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Impact of Wind Topologies on the ISO of New England Nodal Electricity Prices

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Abstract

This study presents a case study on the power system in Independent System Operator New England (ISO-NE). Despite its present low wind penetration, "New England has multiple wind-rich areas ripe for development, making renewable energy an exciting possibility for the region's future".

A multi-objective problem with conflicting objectives has no single solution, but a set of solutions, known as the Pareto set. Using multi-objective evolutionary computation, NSGA-II (Non-Sorted Genetic Algorithm), a set of optimal topologies of wind sites has been produced.

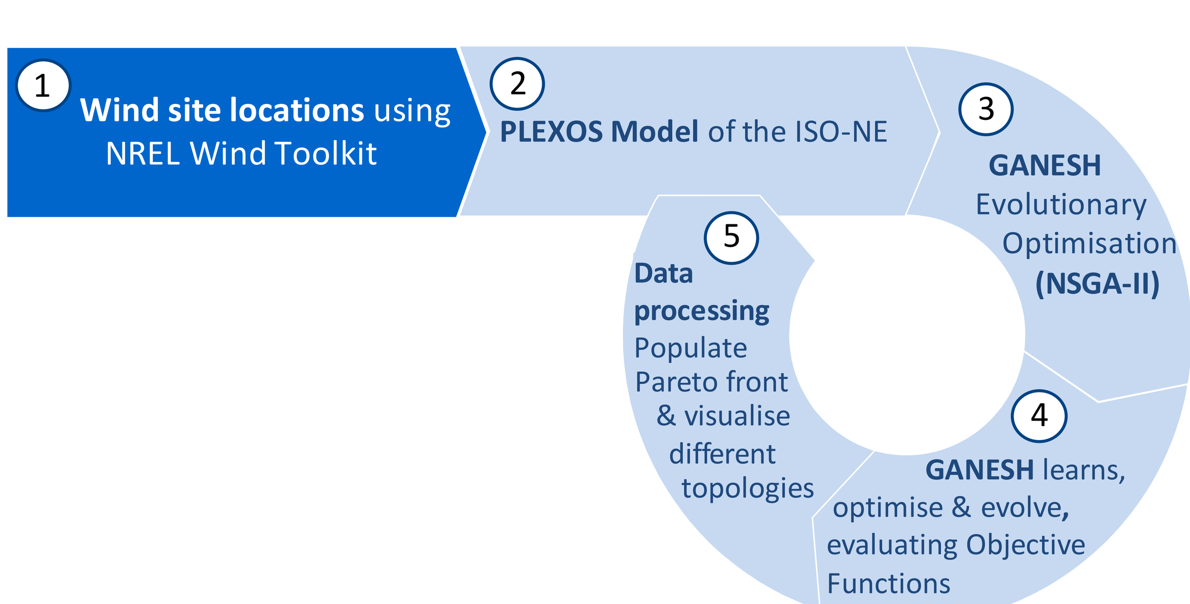
The study explores how different topologies of distributed wind power would impact on nodal electricity prices. Production costing models are used to forecast the expected amount of electricity produced by different distributed wind power topologies on nodal electricity prices using a model of the power system operated by the ISO-NE. PLEXOS, a commercial software, is used to represent the production cost model of the ISO-NE power system by simulating the day-ahead (DA), an intraday 4 hours-ahead (4HA) and real-time (RT) markets.

Study characterisation
3314 nodes (189 above 230kV)
2485 lines (216 above 230kV)
1830 transformers
468 generators (excluding wind sites)
DA/4HA/RT load & wind forecasts
Contingency & regulation reserves
No interconnections with other ISOs
Hydro: DA is passed on to 4HA and RT

DA	4HA	RT
Nuclear	CC	Gas_GT
Coal_ST	Gas_ST	Gas_IC
Biomass	Oil_ST	Jet_Oil_GT
		Oil_GT
		Oil_IC
		Wind

Exhibit 1. On the left, relevant characteristics of the study. On the right, Generators' commitment dispatch for the DA, 4HA, RT markets

