, fossil fuels, and to a lesser extent nuclear, have been dominant.

More recently, however, with mounting environmental and energy security concerns, regulation, technology, and fiscal policy have led to reduced costs for certain renewables relative to other fuels. The European Union has been particularly quick to react, implementing targets and subsidies to push for a swift development of these energy sources. Uptake in the United States and China has been slower for a variety of reasons, including their large hydrocarbon resources, the Chinese focus on rapid, low-cost development, and the American reluctance towards government intervention in the free market. Even so, as costs fall and environmental issues move increasingly into the public, private, and regulatory eye, growth is intensifying in both regions.

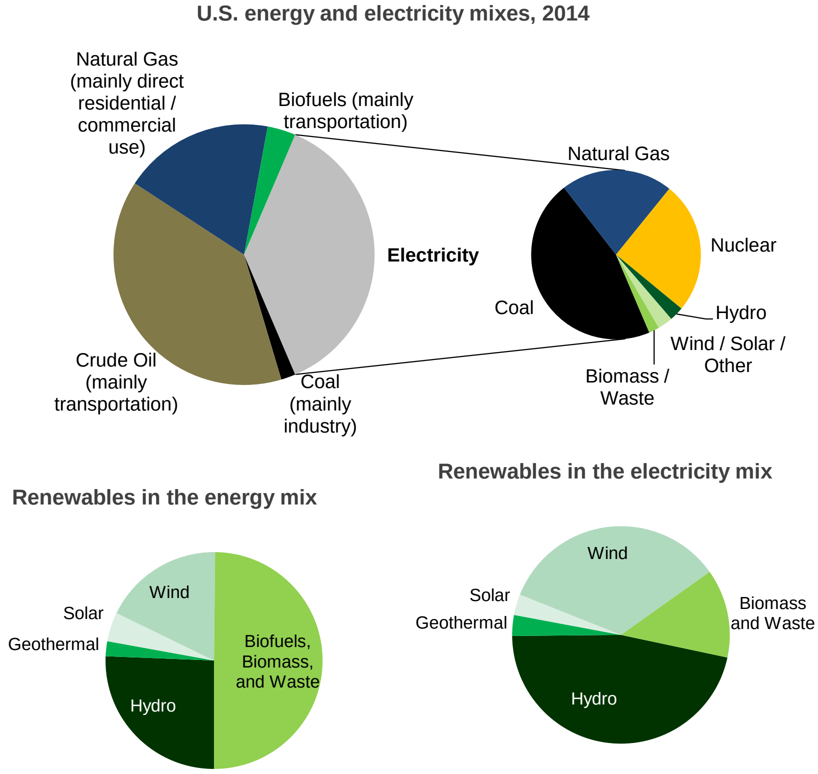
Figure 1: Renewables' share of electricity in select regions, 1990 - 2030



Source: Mirova / BP 2015/ IEA 2015

In the U.S., renewable energy sources accounted for 9.8% of the total energy consumption and 13.5% of electricity generation in 2014, their highest share since the early 20th century. Slightly more than half of all renewable energy was used to generate electricity, with hydro producing about 50%, followed by wind (33%), solar (6%), and geothermal (3%).

Figure 2: Renewables in the US energy mix

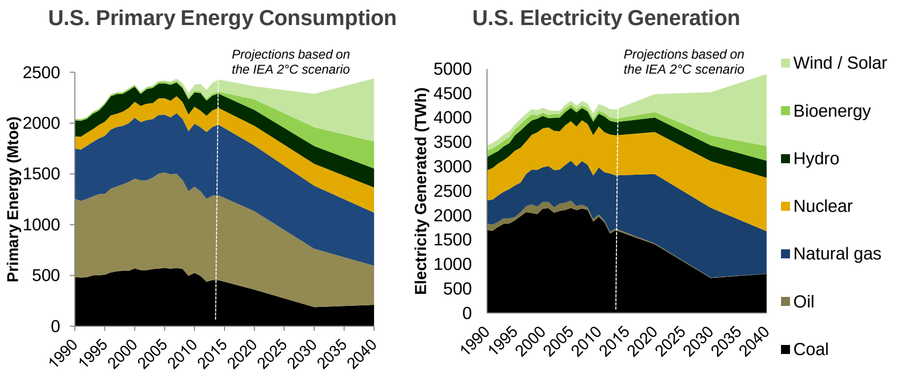


Source: Mirova / US EIA 2016/ IEA 2015

Differentiated growth among renewable energy sources

If the global temperature rise is to be kept below 2°C, the International Energy Agency (IEA) states, renewables (including solar, wind, bioenergy, hydro, and geothermal) must make up at least 33% of the American electricity mix by 2040, while the proportion of fossil fuels must simultaneously decrease; maintaining the current U.S. fuel mix implies a temperature rise of about 6°C. Even so, the growth likely to be experienced by each type of renewable will vary widely.

Figure 3: Evolution of the U.S. energy and electricity mixes in a 2° scenario



Source: Mirova / BP 2015/ IEA 2015

Space is limited for hydropower and geothermal energy, while bioenergy still raises some concerns.

Hydro and geothermal have little growth potential

Large-scale hydropower and geothermal energy, the "historical renewables," have already been implemented in most available sites. As a result, even if their carbon intensity is low and their environmental impacts are limited[1], these energy sources exhibit relatively low growth potential. This is supported by the IEA, which predicts that hydropower will make up 8% of the 2040 US electricity mix, compared to the same value today. Similarly, the share of geothermal energy will rise from less than 1% today to only 2% in 2040, despite advancements in decentralized geothermal heat and electricity production.

The development of bioenergy remains uncertain

Bioenergy refers to plant-based matter used as an energy source and comprises about 50% of the United States' total renewable energy consumption. Though it can be used to generate electricity as biomass or agricultural waste, the majority of plant-based fuels are used in the transportation sector as biofuels like biodiesel or ethanol. These are mixed with fossil fuels or used as additives, sometimes providing a less polluting alternative to crude oil. In 2005, the U.S. became the world's largest biofuel producer, and its biofuel market looks set to continue to expand as pollution standards are tightened and tax incentives increase.

Even so, bioenergy comes with drawbacks: significant pollutant emissions, plus the possible need for dedicated crops which could compete with food for agricultural space. Bioenergy does represent a source of lower-carbon energy[2], but these problems threaten to mitigate its growth, despite the fact that second-generation biofuels seek to reduce the impact they have.

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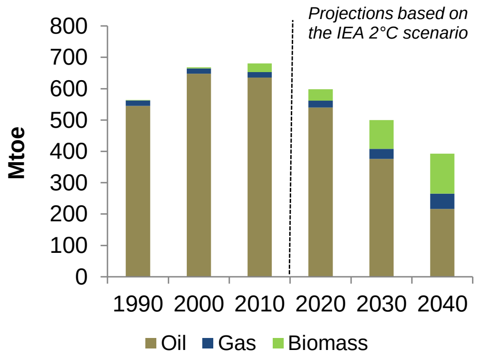
[1] *Though large-scale hydropower projects can be met with opposition because they may displace local populations or disrupt ecosystems, these issues are not particularly pertinent in the U.S. context.*

[2] *The true carbon content of biofuels has proven somewhat controversial; some studies indicate that it is a low-carbon fuel, while others indicate that it is as polluting fossil fuels when its lifecycle and land use changes are taken into account. See Matthews et al. (2014), Searchinger et al. (2008), and Bowyer et al. (2013) for more information.*

Figure 4: U.S. transportation fuel mix



Source: Mirova / US EIA 2015

Wind and solar are the most viable candidates for large-scale implementation in the coming years

Overall, wind and solar promise the highest growth potential of all renewable energy sources in the U.S. This is due to their minimal social and environmental externalities, abundant and easily accessible resources, and falling costs. These factors represent major opportunities for development, which looks set to increase from 10% of power generation today to 31% in 2040 in line with the IEA's 2°C scenario.

Historical development of wind and solar

Wind and solar represent the greatest opportunity, and carry the fewest negative social / environmental externalities.

The heterogeneous levels of growth in wind and solar power across states are typically attributed to utility regulatory structures, large domestic fossil resource deposits, and a shifting political landscape. Firstly, each of the 50 states regulates its utilities independently, many with starkly differing practices. Secondly, regulations mandated at the federal level can face a slow adoption process, or may be challenged by utilities and/or state legislatures, both of which have a potential economic interest in preserving their states' fossil fuel-related activities. Finally, given the highly politicized nature of the climate debate in the U.S., it is often assumed that state politics have a clear impact upon state renewables policy and development, though the relationship is not as simple as Democrats versus Republicans.

