Nodal Project Evaluation Applied to Large-Scale Renewable Energy Procurement: A Case Study of Massachusetts

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Abstract

Evaluating a large number of renewable energy project proposals received in response to a single Request for Proposals (RFP) in a consistent manner independent of size and technology and fully cognizant of location and timing is a significant challenge. The current paper presents a methodology and set of tools for preparing a comparative quantitative evaluation of the economic and environmental benefits and costs of the renewable project proposals over a 25-year time horizon. The paper presents a case study of the large-scale renewable energy procurements undertaken in 2018 to comply with Massachusetts energy diversity and greenhouse gas (GHG) emission reduction goals mandated under its "Green Communities Act" of 2008 and Global Warming Solutions Act" of 2008. Section 83D of the Green Communities Act requires Massachusetts electric distribution companies (EDCs) to acquire 9,450 gigawatt hours per year of cost-effective renewable energy. The quantitative evaluation of each proposed renewable project is based on a scenario analysis approach in which a simulation modeling tool calculates energy costs and GHG emissions in the Northeast region (New England and New York) over the evaluation period for a "but for" case without any of the proposed renewable projects and for individual cases for each proposed renewable project. Working from a single database structure, the simulation modeling tool moves from a 30-year, annual resource adequacy module, to an hourly, nodal, 20-year plus SCUC / SCD, to a detailed capacity market valuation model. The simulation modeling system (ENELYTIX) operates with cloud-based technology utilizing user-friendly Excel interfacing with complex data / information transfer from an OLAP cube on the cloud to users' workstations.

1. Introduction

The objective of this paper is to provide a methodological road map for the evaluation of multiple bids of varying technology, size, scope and locations responding to a single Request for Proposals (RFP)solicitation for energy supplies. It demonstrates that it is possible and highly desirable to be able to evaluate renewable energy projects in a manner that is independent of their size but fully reflective of their physical location within the grid and economic contribution within the energy market.

The paper describes the methodology and analytical tools developed and implemented to evaluate more than 50 distinct renewable energy project proposals, and portfolios of those proposals, bid in response to the RFP issued under Section 83D of the Green Communities Act (83D RFP). Massachusetts electric distribution companies (EDCs) used this RFP to select a cost-effective long-term contract for 9,450 gigawatt hours per year of renewable energy to comply with the requirements of the Massachusetts Green Communities Act of 2008, as part of Massachusetts' efforts to meet the objectives of its Global Warming Solutions Act (GWSA) of 2008 [1].

The comparative quantitative evaluation of the economic and environmental benefits and costs of the renewable project proposals was prepared using a scenario analysis approach. ENELYTIX®,[1] a cloud-based environment for energy systems and markets modeling, calculated the energy costs and GHG emissions in the Northeast region (New England and

[1] ENELYTIX® is a registered trademark of Newton Energy Group LLC, a commercial vendor of ENELYTIX.

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New York) over the evaluation period for each of the more than 51 cases or scenarios, comprised of the Base or "but for" case without any of the proposed renewable projects, and the more than 50 future renewable project cases, i.e., one future or case for each distinct proposed renewable project or portfolio.

ENELYTIX is powered by PSO, a market simulator engine developed and supported by Polaris Systems Optimization. ENELYTIX provided detailed analyses of the impacts of each proposed renewable project including a 30-year nodal system expansion subject to annual resource adequacy, environmental and operational constraints followed by the hourly, nodal Security Constrained Unit Commitment (SCUC) and Economic Dispatch (SCED) chronological simulation spanning over 20 years, and then followed by annual capacity market simulation under ISO-NE market rules. After siting and confirming transmission adequacy, ENELYTIX modeled each proposed renewable project case on the cloud using 601 virtual machines. Since each case generated 330 gigabytes of raw data, ENELYTIX relied upon an additional 27 virtual machines on the cloud to run On-Line Analytical Processing (OLAP) cube processes in order to prepare the results for transfer to an Excel workbook for final workstation analysis and subsequent distribution to the Massachusetts electric distribution companies (EDCs). Despite their size and complexity, using this approach ENELYTIX was able to model, validate and analyze two renewable project cases on the cloud per day.

2. Background and Overall Objective

In 2016, the Massachusetts Legislature passed An Act to Promote Energy Diversity which added Section 83D to the Green Communities Act. Section 83D requires EDCs to solicit and execute long-term contracts for renewable energy with delivery to begin as early as 2020. In March 2017, the EDCs issued the 83D RFP for projects to provide up to 9,450 gigawatt hours per year of clean energy generation including the renewable energy certificates ("RECs") and environmental attributes [2] associated with that energy to be purchased under 15- to 20-year contracts.

