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MODERNIZING NEW HAMPSHIRE'S ELECTRICAL GRID

Presented to the New Hampshire House Science, Technology, and Energy Committee

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1. EXECUTIVE SUMMARY

There is much potential for the New Hampshire electricity grid to run more efficiently and reliably than in its current state. This brief takes on a comparative approach between the Midcontinent Independent System Operator (MISO) in the Midwestern United States and the Independent System Operator-New England (ISO-NE), of which New Hampshire is a member. We evaluated the potential for renewable energy integration, as well as real-time pricing models, into the modernization of New Hampshire's energy grid.

2. STATEMENT OF PROBLEM / INTRODUCTION

New Hampshire's current energy grid is in need of modernization in order to be able to meet new standards of demand and to handle the difficult weather conditions in the state. Prices for electricity have been on the rise in the area and there is no foreseen end to this unless there are new developments in terms of infrastructure in the area. Gas infrastructure in particular is outdated and cannot keep up with the number of gas-fired power plants upon which the grid relies.[1] Furthermore, New England needs over a billion additional cubic feet of pipeline to fully supply the natural gas generators during times of peak demand. However, the development of more pipelines is a highly political issue and the rural location of the state makes energy efficiency difficult as a majority of the state's fuels are imported. [2] Balancing the input of renewable sources of energy and identifying the ways in which they can best be integrated into the current grid infrastructure will prove to be one of the largest challenges in modernizing New Hampshire's grid.

Winters are a major concern in New Hampshire as storm outages are unfortunately very common. Independent Systems Operation-New England (ISO-NE), which is responsible for monitoring the market, demand, generation and transmission within the region, has expressed concerns about fuel security during the harsh winters.[3] In the past couple of years, a stocking program has been running to ensure that there is enough fuel before winter temperatures arrive. [4] Consumers carry the burden of this approach, as there is a possibility that they will end up paying for more than the market value of fuel by virtue of buying early. Clearly, modernizing the grid would help alleviate this burden.

3. OVERVIEW OF THE ELECTRICAL GRID

Energy grids are built upon three principal components: electricity generation, transmission, and distribution. Large-scale electrical generation takes place distal to major population centers and requires a means to transport produced electricity to consumers. The distribution system is linked to the transmission grid through transformers that step down this extreme high voltage to lower voltages for localized transport and consumption (fig. 1). In New Hampshire, these two processes are handled by different entities.

ISO-NE oversees the transmission of energy for: New Hampshire, Vermont, Maine, Connecticut, Rhode Island, and Massachusetts. It is overseen by the Federal Energy Regulatory Commission, and as such, is federally regulated. However, ISO-NE acts independently from the government in the private sector; thus allowing competitive market mechanisms to govern operations. Grids allow for the transmission and in some circumstances, the distribution of electricity to fall under state and federal jurisdiction while generation and supply are left to competitive markets and retail utilities.[5] As ISO-NE is solely responsible for transmission, they do not directly engage in electricity generation, nor distribution to end-consumers. However, they play a key role in facilitating the transmission of energy between these two parts of the system and thus are critical to any infrastructure upgrades or structural changes within the state.

The ISO-NE network providing power to New Hampshire and the surrounding states is comprised of 45 percent natural gas, 20 percent fossil fuel sources, 15 percent nuclear, 10 percent coal, and the remaining 10 percent through mixed renewable sources. In recent years, several states have independently undertaken a modernization of their electrical grids as they lead to greater overall efficiency within each state. This often causes long-term transmission capacities across multiple states and wholesale power markets improve as well.[6] A modern electrical grid will allow for the integration of newer and more efficient technologies, price stability, resistance to extreme weather, and an increase in consumer participation.[7]