Neither resource diversity nor politics entirely explain the variation

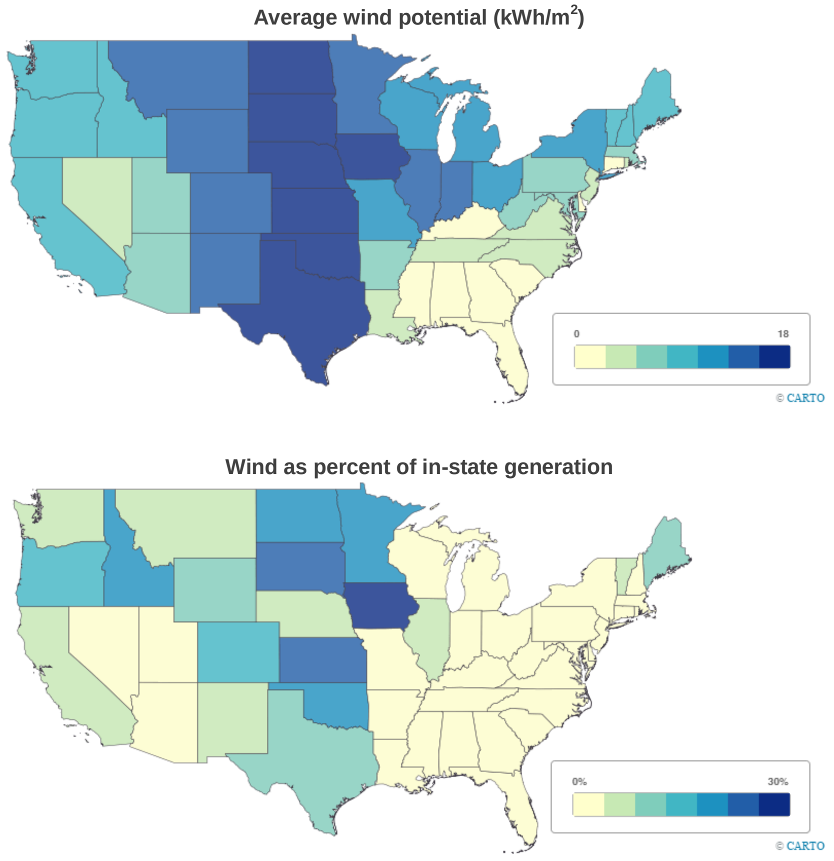
The U.S. territory is vast and diverse in resources, both fossil and renewable. While one might expect that any unevenness in the state-by-state development of renewables would be attributable only to differences in solar and wind availability, this is not necessarily the pattern that has determined the varying degrees of renewable energy advancement among states.

Interestingly, renewable capacity developments do not appear to be linked to the dominant ideology in a particular state either. Whether this is primarily due to limited state-level public involvement or the increasing appeal of renewables to both parties is difficult to discern. So the development of renewables in a particular state cannot be predicted reliably on the basis of politics or resource availability alone.

Florida, for instance, has significant solar resources but supporting policies lag, perhaps in part due to the strong presence of utilities in the political sphere[3]. Though often considered a stronghold of conservatism, Texas has embraced renewables for long-term cost savings, though another explanation could be that the free market ideals embodied by decentralized energy generation are highly compatible with the state's ideological base. Accordingly, the state is endowed with the largest wind energy potential in the U.S. and has developed it extensively.

Massachusetts, however, is one of the top five states in terms of solar capacity installed; though it lacks strong solar resources, the state's progressive culture has led to active participation in the energy transition. Lastly, California possesses strong political will plus large solar and wind resources, a combination which has made it the American leader in renewable energy.

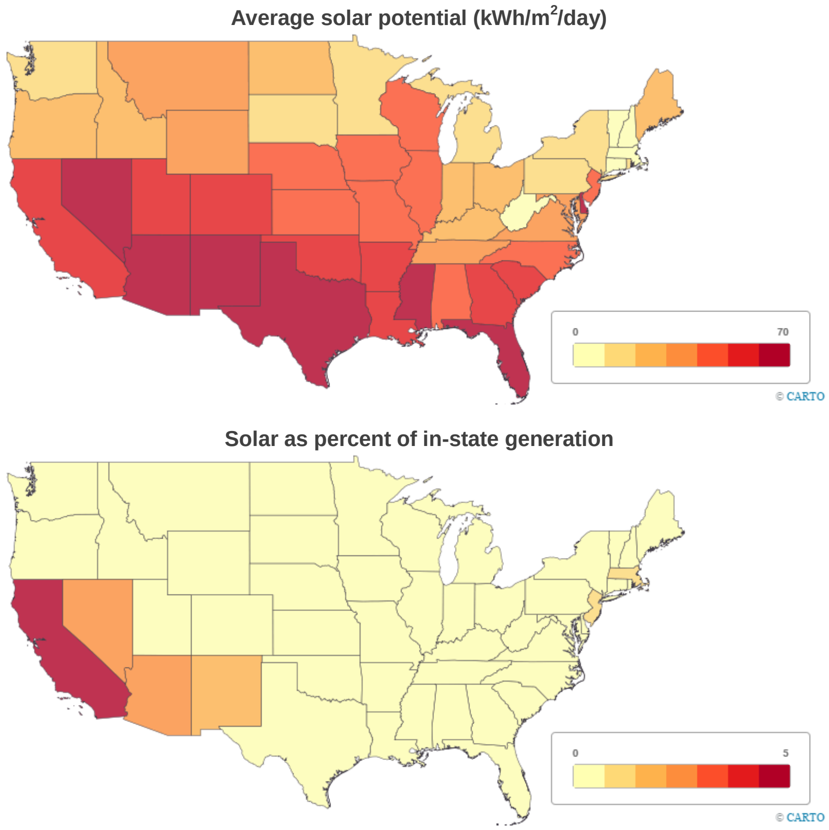
Figure 5: Wind, state-by-state



Source: Mirova / US EIA 2015/ NREL 2016 / Carto

[3] *See Florida Center for Investigative Reporting, 2015 and Dickinson, 2016.*

Figure 6: Solar, state-by-state

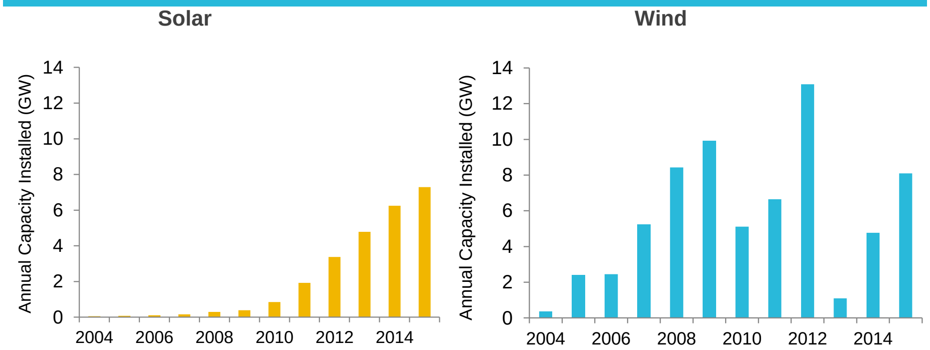


Source: Mirova / US EIA 2015 / NREL 2016/ CartoDB

Despite these differences, however, strong trends are still very much evident in the aggregated view. The observed growth and year-to-year fluctuations in wind and solar installations can be explained, by cost reduction and regulatory support.

The solar market has grown rapidly and steadily in recent years, while wind is a slightly more mature market subject to greater variation. In 2015, wind made up 41% of total annual new capacity additions, a significant increase from 26% in 2014. Solar represented approximately 26% of annual capacity additions in both 2014 and 2015.

Figure 7: historic U.S. wind and solar market development



Source: Mirova / US EIA 2016

Cost reduction and regulation are driving the development of renewables

Cost reduction, policy, and regulation have made large-scale implementation of renewables more and more viable.

The combination of cost reduction, policy, and regulation has made renewables increasingly attractive to developers, investors, and the general populace.

There are currently three main types of support for renewables in the US:

- **Power purchase agreement (PPA)**: often essential to secure financing, a PPA is a long-term contract between an electricity generator and a purchaser which secures a steady revenue stream from the sales of electricity over a set period. It allows a company to host a solar or wind power system at no upfront cost.
- **Renewable Portfolio Standards (RPS) and Renewable Energy Certificates (RECs)**: regulatory standards which mandate sourcing a fixed portion of a state's electricity from renewables (RPS) give rise to the green power market, which then depends on the purchase and sales of RECs.
- **Fiscal policy:**
    - **ITC and PTC**: the Investment Tax Credit (ITC) is a one-time credit of 30% of installed costs typically applied to solar projects, and the Production Tax Credit (PTC) is ten-year production-tied credit typically applied to large-scale wind ($23/MWh). These are the best-known and influential drivers of renewable energy development in the United States.
    - **Modified Accelerated Cost Recovery System (MACRS)**: an accelerated depreciation scheme which can lead to significantly less tax liability upfront and potentially over the project's lifetime..