The EDCs retained the authors [3] as core members of the team who would prepare the quantitative evaluation of the direct and indirect costs and benefits of each Clean Energy Project proposal received in response to the RFP.

The process for preparing a comparative quantitative evaluation of the economic and environmental benefits and costs of more than 50 distinct renewable energy project proposals and portfolios presented a series of challenges.

- First, and most critical, was the inability of the analytic team, i.e., the authors and representatives of the EDCs, to access any of the proposals until a quantitative evaluation protocol was developed and documented in detail.
- Second was the need to develop a 25-year horizon Base Case, i.e., the "but for" case without any of the proposed renewable projects (83D Base Case).
- Third was the need to complete the evaluation within the limited timetable mandated by the Department of Public Utilities. This necessitated the cloud-based analysis introduced above and discussed in Section 5 below).
- Fourth was the need to obtain clarifications on certain details of some proposals from their bidders, i.e., clarification sufficient to enable accurate modeling and evaluation, but not changes that might somehow advantage a bidder.

3. Development of Quantitative Evaluation Protocol

The 83D RFP specified the categories of quantitative costs and benefits the EDCs would use to evaluate the renewable project proposals and grouped them into two categories: *Direct Contract Costs and Benefits* and *Indirect Costs and Benefits*. The quantitative evaluation team developed an 83D Quantitative Protocol which defined the metric to be used to measure each category of cost and benefit and which specified the method to be used to calculate each metric [4].

The 83D Quantitative Protocol specified that the value of each metric was first to be calculated by year in 2017 constant dollars (2017$) and then calculated as a present value. Finally, it was to be calculated as a levelized unit value ($/MWh), i.e., as the present value divided by the present value of the annual energy from the Proposal / portfolio. The 83D Quantitative Protocol specified the core measure of comparison as the levelized net unit benefit per MWh of the project expressed in 2017 dollars.

3.1 Metrics for Direct Costs and Benefits

The 83D Quantitative Protocol defined five metrics to measure direct costs and benefits of each proposal and portfolio of proposals:

i. The locational marginal price (LMP) based market *value* benefit of energy from the proposal / portfolio based upon forecast market prices with the Proposal / portfolio in service, ("proposal case" or "portfolio case");

ii. The direct *cost* to the EDCs of energy from the proposal / portfolio at the delivery point based upon the proposal / portfolio bid price and forecast annual generation;

iii. The market *value* benefit of the RECs and/or clean energy credits (CECs) from the proposal / portfolio based upon forecast market prices in the proposal case / portfolio case;

iv. The direct *cost* of Renewable Portfolio Standard (RPS) Class I eligible RECs and/or Clean Energy Standard (CES) eligible Clean Energy Credits (CECs) from the Proposal / portfolio based upon the Proposal / portfolio bid price and annual generation.

v. Direct *cost* of transmission facilities included in the proposal / portfolio.

ENELYTIX calculated the first four of these metrics by hour over the evaluation period for each renewable project proposal case. The simulation of each case resulted in more than 175,000 hourly values that were then aggregated to annual values.

The net Direct Cost (Benefit) was calculated as the net value of these five metrics.

3.2 Metrics for Indirect Costs and Benefits

The 83D Quantitative Protocol also defined metrics to measure indirect costs and benefits of each proposal and portfolio of proposals. These are costs and benefits that are measured relative to the Base Case described in Section 4. The metrics for indirect costs and benefits were:

i. Savings from changes to wholesale energy market prices in Massachusetts, i.e. from changes to LMPs in Massachusetts in the proposal case / portfolio case relative to 83D Base Case LMPs. This metric is often referred to as the "price suppression effect."

ii. Savings from changes to the Class 1 REC and CEC prices in Massachusetts in the proposal case / portfolio case relative to the 83D Base Case.

iii. Value of the Proposal / portfolio incremental contribution towards meeting the Global Warming Solutions Act (GWSA) over and above compliance with the RPS and the CES in the proposal case / portfolio case relative to the 83D Base Case.

iv. Value of the Proposal / portfolio incremental reduction in exposure to extreme winter natural gas prices in the proposal case / portfolio case relative to the 83D Base Case.

v. Impact of the project on prices in the Forward Capacity Market.

