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February 19, 2021

Hon.Michael Vose
Chair, Science, Technology & Energy Committee
New Hampshire House

RE: HB315, relative to the aggregation of electric customers

Dear Rep. Vose & Members of the NH House Science, Technology & Energy Committee,

I write to you to express and explain my strong opposition to HB 315 as introduced.

By way of introduction, my name is Dr. Amro M. Farid.

- I'm a resident of Lyme, NH an an Eversource customer.
- I'm an American citizen and vote regularly.
- I am an Associate Professor of Engineering at the Thayer School of Engineering at Dartmouth[1] and an Adjunct Associate Professor of Computer Science at the Department of Computer Science at Dartmouth College. My office is located at 14 Engineering Drive, Hanover, NH. I have taught power systems engineering at the graduate level since 2010.
- I maintain a research expertise in intelligent multi-energy engineering systems which includes power systems engineering, economics, and policy. I have published over 140 peer-reviewed publications in these areas and have been externally funded by ISO New England, the Electric Power Research Institute, the Department of Energy, the Department of Defense, the National Science Fouundation, and Mitsubishi Heavy Industries. I have been invited to speak on energy related issues by the International Energy Agency, Hydro-Quebec, the Australian Energy Market Operator, Great River Hydro, the Energy Systems Integration Group, several national laboratories, and a number of prominent universities including MIT, Harvard, Princeton, Stanford and UC Berkeley.
- I am also the Chief Executive Officer of Engineering Systems Analytics (ESA) LLC which is located in Lyme, NH. ESA produces the EPECS (Electric Power Enterprise Control System) Simulation Software that ISO New England uses to conduct its annual renewable energy, energy storage, and demand-side resource integration studies.
- I am the Chair of the IEEE Smart Cities Research & Technical Development Committee[2], Chair of the IEEE Smart Buildings Load and Customers Architecture Subcommitte[3] which

[1] https://engineering.dartmouth.edu/people/faculty/amro-farid
[2] https://smartcities.ieee.org/about/ieee-smart-cities-committees
[3] https://site.ieee.org/pes-sblc/subcommittees/

oversees the IEEE's standard for Blockchain in Energy[4] and Co-Chair of the IEEE Systems, Man & Cybernetics Technical Committee on Intelligent Industrial Systems[5].
- I am a senior member of the IEEE and a member of the ASME and INCOSE.
- I received bachelors and masters degrees in mechanical engineering from MIT and a doctoral degree in engineering from the University of Cambridge, UK.
- I have won a Certificate of Merit for exceptional community service from the United States Congress.

In brief, RSA 53-E, as currently enacted, is a very good law that demonstrates effective bipartisan compromise.

1. It emphasizes economic benefits through ***market competition***.
2. It emphasizes New Hampshire's long-term prosperity through ***systemic innovation***.
3. Its implementation is ***technically feasible*** using today's technology.
4. It does not compromise ***reliable and secure grid operation***.
5. It opens the door to a ***Shared Integrated Grid*** that can deliver quantifiable synergistic benefits through real-time pricing transactive energy mechanisms.

Like all good laws, it is not without points for improvement. However, we cannot make the perfect be the enemy of the very good; especially when the proposed HB315 is vastly inferior in all five respects outlined above. The remainder of my testimony elaborates on these five points.

I. HB315 Inhibits Market Competition

My opposition to HB315 stems from the degree to which it appears entirely inconsistent with the spirit of market competition engrained in New Hampshire's laws; including its constitution, RSA 374-F and RSA 53:E. The NH Constitution at Part II, Article 83 limits and regulates the power of monopolies:

> *". . . all just power possessed by the state is hereby granted to the general court to enact laws to prevent the operations within the state of all persons and associations, and all trusts and corporations, foreign or domestic, and the officers thereof, who endeavor to raise the price of any article of commerce or to destroy free and fair competition in the trades and industries through combination, conspiracy, monopoly, or any other unfair means; [and] to control and regulate the acts of all such" entities.*

As I elaborate later, the language of HB315 does not support the stated purpose of RSA:53:E and instead dilutes its legislative effect. The original purpose of RSA 53:E is stated below:

> *"The general court finds it to be in the public interest to allow municipalities to aggregate retail electric customers, as necessary, to provide such customers access to competitive markets for supplies of electricity and related energy services. The general court finds that aggregation may provide small customers with similar*

[4] https://standards.ieee.org/project/2418_5.html
[5] https://sites.google.com/view/ieee-smc-tc-iis/

> *opportunities to those available to larger customers in obtaining lower electric costs, reliable service, and secure energy supplies. The purpose of aggregation shall be to encourage voluntary, cost effective and innovative solutions to local needs with careful consideration of local conditions and opportunities."*

Furthermore RSA 374-F states:

> *" The most compelling reason to restructure the New Hampshire electric utility industry is to reduce costs for all consumers of electricity by harnessing the power of competitive markets. The overall public policy goal of restructuring is to develop a more efficient industry structure and regulatory framework that results in a more productive economy by reducing costs to consumers while maintaining safe and reliable electric service with minimum adverse impacts on the environment. Increased customer choice and the development of competitive markets for wholesale and retail electricity services are key elements in a restructured industry that will require unbundling of prices and services and at least functional separation of centralized generation services from transmission and distribution services. ...Competitive markets should provide electricity suppliers with incentives to operate efficiently and cleanly, open markets for new and improved technologies, provide electricity buyers and sellers with appropriate price signals, and improve public confidence in the electric utility industry."*

These legal clauses provide motivation for supporting and developing competitive markets in New Hampshire. Therefore, my first and primary critique of HB315 is that it inhibits market competition. To elaborate, I refer to Attachment A in the testimony provided by Assistant City Mayor of Lebanon Clifton Below.

