**THE STATE OF NEW HAMPSHIRE**

**BEFORE THE**

**PUBLIC UTILITIES COMMISSION**

**DE 19-197**

# Electric and Natural Gas Utilities

# Development of a Statewide, Multi-use Online Energy Data Platform

Testimony of Dr. Amro M. Farid

On behalf of
City of Lebanon, NH &
Local Government Coalition

August 17, 2020

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## I. Introduction and Qualifications

**Q1.1. Please state your name, business address, and position relative to this docket.**

A1.1. My name is Dr. Amro M. Farid. 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 Science at Dartmouth College, which is located at 14 Engineering Drive, Hanover, NH. I am also the Chief Executive Officer of Engineering Systems Analytics (ESA) LLC which is located at 89 Washburn Hill Road, Lyme NH.

**Q1.2. Please describe your background and qualifications as they relate to energy data platforms and software development.**

A1.2. I received my B.Sc. in 2000 and M.Sc. in 2002 from the MIT Mechanical Engineering Department. I received my Ph.D. in Engineering in the area of Industrial Automation and Control Systems Engineering from the University of Cambridge (UK) in 2007. In addition to the formal positions stated above, I am the director of the Laboratory for Intelligent Integrated Networks of Engineering Systems (LIINES) at the Thayer School of Engineering at Dartmouth.[2] I am a research affiliate at the MIT Mechanical Engineering Department. I currently also serve as Chair of the Council of Engineering Systems Universities[3] (CESUN). I am the Chair of the IEEE Smart Cities Technical Activities Committee[4], the Chair of the IEEE Smart Buildings Loads and Costumers Architecture Subcommittee[5], and the Co-Chair of the IEEE Systems, Man & Cybernetics Technical Committee on Intelligent Industrial Systems[6]. I am a senior member of the IEEE and a member of the ASME and INCOSE.

[1] https://engineering.dartmouth.edu/people/faculty/amro-farid
[2] https://amfarid.scripts.mit.edu/
[3] https://cesun.org/
[4] https://smartcities.ieee.org/about/ieee-smart-cities-committees
[5] https://site.ieee.org/pes-sblc/subcommittees/
[6] https://sites.google.com/view/ieee-smc-tc-iis/

As an academic, I maintain an active and broad computational research expertise in intelligent energy systems across five research themes: smart power grids, energy-water nexus, electrified transportation, industrial energy management, and interdependent smart city infrastructures. Consequently, we have extensive experience in software engineering and "Big Data Analytics" as they pertain to energy applications. I have published over 140 peer-reviewed publications in these areas. Our research projects have been externally funded by ISO New England, the Electric Power Research Institute, the Department of Energy, the Department of Defense, the National Science Foundation, and Mitsubishi Heavy Industries. This academic research has led to several notable achievements of particular relevance to this docket. 1) The Dartmouth-LIINES has published some of the latest methodological research supporting the integration of variable renewable energy, energy storage, and demand-side resources. 2) We have conducted the 2017 ISO New England System Operational Awareness and Renewable Energy Study (SOARES) and presented it to ISO New England stakeholders in 2018. 3) We have published the first book on the "energy Internet of Things" (eIoT). It discusses how network-enabled energy devices (or the energy Internet of Things) will play an indispensable role in bringing about a cost-effective transition to sustainable energy. 4) We have published extensively on distributed-ledger based "Transactive Energy" markets and control systems where deregulated retail electricity markets support near real-time transactions of electricity from distributed energy resources (DERs) in a manner that is similar to the energy markets found in wholesale independent system operators. The Dartmouth-LIINES has also completed several relevant publications on the Shared Integrated Grid, in general, and the more specific cases of New England region and the State of New Hampshire.

As a professor, I actively teach a course on model-based systems engineering which explains how to collaboratively architect, design, and ultimately implement complex engineering systems including, specifically, complex software systems. I also actively teach a course in power systems engineering from technical, economic, and policy perspectives.

As a small business owner of ESA LLC, we have developed the Electric Power Enterprise Control System (EPECS) Simulator and licensed it to ISO New England for their planned integration of variable renewable energy, energy storage, and demand-side resources. It was the central software used in the SOARES study. ISO New England is currently using the EPECS and plans on doing so until 2025 (at a minimum).

**Q1.3. Have you previously testified before this Commission?**

A1.3. No, I haven't.

**Q1.4. On whose behalf are you testifying?**

**A1.4.** I am testifying on behalf of the City of Lebanon & the Local Government Coalition. I am also testifying as an Eversource customer and New Hampshire ratepayer on my own behalf.

**Q1.5. In what capacity are you working with the City of Lebanon & the Local Government Coalition?**

A1.5. I am serving as a volunteer technical advisor to the City of Lebanon in its development and implementation of a community power aggregation that realizes a "shared integrated grid" in accordance with the legislative objectives of Senate Bill 284 and RSA 53-E as amended by Senate Bill 286. To that end, for several years, the Dartmouth-LIINES has been working with the City of Lebanon and Liberty Utilities to develop a prototype for a distributed-ledger-based transactive (real-time-pricing) energy platform that combines all three elements of a shared integrated grid.

**Q1.6. Explain the interest of the City of Lebanon and the Local Government Coalition in the creation of a statewide, multi-use online energy data platform.**

A1.6. The City of Lebanon and the Local Government Coalition are interested in the development and implementation of a community power aggregations that realize a "shared integrated grid" in accordance with the legislative objectives of Senate Bill 284 and RSA 53-E as amended by Senate Bill 286. As Section III details, the statewide multi-use online energy data platform, herein simply called data platform, is an integral and essential part of realizing such a shared integrated grid.

**Q1.7. Please describe your involvement in DE 19-197 to date.**

A1.7. I have attended most or all of the technical sessions and provided commentary in my areas of expertise. I was the first author to Local Government Coalition scoping comments [LGC-2020-1], identification of use cases [LGC-2020-2], and the responses to Joint Utility Comments [LGC-2020-3].

## II. Overview of Testimony

**Q2.1. What is the purpose of your testimony?**

A2.1. The purpose of my testimony is to testify that a shared integrated grid is the leading industrial concept for New Hampshire to achieve its legislative objectives. Furthermore, such a shared integrated grid cannot be achieved without a data platform that engages the participation and communication of grid stakeholders. It is foundational. I then testify that such a data platform, if developed following the best practice of software systems engineering, is technically feasibly, commercially viable and very much in the best interest of the New Hampshire public.

**Q2.2. Would you summarize your testimony?**

A2.2. This testimony is part of the overall testimony provided by the Local Government

Coalition and augments the testimony provided by Clifton Below, Samuel Golding, April Salas, and Kat McGhee.

I have divided my testimony into four sections labeled below as Section 3-7. Section 3 describes what is meant by a Shared Integrated Grid and explains how it meets the legislative objectives of Senate Bill 284 and RSA 53-E. Section 4 identifies the broad and diverse categories of stakeholders that I expect would use this data platform. Section 5 describes the best software systems engineering practice to identify the data platform's stakeholder requirements and then translate them into a set of functional requirements stated in a technical language appropriate to a software systems engineer. It also summarizes the Local Government Coalition's stakeholder requirements as detailed in the scoping comments [LGC-2020-1] and use cases [LGC-2020-2]. Section 6 provides general guidance on how to best implement the data platform including its inclusion of costumer data, market/financial data, and system data, its use of widely accepted international standards from the IEC, and finally the availability of viable commercial solutions on the market today. Section 7 concludes with guidance on the data platform's governance to maximize the likelihood that New Hampshire's legislative objectives are realized.

## III. Shared Integrated Grid as a Realization of Legislative Objectives

**Q3.1. What is meant by a Shared Integrated Grid?**

A3.2. 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. 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. 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 is attached as Attachment G [Muhanji 2019] 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 slides attached as Attachment C [Farid 2020].