ENELYTIX calculated the first three of these metrics by hour over the evaluation period for each renewable project proposal case. The quantitative evaluation team also used ENELYTIX to calculate the fourth metric but limited the calculation to the benefit from a project or portfolio assuming a repeat of February / March 2014 weather conditions in New England, i.e., a repeat of the "Polar Vortex." The modeling period was for January through March and the valuation was estimated based on the likelihood that such a condition would occur once in fifteen years.

The final indirect metric, the impact of a project and portfolio on prices in the Forward Capacity Market, was not found to be stable or meaningful for the smaller of the projects being evaluated and as a result was not employed in the final ranking of the projects.

The net Indirect Cost (Benefit) was calculated as the net value of the indirect metrics.

3.3. Core Metric

The 83D Quantitative Protocol specified the core measure of comparison as the levelized net unit benefit per MWh of the project expressed in 2017 dollars. This core metric is the sum of the net Direct Cost (Benefit) metric and the Net Indirect Cost (Benefit) metric.

4. Development of the 83D Base Case

Once the 83D Quantitative Evaluation protocol was approved, the quantitative evaluation team focused on development of the 83D Base Case as a point of comparison or reference for measuring indirect costs and benefits as discussed above.

To provide a level playing field for assessing the economic and environmental impact of each project or portfolio of projects independent of size, location and technology, it was necessary to project a possible future generation stock for the region that could meet all constraints in terms of load, reliability and environmental regulations.

The Base Case was structured with the assumption that all legislative requirements for RECs, etc., for each state would be honored but that the GWSA requirement for additional clean energy (the *raison d'être* of the RFP) was not mandated.

The Base Case provides a "but for" or "counterfactual" projection of carbon emissions as well as energy and capacity costs associated with Massachusetts electricity consumption under a future in which the EDCs do not acquire clean energy under long-term contracts from any of the Proposals received in response to the RFP. The Base Case ***explicitly is not a plan*** for the Massachusetts electric sector but rather it is a consistent scenario against which each proposal case and portfolio case are compared.

Both unit additions and unit retirements were accounted for as economic decisions over time in the initial resource requirement component of the evaluation of the Base Case and each proposal case and portfolio case.

Each proposal case and portfolio case provides a projection of carbon emissions and costs associated with Massachusetts electricity consumption under a scenario in which the EDCs acquire the clean energy offered by that proposal or portfolio under a long-term contract. Comparison of results from the project cases with a consistent Base Case provides the basis for consistent "apples to apples" evaluation of the benefits and costs of individual projects not dependent on size, technology or delivery.

The Base Case assumed the following specifically identified generating capacity units and sources of RECs would be in-service during the study horizon:

- existing generating units listed in the 2017 ISO New England Forecast Report of Capacity, Energy, Loads, and Transmission (CELT Report);
- projects listed in the ISO New England interconnection queue as of June 27, 2017 that were either under construction or had major interconnection studies completed and cleared the latest Forward Capacity Auction prior to June 27, 2017;
- distributed photovoltaic (PV) capacity at levels in the ISO-NE's Final 2017 PV Forecast through 2026 and thereafter at levels extrapolated from the ISO-NE PV Forecast;
- renewable generation projects selected under the New England Clean Energy RFP and under Massachusetts Department of Public Utilities (DPU) review pursuant to that procurement;
- renewable generation projects selected under the Connecticut Small-Scale Energy RFP; and
- imports of Class 1 eligible REC into ISO-NE from neighboring control areas at their 2015 levels.

Figure 1 provides a graphic summary of the mix of generation technologies in the 83D Base Case. In order to ensure that New England would meet its resource adequacy requirement the simulation of the Base Case was extended for a "look-ahead" period nine years beyond the end of the evaluation period. Figure 2 provides the fuel mix forecast for the same time period as Figure 1.

The 83D Base Case reflects the fact that the 2016 Act to Promote Energy Diversity included Section 83C, which requires Massachusetts EDCs to acquire up to 1,600 MW of offshore wind capacity under a separate set of 83C RFPs. In order to account for that mandate, the 83D Base Case assumes the development of 1600 MW of offshore wind in four even 400 MW tranches every two years beginning in 2022 [5].