p.1, §1, lines 1-4; **A1** (p.1, lines 14 & 31) strikes the words "provide" and "electric power supply" from the definition of aggregation. Community Power Aggregators (CPAs) are likely to have within their jurisdiction distributed generation assests that do not qualify for direct participation in the wholesale ISO New England market. These may be conventionally-fired municipal generation assets or solar photovoltaic generation assets. Similarly, as CPAs become more sophisticated in their provision of electricity supply, they may develop the capacity to use their municipal load-consuming assets as "*virtual power plants*" that provide kilo-watt-hour (kWh) equivalent electric power supply. Although these electricity supply options are likely to be very cost effective on a kWh basis, HB315 seeks to prohibit these scenarios rather than enhance market competition through an expanded supply portfolio.

p.1, §3, lines 9-20; **A3** (p.1, lines 31-36) prohibits CPAs from providing any demand side management, conservation, or energy efficiency service that are not directly administered through a distribution utility or regional system operator. This statement should strike any neutral observer as 1.) limiting the services that a CPA can provide and 2.) making them perpetually subservient to distribution utilities; both to the detriment of electricity market competition and the stated purpose of RSA 53:E. From a common sense perspective, electricity customers do not need permission from grid operators to turn off their own lights when they leave a room, or turn down

their heat pumps before they go to sleep, so why do CPAs need permission to help customers make these decisions? Furthermore, none of these services are natural monopoly functions nor do they pose a plausible risk to grid operation and in my opinion are sufficient reason to oppose HB315.

p.1, §3, lines 16-17; **A4-A6** (p.1, lines 37-39), similarly, prohibits CPA from meter reading, customer service, and other energy related services. Again, it is difficult to understand how the authors of HB315 seek to achieve greater market competition with limited service offerings. It is well-established in energy economics that market competition grows with more service offerings rather than less. Again, an ordinary electricity customer can go on Amazon.com today and purchase a revenue-grade energy meter and hire a qualified electrician to install it in their electrical panel. So why is it that a CPA can not provide the same product? Or bundle data-centric services with the energy-meter product? It is no secret that many of New Hampshire's investor owned utilities have not invested in "smart meters" (e.g. AMI) that provide a value of electric power consumed as a function of time. In my case, as an Eversource rate payer, I have had to invest several hundred dollars of my own money to buy such an energy meter. Had their been a CPA in Lyme, I would have entertained a meter-reading service from a CPA as a means of making informed real-time decisions about my energy consumption as I now do with my own off-the-shelf energy monitor. Such a meter-reading service would have been even more attractive if the CPA bundled it in with their electricity supply service and not forced to me to buy it out-of-pocket as I have had to do as an existing Eversource customer. This example is exactly the type of real-life market competition that our electric grid needs and that RSA 53:E purposefully intends.

p.1, §3, lines 16-17; **A4-A6** (p.1, lines 37-39), also prohibits "customer service" and "other related services". Speaking as a small business owner, I'd like to kindly ask the authors of HB315 to go up to any small-business-owner in New Hampshire and tell them that there will be a new law that prohibits their business from providing customer service and instead it will be offered by a much larger competitor. I'm sure that we would hear a diversity of "colorful" responses for the simple reason that customer service is integral to the success of any delivered service; be it from a for-profit business, non-for-profit business, CPA or otherwise. Furthermore, the presence of the clause "other related services" in RSA 53-E is an open-ended invitation to spur market competition as is intended by the statute. The prohibition of "other related services" is just a blatant attempt to stifle the potential for any further developments of a competitive electricity market that were not prohibited earlier in the clause.

§5, p.2, lines 4-8; **A9-A10 (**p.2, lines 29-33) prohibits the CPA from serving as a load serving entity (LSE). Again, the proposed language in HB315 is clearly against market competition. Retail customers, businesses, and municipalities can and do act as LSEs today in ISO New England's wholesale electricity markets. I do not see how a law intended to expand market competition would specifically prohibit one type of entity from serving as a LSE, but allows others. If a municipality that has already registered as an LSE becomes a CPA would it need to withdraw its registration? I think it is plain to see that such an action reduces market competition.

§5, p.2, lines 18; **A11 (**p.2, lines 43-44, p.3, lines 1-5) further blocks CPAs from negotiating with utilities to provide access to interval metering data. I have already spoken to my actions as an Eversource customer to install my own energy monitor in my home's electrical panel. However,

such data is not just valuable to the individual homeowner, it is also critical to the development of new ***transactive energy services*** based upon ***real-time pricing***. As is well-known in economics, the availability of data is the basis for competitive, market-based ***innovation***. I will return to subjects of innovation and transactive energy later in my testimony. For now, it is unclear why HB315 would seek to eliminate this clause when the intended purpose of RSA 53:E is to spur market competition.

§5, p.2, lines 18; **A12** (p.3, lines 6-8) is a further limitation on the CPA's access to data; this time through the Electronic Data Interchange (EDI) to which all competitive electricity suppliers (CES) currently have access. Again, I don't see why RSA 53:E that is intended to achieve market competition would be well served by HB315 that would make EDI data available to some competitors and then withhold this same data from others. Such an amendment is clearly against competitive market principles.

§5, p.2, line 18; **A13 (**p.3, lines 11-13), similarly, prohibits CPA's access to individual customer for the research and development of new energy services. Again, if the purpose of RSA 53:E is to develop a competitive electricity market, then why would we introduce HB315 with clauses that directly impede their access to customer data and their ability to research, develop, and innovate? I do not see any strong rationale for this in electric power systems economics and engineering. Furthermore, as an academic with a vibrant research program, I can personally attest to the benefits of research and development activities in the State of New Hampshire; particularly as municipalities partner with leading universities like Dartmouth and UNH. I will return to this subject in the following section of my testimony.

II. HB315 Inhibits Systemic Innovation

In addition to inhibiting competition in retail electricity markets, HB315 also impedes systemic innovation in the modernization of the electric power grid and in the New Hampshire economy more broadly. The modernization of the electric power grid is not just the introduction of new technologies like smart meters, distributed automation, and solar panels. It also comes with commensurate changes in market design, regulations, and energy policy.