Mike Howard President and CEO of EPRI describes the shared integrated grid in his September 2018 article in the EPRI Journal[7]. On the same page, hyperlinked below is a video that explains the shared integrated grid[8]. 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

[7] https://eprijournal.com/welcome-to-the-new-world-of-the-interactive-energy-customer/
[8] Shared Integrated Grid by EPRI: https://youtu.be/PknNL0TnCxQ

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[9]. 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

[9]The Interactive Energy Customer by EPRI: https://youtu.be/-hpxUymaR48. See also The Six Cs by EPRI: https://youtu.be/15A8WKFXt1k.

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."

**Q3.2. What are the legislative objectives of Chapter 286, NH Laws of 2019 (SB 284)?**

A3.2. In the enactment of SB 284, the legislature found that:

> *"In order to accomplish the purposes of electric utility restructuring under RSA 374-F, to implement fully the state energy policy under RSA 378:37, and to make the state's energy systems more distributed, responsive, dynamic, and consumer-focused, it is necessary to provide consumers and stakeholders with safe, secure access to information about their energy usage. Access to granular energy data is a foundational element for moving New Hampshire's electric and natural gas systems to a more efficient paradigm in which empowering consumers is a critical element. By enabling the aggregation and anonymization of community-level energy data and requiring a consent-driven process for access to or sharing of customer-level energy usage data, the state can open the door to innovative business applications that will save customers money, allow them to make better and more creative use of the electricity grid as well as other utility services, and facilitate municipal and county aggregation programs authorized by RSA 53-E. Such a program of robust data is also likely to be useful in local planning, conducting market research, fostering increased awareness of energy consumption patterns, and the*

*adoption of more efficient and sustainable energy use." (Chapter 286:1, NH Laws of 2019)*

**Q3.3. What are the legislative objectives of RSA 53-E?**

A5.2. RSA 53-E:1 states:

*"The general court finds it to be in the public interest to allow municipalities and counties 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 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."*

**Q3.4. How does a shared integrated grid realize the legislative objectives of SB 284 and RSA 53-E?**

A3.4. The shared integrated grid as it is described in my response to Q3.1 is entirely consonant with the legislative objectives of SB 284 and RSA 53-E. 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. 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 SB 284 and 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[10] 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. [Faruqui 2020][11]. He summarizes this saga and the current state grid 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 SB 284 (Data Platform) and SB 286 (RSA 53-E and RSA 374-F amendments) provide a legal pathway to overcome these implicit barriers.

**Q3.5. How is a statewide, multi-use online energy data platform an integral and essential part of realizing such a shared integrated grid?**

A3.5. The 1) network-enabled distributed energy resources and devices, 2) customer

[10] https://www.brattle.com/experts/ahmad-faruqui
[11] Attachment D, also found at https://www.cato.org/sites/cato.org/files/2020-03/regv43n1-6.pdf.

engagement in time-responsive retail electricity services (e.g. access to real-time pricing), and 3) community-level coordinated exchanges of electricity supply and related services all require a state-wide, multi-use online energy data platform as a prerequisite information infrastructure. The statewide multi-use online energy data platform would allow for network-enabled distributed energy resources and devices to communicate the prices and quantities of electricity services that they provide or utilize in real-time. The data platform would allow customers to engage by sending and receiving their consumption and distributed generation data and reporting the status of energy storage capacity to charge or discharge, not unlike spinning reserve. The data platform would send and receive the price and quantity data inherent to the coordinated exchange of electricity at the community level. In short, there is no shared integrated grid without a data platform that engages the participation and communication of grid stakeholders. It is foundational.

## IV. Identification of Stakeholder Users of the Statewide Multi-Use Online Energy Data Platform

**Q4.1. Should the NHPUC Order in DE 19-197 specify the categories of stakeholder users of the statewide multi-use online energy data platform?**

A4.1. Yes. It would be impossible to define the energy data platform with any level of precision without stating explicitly the stakeholder uses of the data platform.

**Q4.2. What are the categories of stakeholder users of the statewide multi-use online energy data platform?**

A4.2. RSA 378:50 specifically mentions customers, utilities, service providers as defined in RSA 363:37 and the office of the consumer advocate but does not explicitly state these stakeholders as explicit users of the data platform. Nevertheless, in order to meet the legislative objectives of SB 286 and RSA 53-E, a broad diversity of stakeholders should be allowed access to the data platform. Please see *Figure 1* below.

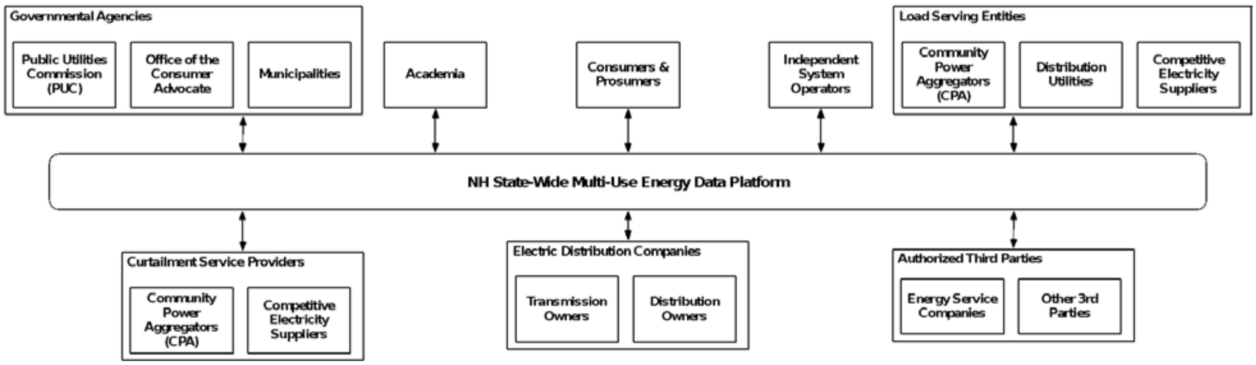


*Figure 1. Interfaces between a NH State-Wide Multi-Use Energy Data Platform and NH Energy Stakeholders*

In Attachment K, labeled [LGC-2020-2], the Local Government Coalition identifies 15 categories of stakeholders.

## V. Determination of Stakeholder Requirements and Data Platform Function

**Q5.1. Should the NHPUC Order in DE 19-197 determine the stakeholder requirements of the Data Platform?**

A5.1. Yes. RSA 378:51-54 provides several high-level requirements for the data platform. RSA 378:51, II requires: “The commission shall open an adjudicative proceeding … to determine governance, development, implementation, change management, and versioning of the statewide, multi-use, online energy data platform.” From an engineering perspective, the first step in the development of any technical artifact is to define its stakeholder requirements and so we would expect this docket to do so as well.

**Q5.2. Should the NHPUC Order in DE 19-197 specify the functional requirements of the Data Platform?**

A5.2. No. It is very important in software systems engineering to distinguish between stakeholder requirements and functional requirements. Please see *Figure 2* below which is drawn from our recent publication identified as Attachment B, [Farid 2016].