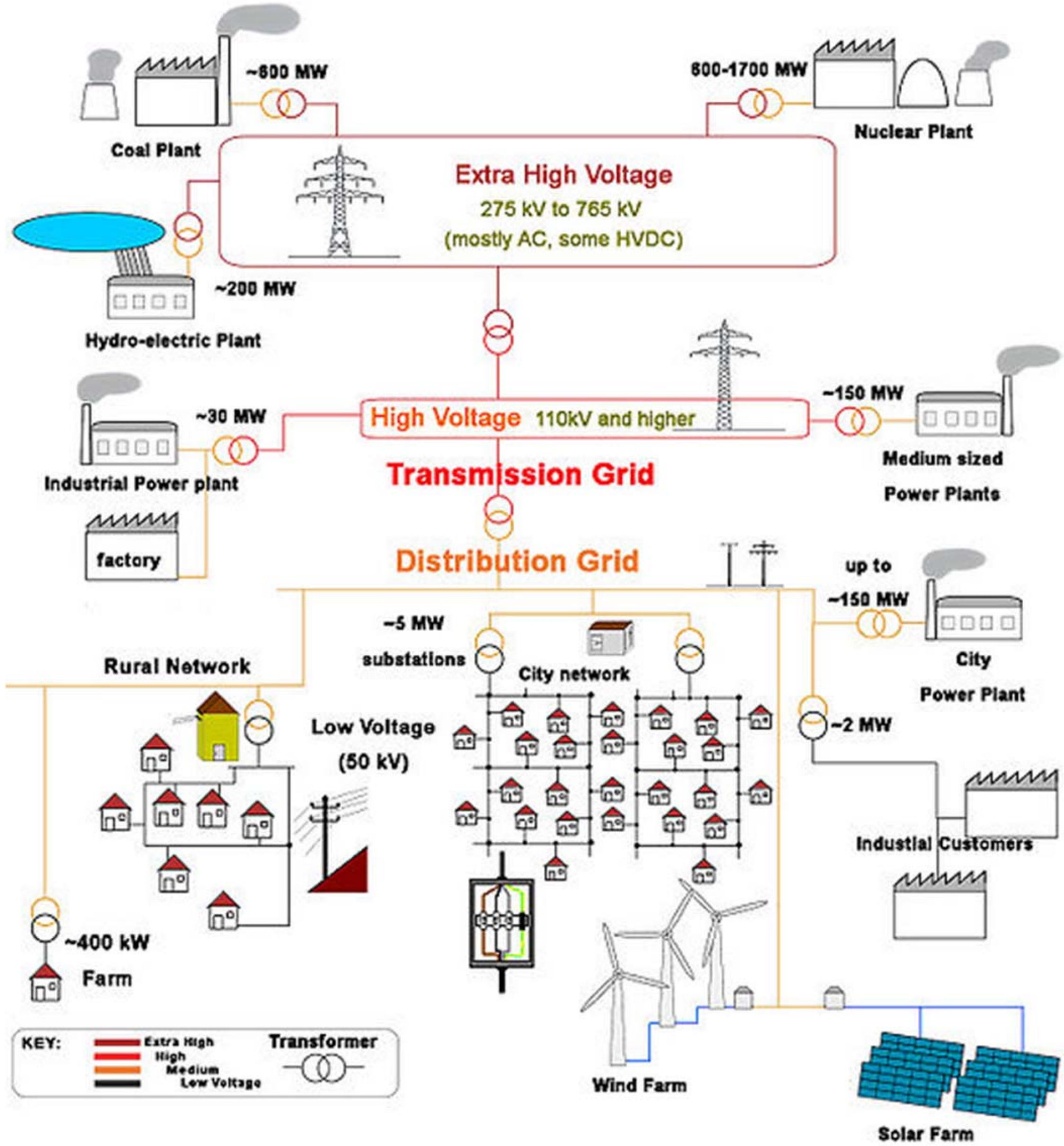

Fig. 1 *Schematic of Transmission and Distribution grid interfaces and internal connections.*

