Utility Companies: Adapting to Technological Innovations and Renewable Energy

Sources

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Introduction

In 2012, in the Mid-Atlantic of the United States, 15% of the total available electrical generating capacity was only used 1% of the time, during peak demand periods. Maintaining this electrical capacity is expensive and challenging especially as utilities face many obstacles and uncertainty. These challenges include emerging distributed generation technologies, increased regulatory requirements concerning environmental impacts and a decreasing customer consumption growth. How utilities, customers and regulators approach these challenges will shape the grid of the future and what our utility companies look like.

FIG. 1: Forecasted US Lighting Energy Consumption and Savings, 2010 to 2030

A major challenge facing utilities is slow or negative growth in energy consumption as the economy experiences sluggish growth and customers invest in energy efficiency technologies and distributed generation projects. The increased penetration of LED light bulbs alone is projected to have an energy savings of 300 terawatt-hours annually by 2030. This represents the annual output of approximately fifty 1000 megawatt power stations, or the consumption of 24 million homes. This also could be represented by $30 billion in energy savings at todays energy rates. For utilities this is lost revenue and deliverable commodities. Figure 1 shows the projected decline in energy consumption for lighting due to increased LED penetration.

As a result of these challenges, electric utilities may be forced to raise rates to maintain profit margins and capacity. The result of this will further incentivise customers to invest in energy efficiency projects and distributed generation projects. Some believe that this will lead utilities into a death spiral of increasing rates and decreasing consumption. Utility companies need to adjust their business models and billing practices to maintain revenue and avoid pushing higher costs onto fewer and fewer customers. Possible alternatives include increasing customer charges on utility bills and decreasing consumption fees, using smart meters to implement demand pricing, decoupling profits from electricity sales, or investigating the advantages of net billing versus net metering for customers with solar panel systems.

The larger challenge facing utilities is how to incorporate emerging technologies into their business models, making them more suitable and adapted to energy demands going forward. A large portion of existing electrical generation is achieved through the burning of fossil fuels which are becoming more strictly regulated. Renewable energy generation is becoming a larger portion of the market as technologies mature, become more affordable, and are subsidized by governments aiming to curb greenhouse gas emissions. Many renewable generation technologies are non-dispatchable assets, only supplying power intermittently without control of when or how much output is supplied. This means generating resources cannot be counted on to supply energy during peak loads. This can cause volatility in energy prices, as happened in Germany, where new regulations and market mechanisms addressing wind power stabilized prices that had become erratic and less predictable with the introduction of wind power.

To more effectively accommodate renewable generation, utilities must invest in energy storage solutions in conjunction with renewable generation. Large scale energy storage will allow renewable energy generated during low demand periods to be fed back into the grid during peak demand periods. Additionally, it will allow for retirement of older more expensive power generation systems that are maintained solely to meet peak demand.

Utility companies must be proactive in adjusting their business models to meet the changing landscape. They should work in conjunction with consumers and regulators to adjust. Companies will have to continue to ensure that they couple their investments in new technology with lobbying efforts to ensure that any subsidies match their business model.
Integration of Renewable Energy into the Grid

As consumers become more aware of climate change they expect that an increasing amount of energy be generated by renewable resources. A national survey showed that Americans chose solar and wind as the most important energy source going forward over natural gas and nuclear. Denmark, Portugal, Scotland and Costa Rica have all achieved periods of one hundred percent renewable energy. Though periods of one hundred percent renewable energy generation have been achieved, full integration of renewable energy generation presents many challenges. First is that renewable energy sources are often non-dispatchable and are reliant on weather conditions. Second being that renewable energies can be used as distributed generation and can increase the complexity of balancing the grid, as energy can be fed into the grid from any point. Where before the distribution network was fed from a transmission network that was maintained Most studies have concluded that renewable will contribute to erosion of utilities revenue and profitability because of the distributive generation available to customers.

As seen in Figure 2 below the peak energy production from solar and wind does not coincide with peak demand. Wind provides a relatively flat energy output and solars output peaks in the middle of the day while peak demand is in the evening.

![Graph showing load, solar and wind profiles for California on March 29, 2015 in a scenario with 11% annual wind and 11% annual solar assuming no curtailment](image)

Additionally, legacy systems already have large amounts of capital invested and operators will want to recoup those investments. In 2012, 82% of electricity production was from fossil fuels or nuclear energy sources. Electrical production is the largest supplier of human based greenhouse gas emissions.