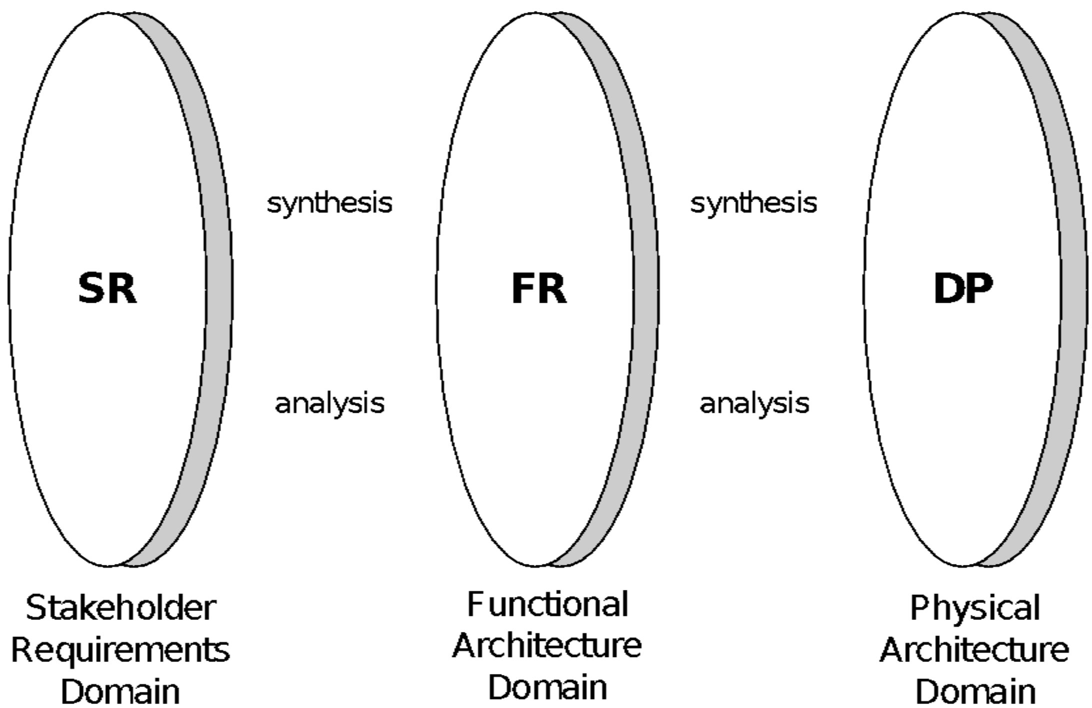


*Figure 2. Three Domains of Engineering System Design and Development [Farid 2016]*

The domain of stakeholder requirements is developed in an open forum of relevant stakeholders stated in the "language of the stakeholder" — be it of a lay, legal, business, or technical nature. The proceeding of this docket is a good example. Functional requirements, in contrast, are part of the functional architecture. They are stated in the language of a technically minded software engineer so that a group of engineers can straightforwardly implement them following a software engineering process. The distinction between the stakeholder requirements and the functional requirements means that the former must be reconciled and translated into the latter in a process that systems engineers call "requirements engineering". This requirements engineering process is often done by a small group of technically-trained (software) systems engineers. The technical activity of requirements engineering requires painstaking attention to detail and follows established formal methods. The interested reader is referred to several dedicated texts on requirements engineering[12,13,14]. Furthermore, the LGC scoping comments marked as Attachment J, [LGC-2020-1] provide an extensive discussion of requirements engineering as it pertains to this docket.

Therefore, it would be entirely inappropriate for an adjudicative regulatory process to conduct the requirements engineering process. It is unreasonable to expect the intervenors of the docket to follow the best practice of the technically-oriented process of requirements engineering.

The conceptual answer above is also the overwhelming precedent of industrial practice. Large complex systems, be they software systems or physical systems have been deployed by many federal government agencies including the Department of Defense, NASA, and the Department of Energy. As a general rule, the stakeholders (e.g. the government agency) defines the stakeholder requirements and then a contracted engineering organization conducts the requirements engineering process to produce the functional requirements.

**Q5.3. Should the Utilities specify the functional requirements of the Data Platform? Platform?**

A5.3. No. The engineering organization conducting the requirements engineering process is not necessarily the same as the engineering organization that designs, develops, and deploys the software system itself. Indeed, it is inadvisable to have them be the same when the design and development organization is operating as a monopoly, as is the case here.

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[12] K. Pohl, Requirements Engineering: Fundamentals, Principles, and Techniques. Springer Publishing Company, Incorporated, 2010.

[13] B. Berenbach, D. Paulish, J. Kazmeier, and A. Rudorfer, Software and Systems Requirements Engineering: in Practice. McGraw-Hill, Inc., 2009.

[14] E. Hull, K. Jackson, and J. Dick, Requirements engineering. Springer Science and Business Media, 2010.

Two types of problems can occur. First, the design and development engineering organization can state the functional requirements in such a way that they themselves create a highly inflated estimate of the design and development cost overall or selectively for certain requirements. This is a very real financial incentive against the interests of stakeholders. Furthermore, the design and development engineering organization can state the functional requirements with an "inward focus" rather than a stakeholder focus. As discussed in Attachment D [Faruqui 2020], utilities need to be "customer," or more generally, stakeholder focused rather than utility-focused. Instead, if another engineering organization states the functional requirements, then there is no such financial incentive. They would state the functional requirements in as straightforward a manner as possible to facilitate competitive cost estimates.

The second problem arises from the distinction between validation and verification[15]. Verification is the process of matching the developed software system to the specified functional requirements. It determines if the system has been "built right". Validation is the process of matching the developed software system to the stakeholder requirements. It determines if the "right system" has been built. When the engineering company responsible for requirements engineering is the same as the engineering company responsible for the design and development, then the distinction between verification and validation is blurred and the "right system" may never be deployed or be "built right". Ultimately, verification should be done by the engineering organization responsible for design, developments, and deployment of the software system and validation should be done by the engineering organization responsible for requirements

[15] D. M. Buede, The Engineering Design of Systems: Models and Methods. Hoboken, N.J.: John Wiley & Sons, 2nd ed., 2009.

engineering.

Finally, as a practicing engineer with an expertise in software systems engineering, I do not interpret RSA 378:52, I that states: "the utilities shall design and operate the energy data platform" to mean that they shall also specify the functional requirements. The processes of design and operation happen after the specification of functional requirements not during. Furthermore, I do not interpret RSA 378:52, I to mean that the utilities shall exclusively conduct all technical activity related to the data platform. Given the fact that the electricity and natural gas distribution utilities operate as monopoly service providers and have a vested interest in their current business model, which includes growth in invested capital and profits that are closely related to growth in distribution system capacity, often driven by growth in coincident peak demands, I do not believe it to be in the best interest of the New Hampshire public to do so.

**Q5.4. Are there commercially viable engineering organizations with expertise in requirements engineering?**

A5.4. Yes, absolutely. The well-known names are Navigant, Booz Allen Hamilton, Exponent, and Accenture. Beyond these, there is no shortage of niche engineering consultancies that are often less expensive.

**Q5.5. Should the NHPUC Order in DE 19-197 use an agile software engineering process to identify stakeholder requirements?**

A5.5. No, the question is a logical non-sequitur. Returning back to *Figure 2*, any software engineering process be it "traditional software engineering" or "agile software engineering" is defined as the process of transforming the (technical) functional requirements into the software system itself — shown as the physical architecture in *Figure 2*. Consequently, the domain of agile software engineering is downstream and not concerned with the identification of stakeholder requirements.

**Q5.6. Should the Utilities design, develop, and deploy the energy data platform using an agile software engineering process?**

A5.6. Yes, the energy data platform should be designed, developed, and deployed using an agile software engineering process.

As an active computational research academic and a CEO of a software development organization, we practice agile software engineering every day. It has no doubt become the best practice of software engineering in the last two decades. In traditional software engineering, the process of taking the functional requirements and turning them into the software system itself happens in one large development cycle called the "systems engineering vee". In contrast, agile software engineering uses several full development cycles. Consequently, project risks, costs, and lead times can often be controlled more effectively than traditional software engineering. It helps software engineers develop effective software products of increasing complexity with each passing iteration. A highly simplified but entirely adequate depiction is shown in *Figure 3* taken from Slide 15 of Unitil's Slide Deck entitled: "Platform Development and Oversight DE 19-197 Technical Session".

