Multi-year Detailed Nodal, Cloud-based Modeling of Economic and Environmental Impacts of the Integration of Significant Quantities of Mandated On-shore and Off-shore Renewable Resources into the Regional Electric Power Grid

Richard D Tabors and Alexandr Rudkevich

JR Hornby, E. Goldis, H. He, X. Li, k. Amoako-Gyan, N. Kumthekar

Tabors Caramanis Rudkevich (TCR)

FERC Technical Conference

June 27, 2018

The Computational objective…

- The integration of parallelized cloud-based computation with data retrieval, aggregation and communication into familiar spreadsheet format focusing on:
  - Speed and efficiency of the analytics
  - Ability to communicate the results to diverse stakeholders
  - Ability to reproduce and defend the process and the results before multiple state regulatory bodies.

Background to the need under MA 83D and 83C

- Massachusetts legislature passed Chapter 169 of the Acts of 2008, the Global Warming Solutions act (GWSA)
  - Including the 2008 Green Communities Act
  - Amended in 2016 by the Energy Diversity Act
- Objective: by 2020 reduce carbon emissions to 75% of the 1990 level and to 20% of 1990 by 2050
  - Primary foci were the energy (electric) and transportation sectors
  - To 2016 progress was slow
- The 2016 act mandated that the three distribution utilities (Eversource, National Grid and Unitil) acquire 9450 Gigawatt hours of ***NEW,*** land-based renewable (83D) and up to 1600MW of offshore wind (83C) through two sequential RFPs
- 83D completed in December, 83C in June. Contract negotiations are underway