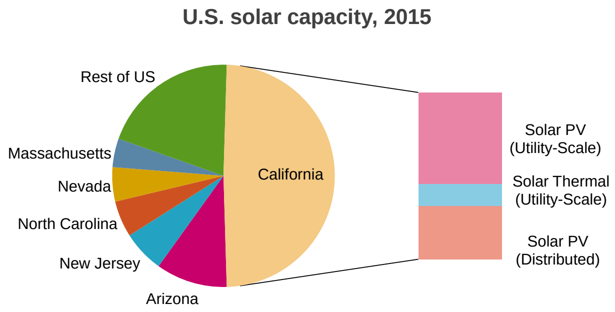
The following case studies serve to demonstrate the financial implications of the aforementioned schemes on a renewable energy project.

Two case studies

Utility-scale solar depends on PPAs, the ITC, and RECs, but decreases in capital cost signal that it will continue to become increasingly competitive alone.

Illustrative case study 1: California, utility-scale solar

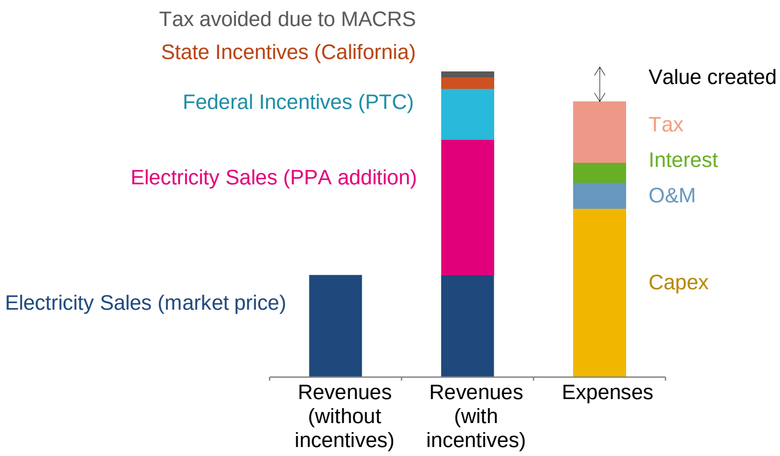
Given that nearly half of the U.S. solar capacity is situated in California and more than half of this is utility-scale, utility-scale solar plants in California are a relevant example of implementation of solar energy in the U.S.



It is evident that the Investment Tax Credit, the sale of solar RECs, and PPAs are instrumental for the economic feasibility of solar power, and its profitability still relies on power purchase agreements somewhat above market price.

The figure below therefore sets electricity prices at $65/MWh (representative of an average PPA at the end of 2014), allowing the plant to be profitable with the help of the ITC and REC sales. Since PPAs often include the purchase of RECs, RECs and a PPA do not necessarily contribute separately to a project's revenues.

Estimation of solar project expenses and revenues



Assumptions: $65/MWh PPA; ITC at 2016 levels; $1.5/WDC installed system cost; 28% capacity factor; $19/kW/year O&M cost factor; 6.6% WACC; $28/MWh wholesale electricity price; tax equity investor with sufficient appetite to use any generated tax credits in same year of production

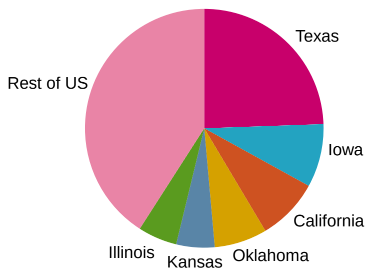
Source: Mirova / US EIA 2016/ DSIRE 2016/ US NREL 2015

Illustrative case study 2: Texas, onshore wind

Texas possesses nearly 25% of the U.S. wind generation capacity and is therefore a representative example of a location which facilitates the growth of wind power.

Wind power in Texas, already nearly competitive at market price, is only made more attractive by the PTC.

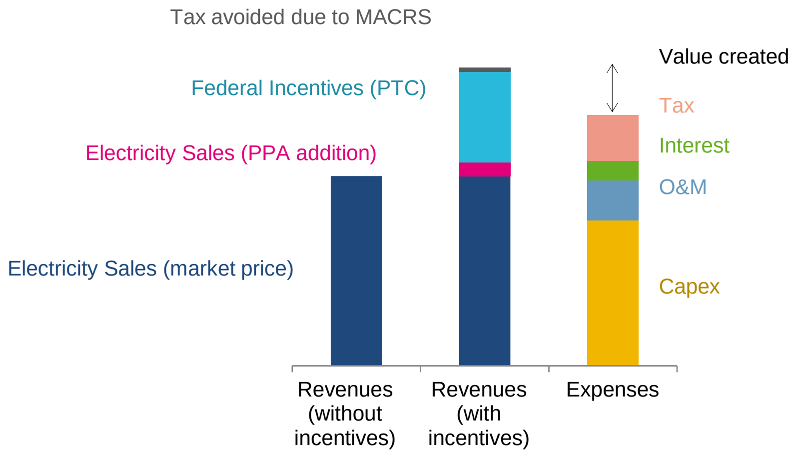
U.S. wind capacity, 2015



The PTC remains a major contributor to the economics of wind power as it begins to approach grid parity. Even with an electricity price of $30/MWh (as modeled below, based on the average PPA price in 2014), only a few dollars higher than the wholesale price in Texas, significant value is created for shareholders.

As costs (particularly capex) continue to fall, onshore wind power will thus continue its current trajectory and will become increasingly competitive with other energy sources.

Estimation of wind project expenses and revenues



Assumptions: $30/MWh PPA; ITC at 2016 levels; $1.3/W installed system cost; 45% capacity factor; $30/kW/year O&M cost factor; 5.2% WACC; $28/MWh wholesale electricity price; tax equity investor with sufficient appetite to use any generated tax credits in same year of production

Source: Mirova / US EIA 2016/ DSIRE 2016/ US NREL2015

These case studies indicate that wind is on track to become fully competitive with other fuels, even without policy aids, while solar still needs to improve its cost structure in order to become completely independent from regulatory support. It is worth noting, however, that with the relatively low wholesale electricity prices in the U.S. (down 27-37% across the country in 2015 compared to 2014 and trending around $25/MWh, largely due to low natural gas prices) even some fossil-fuel plants are straining to remain competitive at market price.

While hardware costs of wind and solar are decreasing, soft costs, like labor, site preparation, and financing, remain significant.

Cost reduction is taking place rapidly

High costs tend to be the first argument employed against renewables and have been a major barrier for installing on-site generation capacity. However, the relatively fast deployment of renewable technologies, high learning rates, and government subsidies have been reducing costs for installers rapidly in recent years. This implies that renewables will continue to become increasingly competitive with fossil fuels.

Solar photovoltaic is still relatively costly, but its price is dropping[4]

Costs for solar installations are split fairly evenly between hardware and soft costs. Hardware costs derive from an often-complex supply chain due to the highly materials- and labor-intensive manufacturing process required to produce the PV module, as well as the necessary electrical and structural components often referred to as the balance of system (BOS). Soft costs include permitting, labor, site preparation, grid connection, financing, and installation fees.

