Use of Cloud Computing in Power Market Simulations

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Outline

- Power market simulators
  - Users and applications
  - Pain points and opportunities
- Cloud Solutions
  - Commercial cloud environment and tools: Amazon cloud as an example
  - Power market simulator on a cloud: PSO and *pCloudAnalytics*
  - Benefits
  - Challenges
- Case Study: Effect of Price Suppression of Offshore Wind in New England
- Conclusions

About NEG and TCR

- **Newton Energy Group** (NEG). Technology company founded in 2012 by John Goldis and Alex Rudkevich
- NEG has developed *pCloudAnalytics (pCA),* a new generation of energy market modeling tools combining advanced analytics with cloud computing technology
- NEG is a member of the Amazon Partner Network
- **Tabors Caramanis Rudkevich** (TCR). Energy economics and regulatory policy consulting company founded in 2014 by Richard Tabors, Michael Caramanis and Alex Rudkevich
- Both companies are located in Cambridge, MA

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Market Engines and Market Simulators

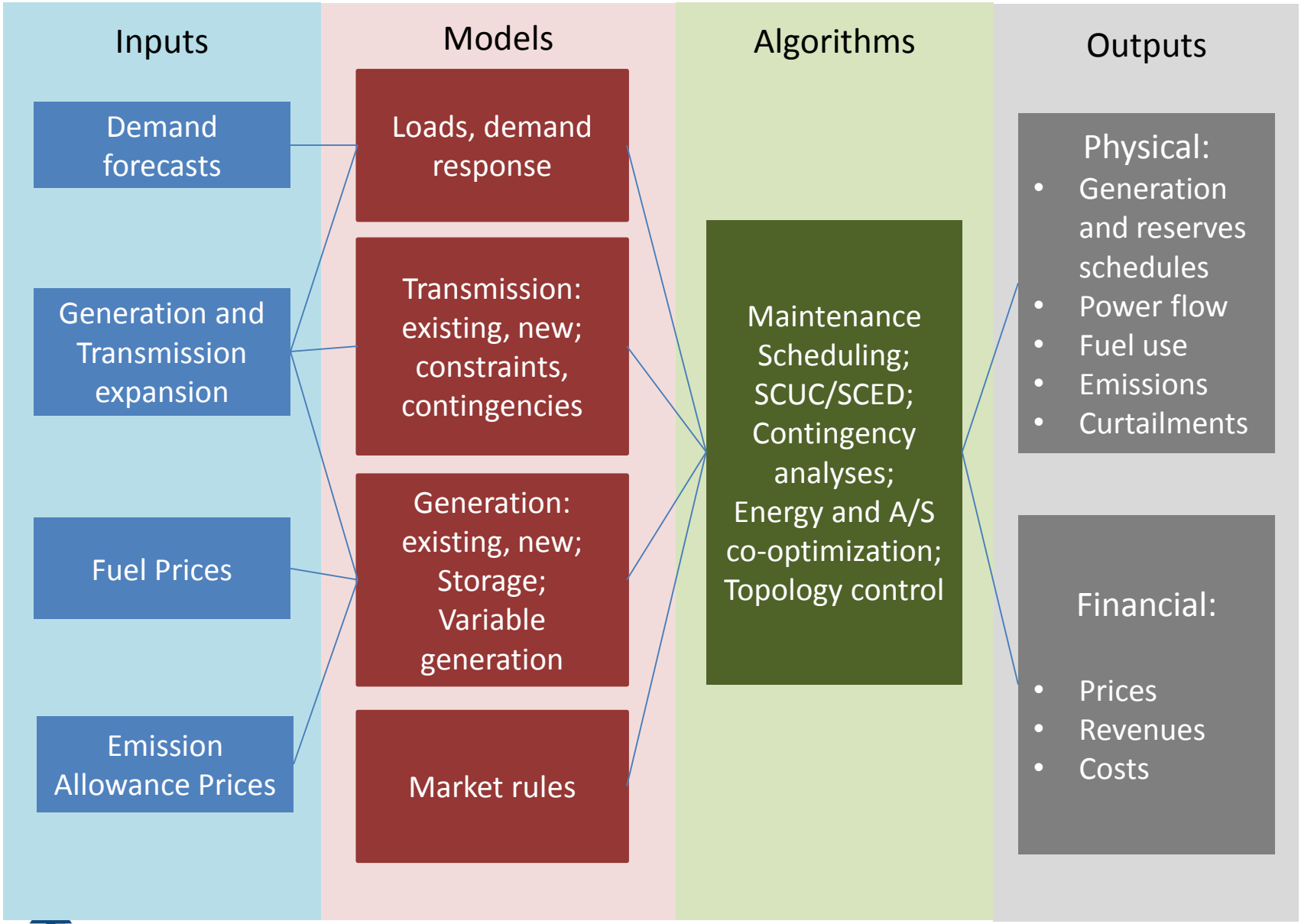
- Market engine
  - used by market operators
  - solves specialized large-scale decision problems to control physical operations and to facilitate transactions between market participants
  - relies on data feeds "from the market"
- Market simulators must
  - replicate the logic of the market engine
  - simulate data feeds (scenarios) addressing the problem studied
  - summarize results over simulation horizon and across scenarios
- A market simulator is a modeling environment for solving a wide range of problems and serving multiple needs within and across organizations participating in power markets

Applications of Power Market Simulators

- Valuation of assets (physical or financial contracts)
  - Cash flow projections under various scenarios
- Transmission planning
  - Assessment of physical flows, economic and environmental impacts of transmission projects. Cost-benefit analyses
- Policy analysis, market design
  - Simulation of the impact of changing regulatory policy, market /operational rules on market performance. Cost-benefit analysis
- Market surveillance
  - Ex post simulations. Impact of bidding behaviors
- Generation scheduling, trading support
  - Detailed simulations of system operations and economics under multiple scenarios with relatively short-term horizons (hour-ahead to month-ahead)
- Risk analysis
  - Cash flow projections under multiple scenarios for risk metrics
- Modeling of variable generation, distributed generation, demand response participation in markets for energy and ancillary services
  - Hourly and sub-hourly simulations of market operations under various inputs and market design scenarios
- Reliability assessments
  - Feasibility assessment of the system using Monte-Carlo generated scenarios