Objectives



Methodology

1

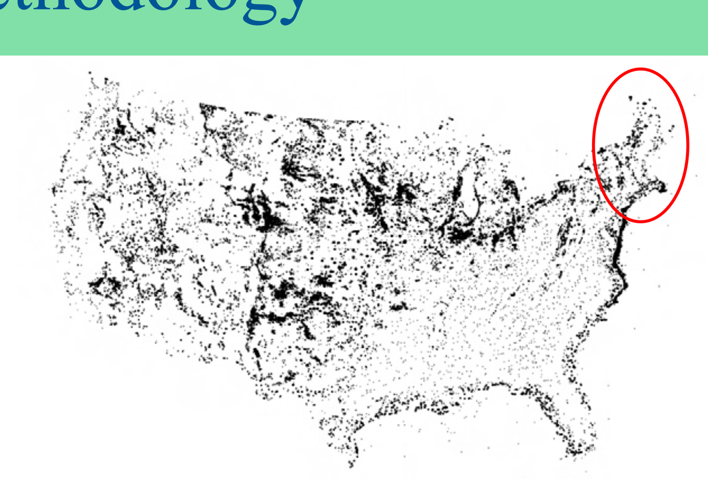


Exhibit 2. 126,000 US study locations provided by Wind Toolkit. In red, highlighted, the 2,738 locations in the ISO-NE modelled in this study

The WIND Toolkit [1] provides power output for onshore and offshore wind sites on a 2-km by 2-km grid with 5-minute resolution from 2007 to 2013. This study is based on 2010 data.

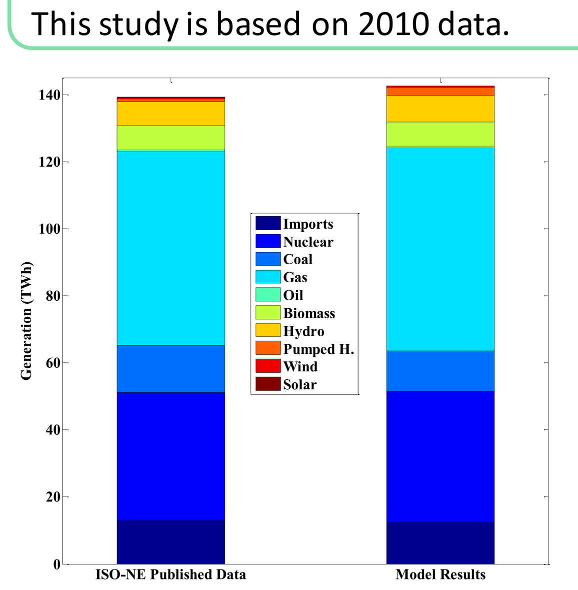


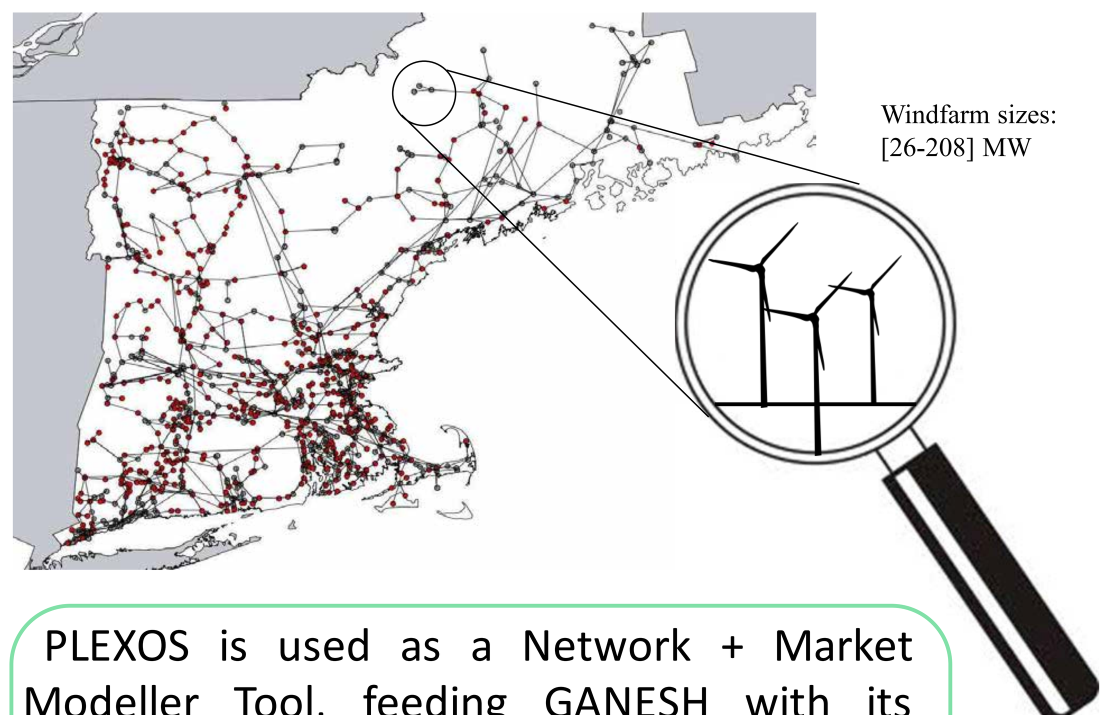
Exhibit 3. Validation of the ISO-NE PLEXOS Model vs ISO-NE Published 2010 Generation Mix Data [2]