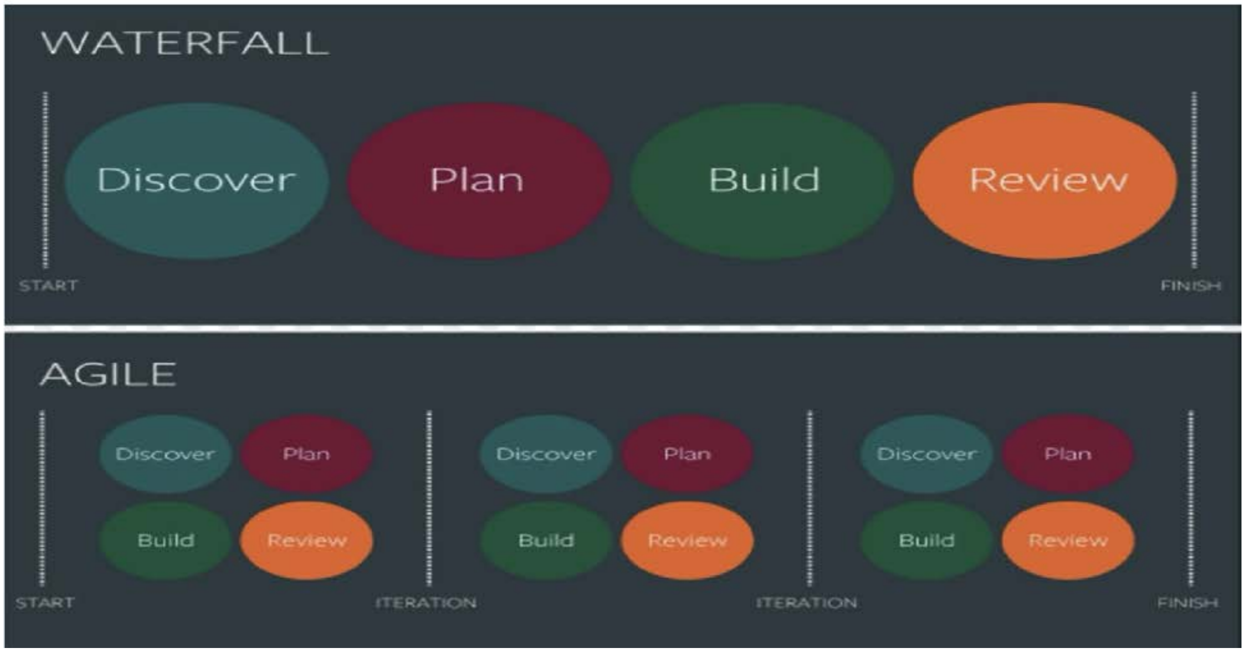


*Figure 3. Unitil's Graphical Contrast of Traditional (Waterfall) vs Agile Software Engineering*

Nevertheless, the answer to this question should be taken in the context of Answer 5.4 above, and Answer 5.13 below.

**Q5.7. Is it a valid alternative to delegate the determination of stakeholder requirements to a governing "data platform council" responsible for the governance of the data platform?**

A5.7. Not by default. While a governing "data platform council" can potentially determine a set of functional requirements for the data platform using an open process of stakeholder engagement, it is not clear how the stakeholder requirements that they determine would have any binding effect on how the utilities "design and operate the energy data platform" as in RSA 378:52, I. In other words, the governing data platform council would first require a strong governance mandate that the utilities would have to follow, short of an adjudicated appeal to the Commission. Furthermore, such a data platform council would have to operate in a manner that is at least as open as this DE 19-197 docket in order for it to gain acceptance by this docket's diversity of intervenors.

**Q5.8. Is it a valid alternative to delegate the determination of the functional requirements to a governing "data platform council" responsible for the governance of the data platform?**

A5.8. No. The requirements engineering process of reconciling and translating stakeholder requirements to functional requirements is a technical process that is best conducted by an engineering organization with that specific expertise.

**Q5.9. How far can the NHPUC Order in DE 19-197 proceed with the remaining technical aspects identified in RSA 378:51 prior to the determination of the data platform's functional requirements?**

A5.9. Not at all with any specificity. In any engineering design or systems engineering process, be it for software or otherwise, be it agile or otherwise, the functional requirements must first be defined as a closed set and agreed upon. No other technical activities can proceed with any level of specificity without defining such functional requirements.

Part of the challenge of the DE 19-197 Docket thus far is that it has sought to have specific answers to the identification of standards, the development of a user-friendly interface, the development of a logical data model, privacy of data, security of data, software development, software implementation, change management, and versioning all before the functional requirements have been fully determined. Consequently, my testimony on these items, out of engineering diligence and best practice, is made in general rather than specific terms.

**Q5.10. Then what are the stakeholder requirements to which the statewide multi-use online platform must adhere?**

A5.10. The complete set of functional requirements must come from the totality of stakeholders intervening in this docket. That said, I'd like to identify several high-level stakeholder requirements on behalf of the Local Government Coalition. The functionality of the statewide multi-use online energy data platform must:

1. Be compliant with all Federal and NH laws. In particular, we note that the implementation of a statewide multi-use energy data platform must specifically support the authorities granted to community power aggregations (CPAs) under RSA 53-E and the reasonable implementation of the statute.
2. Be interoperable with NH stakeholders and beyond through the use of well-established international standards.
3. Be extensible.
4. Be state-wide — a single data hub. While this statement may appear obviously self-referencing, it is important to recognize that grid data, at present, is quite distributed amongst various types of grid stakeholders. Consequently, the creation of a data platform serves to centralize access to this distributed data and it must be designed with functionality to accommodate the input and retrieval of data from all of these stakeholders.
5. The functionality of the statewide multi-use online energy data platform must be implemented by a commercially-neutral grid stakeholder.

The Local Government Coalition has detailed the importance of all five of these categories in its scoping comments filed under tab 27 of the Docket Book in this proceeding[16] and its identified use cases filed under tab 34[17], both of which are incorporated herein by reference as Attachment

[16] https://www.puc.nh.gov/Regulatory/Docketbk/2019/19-197/LETTERS-MEMOS-TARIFFS/19-197_2020-03-11_COL_SCOPING_COMMENTS.PDF
[17] https://www.puc.nh.gov/Regulatory/Docketbk/2019/19-197/LETTERS-MEMOS-TARIFFS/19-197_2020-04-03_LGC_USE_CASES_PROPOSALS.PDF

J [LGC 2020-1] and Attachment K [LGC 2020-2], respectively.

**Q5.11. What stakeholder requirements does RSA 53-E on community power aggregators place on the data platform?**

A5.11. In the identified use cases referenced as LGC-2020-2, the LGC derived a total of seventeen stakeholder requirements (or use cases) directly from the provisions of RSA 53-E. Ultimately, in order to fulfill all of the identified provisions of RSA 53-E, an exchange of data would be required. From cost, benefit, and engineering practicality perspectives, it is only reasonable and prudent to expect that this exchange of data would happen through the data platform and not through an alternative parallel means of data exchange.

**Q5.12. What is meant by an "interoperable" data platform?**

A5.12. Interoperability is a life-cycle property of a software system that allows for humans and machines to readily transmit data to and receive data from the software system through well-established Application Programming Interfaces (APIs) that implement international standards. Utility API at the May 8, 2020, technical session provided a presentation explaining what is meant by an API.

**Q5.13. What is meant by an "extensible" data platform?**

A5.13. An extensible data platform is a data platform that when deployed readily admits new features and functionalities with little or no change (and consequently effort and cost) to the already deployed data platform. In no way does the concept of extensibility compromise the concept of a closed set of functional requirements. Returning back to *Figure 2*, extensibility is a property of the deployed system itself — in the physical architecture domain. Even if the data platform has a closed and clearly identified set of functional requirements, it is entirely possible that the engineering organization that is designing, developing, and deploying the data platform makes technical decisions that leave the architecture itself as fixed and non-extensible. For example, in the many technical sessions, it has become clear that the Electronic Data Interchange (EDI) that utilities use for financial transactions between competitive suppliers is not extensible. It does not appear as though it has admitted any change in the last two decades. Therefore, the EDI, on its own, would not fulfill the extensibility requirement. Rather, at best, it would have to be integrated as a component of a larger data platform that was indeed extensible.

**Q5.14. What is meant by implemented by a "commercially-neutral grid stakeholder"?**

A5.14. As explained in the Local Government Coalition's scoping comments [LGC-2020-1], "it is well-known in economic theory that the market power of a market participant grows increasingly with its access to market data. A statewide multi-energy data platform will house and give access to such large quantities of energy market data that a commercially-interested grid stakeholder has the potential to exercise greater than proportional market power for financial gain; potentially to the detriment of other grid stakeholders." [LGC 2020-1, p.6.]