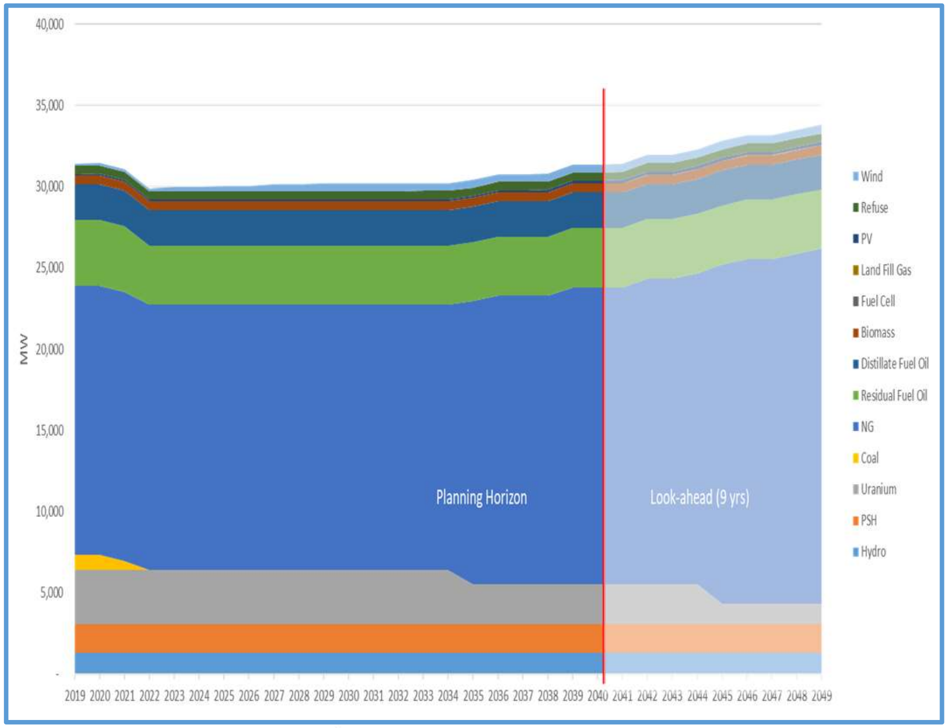
The Analytic Challenges

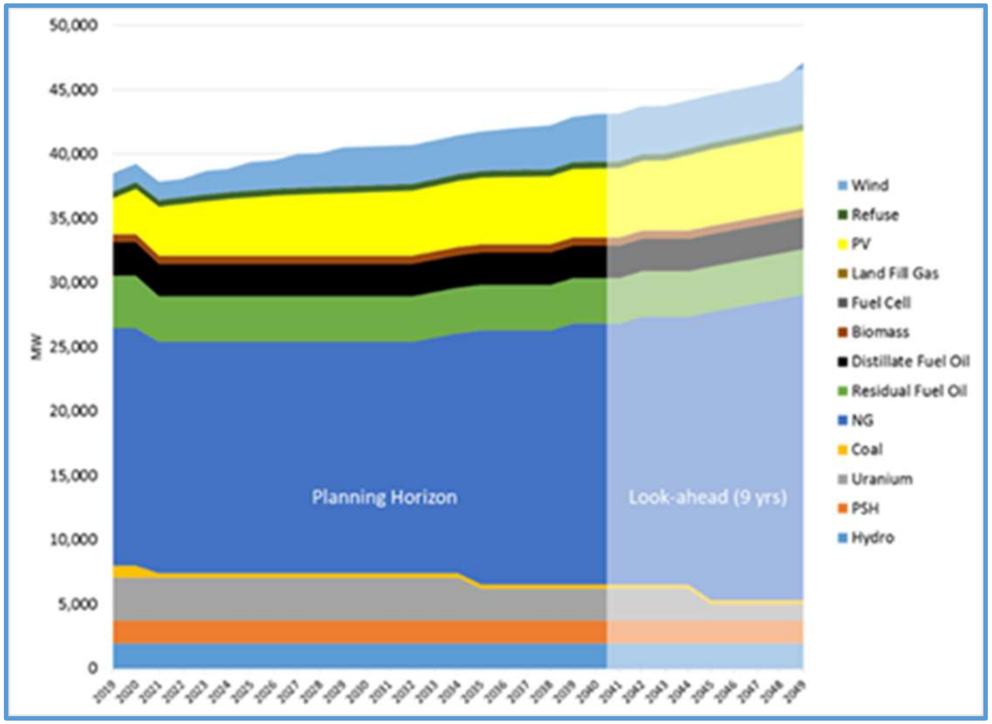
- Without seeing any bid the quantitative team was to:
  - Develop a detailed a quantitative protocol for evaluation (a qualitative protocol was also developed)
    - Define both the direct and indirect quantitative metrics to be used to compare and eventually rank the proposals
    - The final ranking would be on the summation of metric values in $/MWh in 2017 constant dollars
  - Develop the "but for" or Base Case for the New England (and New York) power systems to 2040 with a look ahead to 2050
  - Develop and test the cloud-base project calculation engine
    - Simulate 22 years of hourly nodal prices upon which to calculate and then aggregate the ten metrics to be used for comparison of the bids.

The Quantitative Metrics

- *Direct*
  - Revenue earned from the energy market
  - The direct cost of the contracted energy to the utilities
  - Revenue generated from REC and CEC sold into the market
  - The direct cost of REC and CEC to the utilities
  - The cost (or benefit) attributable to transmission
- *Indirect*
  - Savings from energy price suppression (nodal LMP based)
  - Savings from REC/CEC Price Suppression (State / Region)
  - The contribution value to GWSA (DOER methodology)
  - The positive impact on winter gas related price volatility
  - The Impact on the Capacity Market