State	Number of Sites	Total Wind Capacity (MW)
Connecticut	110	1,258
Maine	1,142	15,558
Massachusetts	512	5,810
New Hampshire	404	5,452
Rhode Island	126	1,492
Vermont	444	6,200
ISO-NE Data	**2,738**	**35,770**
ISO-NE Model	**770**	**35,770**

Exhibit 4. WIND Toolkit locations for New England & ISO-NE Model simplification for computing optimisation

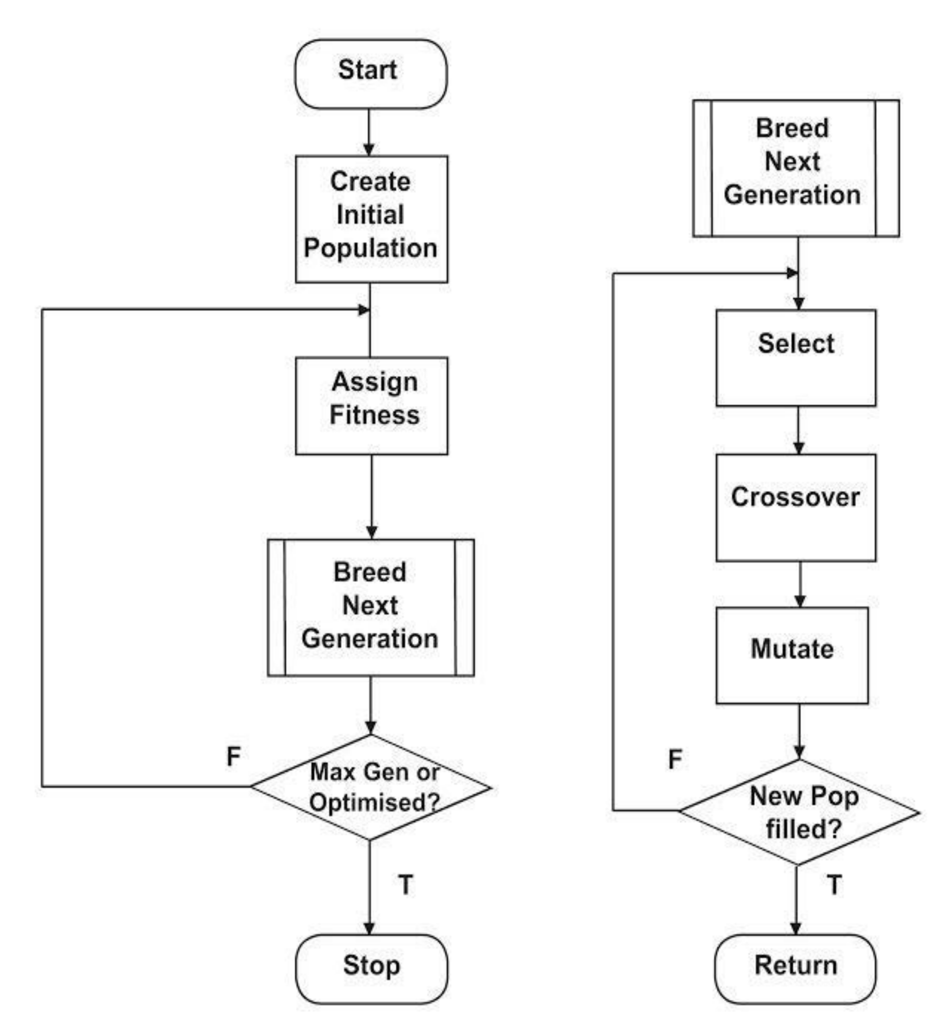
Methods

2 Modelling ISO-NE with PLEXOS



PLEXOS is used as a Network + Market Modeller Tool, feeding GANESH with its results, the optimiser will evaluate the Objective functions, in this study: Total Generation costs & Standard Deviation of hourly Prices

3 GANESH Evolutionary Optimisation



GANESH [3] [4], is a multi-objective evolutionary optimiser (based on a Non Sorted Genetic Algorithm-II algorithm), implemented in Java. It is used to optimise the Objective Functions and modify PLEXOS inputs:

Decision variables = $(x_1, x_2, \ldots, x_{770})$; $x_n = \{0, 1\}$

1. *min* Total Generation Cost
2. *min* Standard Deviation Price

Hard constraint: $\sum x_n = 10$ GW

4 Populating the Pareto front

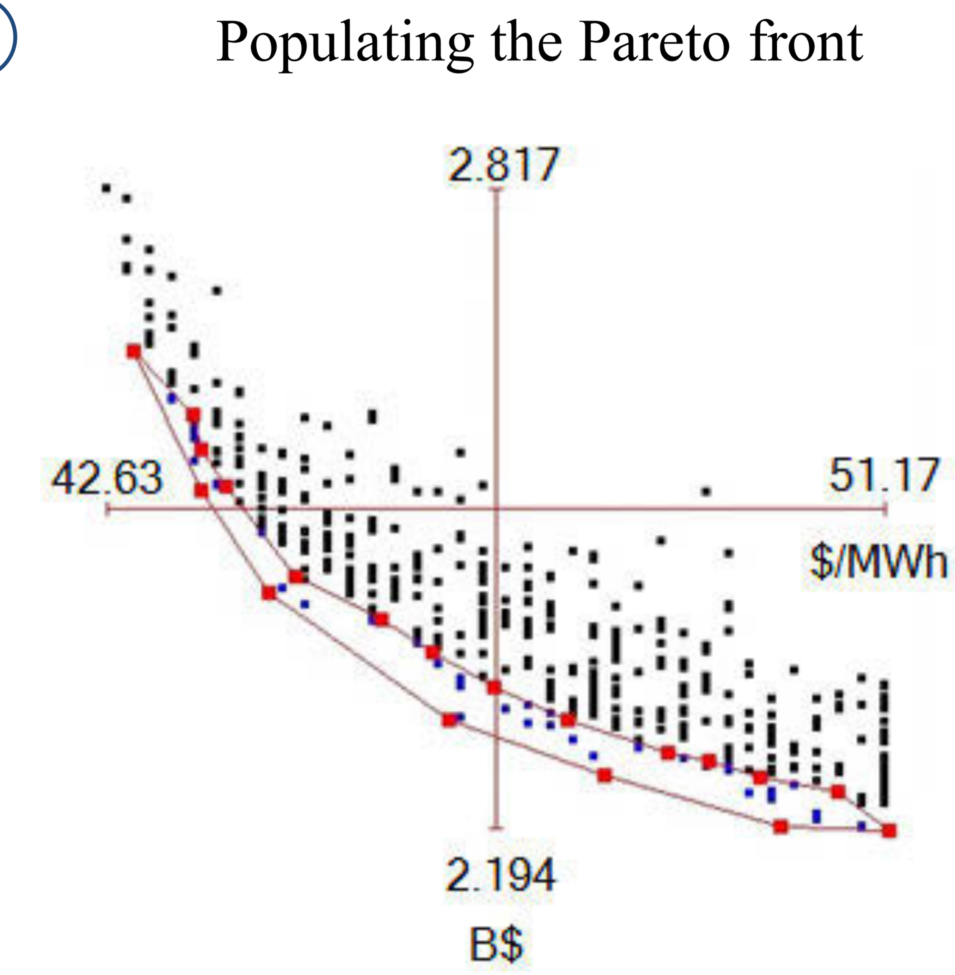


Exhibit 5. Pareto front with optimised wind topologies

The optimised Pareto frontier identifies suitable topologies for optimisation application. GANESH feedbacks loop to PLEXOS a self-adapted wind configurations determined by the crossover and mutation of the population in the embedded Genetic Algorithm