4. NEW HAMPSHIRE ENERGY OVERVIEW

Overall, energy usage in New England is expected to remain flat until 2023 because of energy efficiency measures with half of the states (Connecticut, Vermont, Maine, Massachusetts and Rhode Island) actually experiencing a decline in usage.[8] Of the six states in the ISO-New England grid, Vermont is the most energy efficient of the states. New Hampshire lags behind some of its peer states such as Rhode Island, Maine, Massachusetts, and Connecticut; those states have all created statewide policies towards greater overall energy efficiency with integrated funding mechanisms. [9] New Hampshire itself has seen small deficits in the state's ability to meet current energy demand. At present, in-state energy production levels necessitate a 15 percent annual import of energy obtained from Quebec (Transenergie), NY-ISO, and New Brunswick transmission distributors.[10] However, on an annual timeframe, New Hampshire is simultaneously a heavily net importer of fuel for power generation, and an overall exporter of electrical production to other states within the NE-ISO region [largely metropolitan Massachusetts].[11]

The region's overall demand is expected to grow at a rate of one percent each year. Overall, energy usage in the state is declining, but this decline is being offset by an increase in the price of fuel. The state is also prone to sudden price spikes because of an aging infrastructure.[12] Additionally, New Hampshire could be storing its energy more effectively to offset the high prices. Energy affordability for consumers in New Hampshire is additionally an area for strong improvement. While New Hampshire is a largely rural state and ranks 43rd in energy consumption per capita, it also ranks 23rd for total energy expenditures; suggesting inefficiencies in the costs of energy generation and distribution in the state.[13] This divergence in consumption and cost can be attributed to the challenges of traditional electrical generation and distribution across sparsely populated areas that simultaneously experience harsh winters.

Recent distribution grid audits of energy distribution throughout New Hampshire suggest that the state is currently struggling to meet demand. Importantly, given the limited transmission network access throughout New Hampshire, any interruption in service critically affects electric distributions along the system. The leading causes of electric transmission outages in New Hampshire are human error and faulty equipment. The primary contributing environmental factor to disruptions in transmission are severe ice storms and severe weather.[14]

At present, there are several statewide challenges identified by ISO-NE in the current electricity infrastructure within the state. New Hampshire maintains two grid-ties to New Brunswick, and seven grid ties to southern New England; between which runs a 345 kV transmission corridor. This corridor serves to facilitate transfer of electricity between various regional grids, and serves the state of New Hampshire via a series of lateral 34.5-69 kV lines feeding into local communities. However, this corridor is not performing at optimum capacity. Additionally, new electricity generation sites developed along this corridor are adding additional electricity flux to the system; stressing its capacity to its limit.[15]

Ultimately, this results in little flexibility for routine maintenance outages, and poses serious power supply challenges during critical infrastructure failures. Overall, New

Hampshire would benefit from a more adaptable, flexible, and resilient transmission grid infrastructure. This includes additional medium-high voltage transmission lines (345 kV and 115 kV), and additional lateral transmission structures (115kV) to access population centers throughout the state. Additionally, many of the challenges faced on the lateral distribution systems in NH result from thermal overloading of the transmission system. The addition of transformers and circuit breaker stations may help to mitigate this problem (fig. 2).[16]

Of the six states that are currently a part of the New England energy grid, New Hampshire demonstrates the lowest annual average energy savings range at 68 GWh. Comparatively, the second lowest is Vermont at 113 GWh and Massachusetts has the highest savings at 749GWh. New Hampshire has also demonstrated the lowest annual peak savings capacity at only 11 MW, while Massachusetts is 10 times that.[17] Effective modernization of the grid is expected to allow for a decrease in peak demand from anywhere between 13 and 59 percent, so peak energy savings can be drastically improved.[18]