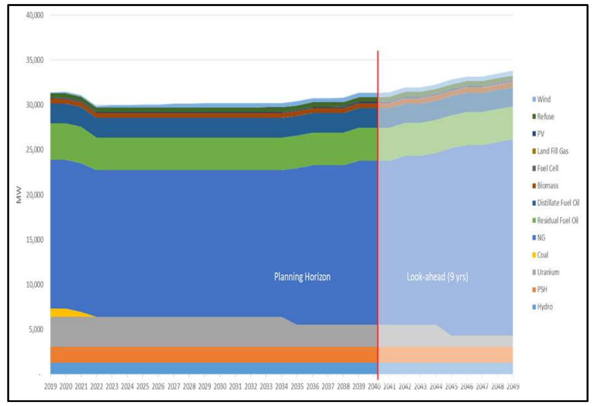

Figure 1: 83D Base Case by Generation Technology – Evaluation Horizon plus Look-ahead

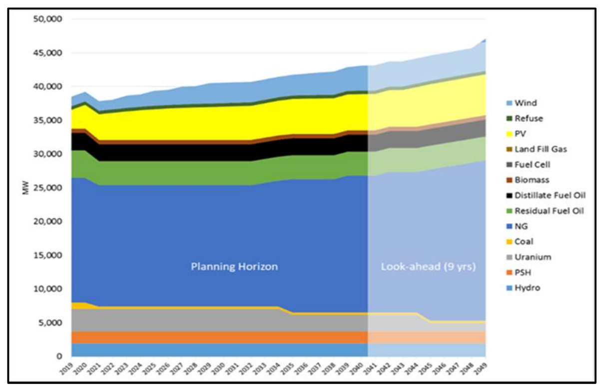

Figure 2: 83D Base Case by Fuel Type - Evaluation Horizon plus Look-ahead

3. Overview of ENELYTIX Modeling Environment

The authors used the *Capacity Expansion* module of the ENELYTIX modeling environment to simulate the long-term expansion and operation of the New England wholesale markets for energy and ancillary services, forward capacity and RECs under the 83D Base Case and for each proposal / portfolio case [3]. Figure 3 provides an overview of the modeling system configured for this project within ENELYTIX. The authors then used modeling system's *Energy and Ancillary Services* module to develop internally consistent, detailed projections of prices in each of the above markets as well as the key physical parameters underlying those market prices such as capacity additions and retirements, energy generation by source, carbon emissions and natural gas burn.

The *Capacity Expansion* module determines an optimal electric system expansion in New England over a long-term planning horizon. Its function is to minimize the net present value of the total cost, i.e., capital, fuel and operating, of the generation fleet serving the wholesale market within the ISO-NE electrical footprint subject to resource adequacy, operational and environmental constraints. Resource adequacy constraints are specified in terms of installed capacity requirements ("ICR") for the ISO-NE system as whole and for reliability zones within ISO-NE. Environmental constraints include requirements for state-by-state procurement of electric energy generated by renewable resources, as well as emissions requirements. The module represents each state's annual Class 1 RPS requirements, Massachusetts CES requirements, state specific RPS resource eligibility, limitations on REC banking and borrowing, and alternative compliance payment (ACP) prices.

The *Energy and Ancillary Services (E&AS)* module simulates the Day-Ahead and Real-Time market operations within the footprint of the ISO-NE and New York Independent System Operator (NYISO) power systems and markets. This module implements chronological simulations of the SCUC/SCED processes, as well as the structure of the ancillary services in ISO-NE and NYISO markets.

The *Forward Capacity Market (FCM)* module uses offer curves developed from results of the Capacity Expansion and E&AS modules. The FCM module models the ISO-NE capacity auction subject to system-wide and zonal installed capacity requirements, Cost of New Entry (CONE) parameters and demand curves.

All three modules use ENELYTIX common Market Model Database (MMD) and PSO optimization engine developed by Polaris Systems Optimization, Inc. The MMD data initially provided by ENELYTIX vendors were augmented by utility vetted ISO-NE data for existing generating units, transmission topology and future electricity demand.

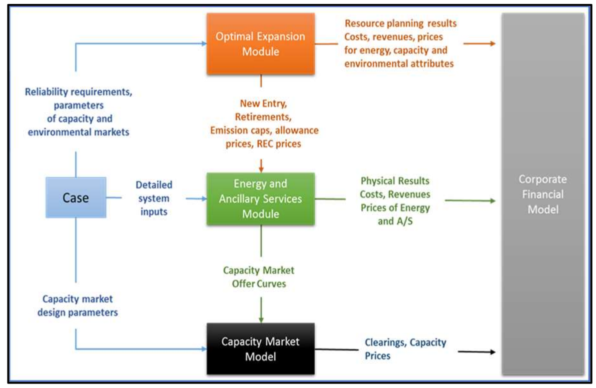

Figure 3: Model Components Configured for the Analysis

As shown in Figure 4, the integration of parallelized cloud-based computation with data retrieval, aggregation and communication in familiar spreadsheet format facilitates the speed and efficiency of analysis as well as the communication of results to diverse stakeholders and the ability to reproduce and defend results before state regulators.