From an economic perspective, the most economically efficient grid does two things. 1.) It sends to consumers monetary signals of the scarcity of electrical supply. 2.) It sends to suppliers monetary signals of the availability of demand. Because electricity demand and electricity supply (especially in the presence of wind and solar generation) are time-varying, then the most efficient prices are time varying as well. Such highly efficient, time-varying rates are the norm in wholesale electricity markets like ISO New England. In contrast, the typical (default) retail electricity rate is quite static as we generally experience from our monthly residential electricity bill. Nevertheless, such static rates create all sorts of market inefficiencies because electricity prices do not reflect the balance of supply and demand. To eliminate economic efficiencies, innovations in electricity market design and regulations are required.

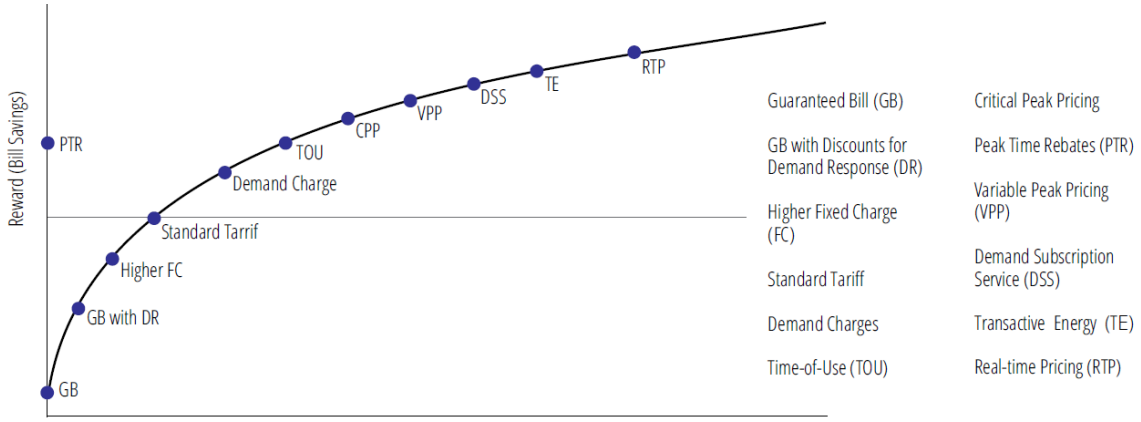

Figure 1. The Efficient Rate Frontier -- Systemic Electric Policy Innovations

One way to characterize these innovations is the efficient rate frontier shown above in Figure 1. The standard static electricity tariff serves as a baseline of sorts. In the meantime, real-time pricing based upon a ***transactive energy*** service sits all the way on the right as the most advanced but also much more economically efficient pricing approach. What is transactive energy? It is a system of market-based economic and control mechanisms that allows the dynamic balance of supply and demand across the entire electrical infrastructure using value as a key operational parameter. It's a technical term that applies to the regional interstate bulk electricity market and transmission grid that ISO New England operations. Given the current reliance on fixed rates, it does not (yet) apply to the retail electricity market and distribution grid although we have the technological means to do so through real-time pricing mechanisms. Between the standard static electricity tariff and real-time pricing based upon transactive energy service, there are a number of different options. It is in this choice that community power aggregators, or community ***choice*** aggregators as they are called in other states, have the potential to offer multiple electricity pricing schemes to New Hampshire residents based upon their preferences. As the New Hampshire resident opts towards more dynamic, even real-time pricing, the more likely that they will see economic savings on their bill. The more static their electricity rate is, the more the tariff includes a premium that is ultimately reflected in higher monthly electricity bills. Everyone is different and electricity markets should be designed to reflect the plurality of its people. The choice of electricity tariff should be left to New Hampshire's residents. Community power aggregators as they are described in RSA 53:E have the potential to greatly expand these choices. Unfortunately, the propsed HB315 severely restricts the types of electricity services that NH residents will be able to choose from.

Systemic innovation in our electric power grid's market structure also has the potential to grow our state's economy. I'd like to offer several examples. To start, the enactment of RSA 53:E in 2019 immediately attracted the interest of "community power brokers" such as NH's home grown Freedom Energy Logistics and Standard Power, along with brokers and suppliers with experience in offering competitive, though usually static, electricity rates in other states. Their presence promises to bring new services to the state's smaller electric customers, reduce electricity bills for everyday New Hampshire residents, and grow the economy through greater market competition.

Similarly, a number of demand response companies (e.g. CPower,) are taking advantage of demand response innovations in the wholesale electricity markets to provide financial benefits to

businesses and municipalities across the state. These cost savings translate to more vibrant businesses. They also translate to municipal budgets as savings to taxpayers and water & sewer utility ratepayers. Such competitive services in the electric power grid, however, are just the beginning in New Hampshire's path along the efficient rate frontier. A new regulatory innovation like 53-E with robust and diverse provisions for CPAs to compete can further advance New Hampshire's economy beyond the relatively modest services on the market today.

Consider the very end of the efficient rate frontier in Figure 1. At this very moment, the United States Department of Energy Building Technologies Office, Solar Energy Technologies Office, Vehicle Technologies Office and the Office of Electricity have released a Funding Opportunity Announcement (FOA) for R&D proposals on "Connected Communities"[6]. Winning projects will be awarded between $3-7M. Upon reading the FOA, one finds that it specifically includes the development of transactive energy services based upon real-time pricing. It also emphasizes the effective collaboration of "connected communities" with local distribution utilities. RSA 53:E, through its existing provisions for CPA, only enhances the potential for such collaborations between CPA and distribution utilities. Innovations in policy and regulations make New Hampshire much more attractive for federally funded projects.

