Impact of Wind Topologies on Nodal Electricity Prices

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Introduction

- This study explores optimal topologies for distributed wind power, co-optimising impacts on nodal electricity prices, and total generation costs. The best wind resources are generally located far from the load centre. Suitable locations for distributed wind power turbines depend both on topological and network conditions
- A production cost model in PLEXOS is used to analyse the impact of different distributed wind power topologies on nodal electricity prices using the power system operated by the Independent System Operator - New England (ISO-NE)
- ISO-NE will be simulated with the day-ahead (DA), four hour-ahead (4HA) and real-time (RT) markets. Yearly simulations are run by a Genetic Algorithm (GANESH) in order to create the Pareto front that co-optimizes our Objective Functions, selecting among the 770 suitable locations where to install 10GW of wind (Hard constraint)

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

Approach to Problem

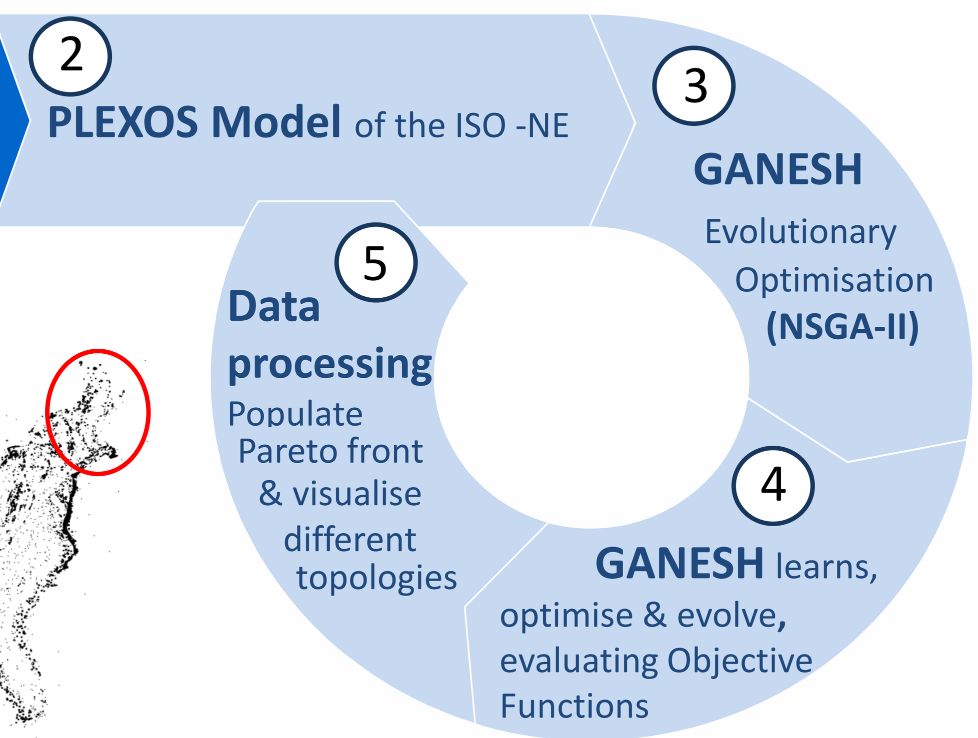

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Exhibit 2. 126.000 US study locations provided by Wind Toolkit. In red, highlighted, the ones modelled in this study

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.