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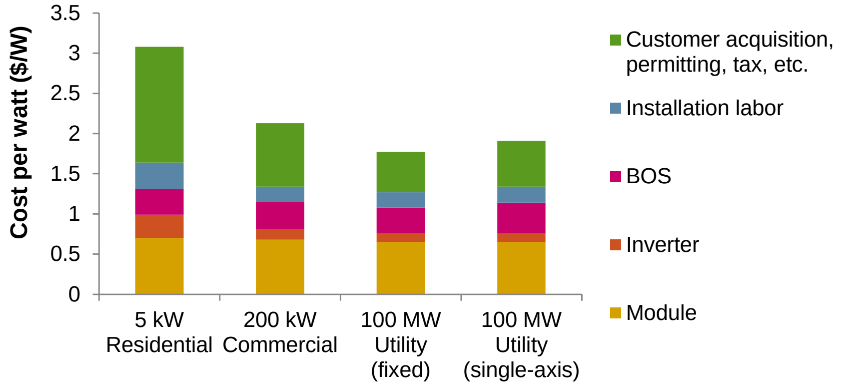
[4] *All figures henceforth will reference polycrystalline PV cells, which represent the majority of the market. Concentrated solar power will likewise be omitted as it comprises a small portion of recent capacity additions.*

Figure 8: Breakdown of solar PV installed costs (poly. silicon, 2014)

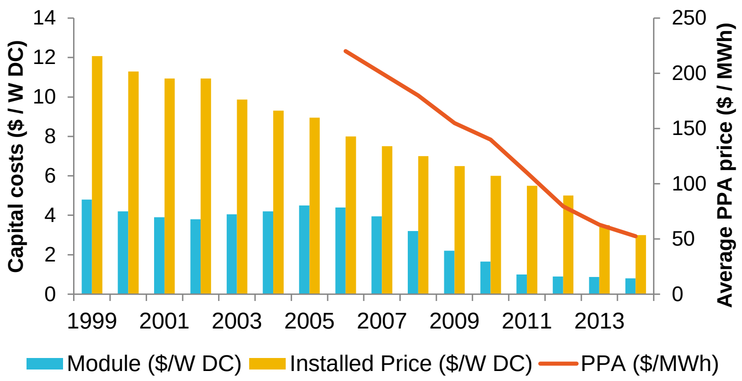


Hardware costs, including the module, inverter, and other electrical components, make up 35-40% of the capital cost for PV systems. Soft costs are generally 40% for large-scale systems and 55-60% for small-scale or residential systems.

Source: Mirova / NREL2015

Photovoltaic technology is relatively new, and still has significant potential for improvement. As a result, module costs have historically provided the greatest opportunity for cost reductions. These costs decreased by 75% between 2009 and 2014, mostly due to decreasing polysilicon prices, advances in technology, and economies of scale. Efficiency alone represents a major opportunity for continued progress; since improved efficiency means more electricity produced per same panel area, it has a direct impact on capital costs. As the technology matures, decreases are slowing, which emphasizes the need for further optimizing BOS and soft costs.

Figure 9: Evolution of solar prices



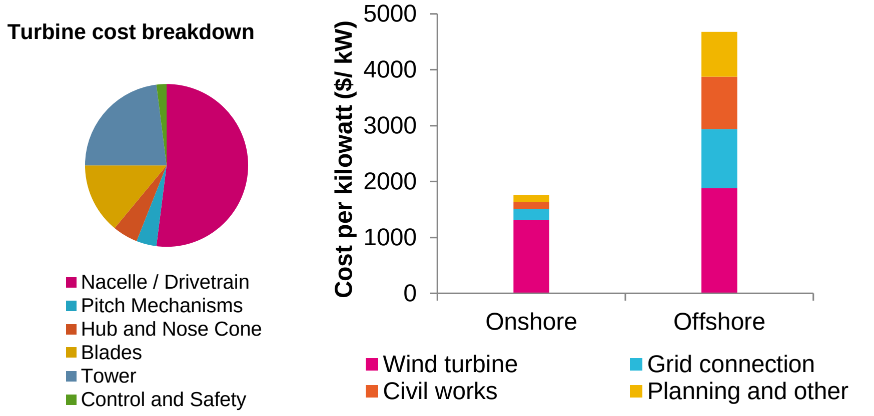
Source: Mirova / US DOE 2014-2015 / US NREL 2013

Wind hardware costs are likewise diminishing due to greater economies of scale

Wind-based power generation technology is relatively mature; the principal components and functions are similar to other means of power generation. As a result, the variation in technology employed by wind projects is relatively low.

Capital costs for wind power consist mainly of hardware (the turbine and all its components) and soft costs like construction, grid connection, planning, and financing. Civil works, grid connection, and planning costs tend to be significantly higher for offshore wind projects than onshore due to greater difficulty of access.

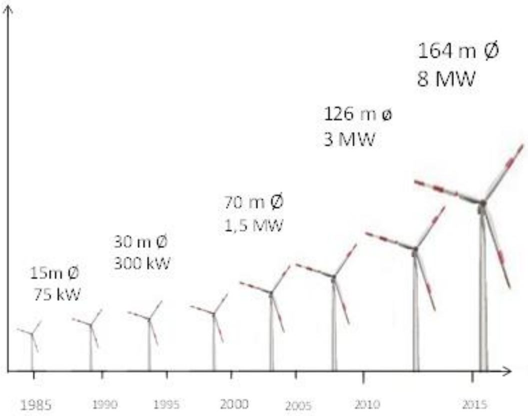
Figure 10: Breakdown of wind installed costs, 2014



Turbine cost represents 64-84% of the capital costs of onshore projects but 30-50% for offshore projects as grid connection, engineering, and construction costs are much higher offshore. *Source: Mirova / US DOE 2015 / NREL 2013*

Hardware cost again provides the largest opportunity for cost reduction. Turbine prices have decreased significantly from their 2009 peak price, as rotor diameters have increased and towers have become higher, allowing for greater electrical output.

Figure 11: Evolution of commercial turbine diameters

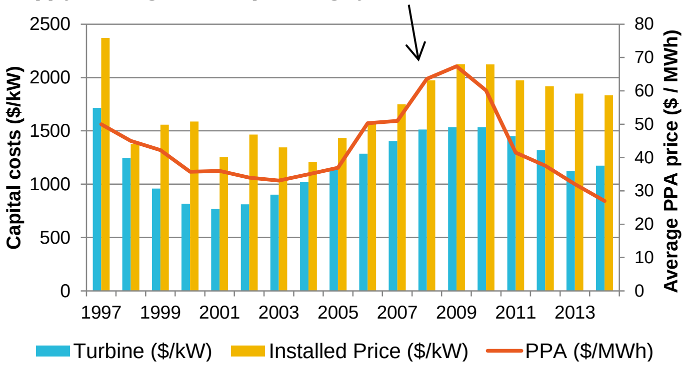


Source : Mirova , based on company data

Increased economies of scale and competition have likewise contributed to hardware cost reduction. Soft costs are largely related to financing and the remoteness of the project, which represent limited opportunity; as technology improves and the most suitable sites are developed, more remote areas will be utilized, implying increased operating and soft costs.

Figure 12: Evolution of wind prices

Decrease in USD value compared to EUR, increased input prices, turbine and component supply shortages, and up-scaling of turbine size.



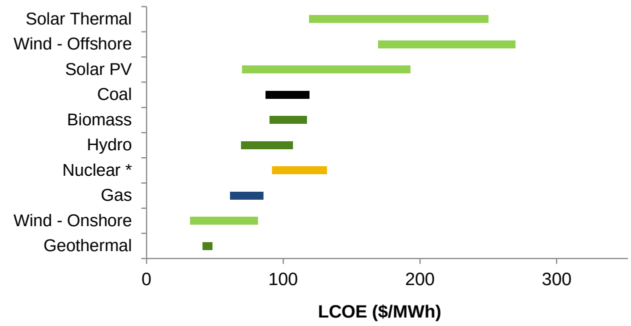
Source: Mirova / NREL 2013 / AWEA 2015

LCOE shows greater competitiveness, particularly for onshore wind

Levelized cost of energy (LCOE) allows for comparability between energy systems and cost structures on a long-term basis; it is calculated by accounting for all of a system's expected lifetime costs and dividing them by the system's expected lifetime output.

For renewables, LCOE is highly dependent on region due to variations in resource availability, incentives, and ease of grid interconnection. As a result, within the U.S. the LCOE of solar and wind systems varies significantly. While biomass, hydropower, and geothermal resources have provided electricity at a price comparable to fossil fuels for several decades, the LCOE of onshore wind has only recently proven itself lower than fossil fuels or the aforementioned renewables. Despite this apparent competitiveness, however, solar and wind LCOEs do not take costs of intermittency into account, which could be costly, including measures to integrate these energy sources into the grid and (potentially) storage. Meanwhile, offshore wind and all types of solar still have significantly higher LCOEs than other fuels in the majority of regions.

Figure 13: LCOE by technology, 2014



Range shown represents regional variation. Assumption of 30 year cost recovery period and 6.1% WACC; wind and solar apply only to utility-scale.

** this price level is still subject to uncertainty given the potential need for additional waste and decommissioning provisions.* *Source: Mirova / U.S. EIA 2016*

Policy and regulation

Even if prices are decreasing, wind and solar have relied on policy support thus far. And while onshore wind is becoming competitive on its own, both wind and solar continue to rely on these mechanisms for the moment.

In general, the structure of the U.S. government provides the federal government with limited powers to impose stringent regulation upon states and companies. Though guidelines can be outlined at the federal level, states retain the ability to challenge these directives and control implementation, again leading to the aforementioned heterogeneity in policies from one region to the next (see annex 1 for an overview of the U.S. utility market).