For example, and to be concrete, a community power aggregation may wish to implement a demand response electricity service that responds in a timely fashion to alleviate congestion on an electric distribution line. Such a service would lower rates first for the demand response participant and second for all electricity consumers on that feeder as a system-wide benefit. The implementation of such a demand response service would require timely information of distribution system data from the distribution utility. The distribution utility, in contrast, has no incentive to provide such data because in most instances it might prefer to upgrade the congested line and be compensated accordingly.

The Local Government Coalition derives the requirement for a "commercially-neutral grid stakeholder" from Chapter 286:1, NH Laws of 2019 quoted on pages 10-11 above.

Implementation by a commercially neutral grid stakeholder is potentially but not necessarily at odds with RSA 378:52, I, which states: "the utilities shall design and operate the energy data platform". Consequently, it is necessary to ensure that the utilities do not have disproportionate market power over other competitive market participants. Curtailing the potential for excessive market power is achieved with several mutually reinforcing measures. First, the data housed and shared by the data platform must, by design, make sure that competing electric grid market participants have access to the same data at the same time. Second, the department of the utility that operates the data platform itself must be isolated in their communication from the departments responsible for the purchase and sale of electricity to grid stakeholders. Third, a governing "data platform council" must be created with the mandate to ensure that the above measures are actually strictly followed. Furthermore, the first three measures are most easily achieved if the utilities collectively outsource the design and development of the data platform to a software engineering organization with this specific expertise. In contrast, neglecting these measures can cripple the development of a vibrant electric retail market and undermine the purpose of the statute.

Alternatively, the State of New Hampshire, through new legislation, may choose to determine that it is more straightforward and in the better interest of the public for the data platform to be designed and operated by an engineering organization that is not directly involved in the purchase and sale of electricity or investment decisions around distribution system capacity and forego the utilities as an outsourcing entity. I return to this issue in Section VII entitled governance.

**Q5.15. What is meant by stakeholder-appropriate, secure, and interoperable access to the data platform?**

A5.15. A stakeholder's access to the data platform is interoperable in that it is through APIs that implement international standards.

A stakeholder's access is secure in that it is authenticated with a stakeholder-specific password. Alternatively, the best practice for access into any data platform with any level sensitivity is a two-factor authentication method. It may or may not necessarily use a password but will use stakeholder-specific information like biometric data. Stakeholder-appropriate access recognizes that different classes of stakeholders have access to different classes and instances of data. For example, a grid customer would have access to their consumption data but not that of their neighbor. They may also have access to data on day-ahead and real-time pricing on their feeder. In contrast, a CPA or competitive supplier would have access to a completely different set of data. The design of which data is accessed by who is part of the detailed design of the data platform. Finally, different stakeholder classes will have the ability to read, write, and append data in a manner that is different from other stakeholder classes. Further explanation is found in LGC-2020-2.

## VI. Implementation of The Statewide Multi-Use Online Energy Data Platform

**Q6.1. Are there any relevant precedents in the electric power sector for the development of an energy data platform?**

A6.1. Yes. Undoubtedly. Every Independent System Operator in the country is simultaneously a wholesale market operator and a data platform operator. I agree with Prof. Paul Hines' testimony which states: "ISO New England, for example, provides access to market data through their "web services" server (see https://webservices.iso-ne.com/docs/v1.1/). This web interface does not have any complicated or pre-developed applications; it just provides access to raw data that authorized stakeholders can use to solve a wide variety of problems." Indeed, if one examines the ISO New England data platform closely it meets many of the stakeholder requirements identified above at the wholesale rather than retail electricity level.

**Q6.2. Do you have any guidance on how the data platform should be implemented?**

A6.2. Yes. In response to Q5.2, I identified the domains of engineering system design and development. I emphasized that this docket must determine a closed set of stakeholder requirements. I also emphasized that these stakeholder requirements must be reconciled and translated to a set of functional requirements in a technical language. From there, the data platform is designed, developed, and deployed. There is also a verification phase to ensure that the data platform is "built right" to meet the functional requirements. There is also a validation phase to ensure that the built data platform is the "right system" and meets stakeholder's requirements. Using the best practice of software systems engineering process is the most likely way to realize a data platform that meets its intended requirements and legislative objectives. Beyond this guidance, my responses to implementation questions are of a generic nature as I have explained in my response to Q5.9.

**Q6.3. What and who are the data sources and users of the data platform?**

A6.3. RSA 378 specifically mentions the Green Button Standard which assumes that all data originates from the customer, passes to the distribution utility, and then is used by the customers themselves, the utilities themselves, and third parties. The Local Government Coalition interprets this flow of data from (single) source to data users as necessary but far from sufficient. Unfortunately, this flow of data is not sufficient to achieve the legislative objectives of RSA 378. Nor is it sufficient to meet the totality of stakeholder requirements including specifically the stakeholder requirements and uses cases submitted in the LGC's scoping comments [LGC 2020-1] and identified uses cases [LGC 2020-2].

Once the final set of stakeholder requirements has been compiled, it will almost certainly reveal that all stakeholders will send data to and receive data from the data platform as shown in Figure 1 in my response to Q4.2. For example, in terms of sending data, all stakeholders will need to send at minimum authentication credentials. Furthermore, in terms of receiving data, all stakeholders will likely need to login to access recent information on available electricity services and prices.

In order for the data platform to achieve its legislative objectives as a centralized data hub, this docket must expand its working paradigm from the one of monolithic data flow described in the Green Button Standard to a multi-input-multi-output paradigm of design and operation.

**Q6.4. What types of data should the energy data platform include?**

A6.4. To provide a generic answer, the data platform should include "customer data", "market/financial data", and "system data". Although these terms are not technically precise, nor do they have well-accepted definitions in the literature, they have been used extensively in this docket's technical sessions. In broad brush strokes, "customer data" refers to the consumption data as most commonly received from meters, including in particular "smart" interval meters. "Market or financial data", at least at present, refers to a lot of the data in the EDI platform. "System data" refers to the data parameters that characterize the physical grid itself either statically or dynamically updated due to changing grid conditions.

Naturally, this broad classification of data is not precise enough to state stakeholder requirements. Nor is it precise enough to state functional requirements. Instead, international standards should be used to precisely state the functional requirements in a technical language. Nevertheless, this broad classification does provide a conceptual understanding.

**Q6.5. Why should customer data be part of the energy data platform?**

A6.5. First, customer data is specifically mentioned in RSA 378:50-53 and is the essence of the Green Button Standard. Second, The Local Government Coalition in its scoping comments [LGC-2020-1] and its uses cases [LGC-2020-2] defines seventeen uses cases as stakeholder requirements. Collectively, these use cases address the data needed to implement RSA 53:E. A careful analysis of these uses cases reveals that they require customer data.

**Q6.6. Why should market/financial data be part of the energy data platform?**

A6.6. The Local Government Coalition in its scoping comments [LGC-2020-1] and its uses cases [LGC-2020-2] defines seventeen uses cases as stakeholder requirements. Collectively, these use cases address the data needed to implement RSA 53:E. A careful analysis of these uses cases reveals that they require market/financial data.

**Q6.7. Why should system data be part of the energy data platform?**

A6.7. In order to meet the legislative objectives of SB 284 and to realize a Shared Integrated Grid, we must develop, deploy and provide retail-electric grid services “beyond the kilowatt-hour”. Such retail-electric grid services are techno-economic in nature. Not only do they provide financial incentives, but they also serve to enhance grid reliability, provide non-wires alternatives to costly grid upgrades, and accelerate the adoption of sustainable and renewable energy resources. Please recall my responses to Q3.1 - Q3.5. Also, the LGC has provided a detailed discussion of “beyond the kilowatt-hour” in its scoping comments attached as [LGC-2020-1].