The DOE Connected Communities FOA is not the only such opportunity. In 2019, the Thayer School of Engineering, partnered with the City of Lebanon and Liberty Utilities to study transactive energy services within the city. Liberty Utilities graciously shared load and system data. The City of Lebanon and the Thayer School of Engineering handled this data with the due care that it deserves. Most of all, the work fomented a healthy dialogue on community power aggregators, transactive energy services and real-time pricing. The work led to several peer-reviewed publications in leading conferences and journals which I attach at the end of my testimony as evidence of innovation in action [Attachment 1-3]. In his recent letter to you and this committee, Gov. Sununu wrote: "*The key for the long-term success of community aggregation will be stakeholders engaging in constructive dialogue to reach achievable policy goals".* The evidence shows that the healthy dialogue exists and is already bearing fruit.

Such collaborations between people and institutions, once initiated, often grow to bring long-term benefits. At this very moment, the Thayer School of Engineering at Dartmouth is collaborating with the Tuck School of Business at Dartmouth, MIT, UNH, the City of Lebanon and Liberty Utilities to propose a $2.5M CPA-based, real-time pricing, transactive energy service project to the National Science Foundation's Smart and Connected Communities program[7]. When federal R&D funding come into the state, it has immediate economic benefits. It creates new R&D jobs, and it supports our public and private institutions for higher education. It also showcases New Hampshire as an "innovative state" that is driving exemplary technical and economic progress. Even if this project is not awarded – this time – the benefits are already realized. The multi-university collaborative links are already established and have value. The cooperation between academia and a local municipality is already established and has value. The cooperation between a municipality interested in community power aggregation and a distribution utility is already established and has value. And there will be other opportunities to seek out federal funding for

[6] https://www.energy.gov/eere/solar/funding-opportunity-announcement-connected-communities
[7] https://www.nsf.gov/pubs/2021/nsf21535/nsf21535.htm

this type of techno-economic multilateral cooperation. RSA 53:E in its current form, without dilution by the proposed HB315, supports market-based competition and innovation.

III. The Enacted RSA 53-E is Technically Feasible

Such "fancy" R&D initiatives should not in anyway lead us to believe that community power aggregators are unattainable "rocket-science". Without qualification, we have the technical werewithall to setup effective Community Power Aggregators in the state today.

In his recent letter, Gov. Sununu says: "*Unfortunately, unanticipated complications and technical uncertainties have kept this policy change from moving forward as quickly as it should."* In some cases, I have attended some of the discussions related to the implementation of RSA 53-E and in others I have been briefed by colleagues that have attended. In my opinion, the "*unanticipated complicated and technical uncertainties*" center around the question of what, how and when data is exchanged between a distribution utility and a CPA. These questions, in turn, strike me as business negotiations rather than any veritable frontier of technical feasibility.

Let's look at this simply. Community Power Aggregators have been around a long time. Nearly a dozen states have CPA laws, and many of those have been successfully implemented some form of CPA. In some states, the CPAs have been more successful than others. And some states have allowed CPAs to do more than others. But nevertheless, the data exchange and information technologies to stand them up has been verified and is available domestically. To argue that CPAs are technically infeasible in New Hampshire when there is overwhelming evidence that they are feasible in other states is equivalent to saying that the distribution utilities and CPAs in New Hampshire are somehow technically inferior. We all know such a presumption to be false. New Hampshire's distribution utiltiies operate fine in other jurisdictions and the individuals involved in forming CPAs in New Hampshire are recognized energy experts outside the state.

So let's call the "*unanticipated complications*" for what they are: real-life business negotiations in an emerging competitive marketplace. The fact of the matter is that the what, how and when data gets exchanged has practical dollar-and-cents implications for both sides. Access to data is equivalent to market competitiveness. Furthermore, we have a retail electricity marketplace that is largely monopolistic transitioning to something that is much more multilateral. For both of these reasons, it shouldn't surprise us that there will be wrangling. It also should not surprise us when each side presents their best arguments to support their side; even if it involves red-herrings like the technical infeasibility of data exchange. As I have found so many times in my career, it's amazing how fast something can become technically infeasible when it doesn't support management's objectives.

One particular red-herring that has surfaced as a part of the implementation of RSA 53-E has been the exchange of power system data. It's a red-herring for the simple reason that there is no mention of system data in RSA 53-E. Furthermore, it is not a prerequisite to standing up a CPA because other CPAs have been implemented before without system data. So the exchange of system data should not be used as a reason to derail CPA implementation. Nor should it be a reason to support HB315 either.

So that my testimony is neither misunderstood nor misconstrued, *I firmly believe that the judicious exchange of system data with relevant grid stakeholders is beneficial for the power grid*. Even though system data is potentially sensitive, there are many precedents where system data has been transferred beyond the transmission and distribution utility under well-defined rules, monitoring, and governance. Consequently, it is insufficient to use the fact that this data is sensitive as a single means of precluding it from being shared with other relevant grid stakeholders. Leading distribution utilities like National Grid (MA,NY) and Con Edison (NY) have created web portals with relevant system data that can be used to understand relevant questions like solar photovoltaic hosting capacity. National Grid's Massachusetts portal is found at https://ngrid.apps.esri.com/NGSysDataPortal/MA/index.html. They have similar portals for Rhode Island and New York. Figure 2 shows GIS maps depicting National Grid's feeders in Massachusetts. Con Edison's portal is found at: https://www.coned.com/en/business-partners/hosting-capacity. Figure 3 shows GIS maps depicting Con Edison's feeders in New York. We actively use this data in the Dartmouth-LIINES to research and develop innovative data-centric products. Even Eversource in Connecticut provides access to an ESRI GIS layer[8], with an array of base map options and full zoom capability, for looking at hosting capacity as shown in Figure 4 below. Despite this fact, Eversource Lobbyist Donna Gamache has testified: "*... [There are] claims that communities who undertake community power plans should or must have a view of our distribution grid ... into the distribution grid. Let me be clear, there is nothing on the shelf that would enable this and therefore no idea on the overall cost and who would pay for this.*"