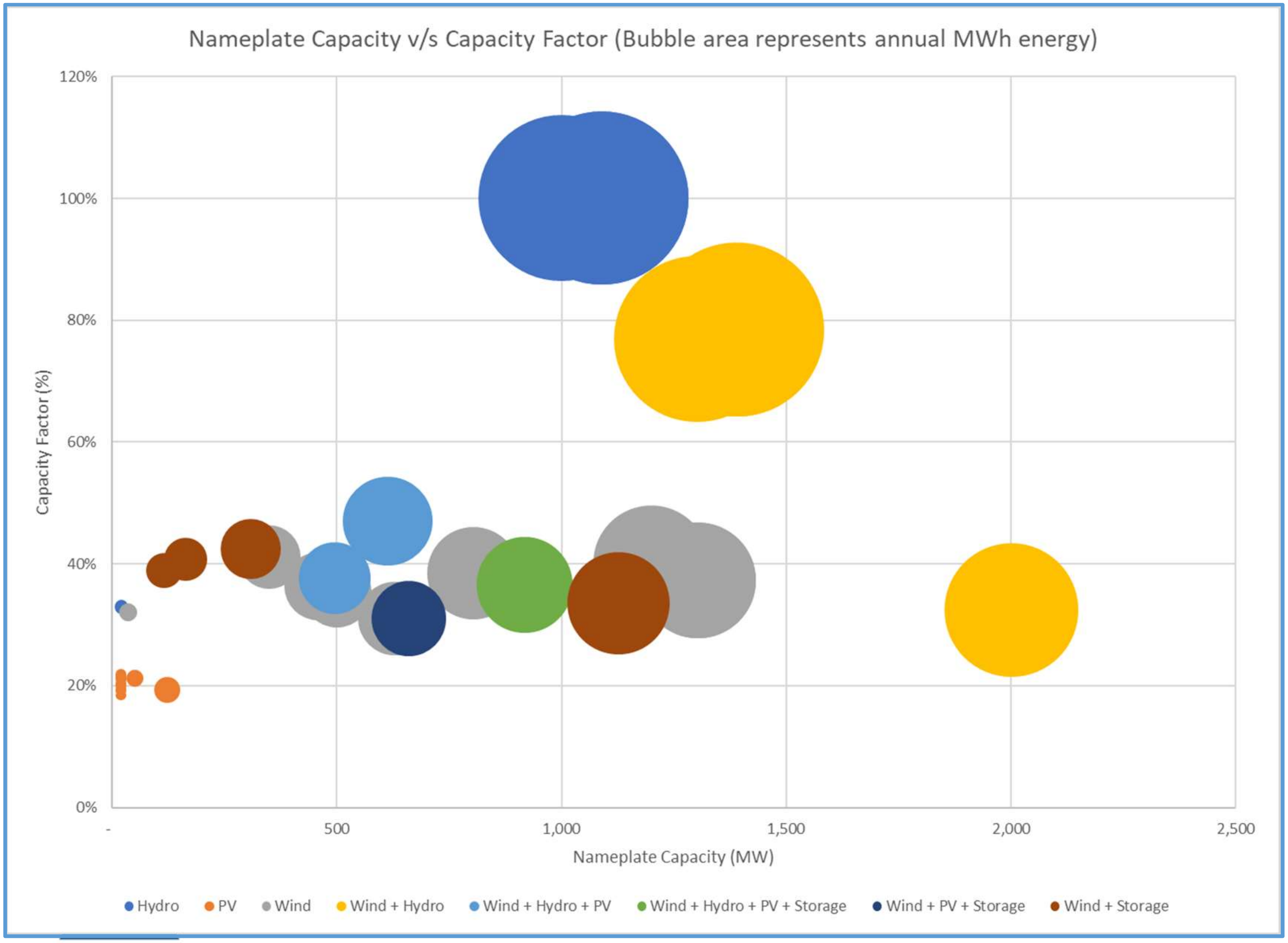
Base Case Planning Horizon and Look Ahead by Technology and Fuel type





The Process

- Simulation modeling of Base Case and each Proposed Project or Portfolio with ENELYTIX®
- Three Modules functioning from *a common database*
  - Capacity Expansion
  - Energy and Ancillary Services
  - Forward Capacity Market
- Proposals received in RFP 83D
  - 46 proposals were evaluated individual and / or in portfolios
  - Size range from 20MW to 1090MW
  - Capacity factors range from 20% to 100% (major hydro / transmission projects)
- Accounted for intermittency of wind and solar
- Located in all NE states except RI and also in NY



Nameplate Capacity v/s Capacity Factor (Bubble area represents annual MWh energy)
120%
100%
80%
60%
40%
20%
0%
Capacity Factor (%)
-
500
1,000
1,500
2,000
2,500
Nameplate Capacity (MW)
Hydro
PV
Wind
Wind + Hydro
Wind + Hydro + PV
Wind + Hydro + PV + Storage
Wind + PV + Storage
Wind + Storage