A simulator must be adaptable to solving a wide range of problems, facilitate a rapid set up of the analysis, produce results within minutes to hours, provide both physical and economic implications of the analysis

Key Components of Power Market Simulators



"Pain points" for Users of Power Market Simulators

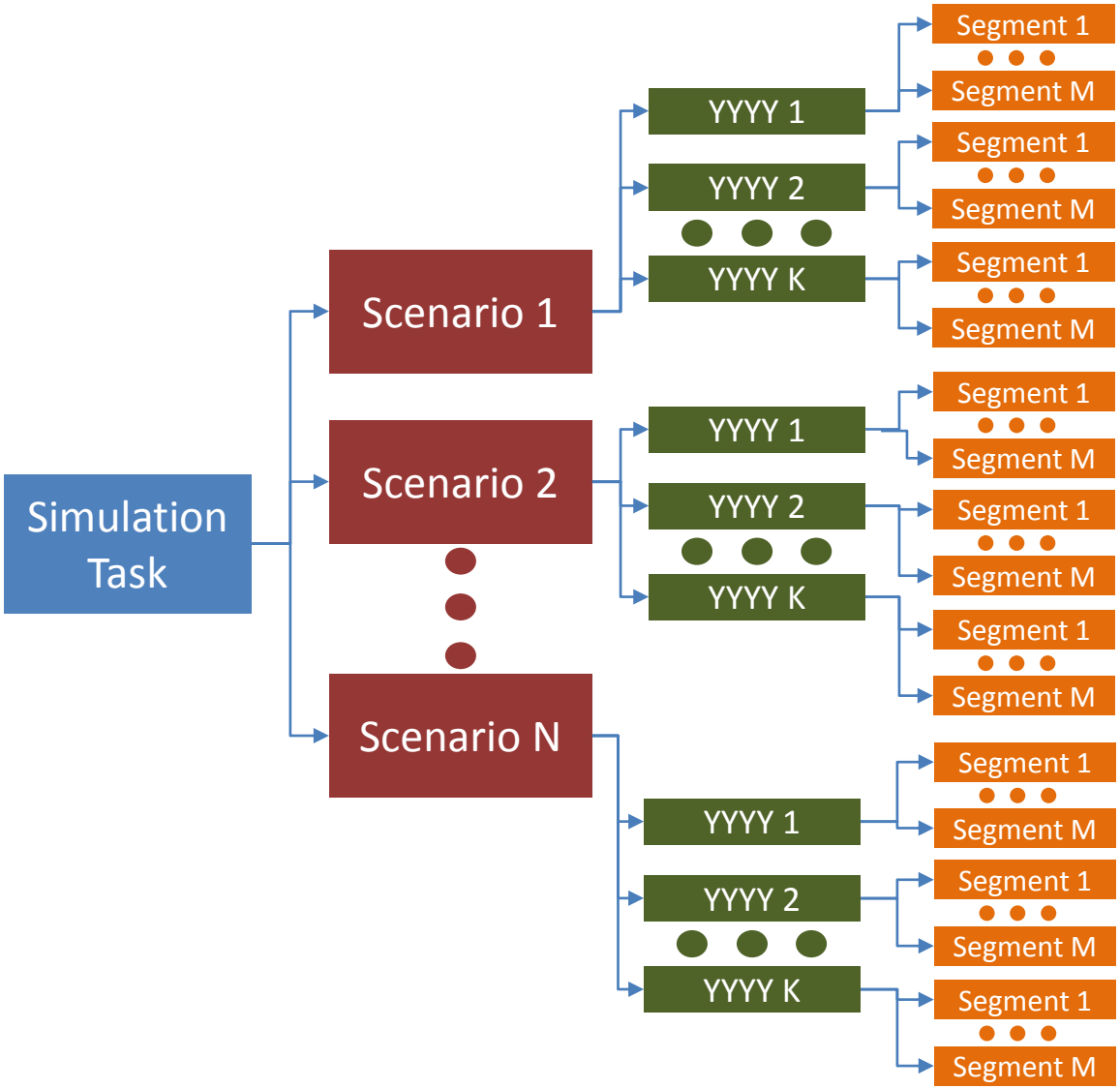
"Pain Point"	Explanation
The curse of "One scenario at a time"	Not set up to generate, execute and post process multiple scenarios in a bulk
Architectures not built for scalability	Hardware: not enough when you need it, idle when you don't Software: • many problems are embarrassingly parallelizable (time domain partitioning) but software is not well designed to take advantage of that • licensing structures often not friendly for running multiple instances in parallel
Turn-around time	Turn-around times for projects are unacceptably and inexcusably long. Tasks that take weeks to complete could be done in a matter of minutes to hours with scalability and parallelization

Current Trends in Simulator Development

- Transition from heuristics to MIP
- Expansion of time scales required by various applications: from minutes to years
- Changing transmission topology
- Increased complexity of resource models (e.g., combined cycle modeling, storage systems combined with variable generation)
- Multiple decision cycles
- Flexible modeling of ancillary services
- Stochastic models of unit commitment and procurement of reserves

Implications:
Significant increase in computational requirements, workflow management and data processing and storage needs

Well recognized embarrassingly parallelizable structure of many simulator problems