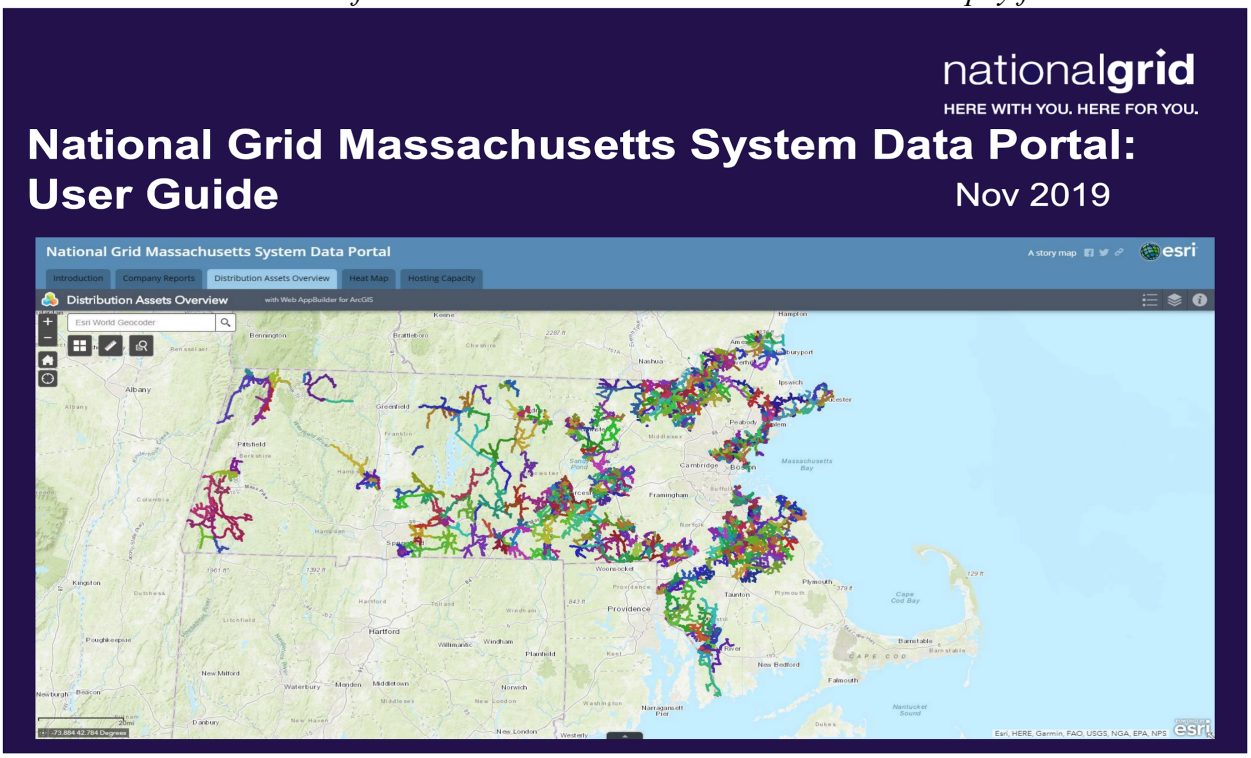

Figure 2. A Screenshot from the National Grid Massachusetts Portal Depicting Distribution System Feeder Data

[8] https://eversource.maps.arcgis.com/apps/webappviewer/index.html?id=4a8523bc4d454ddaa5c1e3f9428d8d8f