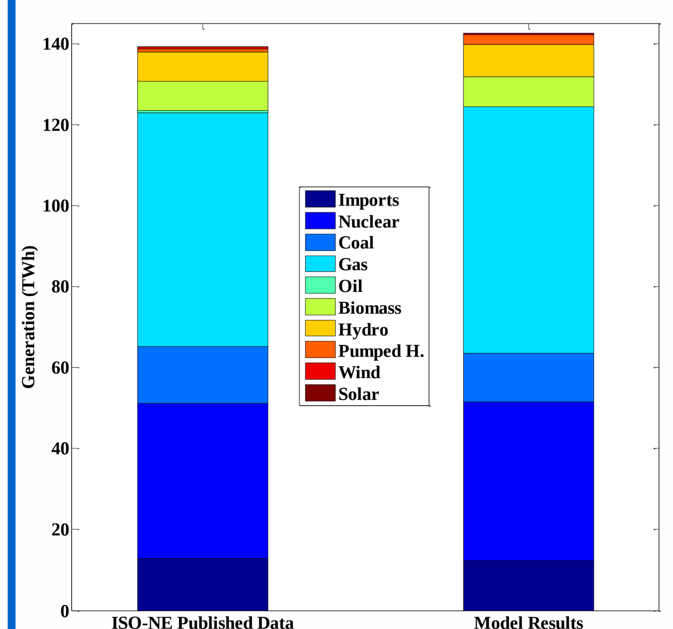

Exhibit 3. Validation of the ISO-NE PLEXOS Model vs ISO-NE Published 2010 Generation Mix Data (2)

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

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.

[2] Martinez-Anido, C. B., Brinkman, G., & Hodge, B. M. (2016). The impact of wind power on electricity prices. *Renewable Energy*, *94*, 474-487.

[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.*

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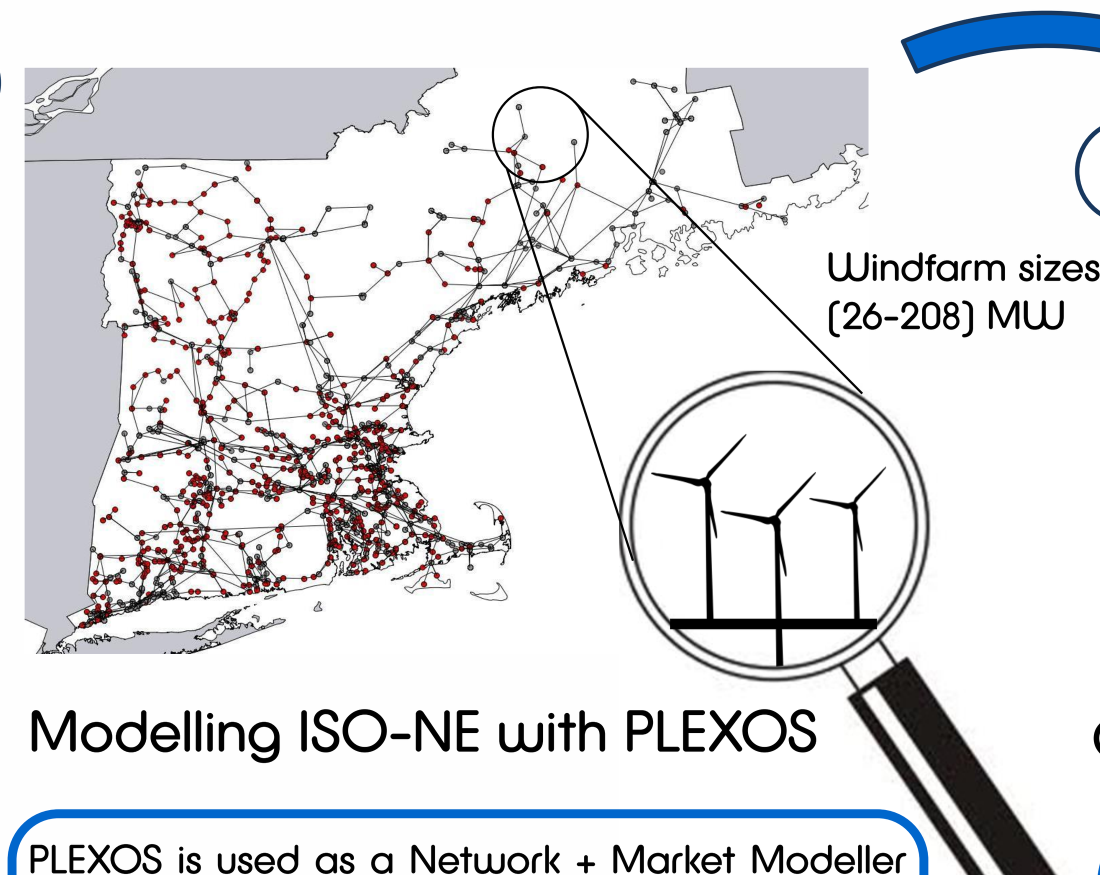