Even so, there have been several regulatory measures implemented at the federal level which promote the development of renewables, typically billed as spurring domestic employment and energy security. These include the U.S. Public Utility Regulatory Policies Act, the Energy Policy Acts of 1992 and 2005, the American Recovery and Reinvestment Act of 2009, and the 2015 Clean Power Plan.

The U.S. federal government has limited regulatory power, made clear by the current block of the Clean Power Plan.

The Clean Power Plan seeks to reduce carbon pollution from electricity generation over a 15-year period by implementing new standards for (coal) power plants and emissions reductions goals state-by-state. When in place, carbon pollution from power generation will be 32% below 2005 levels and a fully-fledged emissions trading system will exist. As of February 2016, the Plan was blocked in 27 states by the Supreme Court after it was challenged on the basis of encroaching upon states' rights. The final ruling is expected to take place in late 2016, after the 2016 presidential election and nomination of a new Supreme Court justice, which implies some risk for its future.

While the Clean Power Plan would positively impact renewables if it is ultimately implemented, other types of regulations have already proven to be highly influential. These include power purchase agreements, renewable energy certificates, renewable portfolio standards, and federal tax incentives.

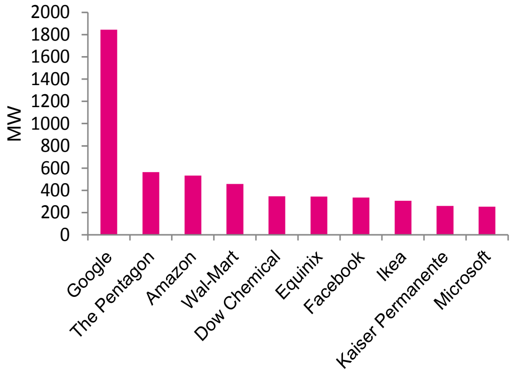
Power Purchase Agreements (PPAs) lock in above-market electricity prices

Renewables operate at zero marginal cost, so their electricity can be sold at a fixed price over the life of the project, typically via a PPA. These play a key role in financing independent power producers, many of which are renewables-focused, as well as renewable energy projects.

Generally, a PPA is a long-term agreement between the owner of a facility which generates electricity and a wholesale energy purchaser. It allows the facility owner to secure a revenue stream from the project, which is necessary for financing, and useful if the purchaser wishes to ensure supply security, when a small number of customers want the bulk of the generation, when the project requires protection from cheaper competition, or when revenues are uncertain, and some revenue guarantee is needed to make the project viable.

Power purchase agreements and the green power market are key drivers of development in many states.

Figure 14: Leaders in renewable energy capacity built via PPAs



Source: Mirova / Bloomberg New Energy Finance 2016

The advantage of a PPA is that it allows a company (or the government) to host a wind or solar power system with zero upfront costs for the buyer itself. A developer builds a system that can be financed by a tax equity investor who thereby becomes eligible for the associated tax benefits. The company then pays potentially above-market rates for the electricity (and RECs) over time, which helps the developer and investor recoup their costs. This structure allows for the construction of large-scale solar projects without the need for capital budget allocation by the government/company.

PPAs vary in terms of the length of the agreement (though typically 15-25 years), the commissioning process, the purchase and sale of renewable energy certificates, price, and insurance. Finally, there are different iterations of PPAs: offsite solar PPAs, which include a solar installation offsite shared by multiple users; offsite corporate wind PPAs, which provide power to corporate customers with high energy loads; rooftop PPAs, essentially a rooftop solar lease which relieves homeowners of large upfront payments; and utility PPAs, in which utilities or large power traders purchase electricity from generators.

Renewable Energy Certificates (RECs) have facilitated development of the green power market

Since it is impossible to track the electrons generated by renewable sources individually, the U.S. renewable power market is instead based on tradable renewable energy certificates (RECs), which make it possible to account for the positive environmental impacts of renewable energy. These are only generated by the energy sources with the fewest negative social and environmental impacts: solar, wind, geothermal, small-scale hydro and biomass.

For each megawatt-hour (MWh) produced, a grid-tied renewable electricity generator produces two separate products: one MWh of physical electricity and one REC, which represents its positive environmental externalities. The generator can sell these two products together or separately, thus choosing whether to keep the RECs for themselves and claim the environmental benefit or sell them.

There are two separate markets for RECs, the voluntary market and the mandatory market. The voluntary segment consists of companies wishing to claim environmental benefit and customers seeking to offset the negative environmental effects of the electricity they use themselves; the mandatory segment consists of entities seeking to fulfill regulatory requirements like Renewable Portfolio Standards. The voluntary market represents about 25% of the total U.S. renewable power market, while the mandatory market represents the remaining 75%.

REC prices vary depending on region and resource type, but typically wind RECs lie between a few cents and a few dollars per MWh, representing 10% or less of the wholesale cost of electricity, while solar RECs (SRECs) are usually bought and sold at much higher prices ($40-100/MWh, often significantly higher than wholesale prices). This discrepancy comes from specific state goals which encourage solar, the high above-market cost of solar, and the desirability of SRECs on the voluntary market. For this reason, sale and self-generation of RECs, particularly SRECs, can lead to significant recuperation of expense recoupment.

Renewable Portfolio Standards (RPS) provide binding targets for implementation of renewables state-by-state

By far the most widespread and influential state-level policies are Renewable Portfolio Standards (RPS), which intertwine the renewable energy certificate market and regulation. RPS effectively created the mandatory market for RECs, requiring utilities to provide a specified percentage of electricity from renewable resources, either through self-generation or purchase of RECs. There is currently no RPS program at the national level, but 30 states have enacted enforceable standards ranging in ambition, approved technology, and timeframe.

The ITC and PTC are the most famous and perhaps the most influential incentives available.

Some examples of this variation include the particularly ambitious RPS are present in California, which seeks to obtain 50% of its power from renewable sources by 2030, and Hawaii, which looks to obtain 100% by 2045. Illinois' standards, however, are technology-based, and stipulate that 25% of renewable power (6% of total) must be obtained via solar and 75% from wind in 2016. North Carolina's standards are demarcated between investor-owned utilities (12.5% renewables by 2021) and municipalities (10% by 2018).

Federal tax incentives, namely the ITC and PTC, deserve much of the credit for recent growth in wind and solar installations

Subsidy and tax incentives constitute a large part of federal support for renewables and act to reduce the cost of installation for individuals, companies, and institutions. As such, energy-related subsidies increased nearly 40% between 2010 and 2013, largely due to an increase in support for renewable energy. In 2013, renewables received the greatest share of direct federal subsidies and support, totaling 72% of all such subsidies. More than two-thirds of these subsidies were direct or tax expenditures targeting up-front capital investments for projects expected to produce energy for at least 20 years.

Tax expenditures typically lead to a special credit, preferential tax rate, or deferral of tax liability. In 2013, this type of subsidy represented an expenditure of $12.4 billion total (42% of total energy subsidies and support), 44% of which went to support renewable energy sources. The two tax expenditures considered to have sizeable impact on the development and deployment of renewable energy in the U.S. are the Business Energy Investment Tax Credit (ITC) and the Renewable Electricity Production Tax Credit (PTC). Both of these allow certain taxpayers to subtract the amount of the credit from the total they owe the state, thus significant tax liabilities are required to fully benefit from these credits. The Modified Accelerated Cost Recovery System can also lead to consequential effects on a company's tax liabilities.

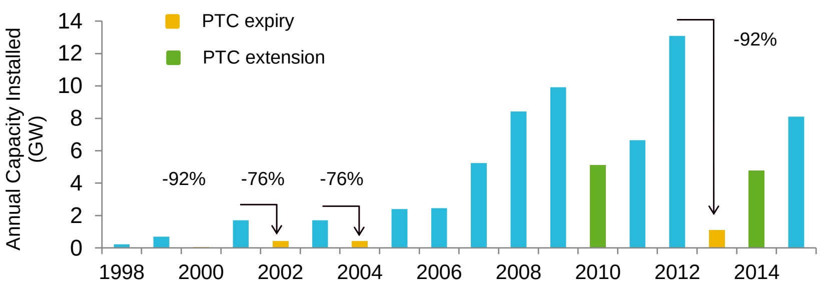
→ The ITC has proven especially beneficial for utility-scale solar

The ITC began in 2005, but greatly expanded in 2008 as part of the Energy Improvement and Extension Act, again in 2009 as part of the American Recovery and Reinvestment Act, and was extended recently until the end of 2019, with a phase-out period between 2019 and 2023. It applies to solar photovoltaics, fuel cells, small wind turbines, geothermal, and combined heat and power. **It provides a credit for 10% (geothermal, CHP) or 30% (solar, small wind, and fuel cells) of all installed costs.** The credit is applicable to commercial, industrial, agricultural, and utility sectors, and it should be noted that it is the sole federal tax credit currently available to commercial solar facilities. As such, it has been hailed as widely successful in promoting the development of solar, particularly utility-scale.