In order for the techno-economic grid services to provide a technical value to the grid in terms of reliability and resilience, the value of the service must be related to actual physical grid conditions. For example, in my response to Q5.14, I described a demand response service that alleviates congestion on a distribution line. Such a service would be impossible without knowing in a timely fashion when a given distribution line is congested. While such a service rarely exists in today's distribution systems, it is entirely commonplace today in the transmission system where day-ahead and real-time energy markets provide locational marginal prices to demand response participants. Such services, to be designed and deployed effectively, perhaps by a CPA, require access to system data. Neglecting to do so, means that such an electricity service would never be offered. As explained in my response to Q5.14, this would be an example where the distribution utility exerts disproportionate market power that prevents another market actor (i.e. CPAs) from providing competitive electric grid services.

The Local Government Coalition recognizes the potential sensitivity of system data and stands ready to engage in a robust discussion on how to secure this data, but ultimately this data is necessary to provide innovative electric grid services beyond the kilowatt-hour.

**Q6.8. Are there any relevant precedents in the electric power sector where transmission and distribution utilities share system data.**

A6.8. Yes, absolutely. 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.

The most obvious precedent is that of the Independent System Operators including ISO New England. Although they are not a transmission or distribution utility, they have access to system data in order to provide reliability-enhancing competitive market services and many stakeholders have varying degrees of access to that data and system typology.

Furthermore, in the distribution system, several utilities have provided system data as part of their customer-facing portals. 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 4 shows GIS maps depicting National Grid's feeders in Massachusetts. We attach [NGrid-2020] for further explanation.

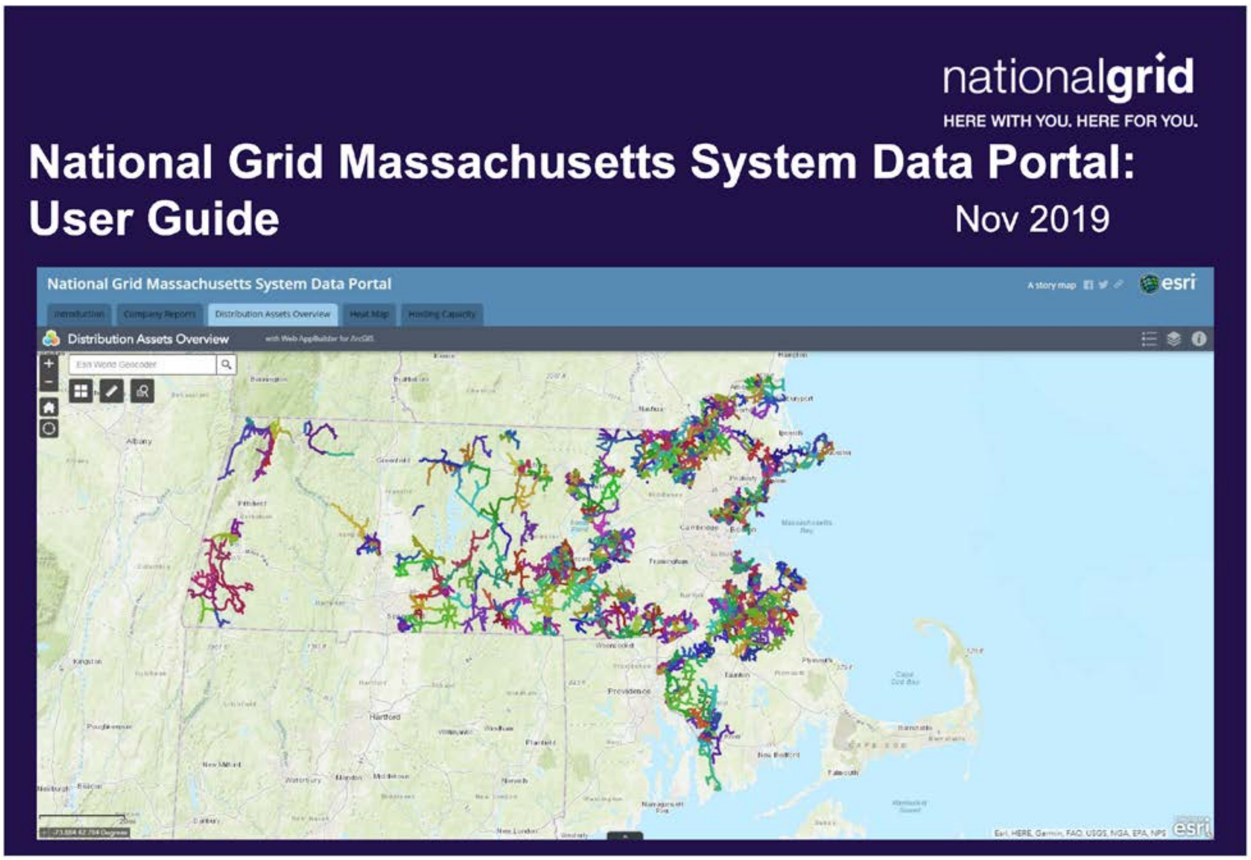


*Figure 4. A Screenshot from the National Grid Massachusetts Portal Depicting Distribution System Feeder Data*

Con Edison's portal is found at: https://www.coned.com/en/business-partners/hosting-capacity. Figure 5 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.

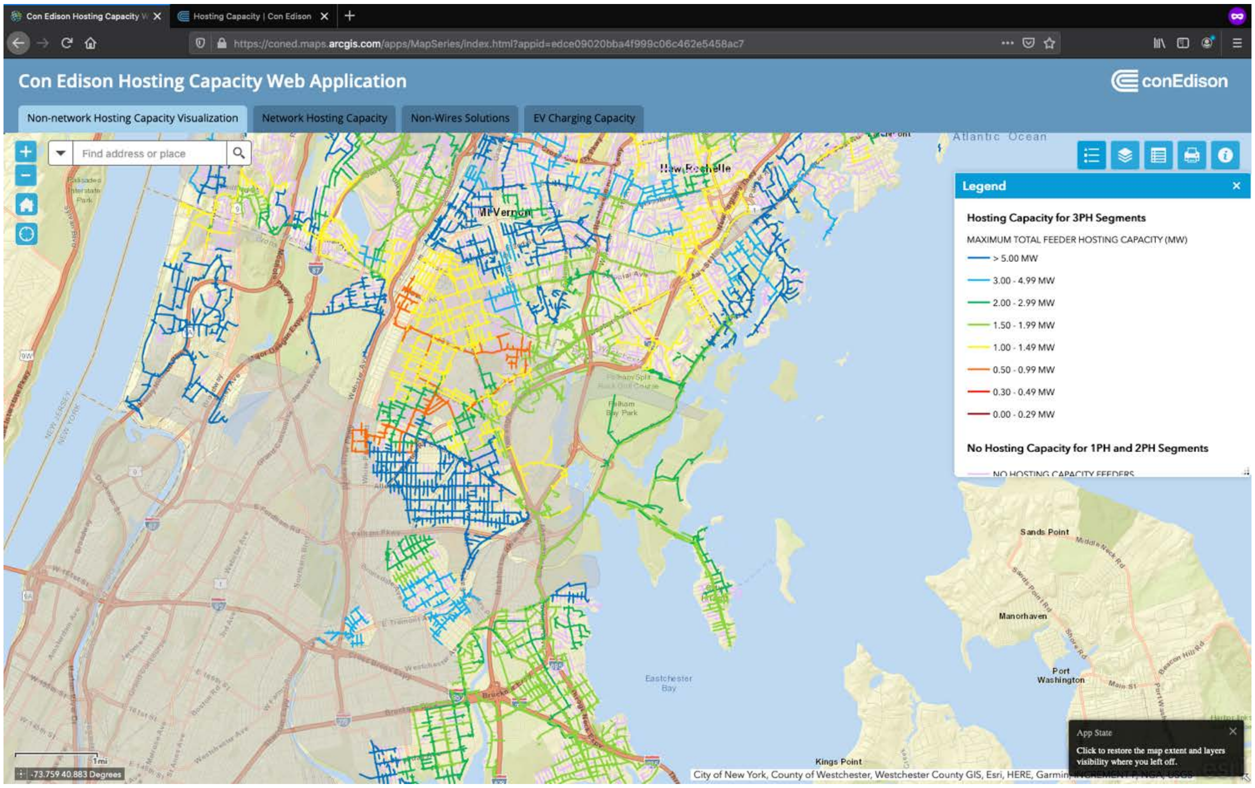


*Figure 5. A Screenshot from the Con Edison New York Portal Depicting Distribution System Feeder Data*

Eversource in Connecticut provides access to an ESRI GIS layer[18], with an array of base map options and full zoom capability, for looking at hosting capacity as shown in Figure 6 below.