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Cloud Solutions

AWS – The Cloud

- Cloud solution: low to no fixed costs
- Amazon Web Services (AWS) offers IT infrastructure as a service
  - Storage
  - Compute
  - Database
  - Networking and Security
  - Application Management and Deployment
- By leveraging these services users create their own virtual hardware environments for managing a variety of business processes. Examples include:
  - Data backup
  - Website hosting for high traffic sites
  - Data analysis, scientific computing
  - Software as a Service (SaaS) – *pCloudAnalytics*

pCloudAnalytics

- Cloud-based implementation
- Simulator: Power Systems Optimizer (PSO)
- Modeling language: AIMMS
- MIP Solver: GUROBI
- Cloud infrastructure: AWS

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Polaris Systems Optimization

AIMMS

GUROBI OPTIMIZATION

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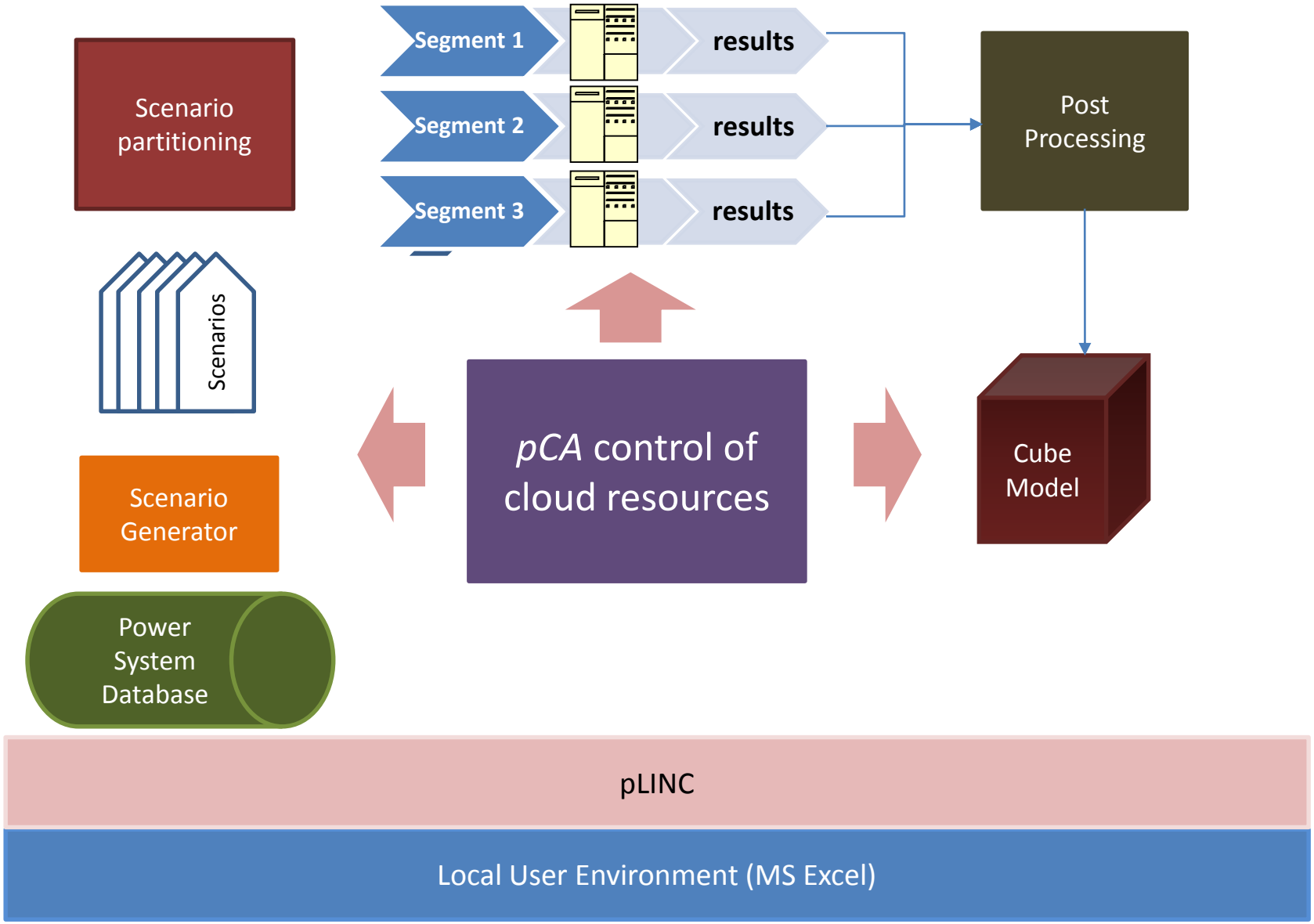
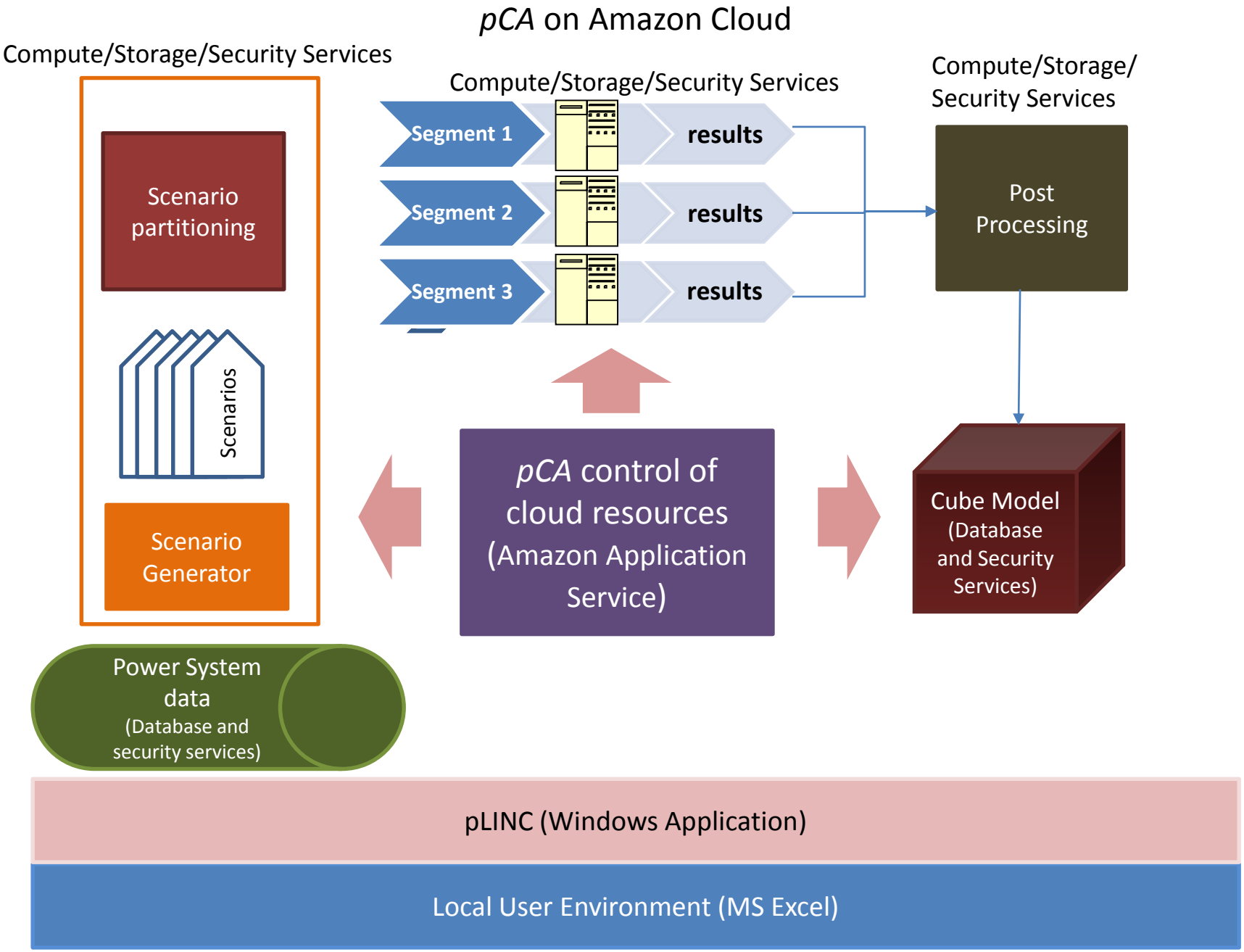
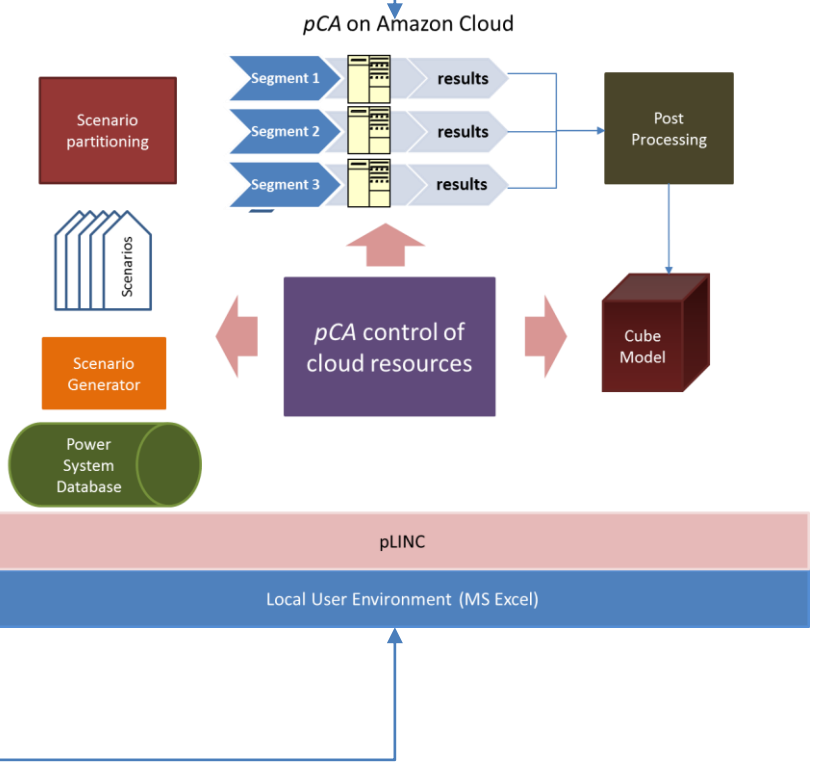
pCA on Amazon Cloud