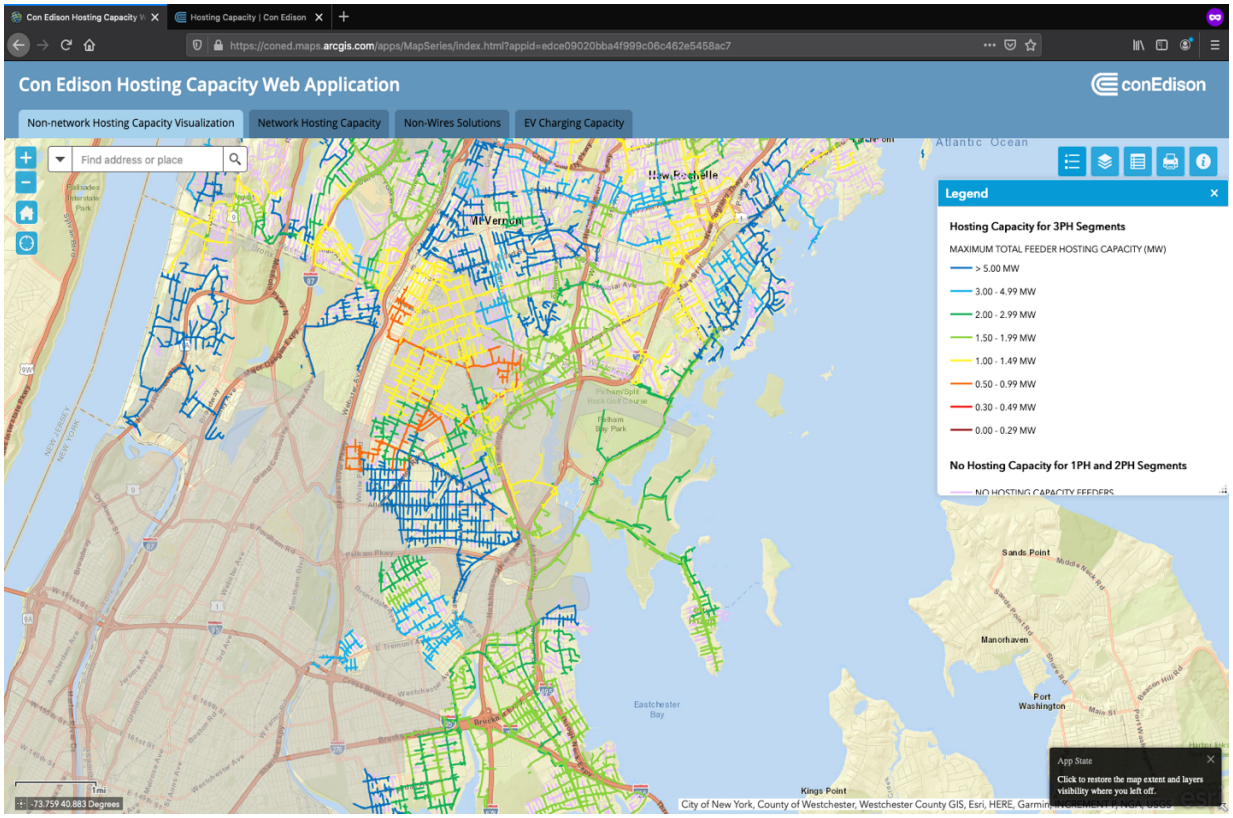

Figure 3. A Screenshot from the Con Edison New York Portal Depicting Distribution System Feeder Data

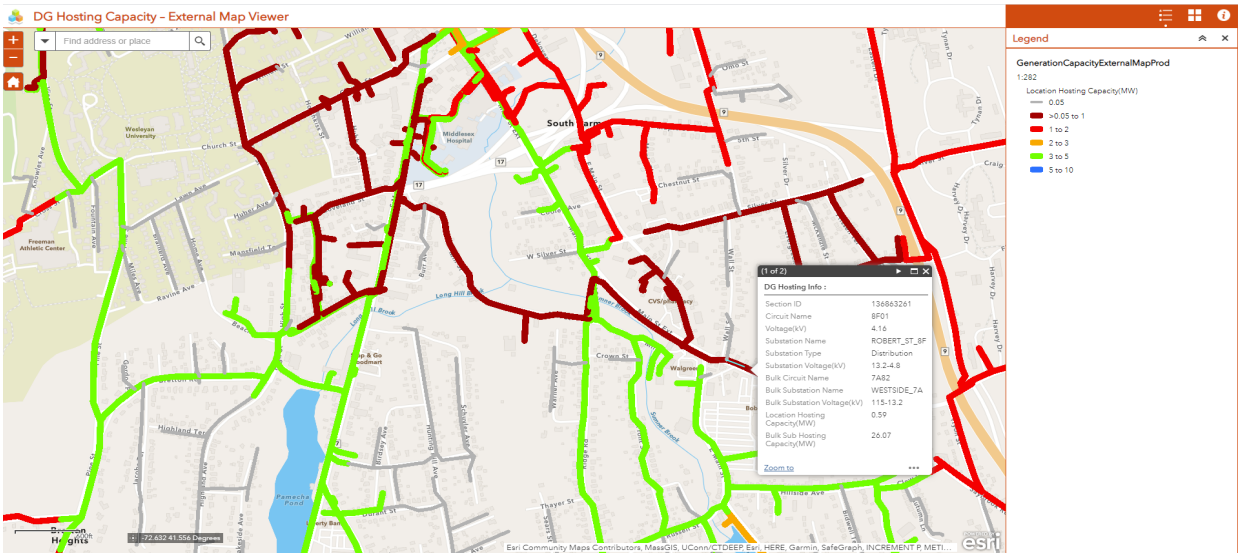

Figure 4. A Screenshot from the Eversource CT Hosting Capacity ArcGIS Map Viewer zoomed to Middletown CT

Furthermore, our research collaboration at the Thayer School of Engineering at Dartmouth involved the exchange of system data from Liberty Utilities. Beyond these immediate precedents, we need to understand that utilities exchange extensive amounts of system data in near real-time with wholesale market operators like ISO New England everyday. This exchange of system data

is used by both parties to ***collaboratively*** provide reliable, secure, and cost-effective service. Many of my ISO colleagues have relayed stories where a control room operator at an ISO calls a control room operator at a utility to ask "Are you seeing what I'm seeing?" And then they work it out. When it comes to reliable, secure, and cost-effective service, there is absolutely no reason to believe that such a ***collaborative environment*** between CPAs and utilities would not emerge. In my opinion, such a collaborative environment would emerge and it would be beneficial to all grid stakeholders and New Hampshire as a whole.

IV. The Enacted RSA 53-E Does Not Compromise Reliable & Secure Grid Operation

Unfortunately, the topic of exchanging system data with CPAs has not only been used to derail CPAs and support HB315, but it has also been used to insinuate that it would compromise the reliable and secure operation of the grid. For example, Eversource Lobbyist Donna Gamache in her testimony to this committee asked: *"How would these communities ensure security of the grid?"* I feel obliged to reject the premise of the question because it contains a logical fallacy that the exchange of system data in terms of a "view into the distribution grid" is equivalent to "ensuring the security of the grid". Utilities do need to see their own grid to secure it, but having "a view of the grid" does not mean that one must secure it! Gamache continued in the same testimony to say: "*Every single week, we receive more than 1 million hits on our system, mainly by bad characters and other countries to shut down our system.*" While I can not independently verify this number, there is a consensus in the electric power systems and cyber-security literature that protecting the grid from cyber-attacks from "bad characters and other countries" should neither be neglected nor underestimated. Nevertheless, and for many reasons, the statement is a remarkable red-herring that plays on the fears of NH residents.

- Utilities are responsible for securing their own grid assets, not CPAs.
- Exchanging system data with CPAs does not somehow absolve the utility from securing its own grid assets, nor does it imply that CPAs must now take on a new role of securing the grid.
- Securing the grid is entirely distinct from securing system data about the grid.
- Receving system data is not required to implement a CPA.
- RSA 53-E makes no mention of system data.
- Therefore, arguments about the cyber-security of exchanging system data do not support HB315 as a means of amending RSA 53-E.
- Finally, system data is exchanged today securely by leading utilities including Eversource.

Ultimately, we have the technology today to support the wide range of innovation that RSA 53-E enables without compromising the reliable and secure operation of the grid. This includes real-time pricing and transactive energy services deployed in an opt-in pilot or made available to early adopter NH residents.