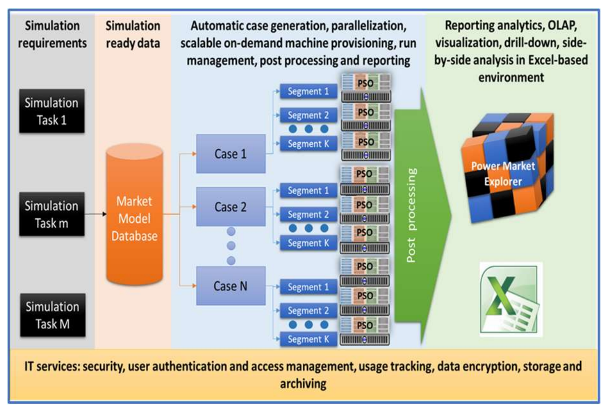

Figure 4: ENELYTIX Cloud-based procedures

4. Overview of Proposals Received

The EDCs received forty-six proposals that ranged in size from 20 MW of nameplate capacity to 1090 MW with capacity factors that ranged from less than 20% to 100% (the major hydro/transmission options), as shown in Figure 5. Accounting for the intermittency of both wind and solar, the effective capacity (summer ICAP) ranged from a low of under 7 MW to a high of 850 MW. Of the 46 proposals received, eight were deemed not to meet the threshold requirements of the RFP. Of the proposals evaluated (and in some instances subsequently aggregated into portfolios) 85% were located in the northern tier states of New Hampshire (34%), Maine (26%) and Vermont (13%)

leaving the remaining 27% to the southern tier of Connecticut and Massachusetts with no project physically located in Rhode Island. The multiple large-scale transmission projects were structured to bring hydro power from Hydro Quebec into northern New England for delivery to the southern load centers. These projects were both DC and AC.

6. Case study: Application of Analytic Methodology

The quantitative evaluation team calculated the direct cost and benefit metrics for each proposal / portfolio from the data provided by the proposals submitted, from the outputs of the simulation

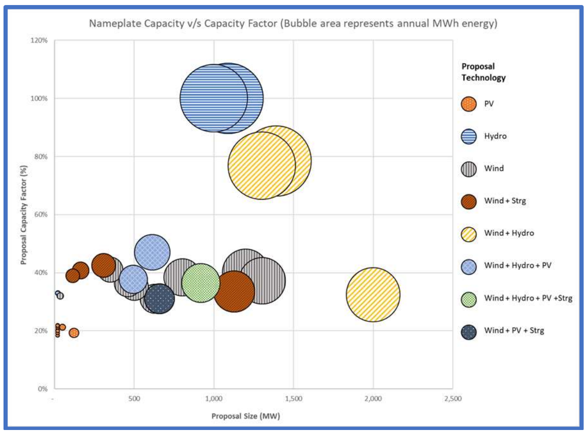

Figure 5: Distribution of 83D Proposals by Technology, Size (MW) and Capacity Factor (%)

modeling of each proposal and portfolio case and from the developed quantitative evaluation workbook for each case.

In the same manner, the quantitative evaluation team calculated values for the indirect cost and benefit metrics of each proposal/portfolio by comparing outputs of the simulation modeling of each case to the outputs of the simulation modeling of the 83D base case, as well as from the quantitative evaluation workbook for each case.

As indicated above, to achieve quantitative comparability between renewable projects of differing technology, size and timing, the analytic methodology developed identified a set of ten direct and indirect criteria whose value could be expressed in terms of a single numeric value, $/MWh denominated in constant 2017 dollars.

In summary, the ten metrics are:

Direct

i. Revenue earned from the energy market
ii. The direct cost of the contracted energy to the utilities
iii. Revenue generated from REC and CEC sold into the market
iv. The direct cost of REC and CEC to the utilities
v. The cost (or benefit) attributable to transmission

Indirect

vi. Savings from LMPs (energy price suppression)
vii. Savings from REC/CEC Price Suppression
viii. The contribution value to GWSA
ix. The positive impact winter gas related price volatility
x. The Impact on the Capacity Market

The definition, calculation and aggregation of each of the ten metrics (denominated in $/MWh) is discussed in Section 2 above. Recall that the procedure is developed to be independent of technology and size but to be fully cognizant of location and timing of delivery of energy and the environmental attributes captured in the metrics.