pCA on Amazon Cloud
Compute/Storage/Security Services
Scenario partitioning
Scenarios
Scenario Generator
Compute/Storage/Security Services
Segment 1
Segment 2
Segment 3
results
results
results
Compute/Storage/ Security Services
Post Processing
pCA control of cloud resources (Amazon Application Service)
Cube Model (Database and Security Services)
Power System data (Database and security services)
pLINC (Windows Application)
Local User Environment (MS Excel)

Three Layers of *pCA*

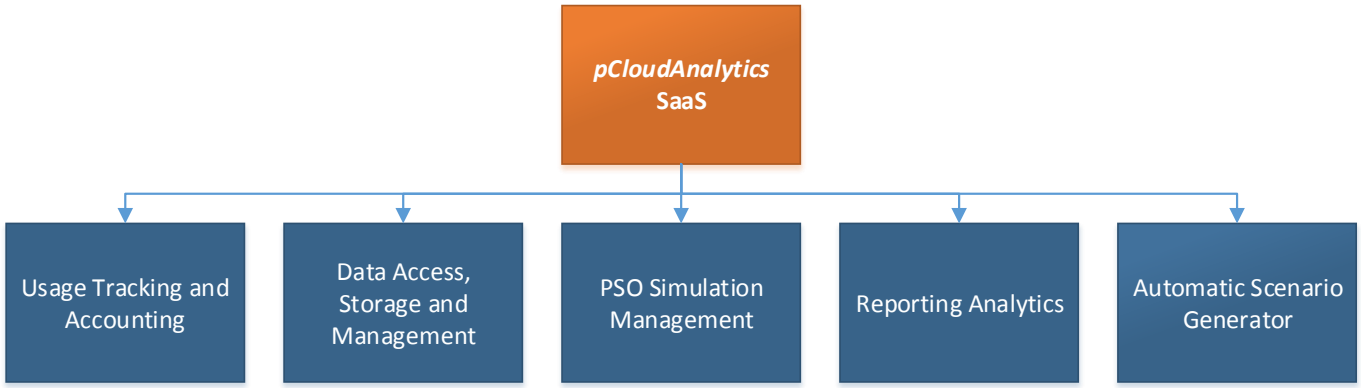
- Layer 1. Amazon Cloud
  - Data needed to run simulations
  - Infrastructure for scenario generation, partitioning, provisioning of virtual machines, execution and post processing
- Layer 2. pLINC provides synchronization and interaction between local and cloud environments
  - Client software
- Layer 3. Local user environment
  - Local directory structure synchronized with the cloud
  - MS Excel for preparing inputs
  - MS Excel for working with post processed results



Power Systems Optimizer (PSO) by Polaris

- Advanced power market simulator developed by Polaris Systems Optimization (psopt.com)
- Similar to major market engines, PSO is written in AIMMS
- Supports all major MIP solvers. When used with *pCA*, PSO is powered by Gurobi
- Current PSO users include: Boston University (Topology Control Algorithms), The Brattle Group, EPRI, NEG (used for multiple consulting engagements)

pCA Services



- Authentication
- User Access
- Usage tracking by user, project, task
- Itemized invoicing

- Cloud/local data synchronization
- Data encryption
- Storage
- Archiving
- Clean-up

- Parallelization
- Machine provisioning
- Run management
- Result processing
- “bad run” management

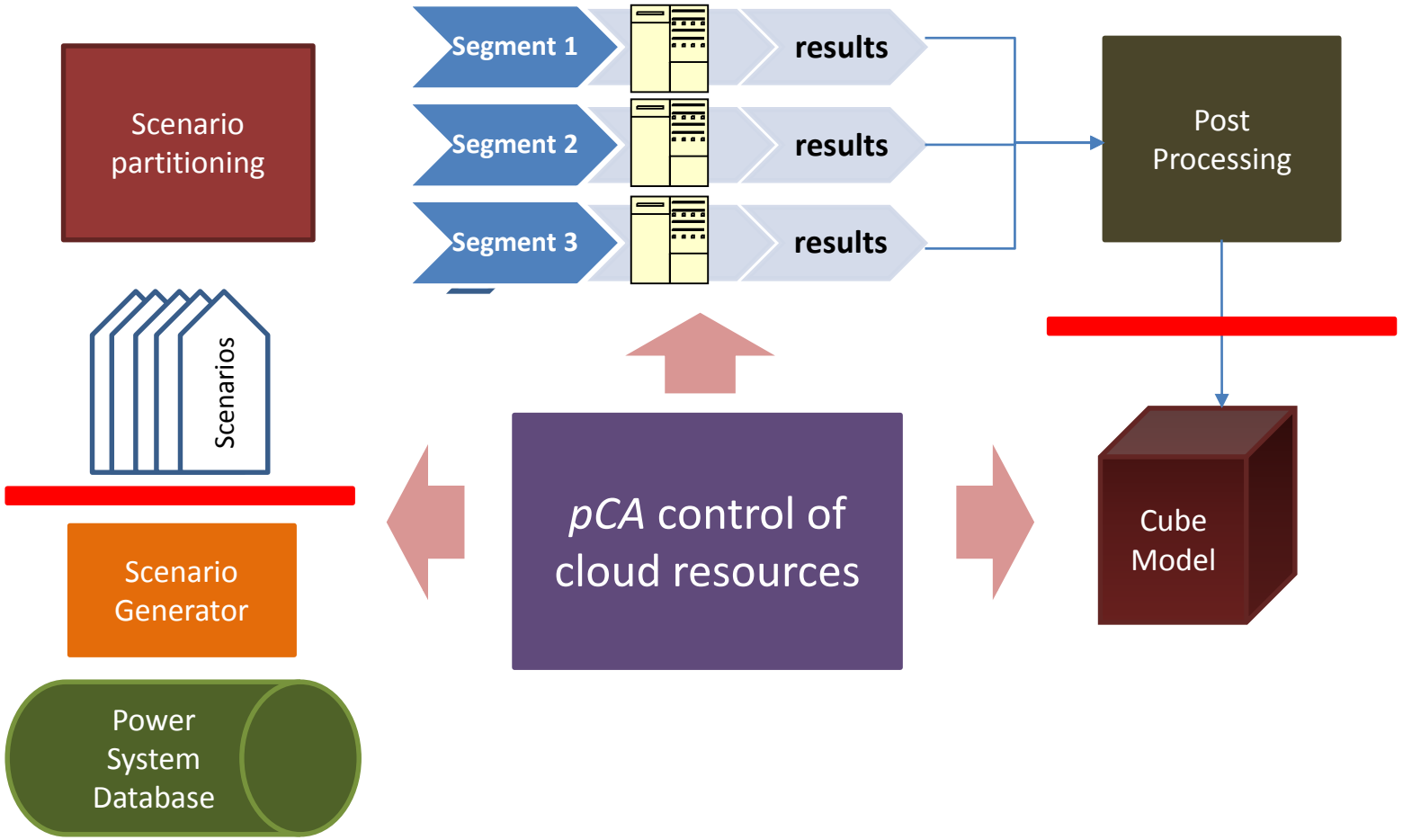
- Accessing all scenarios within the same task
- Excel-based environment for creating predefined and customized reports
- Instantaneous graphical support
- Drill-down