V. The Enacted RSA 53-E Enables a Shared Integrated Grid

Thus far, my testimony has argued against HB315 because it impedes market competition and systemic innovation. My testimony has also argued for RSA 53-E because it is technical feasible and does not compromise the reliable and secure operation of the grid. However, I must go further.

RSA 53-E enables a ***Shared Integrated Grid***. The term Shared Integrated Grid has been developed by the Electric Power Research Institute (EPRI) as the leading institution of electric industry research & development in the United States. To be clear, this is a concept developed by leading electric utilities and has the support of leading electric power systems engineering academics now as well. Since 2017, the Thayer School of Engineering at Dartmouth has been working with EPRI to advance the Shared Integrated Grid through multiple collaborative projects.

Concretely speaking, a shared integrated grid consists of 1) network-enabled distributed energy resources and devices, 2) customer engagement in time-responsive retail electricity services (e.g. real-time pricing), and 3) community-level coordinated exchanges of electricity. The first of these is equivalently called the "energy Internet of Things". The second of these is often referred to as transactive energy services as previously defined. In the New Hampshire context, the third of these is most easily understood as community power aggregations (CPAs). Our recent open-access book, eIoT: The Development of the Energy Internet of Things in Energy Infrastructure, commissioned by EPRI (https://www.springer.com/gp/book/9783030104269) explains how these three elements combine to create a shared integrated grid. I have also presented on the topic of the Shared Integrated Grid, the energy Internet of Things, and eIoT information standards at a recent workshop hosted by EPRI and Stanford University. See attached slides [Attachment 4].

Mike Howard President and CEO of EPRI describes the shared integrated grid in his September 2018 article in the EPRI Journal (https://eprijournal.com/welcome-to-the-new-world-of-the-interactive-energy-customer/). On the same page, hyperlinked below is a video that explains the shared integrated grid (Shared Integrated Grid by EPRI: https://youtu.be/PknNL0TnCxQ). Though the video is worth watching for the graphics, for convenience, it is transcribed here: "*Imagine an energy future when smart appliances, water heaters, thermostats energy, storage, electric vehicle chargers, and rooftop solar are more than customers assets. They are energy solutions integrated with electric grid planning and operation that can enhance resiliency and provide value to customers at all levels of the grid, creating a shared integrated grid. Much like the mobile apps that make subletting an apartment today easier than ever before, network operators can seamlessly enable a shared integrated grid by introducing a platform to better utilize shared energy resources. By connecting to this platform through an app many different businesses can offer shared energy solutions for customers enabling next-generation demand response, more efficient use of grid assets, more robust ancillary services, and improved hosting capacity to support more electric vehicles and solar PV on the grid. Smart water heaters that work hardest when electricity demand or prices are low, thermostats that enable network operators to reduce peak demand and operate distribution assets more efficiently, and customer-owned chargers that fuel electric vehicles with the capability to shift charging to times of excess generation capacity.*"

"In this future, grid investments can expand to include acquiring grid services from customers' assets. Transmission and distribution companies can harness these emerging technologies which provide customer energy solutions and grid support. Participating customers can receive incentives to share their resources for grid support, and society can benefit through a lower overall cost for all customers. Realizing this vision requires a platform that fully integrates grid planning and operation with those distributed energy resources that customers have opted in to share with

the grid. In addition to buying a water heater from a store or website, a customer can purchase it from any qualifying solution provider through a shared integrated grid e-commerce platform, by logging into an app that is integrated with the network operations and planning system, and with one simple click selecting a smart water heater to be installed by a trusted service provider, with incentives based on the customers' needs and the value to the grid. For customers, the app can provide customized alerts over the life of an appliance identifying service needs and offering energy-saving tips. For network operators, the same platform serves as a standard interface connecting the asset to utility planning systems and distribution operation systems and linking to aggregated services for the bulk power system, through secure interfaces enabling real-time operation and planning, with a customer-owned asset like a water heater treated as a wire's asset for the purpose of grid investment planning. The result: a connected device such as a water heater can then optimize energy use based on grid needs shifting from heating water as needed over the course of the day to working at times when energy demand is low and limiting use when demand is high, all without impacting the customer's comfort."

"Through this approach, the definition of transmission and distribution investments expands to include grid services delivering greater value to customers and all levels of the grid. Connected technologies can create a shared integrated grid, a new e-commerce reality, and a win-win situation for network operators and every customer; a cost-effective approach that enables better-informed resource planning and strategic capital investments at the individual customer level; unlocking better service quality, improving the customer experience, and providing greater value by integrating resources from the customer's home to the community and the grid as a whole. The shared integrated grid, a key component of the integrated energy network can provide for clean cost-effective electricity with greater customer choice, comfort, convenience, and control The Electric Power Research Institute is leading collaboration with industry and other stakeholders to enable this customer-focused energy future."

Another video on the same page explains the role of the interactive energy customer in the shared integrated grid (The Interactive Energy Customer by EPRI: https://youtu.be/-hpxUymaR48. See also The Six Cs by EPRI: https://youtu.be/15A8WKFXt1k). For convenience, it is transcribed here: *"The grid that has served electric utility customers well for more than a century is changing, adapting to new demands, and evolving to meet new expectations. Originally designed for one-way service the grid has become an integrated energy network, an enabler of new technologies that provide greater customer choice and enhanced service reliability and affordability. In an era of e-commerce enabled by mobile apps increasingly connected customers expect streamlined access to products and services that align with their lifestyle. A convergence of new technologies and rising customer expectations presents forward-thinking utilities greater opportunities to connect with customers, when and how they want to become more than an energy provider: an energy partner, making a better quality of life possible for all. The interactive energy customer is central to a shared integrated grid, one that redefines utility capital investments by encouraging customer-specific improvements that deliver value to all, empowering customers to make better energy management decisions, enabling utilities to better draw from customer-owned resources, to actively manage today's resources and better plan for the future, enhancing cybersecurity to securely manage the data, making this new utility reality possible and encouraging efficient electrification to make the most of our natural resources while delivering reliable, safe, affordable,*

and cleaner energy. The technology to enable this energy future already exists, customers are ready for the change, forward-thinking utilities can take a bold step forward by embracing new and emerging technologies to expand their energy service capabilities, enhance service quality, drive greater value, and better engage with the interactive energy customer."