Results

5 Optimal Topologies visualisation

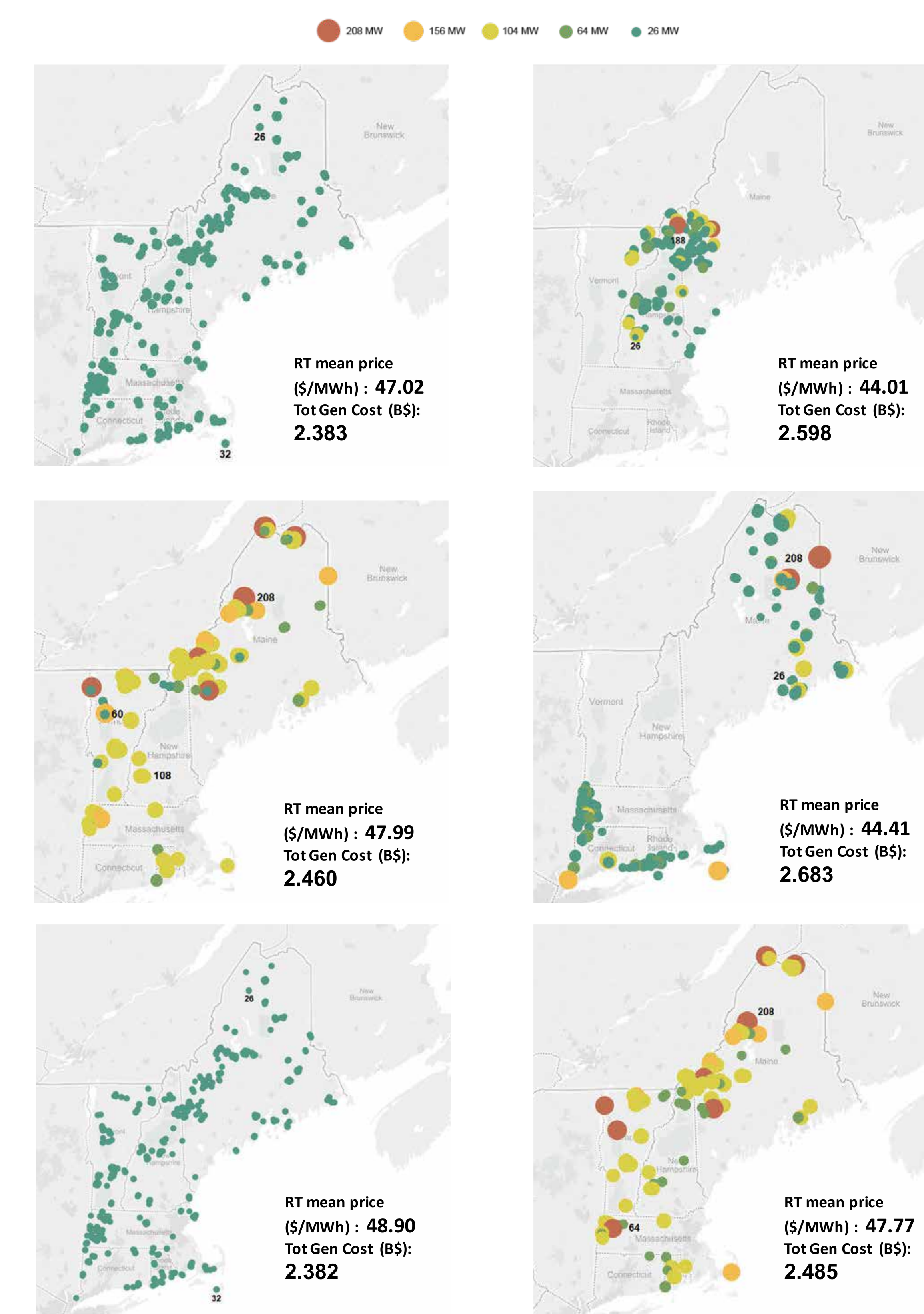


Exhibit 6. Wind Topology scenarios for the ISO-NE Model visualisation results

Conclusions

- An approach to apply multi-objective evolutionary optimisation for evaluating high penetration of wind has been proposed providing meaningful insights in previous uncertainties
- Different wind topologies impact on nodal prices. RT mean price in 2010 was 49.58 $/MWh. This study proposes optimal wind topologies for reducing ISO-NE RT prices in up to 13%
- Large penetration of wind (up to 32%) will impact on ISO-NE generation mix, lowering Total Generation Costs and reducing Coal and Gas consumptions (Exhibit 7)
- In this study, there are not interconnections with neighbouring regions. It would be valuable as future work to analyse prices with those interconnections to incorporate electricity exchange revenues in the cost analysis of different wind topologies