- Data tagging
- Scenario definition
- Automatic generation of PSO inputs for all scenarios at once

Key Features of *pCA*/PSO

- Modeling of market operations through decision cycles
- Multi-scenario logic supporting automatic scenario generation, parallelization, simulation scheduling, and post-processing
- Vast computational resources of Amazon data centers at user's disposal → very short turn-around time
- Usage-based pricing of software and hardware
- *pCA* could be used by customers with no CEII certification (certain input data and results not accessible by the user)
- Data security: *pCA* is a "private cloud" built within Amazon Web Services

New Challenges – new potential bottlenecks that require special attention



Addressing these problems require customized solutions to balance performance efficiency and costs

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Case Study:

Price suppression effect of offshore wind in New England

[The Unheralded Value in Offshore Wind]

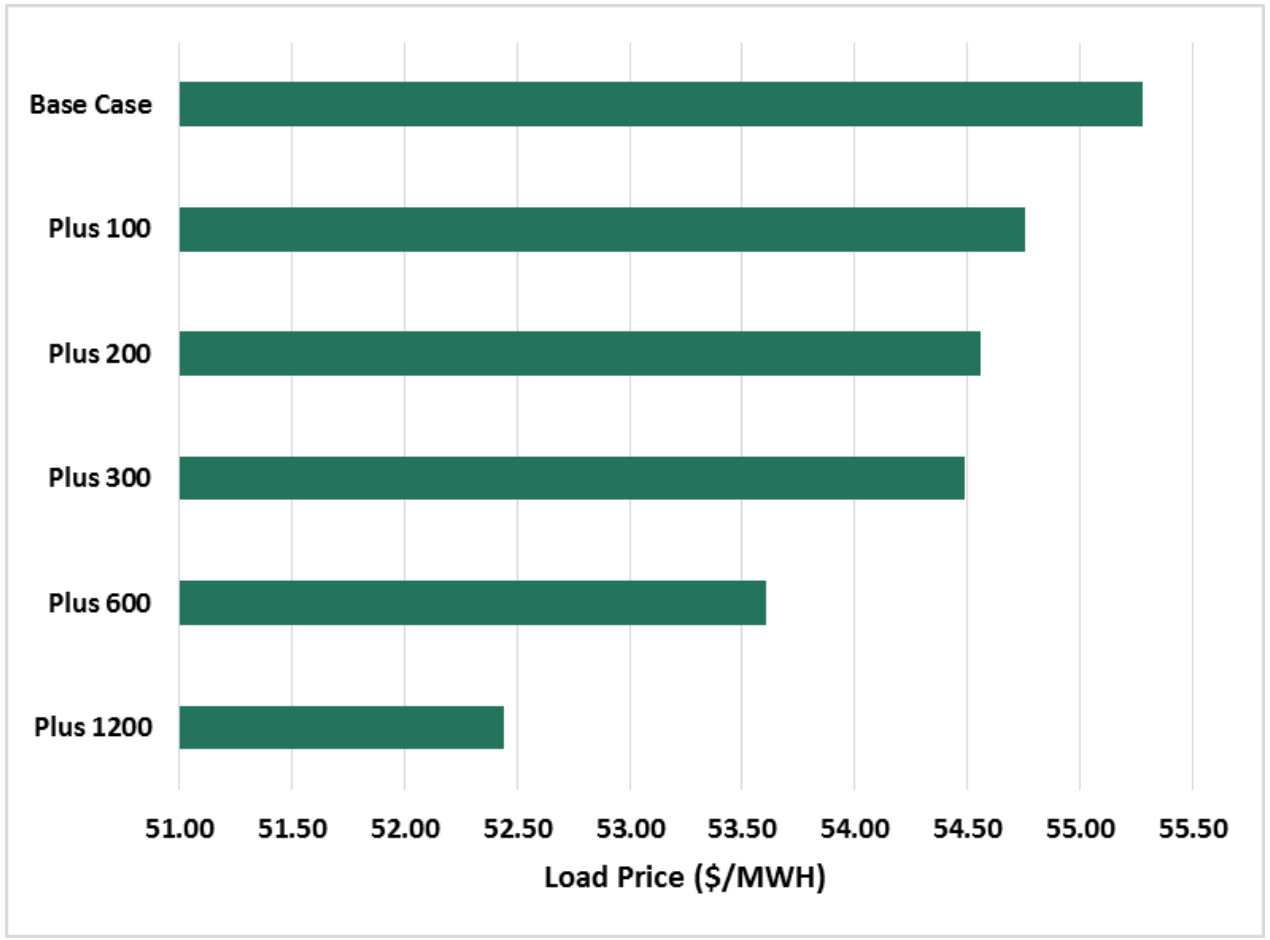
Objectives

- To evaluate the price suppression effects of an increasingly large installation of offshore wind generating resources
  - Located in the vicinity of Block Island, RI
  - Electrically connected to the ISO NE grid at Brayton Point
  - Modeled Year: 2015
- Installation
  - 100MW, 200M, 300MW, 600MW, 1200MW offshore wind farms