→ The PTC favors development of large-scale wind systems

The PTC was established by the Energy Policy Act of 1992. Since then, it has been extended in one- or two-year intervals, and recently received another extension (with phase-out) to the end of 2019. This unpredictability has been cause for consternation in the industry as capacity additions tend to drop sharply as an expiration date approaches.

Figure 15: historic U.S. wind capacity additions



Source: Mirova / US EIA 2016

The PTC allows owners of qualified renewable energy facilities to receive tax credits for each kWh of energy generated by the facility over a 10 year period. **Under the full PTC, owners receive 2.3 cents/kWh for the production of electricity from utility-scale wind turbines, geothermal resources, or closed-loop biomass systems, or 1.1 cents/kWh for other biomass and small-scale hydroelectric sources.** Even so, this credit has been used primarily for large-scale wind energy systems.

→ The Modified Accelerated Cost Recovery System can also lead to less tax liability, especially coupled with the ITC / PTC

Along with the ITC and PTC, the Modified Accelerated Cost Recovery System (MACRS) has helped to fuel recent growth in annual renewable energy installations. It allows investments in renewable energy property to be partially recovered over five years through annual tax deductions, leading to greater market certainty and an accelerated rate of return on solar and wind investments. Recently, bonus depreciation under MACRS was extended, allowing companies to depreciate 50% of the basis during the first year, before the rest depreciates over the usual five-year period. The bonus depreciation policy is nevertheless set to be phased out beginning 2017.

Use of the tax credit funds to immediately offset existing tax liability leads to a significantly greater net present value of the incentive (approximately 57% of CAPEX; 30% PTC and 27% MACRS) than if the credit is used to offset tax liabilities incurred only once the project becomes profitable (about 31% of CAPEX; 10% PTC and 21% MACRS)[5]. For this reason, large utilities with existing tax appetite are able to use the incentive far more effectively than smaller entities without the ability to immediately apply the credit; the latter would likely derive more benefit from direct subsidies or grants.

Numerous other incentives also contribute to ultimately making renewables both financially and environmentally attractive.

Other types of regulation have also impacted renewables

In addition, there are many other types of policy and regulation which have impacted renewables. These are presented in appendix II and include

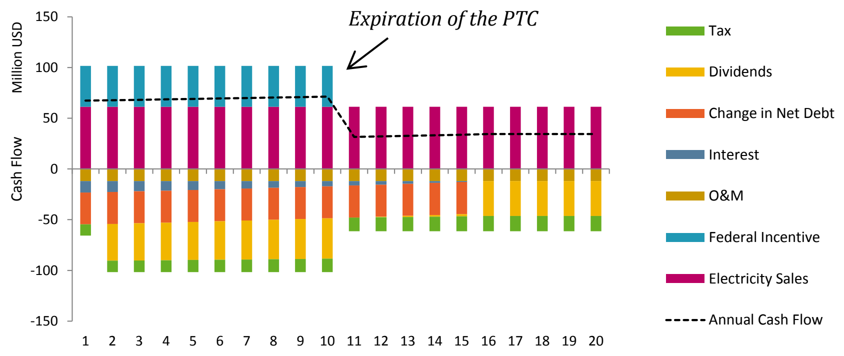
- State-level incentives and policies, including direct and tax subsidies, feed-in tariffs, net metering, and interconnection standards;
- Direct federal subsidies.

Review of project cash flows

With the current price structure and all of these incentives employed, a positive cash flow is obtained within the first few years of plant operation. This is in part due to the application of MACRS and the PTC/ITC (see case studies on pages 10 and 11). Since depreciation is treated as a deduction from taxable income, it eliminates the projects' relatively small annual income tax expense and typically leads to net operating loss. Thus these projects have greater tax savings early in their lifetime, increasing the incentive to invest and increasing the likelihood of non-negative cash flow.

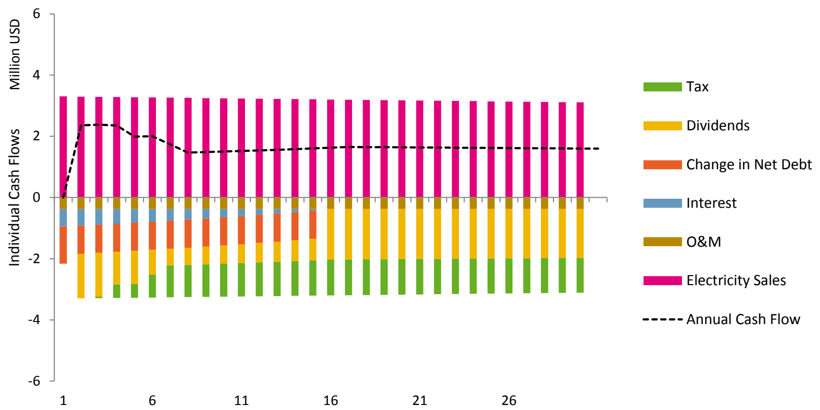
[5] *See Bolinger, 2014.*

Figure 16: Wind case study cash flow diagram



Source: Mirova

Figure 17: Solar case study cash flow diagram



Each of these diagrams follows the same set of assumptions as the case studies: see page 10 for the parameters applicable to solar and page 11 for those applicable to wind. Assumptions include financing with 80% debt and 20% equity; all value created is attributed directly to shareholders.

Source: Mirova

Renewables and the marketplace

With an understanding of the mechanisms driving development of renewables, the following turns to the value. This is particularly pertinent as the wind and solar value chains diverge somewhat from those of other fuels for power generation; understanding these value chains allows for deeper insight into both present and future industry challenges, opportunities, and risks.

The solar value chain

The solar value chain is international and depends on a highly capital-intensive cell manufacturing process.

The solar value chain is international and consists of three major steps: manufacturing, installation, and operation, though the process and the actors involved vary slightly depending on the type of technology employed. Here, the focus will be on polycrystalline solar cells as they make up the majority of the market. However, monocrystalline silicon, thin film, and concentrating solar power chains diverge somewhat, particularly in manufacturing.

For polycrystalline solar cells, the manufacturing process is multi-step:

- **Silicon production.** Silicon, a semiconductor, is the raw material for photovoltaic cells. The first step in creating a solar panel is production of ultrapure silicon, which takes place in two stages: the transformation of quartz or sand into metallurgical-quality silicon, then its purification into solar-grade/polycrystalline.
- **Wafer production.** Before being transformed into photovoltaic cells, the purified silicon must be transformed into a large ingot, and then cut into slices. These slices are called “wafers.”
- **Cell production.** The wafers must be chemically treated and metallic parts must be added for them to become cells.
- **Module production.** A single cell does not generate much electricity, so many cells are assembled into a module, which produces greater quantities of electricity and includes a protective structure.

Though some of the largest silicon / cell / module producers are vertically integrated, manufacturing of a complete panel ready for balance of system (BOS), installation, and grid integration, does not necessarily take place at a single factory site, or even within a single company. Instead, it is often distributed between two or three: one to produce the ultrapure silicon required, often another to treat this silicon such that it becomes appropriate for PV applications, and potentially a third to fuse these cells together into modules. This is largely due to the split in capital intensity between cell and module manufacturing: cell manufacturing is highly capital-intensive ($1-2 million / MW of plant capacity), while module/panel production is less so, allowing it to be either done on-site at the cell producer or closer to the end-market by smaller local players. The market for BOS elements, including the inverter and its associated electrical components, is dominated by a few large players.

The majority of global solar cell production takes place in China, while the majority of solar cell installations take place in the U.S. and Europe. In China, production of solar cells is significantly less expensive than in the United States ($0.91 versus $1.19), attributed to less strict regulation, lowered environmental standards, and inexpensive labor. From a social and environmental point of view, this poses risks, particularly as Chinese companies are not held to high standards of transparency.

Installation represents low capital costs but high labor costs. As a result, the market for installers tends to be regional and fragmented. Though some concern must be paid to worker and site location, installation of solar power usually provides a positive impact on local economic, social, and environmental value creation with minimal inherent risk.