Wind Power

Wind power is increasingly becoming a viable energy source and is one of the cheapest renewable energy sources. Spain, a leader in integration of wind energy, had 23 GW of wind power in 2013. In the United States there were 843 wind power plants that supplied 7% of the nations electricity in 2015. In the great plains where wind is more viable, Iowa and South Dakota receive \( \frac{1}{4} \) of their power from wind.

Wind power will become increasingly viable and projects will become more reliable investments for utilities as more data becomes available allowing for better forecasting and site planning. Additionally, improved technologies in wind turbine construction and design will increase energy production and the quality of energy produced. Also, increased investment in design research and development will allow for custom turbine designs tailored for each project and location so that the turbines are ideal for that setting. Individual utilities should investigate wind turbines to determine if wind energy is a viable option and what level of investment is ideal.

Solar

Solar photovoltaic power is becoming increasingly affordable and is increasing in market penetration. Annual installed capacity jumped from 58 MW in 2004 to 6,201 MW in 2014 while the cost of residential installation was halved. Utilities must find ways to engage customers who want to invest in solar power while still protecting their business. As solar becomes increasingly affordable existing subsidies and utility pricing for solar consumers should be reevaluated and adjusted to maintain proper market balance. Figure 3 below shows the increase in solar capacity with the dropping price of residential solar.

![Graph showing annual installed residential solar price and capacity](image)

Solar power has the added difficulty that it can be fed into the grid at any point. This can make management of the grid difficult as in addition to customers energy loads changing a utility will also have to balance solar energy being fed back into the grid. This is especially difficult as the amounts of power needed by consumers and being fed back into the grid can be affected by passing clouds. Similarly, to wind power as solar continues to mature and increasing amounts of data becomes available utilities will be able to more accurately forecast how to manage the grid as renewable energies increase in penetration with extreme learning machines. These extreme learning machines will allow utilities to know where there will be excessive and inadequate generation and enable
the utilities to plan accordingly and make necessary generation adjustments.\textsuperscript{14}

**Energy Storage**

A key component of integration of renewable energy into the grid is the ability to store energy. Energy storage increases operational flexibility and the ability to meet the dynamic needs of the electrical grid. As renewable energies are often non-dispatchable their production will not necessarily sync with demand. Investments in energy storage will allow for the capture of excess energy produced by renewable means during low demand periods. This energy then can be fed back into the grid when energy produced from renewable energies does not meet the demand. Often times excessive renewable production is curtailed, or isolated from the grid to protect the grid from excess energy. In Spain during 2013, 1100 GWh of wind power was curtailed. These curtailments represent and estimated 70 million euros of economic losses per Spanish Wind Energy Association just from January to April of 2013.\textsuperscript{10} With the average annual Spanish household consumption of 2749 kwh this curtailed energy is enough for the annual consumption of 400,000 households.\textsuperscript{15} It is estimated that energy storage capacity of 1-3 days would allow for 90% wind penetration of an electrical grid.\textsuperscript{16}

Figure 4 shows the impact of high amounts of solar generation on the grid load profile. During peak solar generation, there is excess energy available. The challenge for utilities is to find ways to economically and efficiently capture this excess generation. Figure 5 shows the inherent variability of how much power will be generated from a renewable resource, in this case wind in Spain. This illustrates how difficult it is to build a system reliant on output from renewable sources.

![FIG. 4: Example of an analysis of the impact of high VG on net load shape and resulting over-generation\textsuperscript{8}](image)

Currently pumped hydro is the leading energy storage solution, with other technologies being studied and investigated. Pumped hydro has been in use since the 1890s and accounts for 99% of bulk electrical storage worldwide. The first pumped hydro storage facility built in the United States was Connecticut Light and Powers Rocky River Station in 1929. Pumped hydro storage initially saw widespread adaptation with nuclear power. This is because nuclear power plants cannot ramp up and down quickly to meet grid demand. Pairing nuclear generation with pumped hydro storage allows nuclear plants to operate at a constant output.\textsuperscript{17}