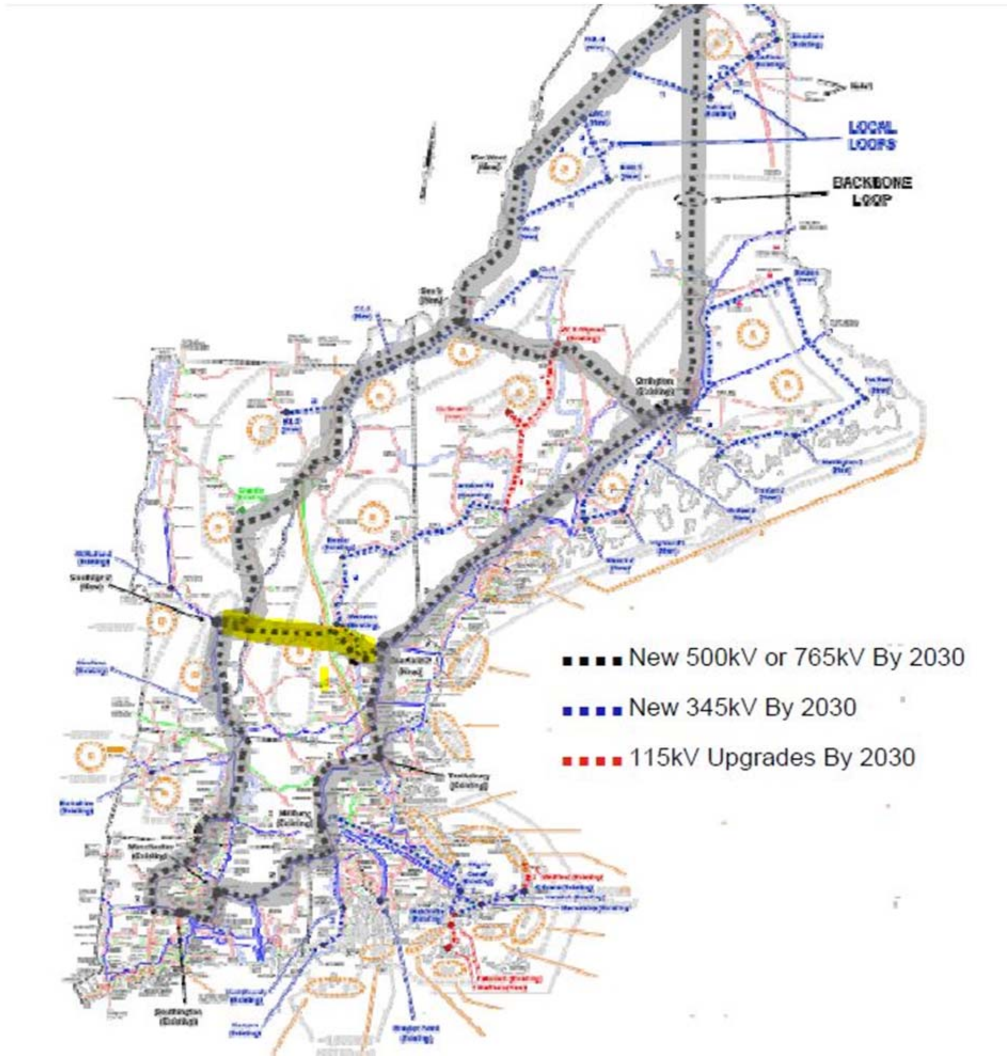

Fig. 2 *Major existing electricity transmission corridors, and proposed upgrades.*

5. METHODOLOGY

This paper takes a comparative approach in analyzing the Midcontinent Independent System Operator (MISO), the electric grid in the Midwest, and Independent System Operator- New England (ISO-NE), the electric grid in which New Hampshire participates. While MISO is responsible for more states than ISO-NE, there are still similarities between the two that makes MISO a good model for comparison with ISO-NE. The two areas are pretty similar in terms of climate, with both areas having incredibly cold winters, cold enough that they certainly have an impact on energy demand, and both areas having very warm summers as well. The two areas have similar issues with peak demand due to their climates, which is something that is very important for New Hampshire while investigating how to modernize the electric grid. Furthermore, both areas are relatively similar in terms of how densely populated they are. Both the

Midwest and the New England area have a couple of cities, but both areas have lots of land that is mostly small towns, or even totally unpopulated. This effects the dispersion of demand and ability to consolidate in terms of distribution. Even though the Midwest grid is responsible for about five times the megawatts of energy as the New England grid, the composition of states is similar and that is what is pertinent for a model for the New Hampshire grid.[19]

6. RENEWABLE ENERGY

6.1 Renewable Energy in New Hampshire

A significant component of grid modernization in New Hampshire is the opportunity it provides to incorporate more renewable energy sources into our electric grid. Not only will this help the functionality of the grid by lessening the burden on other fossil fuel energy sources, but it will also help the state reach its Renewable Portfolio Standards (RPS) goal of relying on renewable sources for 25 percent of the state's energy by 2025.[20] As of 2013, renewables comprised 16 percent of the state's energy mix.[21] There is still much work to be done in order to reach the RPS goal, and effective grid modernization would take into account an increase in renewable energy.