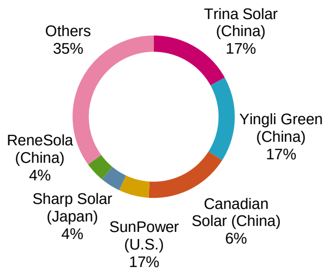
Finally, utilities can purchase the panels and use it to generate power to sell into the grid, or homeowners mount residential PV systems. Some companies lease rooftop space from residents and sell them the resulting power at a lower rate than the local utility.

Figure 18: Solar value chain and market leaders

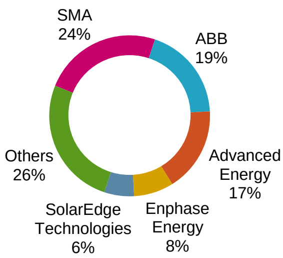
Manufacturing

Silicon wafer manufacturer	Raw material (ultrapure silicon) production and processing
Cell producers	Creates cells by adding contacts, coatings, and alteration of the wafer
Module producers	Solders cells together and applies frames for mounting

Top cell and/or module producers (% U.S. residential market, 2014)



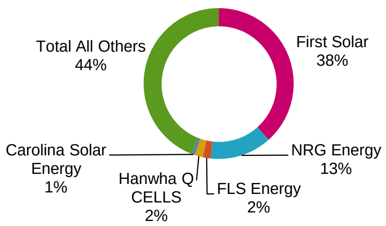
Top U.S. inverter vendors (by MW_{ac} shipped, 2014)



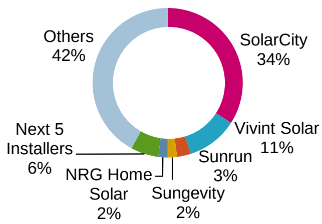
Installation

BOS	Puts modules into array structure, adds essential electrical components for grid connection (i.e. inverter)
Integration and installation	Installs modules in their final location, integrates with the grid

Installers (utility-scale by MW, 2014)



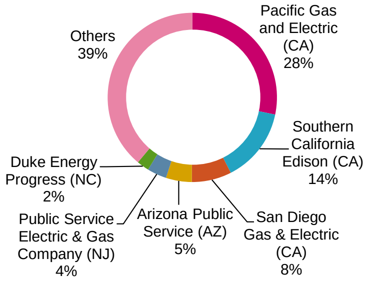
Installers (residential by MW, 2014)



Operation

Utility / IPP	Generates power (and SRECs)
Homeowner	Use the electricity themselves or sell it back onto the grid
Solar equipment lease	Leases panels to commercial / residential establishments

Utilities (by total installed solar capacity, 2014)



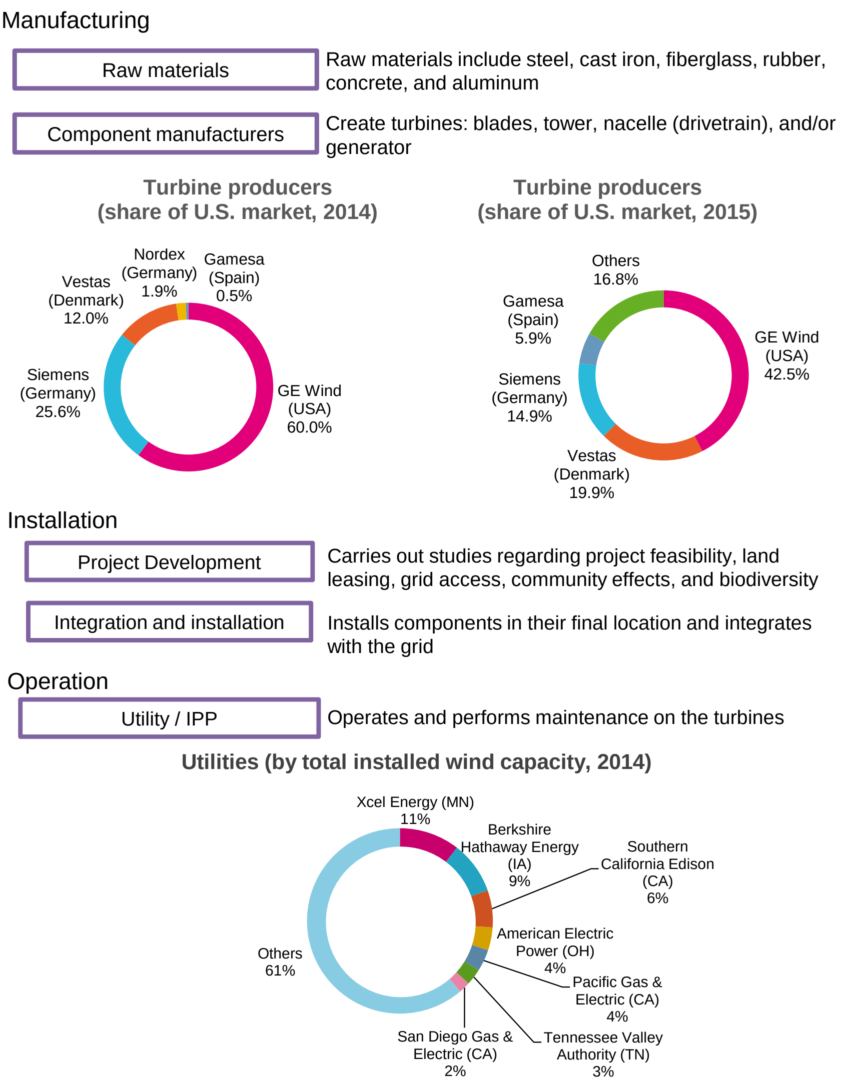
Source: Mirova / SEIA 2015/ Solar Power World 2015 / SEPA 2015

The wind value chain is more straightforward, and turbines' size favors decentralized manufacturing.

The wind value chain

The wind value chain consists of manufacturing, installation, and operation steps. After obtaining the raw materials necessary (including steel, cast iron, fiberglass, rubber, concrete, and aluminum) from individual suppliers, component manufacturers create the turbine, including the blades, tower, drivetrain, and/or generator. Compared to solar modules, manufacturing turbines is relatively straightforward, if capital intensive, although the large product size means market access is somewhat limited by factory location.

Figure 19: Wind value chain and market leaders



Source: Mirova / AWEA2015 / NREL 2016

Though the world's largest wind turbine manufacturers are in China, they occupy very little of the U.S. market share. This is because nacelles, blades, and towers are large and expensive to ship, especially if not entirely on ocean-going vessels. Most areas of high U.S. wind potential are in the country's interior, so land transportation of the turbine components is necessary after arrival at the seaport. As a result, 88% of the wind capacity installed in the U.S. in 2015 used a turbine supplier with at least one domestic manufacturing facility. Vestas, for example, operates manufacturing plants in Colorado, conveniently located near areas of high wind potential.

Installation again leads to relatively low capital expenditures but potentially high permitting and labor costs, depending largely on the remoteness of the installation. Installers tend to be numerous and vary by region, and must be careful to continuously ensure worker safety. Installation of wind turbines represents low inherent environmental or social risk, though onshore wind does have more potential than solar to cause community disturbance through noise and shadow. Ultimately, utilities or independent power producers operate the turbines; few homeowners or commercial establishments are able to implement on-site wind power due to space and licensing restrictions. Maintenance is increasingly being undertaken by the manufacturer through lifetime contracts.

Conclusion

Regulation and government policies play a crucial role in the development of renewables in the U.S., as evidenced by the steep decline in wind capacity installations each time the PTC is set to expire, and by the contribution MACRS and tax credits make to the financial feasibility of wind and solar projects. Given the recent and relatively long-term extensions of the influential ITC and PTC, short-term prospects for continued development of the American renewable energy market are positive, particularly at the end of the value chain. Large utilities are able to take full advantage of the tax credits and RPS to increase the profitability of their wind and solar projects. Utilities which position themselves as leaders in facilitating access to renewables, whether utility- or residential-scale, will thus be positively situated from economic and regulatory standpoints.

Within the intermediate steps of the value chain, solar represents more technological opportunity for improvement than wind as it is less mature. Efficiencies of solar modules continue to increase and new (non-silicon) cells are being continuously developed: though thin-film cells have been falling from favor, very rapid advances are being made in perovskite and heterojunction cells. As a result, the likelihood of new players entering the market with a larger variety of technologies is high in the mid-term. For silicon cell producers, prices will likely continue to fall, leading to more competitive prices, greater competition between existing manufacturers on price, and greater implementation (as solar still remains relatively expensive). However, the solar supply chain comprises many overseas players with low transparency and frail regulatory frameworks, making its detailed analysis outside the scope of this paper.

Excluding major political or economic shock, renewables seem set to continue their conquest of the American electricity mix.