Modelling ISO-NE with PLEXOS

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 Prices

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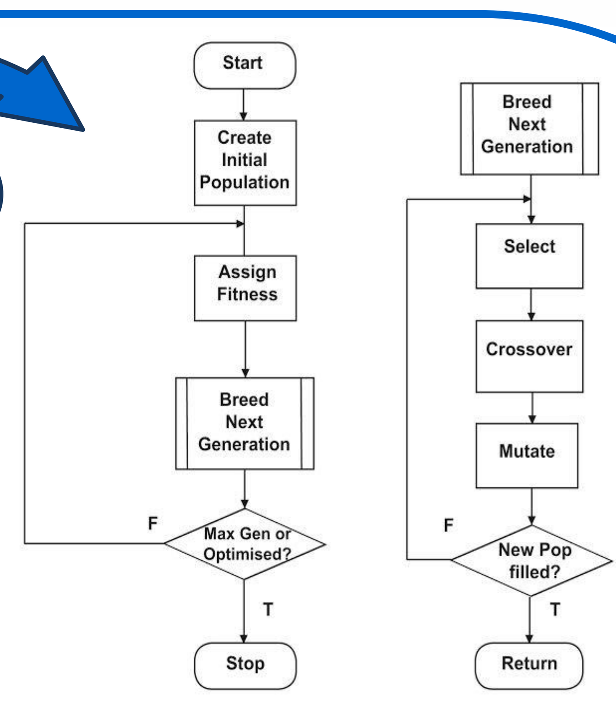

GANESH Evolutionary Optimisation

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

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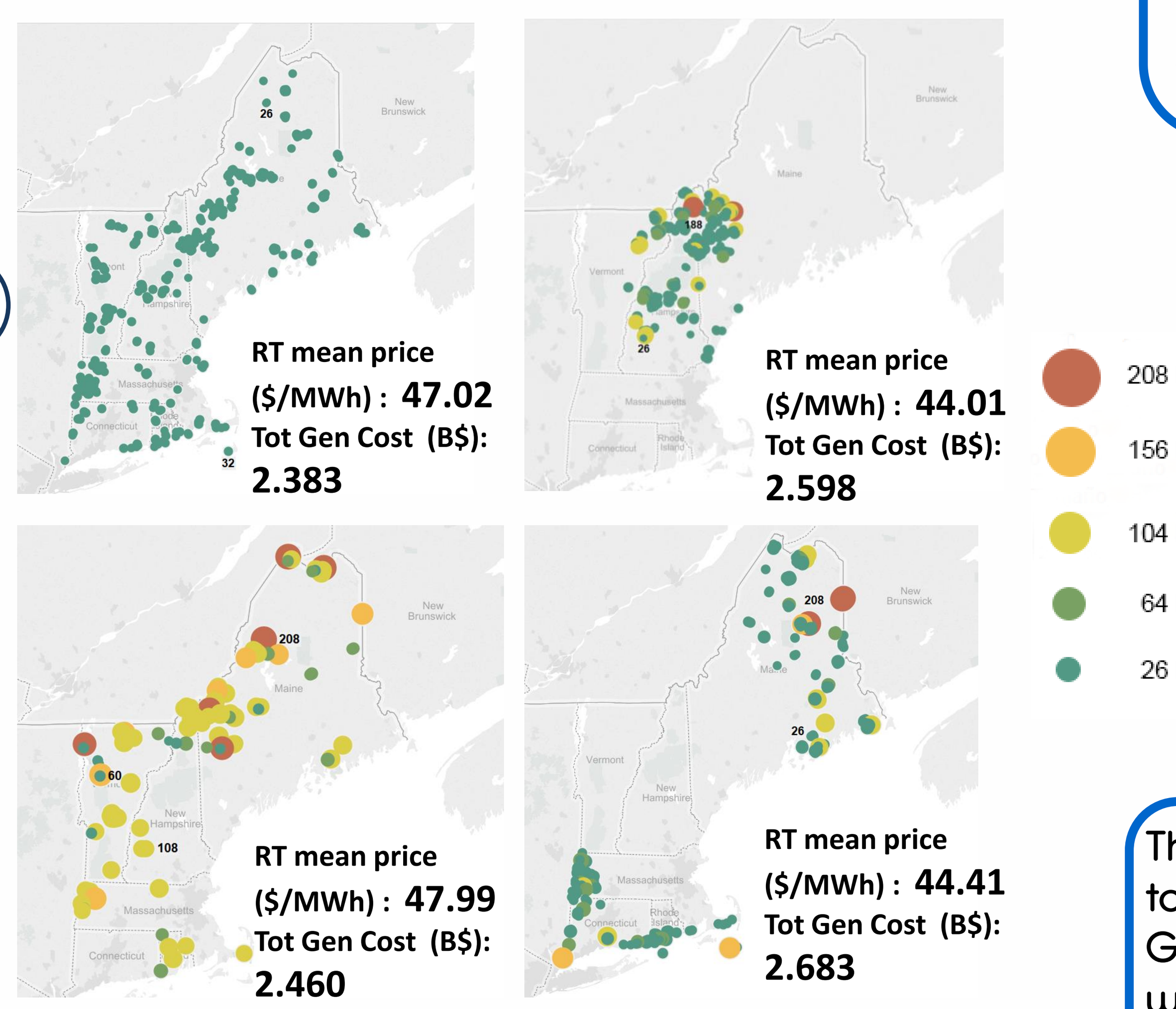