The shared integrated grid as it is described above is entirely consonant with the legislative objectives of RSA 53-E, RSA 374-F, and the emphasis on competitive markets in New Hampshire's constitution. It specifically enables the state's energy systems to become more distributed, responsive, dynamic, and consumer-focused. It promotes innovative business applications that will save customers money, allow them to make better and more creative use of the electricity grid, and facilitate municipal and county aggregation programs authorized by RSA 53-E. It will enable animated and competitive retail electricity markets and help customers to obtain lower electric costs, reliable service, and secure energy supplies. It also emphasizes the type of ***effective collaboration*** that Gov. Sununu has sought by writing: "*The key for the long-term success of community aggregation will be stakeholders engaging in constructive dialogue to reach achievable policy goals".* In short, the shared integrated grid is the leading industrial concept for New Hampshire to achieve its objectives.

While a shared integrated grid can realize the legislative objectives of RSA 53-E, in many ways its implementation has been elusive for a variety of non-technical and often implicit barriers. The distinguished energy economist Dr. Ahmad Faruqui in his recent article in the journal Regulation entitled "Refocusing on the Consumer: Utilities' regulation needs to prepare for the "prosumer" revolution" recounts the more than 50-year saga of trying to advance a basic building block of grid modernization: customer access to meaningful choices of time-varying rates. [Attachment 5] . He summarizes this saga and the current state grid of modernization in this way:

"It's obvious that both regulators and energy executives are frozen in time and they know it. They spend much of their time blaming each other for the delays. The blame game continues unabated at many industry events. The pace, ambiguity, and inconclusiveness of this regulatory drama seem to be a reenactment of the play Waiting for Godot. . . . "

"While every state is in a big rush to move ahead with decarbonization and has specified some very aggressive timelines for becoming 100% decarbonized, just about all the policy solutions are on the supply side. There is almost no inclusion of dynamic load flexibility, which could help deal with the intermittent nature of renewable energy."

"For those of us who work in the electric utility industry, the time has come to rethink regulation, reimagine the utility, and reconnect with the real customer. That journey can no longer be delayed. ...This journey will involve finding new ways to engage with customers and observing those customers in real-time to understand their energy-buying decisions. Unless these steps are undertaken, the customer is going to leave both the utility and the regulator in the dust."

The enactment of RSA 53-E and RSA 374-F provide a legal pathway to overcome these implicit barriers and realize the Shared Integrated Grid and create quantifiable synergistic benefits in New Hampshire. My laboratory at the Thayer School of Engineering at Dartmouth recently conducted

the New England Energy Water Nexus Study as a collaborative project, funded by the United States Department of Energy, and now published in the prestigious peer-reviewed journal Renwable and Sustainable Energy Reviews [Attachment 6].

Balancing Performance	
Average Load Following Reserves	1.24–12.66%
Average Ramping Reserves	5.28–18.35%
Percent Time Curtailed	2.67–10.90%
Percent Time Exhausted Regulation Reserves	0%
Std. Dev. of Imbalances	3.874–6.484%
Environmental Performance	
Total Water Withdrawals	0.65–25.58%
Total Water Consumption	1.03–5.30%
Total CO_2 Emissions	2.10–3.46%
Economic Performance	
Total Day-Ahead Energy Market Production Cost	29.30–68.09M$
Total Real-Time Energy Market Production Cost	19.58–70.83M$

Figure 5. A Balanced Scorecard from the New England Energy-Water Nexus Study Showing the Quantifiable Cross-the-Board Synergistic Benefits of Flexible Energy-Water Resources.

The premise of the project was to quantify the benefits of using "energy-water resources" like water heaters, water utilities, and wastewater utilities as flexible resources in the ISO New England energy markets. The values shown in Fig. 5 assume a modest penetration of ~5% of peak electricity load of these resources. The wide ranges in values stem from six different future energy scenarios; ranging from "business-as-usual" to "high renewables". Fig. 5 summarizes the final conclusion of the work: ***In ALL the future energy scenarios studied, enabling the flexible participation of energy-water resources improves the grid's reliable balancing operation, improves the grid's environmental performance in terms of water use and CO2 emissions, and saves tens of millions of dollars per year for New England's residents WITHOUT trade-off.***

The primary impediment to realizing these benefits is that real-time prices that we see in the wholesale electricity markets must translate down to customers with energy-water resources in the distribution system. The Shared Integrated Grid is the techno-economic vehicle for real-time pricing transacive energy service in the distribution system. RSA 53-E, in turn, is the legislative vehicle for enabling the Shared Integrated Grid through CPAs. Therefore, I urge the New Hampshire legislature to "stay-the-course" and oppose HB315 for what it is: a regressive bill that hinders market competition, systemic innovation, and a whole host of quantifiable technical, economic, and environmental benefits.

VI. Conclusion

This testimony that I have provided here is that of a volunteer and engaged citizen-scientist. It is my technical opinion based on a decade of well-developed academic credibility, and accumulated scientific expertise in power systems engineering and economics. I can attest that my testimony is free from any financial conflict of interest; including with any of the investor owned utilities and with any of the emerging community power aggregators. As a voting citizen and an Eversource rate payer, it is my preference to purchase electricity from another source; if given the choice. As a scientist and academic, my research publications demonstrate extensive evidence that such market competition and innovation would spur synergistic technical, economic and environmental benfits across the state; as RSA 53:E, RSA 374, and the state constitution intend.

Sincerely,

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