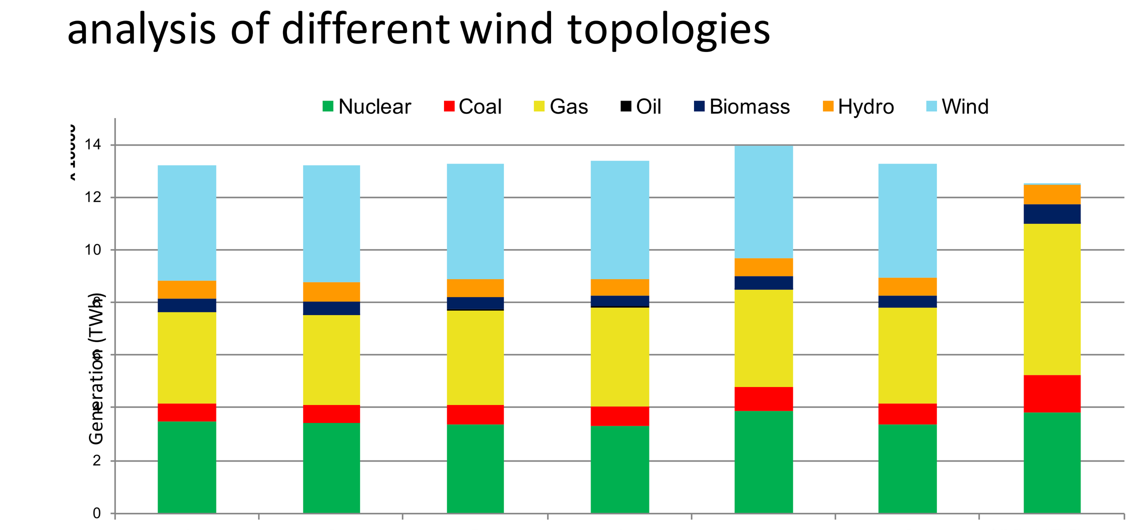


Exhibit 7. Six different optimal ISO-NE Models vs ISO-NE 2010 Data

References

[1] Draxl, C.; Hodge, B. M.; Clifton, A.; McCaa, J. (2015). "The Wind Integration National Dataset (WIND) Toolkit." Applied Energy (151); pp. 355-366.

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[3] Oliver, J. M., Kipouros, T. and Savill, A. M. (2013), "A Self-adaptive Genetic Algorithm Applied to Multi-Objective Optimization of an Airfoil", in *Evolutionary Computation IV*, Springer, pp. 261-276.

[4] Oliver, J., Kipouros, T. and Savill, A. M. (2013), "An Evolutionary Computing-based Approach to Electrical Power Network Configuration", *ECCS'13 European Conference on Complex Systems; Satellite Workshop: Integrated Utility Services IUS'1, Spain.*