The highly detailed performance characteristics modeled in ENELYTIX generate gigabytes of individual hourly values. As depicted in Fig. 4, these simulated values are loaded into Power Market Explorer (PME), a multi-dimensional OLAP cube component of ENELYTIX. The PME cube is accessible from within Excel on the user's desktop. Analysis presented to the user via pivot tables and graphs is dynamically aggregated and summarized results with summaries and aggregations performed by the server machine hosting the PME Cube on the cloud.

The desktop-based analysis focused on further reduction in detail through the application of standard financial techniques to calculate the net present value of the financial flows and to arrive at a value or cost in $/MWH for each of the attributes.

Figure 6 to 9 provide a "waterfall" picture of the manner in which each of the ten metrics contribute to the single summation value for four examples of types of bids received.

Moving from left to right across Figure 6 steps through the positive and the negative metric values of the project to show the way the metrics summed to arrive at the comparative value.

i. $51/MWh to the positive
ii. $47.5/MWh to the negative
iii. $24.3/MWh to the positive
iv. $0.0/MWh (A does not participate in the REC market receives credit for its environmental attributes through CECs)
v. $12/MWh to the negative
vi. $4.9/MWh to the positive
vii. $11.7/MWh to the positive
viii. $8/MWh to the positive
ix. $1/MWh to the positive

x. $3.3/MWh to the negative
xi. TOTAL VALUE $38.1/MWh

For bidder A (Figure 6) in this analysis, the direct benefits (i-v) sum to $15.41/MWh and the indirect (vi-x) to $22.39/MWh, indicating that the hydro projects' principal value is not in terms of the energy being provided but rather in terms of the indirect benefits in price suppression and contribution to GWSA.

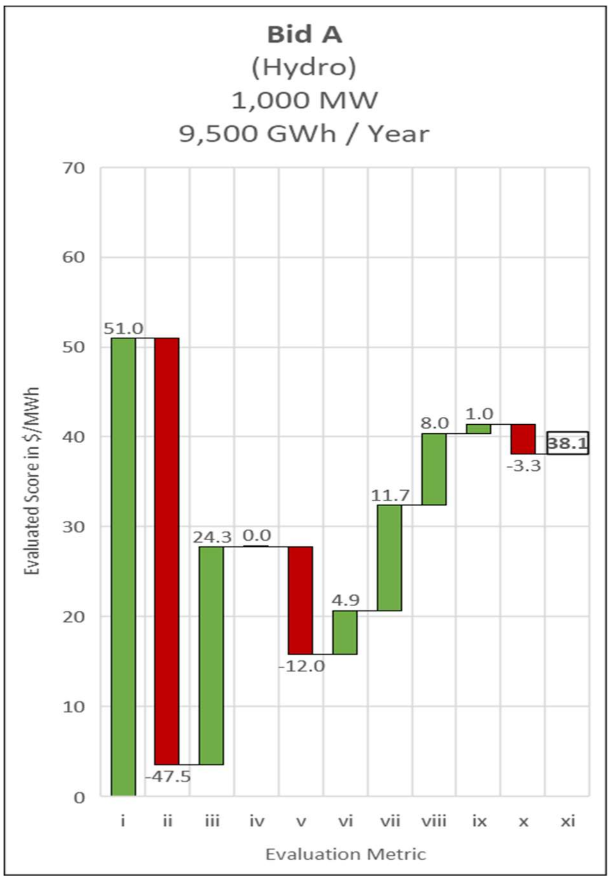

Figure 6: Bid A 1000 MW Hydro

Focusing on Bid B (Figure 7) shows a significantly different picture. Bid B is a wind project that by nameplate is larger (1300MW) but that generates half the energy of Bid A. The direct benefits are 10.27 $/MWh while the indirect benefits are 22.64 $/MWh for a total of 32.9 $/MWh, similar in value to those of A, and also primarily comprised of indirect benefits. Unlike A, B does participate in the REC market and the proposed cost is split between the energy price and the REC price. B's smaller energy product has the impact of increasing the $/MWh transmission cost for a transmission line sized and priced similarly to A's.