Numerous forms of renewable energy technologies exist, including solar (both photovoltaic and Concentrating Solar Power), wind, and biomass.[22] Solar photovoltaic (PV) technology uses solar energy to directly create electricity, whereas Concentrating Solar Power technology (CSP) uses parabolic mirrors to generate heat from solar energy, which is in turn converted to electricity via generator.[23] Currently, solar PV energy ranks among the fastest growing technology, growing at a rate of 60 percent per year worldwide, while wind energy growth ranks at 27 percent per year.[24]

6.2 Bringing Renewable Energy to Scale

Both solar and wind energy sources are variable, which contributes uncertainty relating to supply.[25] Supply fluctuates based on weather and time of day; some days may produce excess amounts of electricity while other days may underperform. Two elements may be incorporated into the electricity grid in order to facilitate renewable energy use: firstly, real-time pricing, which produces "active consumers" and which will also serve an additional benefit of mitigating current peak demand (see Section 8), and secondly, "fast-acting (high speed) controls" to "mitigate load and voltage fluctuations" when there are sharp changes in electricity production.[26]

For this reason as well as the ever-present problem of peak demand in New Hampshire, energy storage is important. In 2013, the Federal Energy Regulatory Commission issued Order 784, which would encourage energy storage efforts.[27] Concentrating Solar Power technologies (CSP) already incorporate a level of storage in their system,[28] although it is not clear if there is storage available to a scale sufficient to the utility level at the moment. There are several energy storage options currently available, including battery storage, but only two are suitable for large-scale operation: Pumped Hydro Storage (PHS) and Compressed to Air Energy Storage (CAES).[29] While PHS would involve elevating water from lower to higher reservoirs, CAES would involve storing air under pressure (typically underground or in tanks or pipelines, similarly to natural gas).[30] Since energy storage is already a key component of electricity grid modernization according to the Department of Energy, it may be relevant for New Hampshire to invest more significantly in these resources so as to mitigate peak demand all the while increasing renewable energy sources.

6.3 Raising Caps on Net Metering

Another potential solution to incorporating more renewable energy into the electricity grid is raising caps on net metering. In an increasing number of communities in New Hampshire, citizens choose to establish solar panels on their homes; raising the limit for net metering may help mitigate current increased electricity demands in the state.[31]

7. INFRASTRUCTURE AND RELIABILITY

7.1 Current Infrastructure Challenges in New Hampshire

The New England grid as a whole is struggling to meet peak demand due to infrastructure failures. From the old age of the infrastructure, to difficulties with the operation, this is an area where improvement can make many differences, including financial ones, for the states involved. This situation will continue to escalate because the current natural gas pipelines cannot handle rising demand, particularly in the winter, and more dependency is turning to natural gas instead of oil or coal.[32] Furthermore, as mentioned above, New Hampshire itself is not storing energy in an efficient manner as compared to other members of ISO New England. New Hampshire's energy savings rate is only 68 GWh, while other states are up to 11 times that rate.[33] Another issue is that as the workforce ages and changes there are less power engineers, and other skilled workers that are needed to keep up with the maintenance of the power systems. Without updates to the system that require less manual labor, or concentrate the need for manual labor, the energy system will run into major difficulties with upkeep.[34] Changes may be necessary not only to keep prices down, and customers happy, but also to ensure that citizens are simply able to continue having access to the energy they need during peak demand. Additional challenges are faced with the implementation of federal energy policies. Federal regulations requiring the transition away from oil and gas based energy production will necessitate the decommissioning of current power generation facilities within the state, placing additional stress on the energy distribution system.[35]