While mature, and fielded in large scale projects pumped hydro has limitations and some locations are not geographically suited. Additionally, pumped hydro is not an energy dense medium so it requires a large amount of water or a large elevation change. The strengths of pumped hydro are that it has a quick response time with rapid start and stop, it can match load changes, and can maintain frequency and voltage for the grid. Pumped hydro is ideally suited to be paired with wind power. As wind turbines deliver very uneven and unpredictable power and balancing the power with pumped hydro storage makes the power more reliable and useable to the grid and consumers.\textsuperscript{16}

Another factor that must be considered is that when investing in and creating energy storage systems is to ensure that the storage systems are capturing and storing the energy from the desired renewable source. In the Netherlands after investing in pumped hydro storage coupled with wind power a study was conducted. The study determined that the energy being stored was not the wind power they intended to capture, but rather cheap coal power. Additionally, this caused more expensive natural gas power plants to be left idle. The result was an actual increase in the carbon emissions of the Netherlands, the opposite of their intentions.\textsuperscript{18}

Utilities must invest in a diverse range of energy storage solutions that match up with the energy storage capacity and discharge rates that meet their demand profiles and enable them to consistently maintain quality energy delivery. In addition to pumped hydro storage compressed air, flywheels, capacitors, super capacitors and batteries are all being investigated to determine their economic viability and applicability as storage for the grid.\textsuperscript{19}
Billing and Interacting with Customers

As customers consumption habits change with higher efficiency technologies and the increased penetration of consumer solar photovoltaic, utilities are going to have to adjust their billing practices and how they communicate with their consumers. Though for utility companies any change to billing practices will be a costly challenge, as the computer systems that utilities use to generate bills are large and complex. Any change to these systems would be expensive. Utilities would have to ensure that it is implemented smoothly as this is where they generate their revenue and is a major point of customer interaction. Any billing issues would sour customers relationships with their utility.13

One possibility is with increased consumer produced renewable energy is for utilities to shift from a Utility-side business model to a customer-business model. A utility-side business model is the status-quo, with electricity being a supplied commodity. A customer-side business model would be the utility acting as an electricity service provider. In a customer-side business model utilities would shift away from having a smaller number of large generating assets customers creating many small generating assets with utilities functioning as an intermediary transmitting power. Though the business model needs to be further developed; the cost and revenue structure would be more complex for utility companies. Another issue is that the economies of scale will not be met as customers invest in smaller scale projects.6

As solar penetration continues to build utilities must find a way to receive revenue from customers who are co-generating. With net-metering customers are receiving a subsidy in the form of receiving credits for energy fed back into the grid at retail price. This acts as a subsidy and can drastically reduce what a customer pays in their monthly electricity bill. This is a problem because though the customer may be using a small net amount of energy: they are still utilizing the grid transmission and distribution infrastructure. With net metering customers with solar panels do not pay for maintenance of the grid. A shift in billing structure would change that. One alternative is net-billing, the process of the consumer being credited at wholesale price for any energy that they feed into the electrical grid.20

This is something that has been tried in developing countries where utilities cannot afford to heavily subsidize residential solar installations. In Chile where this has been implemented it was found that even with the smaller subsidy of net-billing that solar installations had payback periods of 6-13 years depending on the region of the country. Though it should be noted that the energy rates in Chile are relatively high, and the shorter payback periods where in regions with higher utility costs.21

The push-back against Nevada Public Utilities Commission recently approved NV Energy increasing service charges and decreasing what solar owners were credited for feeding energy back into the grid illustrates the importance of utilities communicating with their customers. The change of the feed-in-tariff paid to customers reduces the financial incentives to invest in solar energy such that many solar companies withdrew their operations from the state. Nevada would have been better served to match their change in regulations to Hawaii who reduced their feed-in-tariff paid to customers. Hawaii set the feed-in-tariff at between whole sale prices and retail electrical rates. Thus, easing the strain placed on utilities while still incentivising investment in solar, just not at the level it was previously.

The Nevada Public Utilities Commission should have fostered a more open dialog between the consumers and the utility NV Energy to create an understanding of each opposing sides requirements and desires for the utilitys business model going forward and its ability to supply affordable energy to all customers. This backlash has caused neighboring states like Arizona to place their rate model changes on hold while the observe what happens in Nevada.