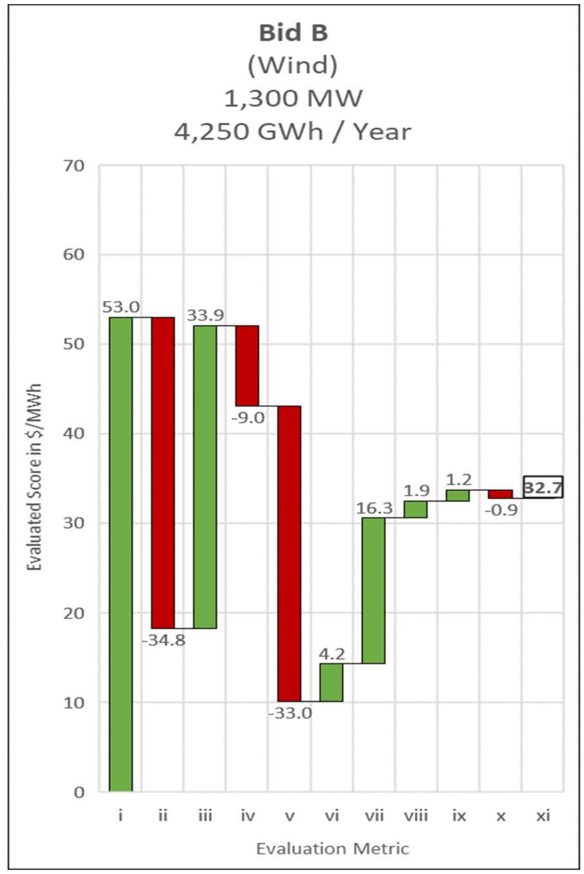

Figure 7: Bid B 1300MW Wind

By comparison, Bid C (Figure 8), a combination of wind, PV, and storage, is half the capacity(MW) of Bid B, generating only one-third of the energy yet showing a value of $52.67/MWh for the first four direct benefits but a negative of $36.47/MWh of the cost of transmission (v) or a net of $16.21/MWh for direct and $29.97/MWh indirect for a total of $46.2/MWh. Bid C provides the greatest value per MWh, given its far smaller installed capacity and energy provision. Bid C provides evidence that the methodology is size-independent.

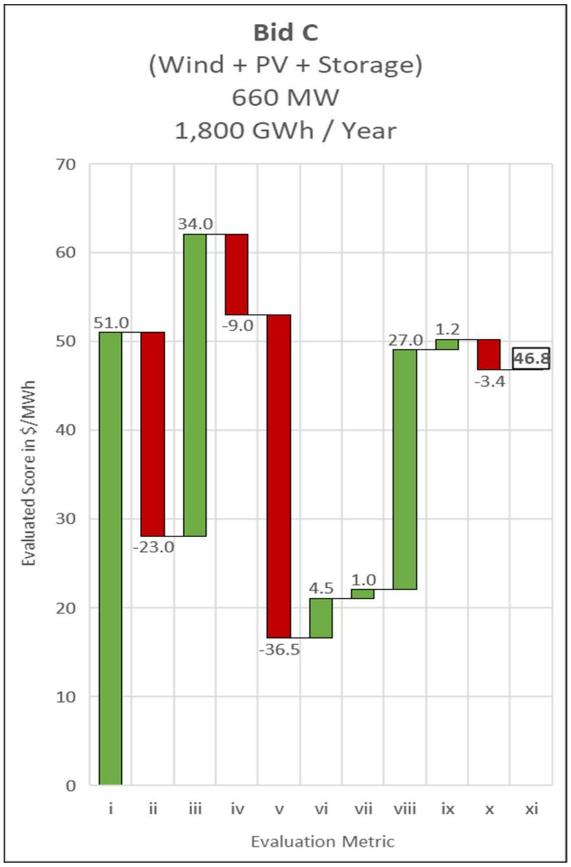

Figure 8: bid C 660MW PV + Wind + Storage

Portfolio Bid D (**Error! Reference source not found.**) is aggregation of 13 projects involving relatively low capacity factor PV. D provides a view of the effect of a portfolio of hydro, wind, PV and storage projects. It has 2,800 MW of capacity and generates 8,250 GWh per year. In total, Bid D shows direct benefits of $17.96/MWh and indirect benefits of only $7.83/MWh for a total of $25.8/MWh.

7. Summary and Conclusions

This paper provides a methodological road map for the evaluation of multiple bids of varying technology, size and location responding to a single solicitation for energy supplies. It demonstrates that it is possible and highly desirable to be able to evaluate renewable energy projects in a manner that is independent of their size but fully reflective of their physical location within the grid and economic contribution within the energy market.