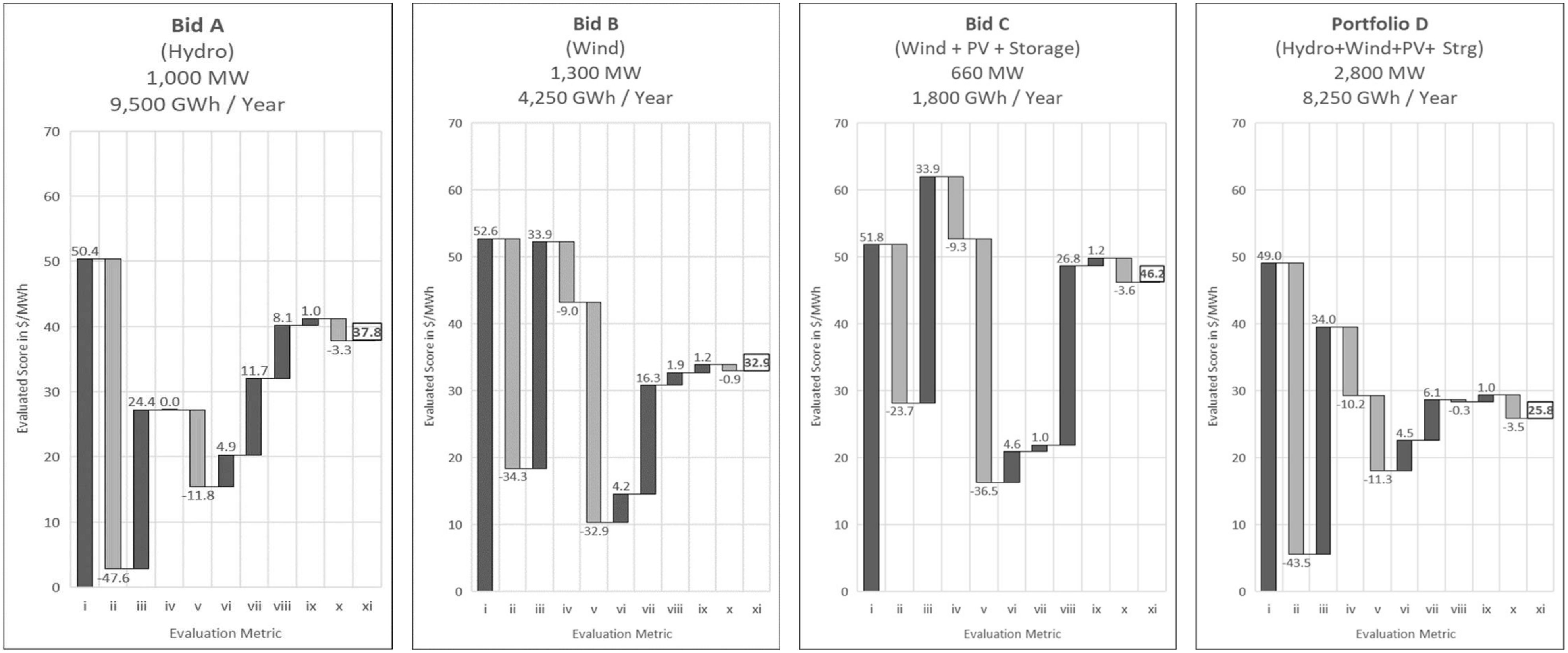
The Size of the Problem

- For the each proposed project
  - Calculation of the complete nodal representation of the NE power grid
  - Hourly for the 22-year evaluation period
  - An additional 3-month scenario assessing the impact of the proposed project on the system economics under conditions of extremely high natural gas prices.

Computation on the Cloud

- To evaluate each proposed project required:
  - committing 601 virtual machines,
  - generating 330 Gigabytes of data per run.
  - Calculating / aggregating the inputs required to then calculate the direct and indirect metrics values
    - Committing 27 virtual machines per annual run
  - Transferring the results to local servers that were used to compile the results into the Direct and Indirect summary workbooks and into the environmental (GWSA) workbook.

From 330 Gigabytes to a single value…



The Computational Bottom Line

- The project demonstrated the ability to integrate parallelized cloud-based computation with data retrieval, aggregation and communication of the results to local servers in a familiar spreadsheet format
- The project demonstrated this could be done
  - Effectively and efficiently
  - The results could be formatted quickly to communicate the results to diverse stakeholders
  - The results could be stored so as to be reproducible and defendable in complex regulatory proceedings.

Richard D Tabors, Ph.D.
President
Tabors Caramanis Rudkevich
75 Park Plaza
Boston MA 02116

617 871 6913
rtabors@tcr-us.com