There are numerous physical infrastructure challenges facing New Hampshire in the process of modernizing the energy grid system. The largest handicap on state electrical generation costs is a heavy dependence on natural gas as both the primary electric and thermal energy production in the state. As a result, the state is susceptible to market shortages and price spikes based on the volatility of the natural gas market. This is further exacerbated by the fact that New Hampshire is the extreme end of the natural gas supply chain.[36] A proposed solution to this challenge is increased development of variable output renewable energy (solar PV, and wind) through small-scale distributed energy production and storage throughout the grid where monitoring and distribution can be controlled through SMART grid responsive feedback technologies. This solution may likely reduce the dominance of natural gas in the state energy generation portfolio. However, this proposed solution will necessitate a restructuring of transmission lines across New Hampshire. Small-scale generation, storage, and distribution will require more robust transmission line networks to manage and transport electric generation from generation sites to areas in demand.

7.2 Midwest Electric Grid Case Study: Cost Savings

Looking at the Midwest electric grid, MISO, something important that was done in the Midwest was an evaluation of the value of the electric grid. It is important to examine the nature of weak electrical distribution infrastructure in New Hampshire as it may result in unquantified negative financial outcomes for the state. For comparison, In just one year, 2014, it was determined that $2.2 billion dollars in benefits were provided to members of MISO due to savings because the electric grid performed more reliably.[37] This dramatic number necessitates a deeper look at what was done in the Midwest to better the electric grid. New Hampshire may benefit from a similar financial operations audit of the state's electric grid. Out of the many steps undertaken in this improvement process, three are important for the New Hampshire government to follow: improved reliability, efficient market operations, and wind integration.

7.3 Midwest Electric Grid Case Study: Improved Reliability

First, there was a focus in the Midwest on improving the reliability of the grid. These improvements in reliability should be thoroughly evaluated by this committee because many of them are focused on the staffing of the grid, which may be bettered just on the state level, no matter how surrounding states respond. This is also an important focus because, as mentioned above, the number of power engineers is declining so it is necessary to better training and determine how to use this type of employee in the most efficient and effective manner. In the Midwest operators were trained above the North American Electric Reliability Corporation (NERC) requirements, with more hands-on training to fully prepare them for the job. These operators were expected to do daily evaluations of the operations to ensure that they remained functional and participate in drills to prepare for an emergency situation. [38] MISO improved the technology that operators were using to monitor the system so that they had live data and real-time market results to ensure that they truly were up to date with the functions of the electric grid. Furthermore, some of these employees were used for the 24/7 back-up control center, which allowed MISO to stop any issue before it escalated and ensure that all customers continued to receive their electricity.[39] All of these changes in the reliability of the grid operations accounted for $425 to $470 million in savings for MISO.[40]

7.4 Midwest Electric Grid Case Study: Efficiency

The next important aspect of the MISO electric grid is that the market operations are efficient. In this case in the Midwest, MISO moved from a decentralized market to an incredibly organized real-time and day-ahead energy market. The two markets operated very similarly, but the day-ahead market set financially binding standards for companies to follow in terms of the price of each energy transaction. This allows for demand to be understood and dealt with slightly in advance.[41] ISO-New England operates with use of Day-Ahead and Real-Time Energy markets as well, but can adopt better practices from the Midwest's market.[42] The markets in the Midwest "use security constrained unit commitment and centralized economic dispatch,"[43] which is an efficient way to ensure that resources are priced and dealt with based on demand.[44] This system is something that New Hampshire may attempt to emulate, particularly due to the efficiency. The true efficiency is showcased by the fact that these operations saved MISO $420 to $470 million.[45]

A successful part of the MISO grid rehabilitation that would also be a positive change in New Hampshire, partially due to the similar climate and comparable amounts of lightly populated areas, is the increased development and reliance on wind energy. An important tactic that the New Hampshire government may wish to emulate is the reliance on regional planning to ensure that wind resources are placed in the most economically efficient areas.[46] This was determined based on a calculation including rate of return, property tax-rate, insurance cost rate, fixed O&M, and depreciation.[47] This has great impacts because it reduces costs, while increasing outputs, which also allows for the installation of fewer turbines. While this may sound simple, this calculated approach allowed for $288 to $337 million in savings.[48]

The financial savings found in the Midwest speak for themselves to highlight the fact that these changes may be beneficial to other grids. It is important that the New Hampshire government is not only ensuring that citizens are provided with the best possible services, but also that all steps are being taken to save as much as possible, both for the state and its citizens. The changes taken in the Midwest are not terribly complicated, and may all be easily implemented on the state level, so that even in the rest of the ISO-New England grid chooses not too progress, the New Hampshire government is fulfilling its duty and providing citizens with the services they deserve.