The project review process begins with the detailed development of a protocol that defines the metric for measuring each direct and indirect cost and benefit to be evaluated in the quantitative analysis of each project proposal. The quantitative analysis itself then proceeds to calculate the potential impact of each project proposal on the New England electric system when integrated into the system taking into consideration the long-term capacity requirements and a detailed, hourly, nodal evaluation of the operational benefits and costs. The analysis is undertaken in two steps. The first step is a simulation of a scenario in which the proposed project has been selected using a state-of-the art cloud-based power system simulator, ENELYTIX. The second step is an analysis of costs and benefits by year using a complex spreadsheet-based workbook that processes and aggregates the economic and environmental data from the simulations into the common value ($/MWh in 2017 dollars) that becomes the common denominator for quantitative evaluation of the individual projects. These ten direct and indirect metrics are then summed to arrive at a single quantitative value of merit and quantitative project ranking.

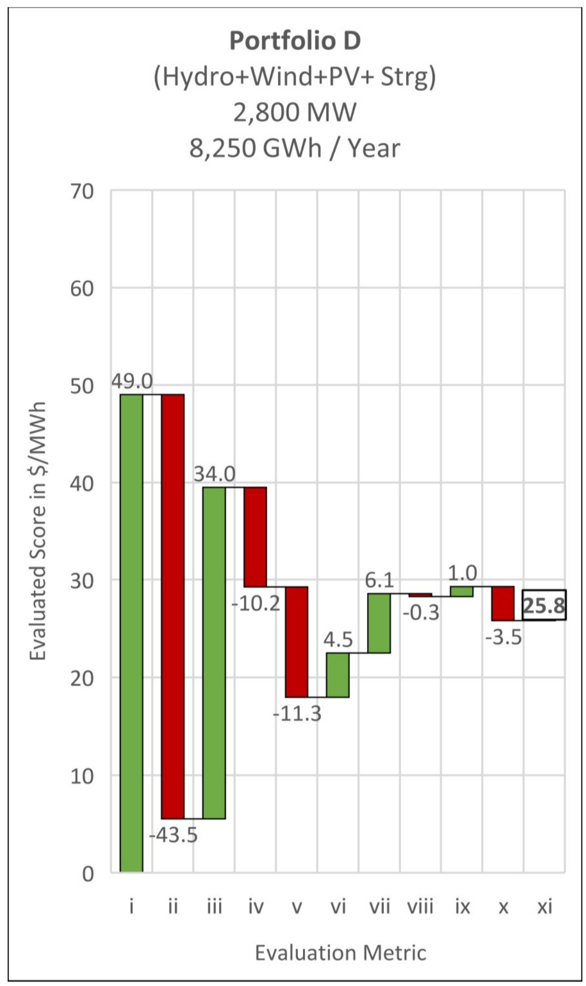

Figure 9: Portfolio D 2800MW Hydro + Wind + PV + Storage

8. References

[1] The Global Warming Solutions Act (GWSA) was signed into law by Massachusetts Governor Deval Patrick in August of 2008. The Act requires the Executive Office of Energy and Environmental Affairs (EEA), other state agencies, and the public to design and implement a statewide framework to reduce greenhouse gas emissions. By 2020, levels must be 25% lower than they were in 1990. By 2050, greenhouse gas emissions are required to be 80% lower than the level of emissions that were present in Massachusetts in 1990. The GWSA is designed to attract clean energy businesses and jobs, reduce energy costs, and increase the energy independence of Massachusetts by initiating improvements to transportation, buildings and new and cleaner energy supplies. http://www.mabizforcleanenergy.com/ma-supports-clean-energy/gws/

[2] Environmental Attribute means all of the New England Power Pool Generation Information System Certificates and any other present or future environmental benefits associated with the Firm Service Hydroelectric Generation energy deliveries contracted for as part of the 83D RFP.

[3] The authors of this paper are employees or affiliates of Tabors Caramanis Rudkevich (TCR). TCR was the analytic engine of the Quantitative Evaluation team that also included representatives of the Massachusetts Electricity Distribution Utilities (Eversource, National Grid and Unitil), the Massachusetts Department of Environmental Resources (DOER) and an Independent Evaluator (New Energy Opportunities).

[4] See Appendix 3, Long-Term Contracts for Clean Energy Generation Projects Pursuant to Section 83D of Chapter 169 of the Acts of 2008: Quantitative Evaluation Report, Tabors Caramanis Rudkevich, June 2018.

[5] The parallel process of project and portfolio evaluation of the first tranche of offshore wind under the Massachusetts GWSA was completed in the summer of 2018 with the choice of single supplier to provide 800 MW in the first tranche.