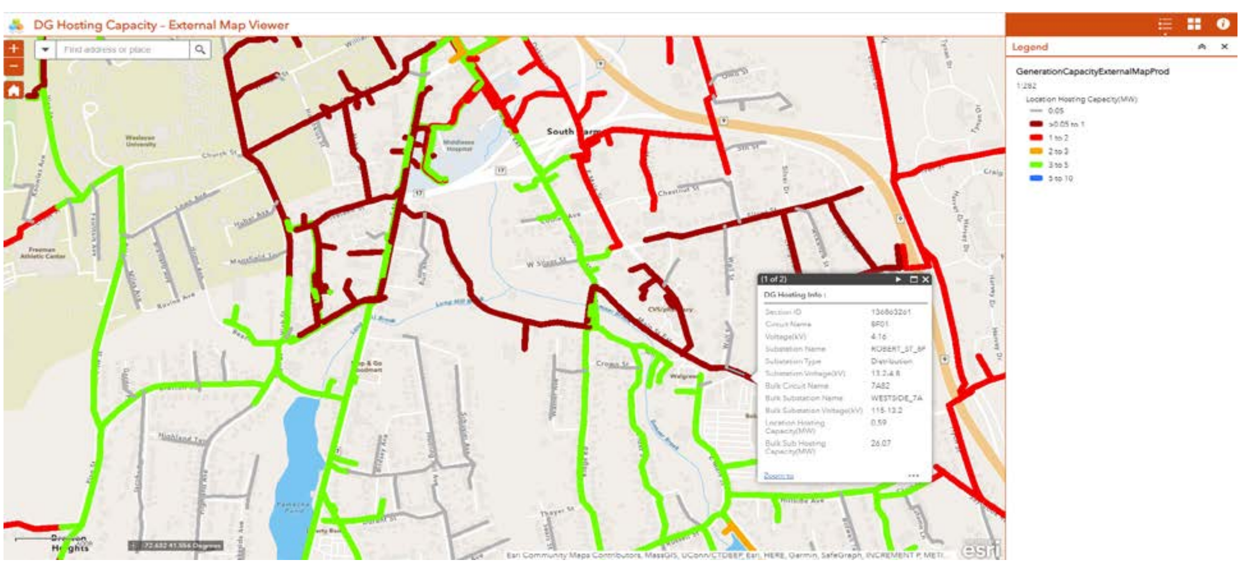


*Figure 6. A Screenshot from the Eversource CT Hosting Capacity ArcGIS Map Viewer zoomed to Middletown CT*

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

Given these precedents, we believe the New Hampshire energy data platform should not lag behind neighboring states in terms of access to system data.

**Q6.9. Which international standards are most appropriate to the implementation of the statewide multi-use online energy data platform?**

A6.9. The data platform must adhere to a logical meta-data model that is determined during the design of the data platform and prior to its implementation in software. As stated in [LGC-2020-1 at Page 1], a logical meta-data model includes 1) a set of data fields that are populated with instantiated numerical and textual data 2) a set of classes which serve as containers of data fields and 3) a set of relationships between the data fields and their classes. These three components of a logical metadata model are drawn directly from the complete set of functional requirements. Normally, the Unified Modeling Language (UML) is used to graphically convey the logical data model. Figure 6 shows a standard UML metadata model of three-phase network components [EPRI-2020, p. 5-37].

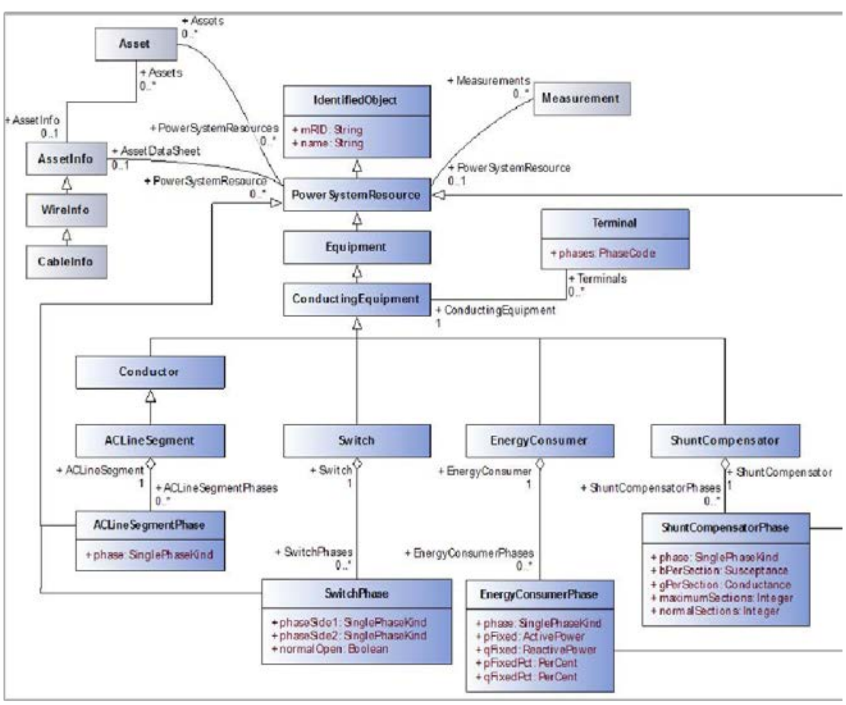


*Figure 7. A Standard UML metadata model of three-phase network components*

A number of off-the-shelf software packages (e.g. IBM Rhapsody, Dassault's Magicdraw) are then used to automatically translate the UML model into an object-oriented programming language (e.g. JAVA, C++, etc).

**Q6.10. Which international standards are most appropriate to the implementation of the statewide multi-use online energy data platform?**

A6.10. The International Electro-technical Commission (IEC) maintains a group of standards that together describe the entire standard metadata model of the electric power grid in UML. They are collectively referred to as the "Common Information Model" or CIM for short. The CIM is without a doubt the lingua-franca of machines, automation, and computers in the electric grid. The CIM includes the following:

IEC 61970 — Information exchange among systems directly involved with operation and planning of the overall interconnected electric grid which rely on power system network models to analyze the behavior of the entire interconnected grid at all voltage levels. This often involves interactions between systems at various different participants in the grid (e.g. RTO, TSO, DSO, microgrid, generator, consumer).

IEC 61968 — Information exchange among systems supporting business functions that support power system operations, maintenance, and customer support. This includes major business functions such as asset management, work management, meter data management, customer information, geographic information systems, and engineering design.

IEC 62325. — Information exchange among systems directly involved with electricity market business processes such as transmission capacity allocation, forecasting, bidding, contracts, clearing, and settlement.

EPRI as one of the primary contributors to these standards and has produced an excellent and highly digestible primer on the Common Information Model which is attached here as Attachment A [EPRI-2020] for convenience[19]. Indeed, Figure 7 above is part of the CIM. Furthermore, pages B-4 to B-7 of this primer recounts how the Common Information Model was used to develop the Green Button Standard referenced in RSA 378:53. In other words, the Green Button Standard is simply a subset of the CIM.

The New Hampshire data platform, however, will have to go beyond the Green Button Standard to meet the totality of stakeholder requirements. Consequently, Figure 8 shows the breadth of CIM standards.