8. PRICING MODELS

8.1 Pricing Challenges and Peak Demand

Pricing is a concept that is important in terms of the grid, both in New Hampshire, but nationally as well. As technology continues to develop and the push for renewable energy continues citizens are less and less willing to simply accept the price and type of energy put in front of them; instead they want to exercise their decision-making power.[49] This becomes important due to the ebbs and flows of the distribution market for energy. Every year there are time periods of "peak demand" for energy, which is when overall, consumers are requiring more energy. At this point it is very hard for the energy companies to keep up with the demand, sometimes more infrastructure is required simply due to these times of extreme demand, and often this is when companies have flaws with their operation. While customers are vaguely aware of the idea of peak demand, they do not usually feel a direct economic impact based on their decisions related to energy use.[50]

8.2 Smart Grid Technology and Real Time Pricing

A concept that is being developed and implemented around the United States is that of a "smart grid," which "incorporate[s] technology that computerizes the electric utility grid to enable digital communication among grid components."[51] Essentially, the smart grid concept allows for energy companies to utilize current data when they are making operational decisions. One of the most important aspects of this is the ability to have real-time pricing, which means pricing energy based on current demand. Often, pricing is done simply based on if demand falls under peak or non-peak in order to maintain simplicity for the customer.[52] This means that the company can raise the price during peak demand in order to incentivize customers to use less electricity during that time, something that New Hampshire has started to do. This has a large impact on the efficiency of distribution and the electricity company because it reduces their chance of an infrastructure, or other type of, failure when they are dealing with too much demand, they may be able to permanently condense their operations, and overall they can have a steadier amount of demand throughout the year instead of spikes. Another important feature of real time pricing is that it can take into account the elasticity of demand for the customer, which is very helpful it terms of predicting how the consumer will respond to changes in price, or anything else. [53]

8.3 Midwest Electric Grid Case Study: Real Time Pricing

While it is a positive step that New Hampshire has recognized these benefits and has begun to do real time pricing, not only is there still room for improvement in terms of the efficiency of said practice, but there are also other options that can be adopted from the operations of the Midwest grid. A general step that was taken in the Midwest was to develop an overall market vision and road map while developing new practices. Goals of the market vision included "develop transparent market prices reflective of marginal system cost and cost allocation reflective of cost-causation and service beneficiaries" and 'support market participants in making efficient operational and investment decisions."[54] Since these goals deal with finances and pricing they are very relevant to the idea of real-time pricing. Furthermore, when dealing with any operational scheme, but particularly one that has to do with pricing, since pricing is something that has a very direct effect on the consumer, it is incredibly important to make sure that all goals are clearly defined. The link between pricing mechanisms and the development of a market vision is very important because you do not want to make any changes in pricing that you end up going back on because you had not fully thought how they fit into other decisions. Pricing is something that will always strike a more emotional chord with the consumer, which leaves far less room for error.

Once it is determined how pricing fits into the New Hampshire market vision, another practice that may be adopted from the Midwest grid is the use of Extended Locational Marginal Pricing. Around the United States, Locational Marginal Pricing is relied upon instead of Extended Locational Marginal Pricing. Locational Marginal Pricing is a system that allows for price points to be set up "based on the value of the next megawatt of energy needed to satisfy demand, given system congestion."[55] While this system has many benefits, the flaw is that it does not take into account the operating cost at the disparate locations, which often ends up with the price being too low for what the company needs. Therefore, uplift payments are used in order to make up the difference, but this is not the most efficient system.[56] The difference with Extended Locational Marginal Pricing (ELMP), which is what is used in the Midwest, is that the system incorporates costs, such as the operating cost, into the price point so that it more accurately reflects the value. Prices through ELMP are able to naturally take into account factors such as emergency responses, errors, deviations in day-ahead prices, units operating at their minimum or maximum.[57] A system like this allows for the reduction in spikes and it is far more efficient to follow a system that naturally adjusts, than one that relies on uplift charges. Changes like this are ones that New Hampshire itself has the power to implement, and are ones that may greatly benefit the state in terms of pricing and overall efficiency.