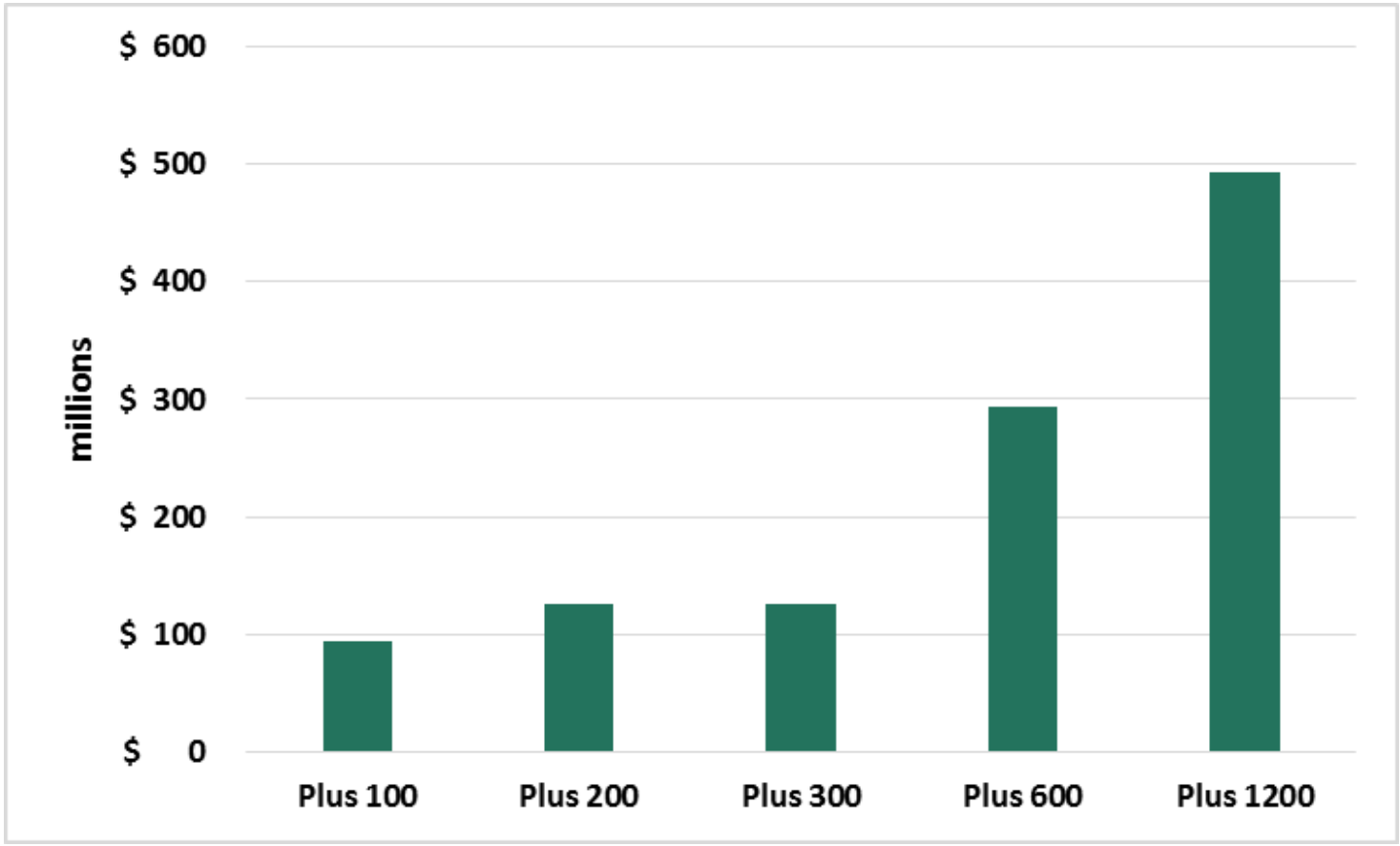
Major Changes in Generation

- Retirements of:
  - Vermont Yankee in the Fourth Quarter of 2014
  - Salem Harbor Units 1-4 on June 1, 2014