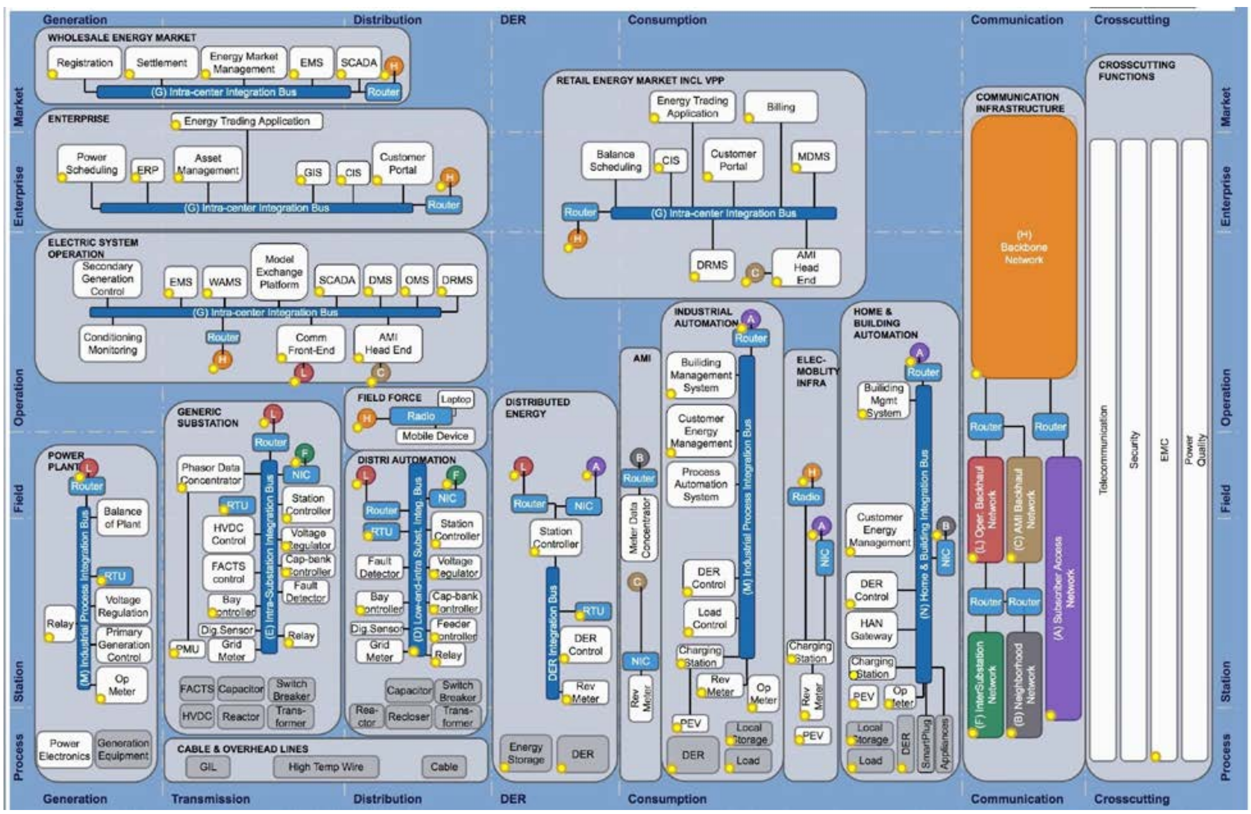


*Figure 8. A Graphical Arrangement of Common Information Model Standards and Their Scope.*

Further discussion on the Common Information Model can be found in [LGC-2020-1 at

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[19] Also available for download at: https://www.epri.com/research/programs/062333/results/3002018634.

pp.11-12]. In order for the New Hampshire data platform to be interoperable, it would have to adopt these widely recognized international standards.

**Q6.11. Can you estimate the financial benefits of a statewide multi-use online energy data platform?**

A6.11. This is a very difficult question to answer precisely for the simple reason that the data, on its own, has no value. It only gains value when it is used to make decisions that improve existing services and create new ones. The best analogy is a telephone line. On its own, it is pretty worthless. However, as we all know, the telephone has transformed commercial activity and can have tremendous financial value.

Let's develop a practical scenario. Let's assume that a data platform enables a time-varying transactive energy service (price-incentivized time-varying, active demand response). Let's also assume that such a service can be aggregated up to the wholesale ISO New England level. Let's also assume that the adoption of such a service is a relatively modest 7-8% of peak load. Let's also assume that such an energy data platform has also been applied to the remaining New England states. Finally, let's assume that the generation mix continues "business-as-usual" without much change from today's current mix.

In such a case, our peer-review research, attached as Attachment H [Muhanji 2020] shows that in only one year, the Day-Ahead Energy Market would see a savings of approximately $68M. Similarly, in only one year, the real-time energy market would see a savings of approximately $68M. With about 10% of the population of the New England population, New Hampshire would expect to benefit by $6.8M in one year alone. While this estimate may seem large, it is actually very conservative because it does not include all of the line and substation congestion that could be avoided by virtue of demand response acting as a non-wires alternative or other grid services that might be enabled by the platform.

**Q6.12. Are there commercially available third-party solutions for the statewide multi-use online energy data platform on the market today?**

A6.12. Yes. We have received strong presentations from mPrest[20] and Kevala Analytics[21] about their virtual data platforms[22]. Please see Attachment E [mPrest 2020-1]. While this solution would have to be matched to the functional requirements discussed above and likely customized to New Hampshire's needs, its current implementation as described in the attached slides is an excellent starting point from which to discuss practical implementation avenues. Furthermore, as stated in their email, Attachment F, [mPrest 2020-2]), a perpetual license for 650,000 customers would cost $750,000 or $1.15 per NH customer and includes not only a data platform but also a myriad of ready to use applications that should have significant value to distribution system operators and other stakeholders.

**Q6.13. How viable are these commercially available third-party solutions?**

A6.13. At such a capitalized cost of approximately $1.15 per NH customer, and specifically in reference to RSA 378:51,IIII, we can surmise that available third-party solutions for the core of an extensible data platform are likely viable. Their cost can be reasonably recovered from customers in the public interest. Furthermore, the data platform when combined with a time-varying active demand response rate could help to materially reduce electricity prices and costs for the New Hampshire public.

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/[20] https://www.mprest.com
[21] https://kevalaanalytics.com/
[22] An mp4 video recording of their presentation can be downloaded from: https://drive.google.com/file/d/1-bMY5Edmmi5uckVHAGYVAY8NKzIN3mZC/view. Alternatively, mPrest's presentation can be viewed at: https://app.box.com/s/qjkbae4skxpzxhrwkktxp1z50xvv7mhl.

## VII. Governance

**Q7.1. Are there any relevant precedents in the electric power sector for the governance of an energy data platform?**

A7.1. Yes. Again. The governance model of ISO New England is a very relevant precedent. Working with the NEPOOL they engage actively and frequently with a wide array of stakeholders through such committees as the Planning Advisory Committee and the Consumer Liaison Group. These committees draw a wide variety of stakeholder types to provide input and feedback to ISO New England's activities. Again, given that ISO-NE is not just a market operator but also a data platform operator, I'd expect there to be similarities in governance.

**Q7.2. Describe the role of governance in ensuring a successful data platform.**

A7.2. In relation to my testimony above, the governance of the data platform should serve to ensure that the data platform create a level playing field within a dynamic retail electricity market. Again the accessibility of data directly impacts market power and a competitive electricity marketplace requires equitable access to data. Naturally, the data itself must be accurate, timely, and interoperable but these technical requirements serve to enable a dynamic marketplace. I agree with Rep. Kat McGhee's insightful testimony on this subject.

**Q7.3. Describe the role of governance in ensuring a successful data platform.**

A7.3. It should include all of the stakeholder categories shown in Figure 1 in my response to Q4.2. It's difficult to imagine a level playing field with respect to data otherwise.

**Q7.4. Does this conclude your testimony?**

A7.4. Yes, it does.