9. POLICY RECOMMENDATIONS

9.1 Increasing Renewable Energy

Grid modernization is important because it will allow New Hampshire to move towards more renewable resources and the ever important, and ever approaching, goal of 25 percent renewable energy usage by 2025. Renewable energy must nearly double within the next decade in order to reach this goal. As the most rapidly growing forms of renewable energy include photovoltaic solar (PV), Concentrating Solar Power (CSP), and wind, these may be sectors to develop in New Hampshire. Moreover, the incorporation of real time pricing, storage, and fast acting controls to mitigate shifts in voltage and load are all important priorities for grid modernization.

9.2 Investing in Energy Storage

Energy storage is already a priority for many utilities and institutions looking ahead to the future of electricity delivery. If brought to scale, energy storage has the potential to minimize peaks in demand and facilitate grid reliability. Currently, Compressed to Air Energy Storage (CAES) and Pumped Hydro Storage (PHS) are both forms of energy storage that may be brought to scale in New Hampshire, and may be worth exploring further for potential investment.

9.3 Real Time Pricing

Furthermore, through real time pricing, the use of extended locational marginal pricing, and an overall market vision that includes pricing, the consumer and distributor alike should be able to come out in better, far more reliable place. Reliability is really a concept that should drive the grid modernization for New Hampshire, and a concept that is important enough the New Hampshire must act.

Real time pricing and extended locational marginal pricing may play an important role in establishing energy grid reliability. Real time pricing may better reflect the costs of energy production within the state, and encourage consumers to adjust their energy utilization behavior as to lessen peak demands on the grid. Increased price-sensitivity in the energy market structure may help to modulate spikes in peak energy demand in the future.

9.4 Improving Reliability

Improving the reliability of consistent and adequate energy generation in the state will depend heavily on the restructuring of the energy grid as it is modernized. Currently, one of the largest contributing factors in adequate and consistent energy production is the market pressures and variable supply of natural gas. New Hampshire may benefit from increasing the diversity of its fuel source options, with a specific focus on in-state sources. This will dampen the variability in energy production price driven by natural gas price fluctuations.

Incorporation of higher capacity powerlines to rural areas will increase the ability of distributed variable power generation sources like photovoltaics to be utilized successfully. SMART grid technology will assist in the management of these assets and provide the necessary data structures to allow real-time pricing models to be effective. Further, New Hampshire may benefit from creating incentives for private investment in local energy production.

Local fuel sources such as wood biomass may be incorporated into the overall state energy production as well. The New Hampshire Office of Energy and Planning estimates that 54 MW of power generation driven by in-state wood biomass resources would be economically viable. This solution reflects the sustainable harvest of NH forests and reflects utility scale energy production.[58]

9.5 Centralize Energy Efficiency Incentives

Current New Hampshire energy incentive structures such as rebates and tax incentives for the installation of variable output renewables are disparate and lack cohesion. A centralized database or publicly accessible forum that eliminates the barriers to public knowledge of these incentives will improve their effectiveness. Energy efficiency will play a key role in mitigating the increases in peak demand in the future.

10. CONCLUSION

While New Hampshire is a member of ISO-New England, this does not mean that the state is limited in its pursuit of changes on its own. Currently, the New Hampshire electric grid is not operating as efficiently and effectively as it might. This inefficiency impacts both distributors and New Hampshire citizens. As shown by the model of the Midwest electric grid, there are many beneficial changes that New Hampshire can make to its grid, and these are changes that New Hampshire may undertake without the other members of ISO-New England. Through improved reliability, efficient market operations, and wind integration New Hampshire itself may definitely take steps to improve the electric grid.

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