Given that wind turbine technology is mature, the likelihood of actors competing on the basis of technology is low. Instead, the competition regarding wind turbines will be cost-related; achieving economies of scale on bigger and more streamlined turbines will be the source of short-term cost reduction (from a peak in 2009), but not as drastic in nature as those facing solar. Given that operations and maintenance contracts are often sold by the turbine manufacturer covering the lifetime of the plant, this will also present an opportunity for cost-competition. These opportunities combined with the uncomplicated and uncontroversial turbine supply chain indicates that turbine manufacturers are well-suited for investment.

Going forward, reinstatement of the Clean Power Plan, a key piece of renewable energy-promoting climate policy, is highly contingent on the nomination of a climate-friendly Supreme Court justice to replace Antonin Scalia. Even so, whether this is necessary for a coal phase-out and overall reduction in carbon intensity of U.S. generation or whether these measures serve primarily for political signaling is unclear; the decreasing competitiveness of coal and bankruptcies of U.S. coal giants are already taking place, primarily due to the shale gas boom and the resulting low gas prices. National renewable portfolio standards are constantly under discussion, but no progress has been made in this regard for several years. In general, the high level of uncertainty brought by the presidential election taking place this November prohibits further speculation regarding regulatory movement.

Favorable financial structures, solutions to grid and intermittency concerns (namely electric storage) and political consensus on the necessity of decarbonizing electricity generation (through regulation like the Clean Power Plan) will be crucial. Some competition for new capacity will derive from readily available, inexpensive, domestic natural gas, which still represents a means of decreasing the carbon intensity of the electricity mix, even if not to the extent of renewables.

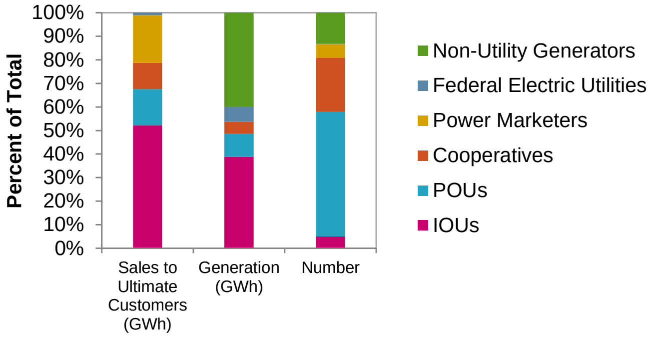
Regardless, as time passes and renewables become known for both the cost and carbon savings they bring, they will likely comprise increasingly greater portions of the U.S. electricity mix. For wind, which is already competitive compared to fossil fuels, turbine manufacturers and utilities stand to contribute to, and benefit most from its continued development. Some cost reduction still needs to take place for solar to achieve the same level of deployment, but if current trends continue, companies which facilitate U.S. solar installations (whether at utility or residential scale) are likewise well-situated.

Appendix

I: Deregulation of utilities opened the door for independent power producers

There are two major types of utilities in the U.S., publicly owned utilities (POUs) and private investor-owned utilities (IOUs). POUs are member-owned cooperatives, government-owned, or municipally-owned utilities, kand are generally exempt from regulation. IOUs, on the other hand, are large, vertically-integrated, and regulated at the state level by regulatory commissions. The Federal Energy Regulatory Commission regulates wholesale prices, but per the U.S. constitution it is only allowed to intervene if interstate transmission is involved.

Figure 20: U.S. Utility Market Overview



Source: Mirova / APPA 2015

Since the mid-1990s, restructuring of the electricity market has taken place in 16 states, allowing non-utility generators (such as independent power producers, or IPPs) to sell electricity to utilities and for retail providers to buy electricity from generators and sell it to end-use customers. This deregulation occurred with the hope that incentives provided by competition would improve efficiency and lower consumer costs, but many of the IPPs made possible by deregulation are also major contributors to the expansion of the renewable energy and electricity market.

It is also worth noting that utility ownership of transmission infrastructure is managed on the state-level, but few state regulatory frameworks require cooperative management. Building new infrastructure falls into a mixture of local, state, and federal jurisdiction depending on the project. The only standardized transmission-related regulation is the pricing of wholesale transmission transactions, which is regulated on the federal level.

II: Other influential incentives are also present

State fiscal incentives complement the federal

Numerous state-specific financing programs and incentives are also in place to improve feasibility of implementation for customers. Some of the more popular include public benefit funds for renewable energy (present in 16 states) and property-tied financing plans (through the Property Assessed Clean Energy program present in 31 states).

Many states also offer incentive programs for renewable energy projects or manufacturing facilities within the state's borders. Typically this takes the form of an up-front rebate or an ongoing performance-based payment to solar energy facilities. Coupled with state net metering programs, incentive programs have been a major driver for customers to invest in on-site PV. The majority of these projects have been to support solar PV projects, but wind has been the largest recipient of funds.

In total, approximately 27 states have some type of cash rebate program targeting customer-sited renewable energy. In most states, there are also similar programs on the municipal scale. Program designs, funding sources, and funding levels vary greatly between states, but most apply a small fee to retail electricity sales which is then re-administered by a state agency or utility. Between 2010 and 2017 such charges are expected to collect more than $7.2 billion for renewable energy, or 2% of estimated total investment flows.

For example, California's residential solar sector aims for 3000 MW of customer-sited PV by 2016. The state aims to achieve this largely by offering cash incentives on solar PV systems of up to $2.50 per watt, which can cover up to half of a solar energy system's total cost. Massachusetts serves as a more representative example: it offers a 15% tax credit (up to $1000) against state income tax for the net expenditure of a renewable energy system at an individual's residence. Sales tax and value-added property tax are also waived for renewable energy equipment, and the federal ITC / PTC still apply.

Other state policies can also help or hinder development

Lastly, it should be noted that since utilities are largely regulated at the state level, regulations concerning their rate structures have a high impact on the deployment of renewables within that area. The three most pertinent structures are interconnection standards, which describe how utilities treat renewable energy sources wishing to connect to the electric grid; net metering, which allows customers who generate their own renewable energy to receive compensation for the electricity they generate; and feed-in tariffs, which obligate utilities to pay pre-established above-market rates for renewable power fed onto the grid.

Interconnection standards are processes and technical requirements that describe how electric utilities treat renewable energy sources that need to connect to the electric grid. Establishing standard procedures reduce the uncertainty and delays renewable energy systems can encounter when obtaining electric grid connection in states without interconnection standards. As of 2015, 46 states have implemented regulatory requirements for interconnection standards in order to facilitate development of renewables and distributed generation.

Net metering enables residential or commercial customers who generate their own renewable electricity to receive compensation for the electricity they generate. Net metering rules require electric utilities in a state to ensure that customers' electric meters accurately tract how much electricity is used on site or returned to the electric grid. When electricity generated on site is not used, it is returned to the grid; when on site generation is not sufficient to meet the customer's needs, the customer uses electricity from the grid. In effect, excess electricity is returned to the customer at a later time when they otherwise would have paid for it.

The EPAct 2005 required every public utility to offer net metering to their customers. Since then, 44 states have authorized net metering, and three states (Idaho, South Carolina, and Texas) have further implemented net metering programs. However, though most states and territories have authorized net metering, the approaches differ with regards to terminology, capacity limits (ranging from 20 kW in Vermont to 10 MW in Massachusetts and 80 MW in New Mexico), eligible technology (all include solar, but not all include other renewables), net metering credit retention (indefinite rollover in Alaska, one-year rollover in Hawaii, while California offers to pay customers for unused credits), and REC ownership.

Lastly, feed-in tariffs encourage the development of renewable energy by obligating electric utilities to pay pre-established above-market rates for renewable power fed into the grid. These tariffs, which may vary depending on the type of resource used, provide renewable generators with a set stream of income from their projects. While most common in Europe, six US states (California, Oregon, Washington, Maine, Vermont, and Hawaii) have feed-in tariff schemes mandated by state regulation, and several additional areas have similar programs voluntarily-provided by utilities.

Large direct subsidies have also been provided to renewables

These quintessential subsidies comprise direct payment of federal funds for energy-specific purposes totaling $12.9 billion (44% of total subsidies and support) in 2013, 64% of which was to support renewable energy sources. The Department of the Treasury provided $8.2 billion of these direct expenditures (62%), all of which went to support renewable energy under the American Reinvestment and Recovery Act of 2009 Section 1603 grant program. The fuel mix of direct expenditures has changed considerably over the last years: funds provided for renewables increased by 175%, while gas, petroleum liquids, and nuclear received less support. Support for coal also appeared to grow, but this is mainly attributable to a large new program for carbon capture and storage.

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