Exhibit 6. Wind Topology scenarios for the ISO-NE Model visualisation results

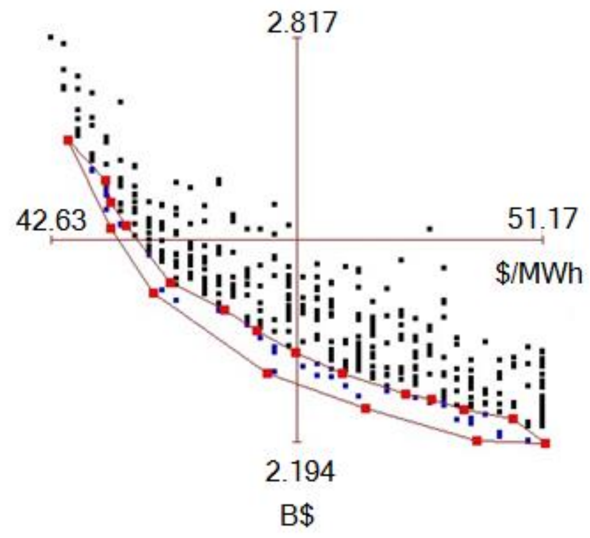

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Exhibit 5. Pareto front with optimised wind topologies

The optimised Pareto frontier identifies suitable topologies for optimisation application. GANESH feedbacks loop, self-adapts PLEXOS wind configurations determined by the performance of the Objective Functions

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

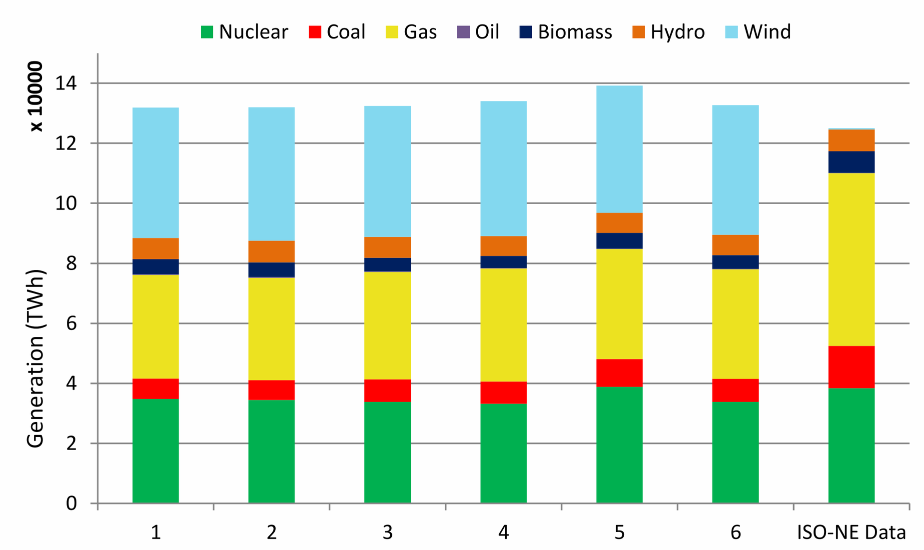

Exhibit 7. Six different optimal ISO-NE Models vs ISO-NE 2010 Data

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