AUTUMN LANE
ENERGY CONSULTING LLC

Future Grid – Thoughts on a Path Forward

NEPOOL MC/RC – May 27, 2020

Peter D. Fuller

Presented with the endorsement of NEPOOL Members NRG Energy and Sunrun

AUTUMN LANE
ENERGY CONSULTING LLC

Overview

- **While the precise dimensions of the future grid's mix of resources is unclear, we can be fairly certain of the broad outlines**
- **The 'gap study' proposed by NESCOE, NEPOOL and ISO-NE will undoubtedly be helpful in developing some quantitative estimates, but the focus of our efforts should be the broad outlines, not the precise details**
  - **Forecasts are always wrong**
  - **We're not trying to intercept an asteroid at a specific point in time and space – we're trying to establish a foundation and a framework for clean energy and reliability resources to thrive in a competitive market structure**
- **Don't let a desire for precision obscure the bigger picture objective**

The Four-Product Future*

AUTUMN LANE ENERGY CONSULTING LLC

Renewable Energy	Storage	Grid Edge Resources/ Responsive Demand	Flexible Dispatchable Generation
• Primary source of electric energy for consumer needs • Growth in grid-connected projects follows from improving economics and state RPS and related clean energy goals • Rate designs, consumer demand and technological advances drive distributed resource growth	• Two-way operation balances variability of both renewable energy generation and consumer demand • Meets peak demand and ramping needs – capacity and ancillary services • Distributed storage also supports resilience	• Advances in data and telecomm support distributed resources and programmable responses to price and reliability needs • Real-time pricing/variable rate designs provide consumer incentives and business opportunities to link retail loads and edge resources with wholesale markets	• Fast-start dispatchable capacity to ramp as needed to fill short-term imbalances • Hydrogen and RNG may provide lower net emissions and longer-term/seasonal storage

* With thanks to my former colleagues at NRG Energy

The Big Questions

Autumn Lane
Energy Consulting LLC

- **The key question we should be trying to answer:**
  - **Given a future resource mix scenario*, do the markets we have today (plus ESI) provide sufficient revenues to support:**
    - **i) renewable/non-emitting resources that achieve the region's emission reduction targets, and**
    - **ii) dispatchable resources and operating capabilities that achieve required levels of security and reliability?**

- **Conceptually, markets developed around fossil fuels and central-station rotating machines are probably not a good match for a system focused on low emissions, inverter-based resources and a dynamic 'grid edge' of DER and responsive load**

* More thoughts on constructing resource mix scenarios in later slides

Autumn Lane
Energy Consulting LLC

Preview of Coming Attractions

- **The 2016 NEPOOL Economic Study was pretty definitive**
  - **"New resources will likely require sources of revenue in addition to the wholesale energy market to remain economically viable. Natural gas units show the greatest energy market revenue shortfall as a result of their production costs being higher than the $0/MWh fuel costs of renewables, but renewable resources also show significant revenue shortfalls relative to their assumed annual fixed costs."**
    - **The report likewise suggested existing resources may be revenue-inadequate in the energy market**
- **Recognizing that the 2016 study probably didn't look far enough into the future or deeply enough into emission reductions, a new study is warranted. Nonetheless, the clarity and extent of the result in 2016 suggests that we'll find a similar answer this time around**

Autumn Lane
Energy Consulting LLC

Future Resource Mix Scenarios (aka, things we need to include in any study)

- **Aggregate emission reduction goals – what level of emission reductions should we assume – 80%, 90%, 100%? And in what year – 2040, 2050?**
- **Broad brush resource mix assumptions/scenarios – what are the rough proportions of wind, solar, hydro and nuclear in the energy mix?**
- **Electrification of demand – How much replacement of internal combustion engines and combustion heat sources should we assume – 50%, 75%, 100%?**
- **Responsive demand and distributed resources – How much of the demand will be actively adjusting to market conditions – 10%, 20%, 30%, more? How much load modification and load/supply balancing will come from active and non-dispatchable edge resources?**
- **System security and reliability – given all those assumptions, how much dispatchable capacity will be needed to ensure reliability on daily and seasonal time-scales? How much energy storage, and with what duration(s)?**

Then, use appropriate modeling tools to estimate costs and market revenues for each resource type.

Other Considerations (aka, some things we don't)

- There are real technical and policy challenges in reaching a reliable, low-emission future, but many are not central to designing a market structure
  - Transmission topology – assume a single bus, or a simplified system with a few zones
  - Inertia, fault current, etc – assume the technical challenges of an inverter-based system can be solved with power electronics, synchronous condensers or other technological applications and innovations, provided the needs are made clear and the markets provide compensation for these services
  - Feasibility of specific new technologies – assume resource characteristics – eg, long-duration storage, emission-free thermal generation – rather than trying to prove out any specific technology
  - Fuel infrastructure, ie, gas pipelines, LNG – overall gas usage is likely to decline with electrification and more reliance on renewable sources
- All these challenges will best be addressed in the context of a robust market for grid services that transparently values what the system needs

AUTUMN LANE
ENERGY CONSULTING LLC

Stay focused on the task at hand

- While it could be interesting to give policymakers a comprehensive economic comparison of, for example, 80% vs. 90% vs. 100% decarbonization, that's not our task here
- While it could be interesting to determine whether we need a higher voltage bulk network - potentially including offshore cables - to integrate the future resource mix, that's not our task here
- While it would be interesting to evaluate the technical potential and viability of hydrogen electrolysis and storage, CCS, modular nuclear, and any number of other cool technologies, that's not our task here
- **Our task: Will our current market designs support a reliable low-carbon resource mix? And if not, what should we do about it?**

Practical Suggestions

- Since the detail matters far less than the broad themes, use the scenario(s) from an existing study, such as the Brattle study (2019) or similar, to save some study time
  - These studies are highly consistent: a system with lots of electrification, served with lots of renewable resources, needs lots of storage and dispatchable generation and may be 2x to 3x larger than our current peak and energy demand
- Given the results of the 2016 NEPOOL Study, begin a parallel effort to identify options that could provide "sources of revenue in addition to the [current] wholesale energy market" that will be needed to support emission goals and reliability

DRAFT

AUTUMN LANE
ENERGY CONSULTING LLC

Pete Fuller

pete@autumnlaneenergy.com

508/944-5075