Shared solar is one alternative for utilities to incorporate solar and increase customer engagement and satisfaction. Shared solar is large centralized communal or utility owned solar generation projects. The centralized model allows all customers to have access to solar power, creating greater market penetration. Additionally, the increase in large centralized solar generation could lead to increasing the grid power quality, compared to the effect of many small generation sources.13

Another option for utilities is to drastically change prices during the day to incentivize consumers to use electricity when cheap renewable energies are producing cheap electricity. Models have shown that a significant difference in electricity pricing can cause consumers to change their load pattern. It was found to be more effective in shaping consumption patterns than day night meters versus flat electricity rates. More research is necessary to determine the usefulness of this pricing model in changing behavior. Additional ideas are tying smart meters into smart appliances to possibly shift power consumption when convenient.22
Regulators face a real challenge going forward of protecting existing investments while at the same time promoting emerging technologies, new efficiencies, competition and protecting the environment. Utilities must make sure that they maintain open dialog with the regulators to ensure that their actions and those of the regulators are in sync and moving towards a common goal.

This is most evident in Spain with the introduction of wind power. There the energy companies created a wind energy lobbying group that was very active during the crafting of wind energy legislation in parliament. They sought two aspects the first being to create an incentive for wind energy producers to enter the open market place, where before they had been allowed to sell at a fixed guaranteed price. And the second was they lobbied regulators to raise the ceiling on total wind energy capacity. The result was Spain saw wind energy penetration than in other Western European nations attempting to integrate wind into their national grid.

As wind power penetration increased in Germany it caused energy prices to decrease, though simultaneously there was an increase in the volatility of the energy market. This is because the market rules required projecting out energy production for purchase one month in advance. Because wind power is so hard to predict, especially so far out, the wind energy producers rarely matched their projections. Regulators responded to market volatility by changing the energy market place for wind power to a day ahead projection thus greatly increasing the reliability and accuracy of energy projections.

Pumped hydro storage also faces a challenge of water use restrictions and market uncertainty. Both factors have caused several pumped hydro storage projects to be abandoned by utilities. From 1986 to 2005, 45 preliminary permits were issued for pumped hydro storage feasibility studies by the Federal Energy Regulatory Commission. Seven of these projects filed for licensing though none of them were ever built, though one is now part of another feasibility study.

Though by 2010, the Federal Regulatory Commission had granted preliminary permits to more than 28.6 GW of pumped hydro storage projects, more than the existing pumped hydro capacity storage capacity of the United States. Many of these projects are novel off-stream solutions with less than a quarter of them involving a traditional dam. These off-stream systems will utilize underground caverns, mines and quarries and will have less of an impact on aquatic life. Additionally, use of groundwater instead of surface water will further reduce any negative impact of aquatic life. Both changes should reduce resistance from environmental advocates.

Additionally, investment in pumped hydro storage was hindered by the availability of cheap fossil fuels making pumped hydro storage less economically attractive. Utilities who are committed to integrating renewable could pair renewable energies with pumped hydro storage. To encourage pairing pumped hydro with intermittent renewable energies; regulators could tax or cap carbon emissions which would make pumped hydro more economically advantageous.

Another factor that hindered further integration of pumped hydro storage was regulatory confusion over the classification of pumped hydro storage. This is because energy storage is neither generation or transmission. When the energy market was deregulated it was unknown how energy storage would fit into the new marketplace. This was remedied in 2007 with Federal Energy Regulatory Commission Order 890 which allowed transmission regulators to allow energy storage to have a greater role in the market.

**Conclusion**

Faced with a changing landscape of increased regulations, reductions in energy consumption rates and consumption patterns, utility companies should take a multifaceted approach to adapting their business to maintain profitability going forward. There is no one small change utility companies can undertake to ensure their future, rather there will be a series of several larger changes that will significantly change how our utilities operate and how we interact with them. Each utility company should find the right combinations that work in their geographic and regulatory environment. It must also be achievable with their existing investments and infrastructure.

Utility companies should engage with their customers to increase consumer understanding of how electrical production and delivery works, as well as to try and shape consumer behavior to ease stress on the grid. This will be difficult because for a long-time companies preferred to shield their customers from what determined their electricity bills. Utility companies need to explore what can be done through changing billing practices and further utilizing the capabilities of smart meters to engage customers. This is especially important in places with high solar penetration as consumers still utilize the grid, though they may not be paying for their utilization of the grid if they do not have a large enough net electrical consumption.

It is important that companies find ways to effectively integrate renewable energy generation technologies into the grid. As awareness about global climate change increases regulators and consumers expect that increasing amounts of electrical generation will come from renewable or cleaner sources. Utilities need to find ways to effectively manage the stress that the distributed nature of generated renewable energy places on the electrical grid. As distributed renewable generation, can be fed into the grid at any point in the transmission and distribution network, it present unique challenges. Additionally, as many renewable energy sources are non-dispatchable, companies should invest in large scale energy storage so-
olutions. Storage will allow utilities to capture excess renewable electrical generation and level the energy delivery, so that renewable energies such as solar and wind can be a reliable part of the grid.

Utility companies are already very engaged with politicians and regulators. Utilities must be proactive in providing a voice in new regulations and subsidies and be drivers in innovation and change. They should continue to be anticipatory in what will be the future regulatory environment and prepare their business looking forward. This is exemplified in Spain where the utility’s proactive approach to regulation allowed them to influence regulatory change concerning wind power. The impact of this proactive approach resulted in utilities committing to investment in wind power, wind power becoming effectively integrated into the wholesale market and a large amount of wind power generation capacity. Spain saw more wind power than elsewhere in Europe where other countries also attempted to increase the penetration of wind power.

Utility companies must continue to be proactive in adapting to the changing demands being placed on them and the grid as consumption patterns change and regulatory stressors increase. Outreach to stakeholders and investment in new and emerging technologies will drastically change how utilities operate and how customers interact with them.

1 T. Krishnamurti, Energy Policy 41 pp. 790–797 (2012).
2 US Dept of Energy - Energy Efficiency and Renewable Energy, Building Technologies Program (2012).
3 N. C. Inc., US Dept of Energy - Energy Efficiency and Renewable Energy, Building Technologies Program (2012).
4 K. W. Costello and R.C Hemphill Eletric Utilities’, The Electricity Journal 27 pp. 7–26 (2014).
5 J.C. Ketterer, Energy Econ 44 pp. 270–280 (2014).
6 M. Richter, Renewable and Sustainable Energy Reviews 16 pp. 2483–2493 (2012).
7 S. Edelstein, Christian Science Monitor (2016).
8 P. Denholm and M. O’Connell and G. Brinkman and J. Jorgenson, National Renewable Energy Laboratory (2015).
9 I. G. Moghaddam and M. Nick and F. Fallahi and M. Sanei and S. Mortazavi, Renewable Energy 55 pp. 252–259 (2013).
10 S. M. Martinez and E. G. Lzaro and A. H. Escribano and M. C. Carretn and A. Molina-Garcia, IEEE Power and Energy Society General Meeting (2015).
11 D. Keating, J. Muyskens, and S. Granados, Washington Post (2015).
12 R. Baos, Renewable and Sustainable Energy Reviews 15 pp. 1753–1766 (2011).
13 P. Augustine and E. McGavisk, The Electricity Journal 29 pp. 36–42 (2016).
14 T. T. Teo, T. Logenthiran, and W. L. Woo, IEE Innovative (2015).
15 D. Romero-Jordan, P. D. Rio, and C. Penasco, Institut d’oconomia de Barcelona 24 (2012).
16 S. Rehman, L. M. Al-Hadhrami, and M. M. Alam, Renewable and Sustainable Energy Reviews 44 pp. 589–598 (2015).
17 C. Yang and R. B. Jackson, Renewable and Sustainable Energy Reviews 15 pp. 839–844 (2011).
18 B. C. Ummels, E. Pelgrum, and W. L. Kling, IET Renewable Power Generation 2 pp. 34–46 (2008).
19 K. Bradbury, L. Pratson, and D. Patiø-Echeverri, Appl. Energy 114 pp. 512–519 (2014).
20 D. Watts, M. F. Valds, D. Jara, and A. Watson, Renewable and Sustainable Energy Reviews 41 pp. 1037–1051 (2015).
21 S. Comello and S. Reichelstein (2016).
22 J. V. Douw, Z. Lukszo, and P. M. Herder, IEEE 13th International Conference on Networking, Sensing, and Control (2016).
23 T. Stenzel and A. Frenzel, Energy Policy 36 pp. 2645–2657 (2008).