ISO NE Average Load Price



ISO NE Savings Relative to Base Case



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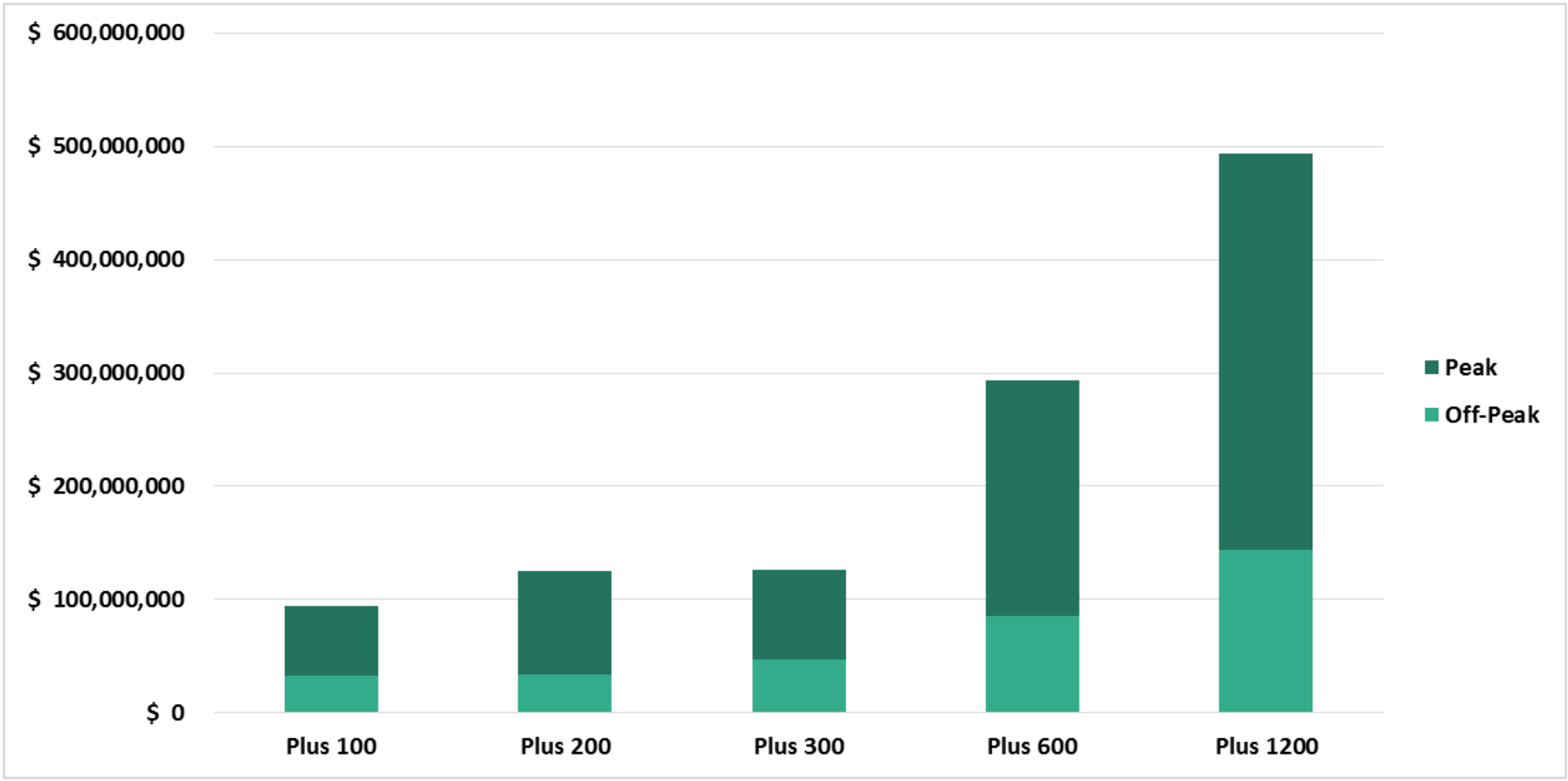
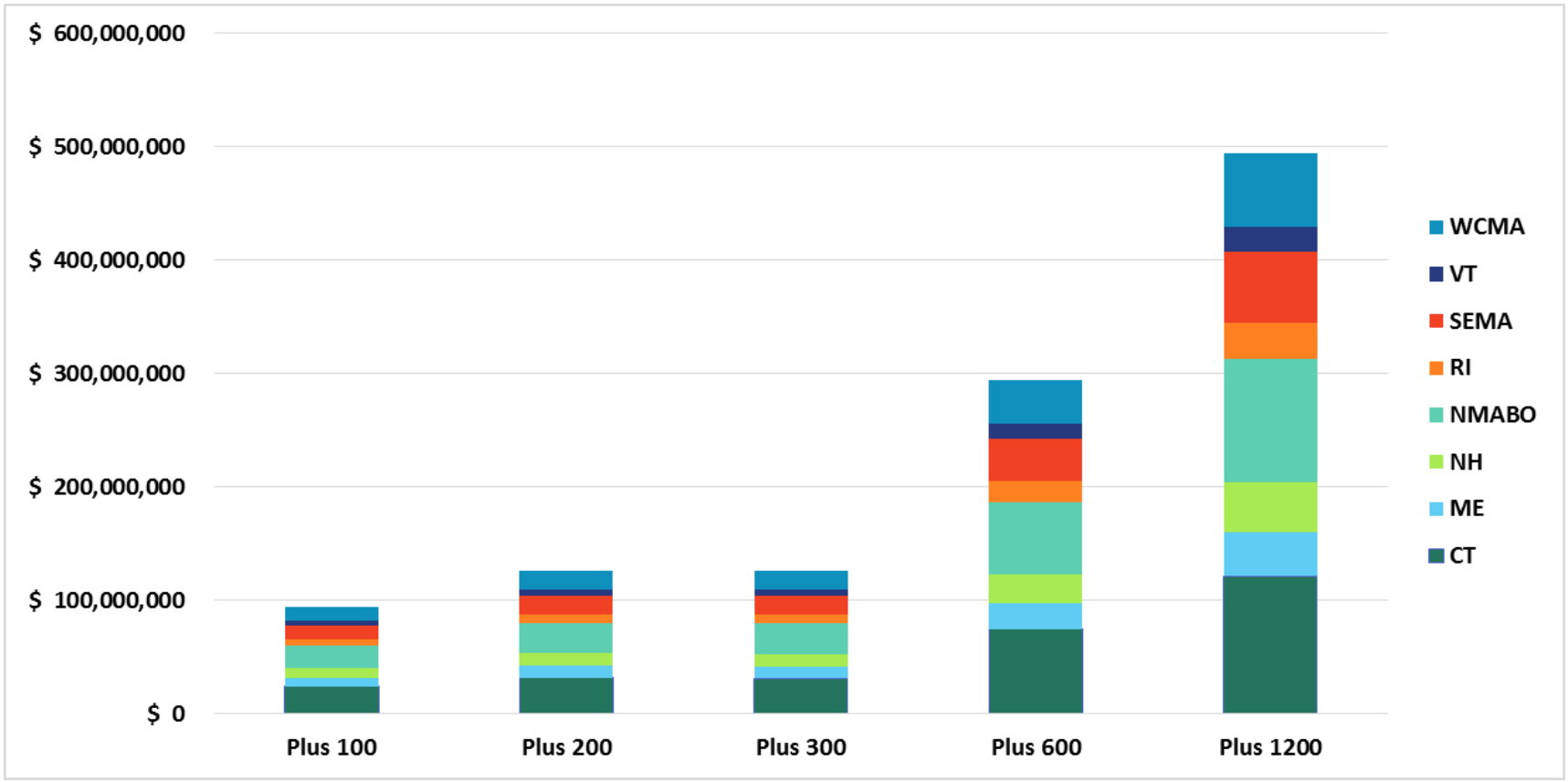
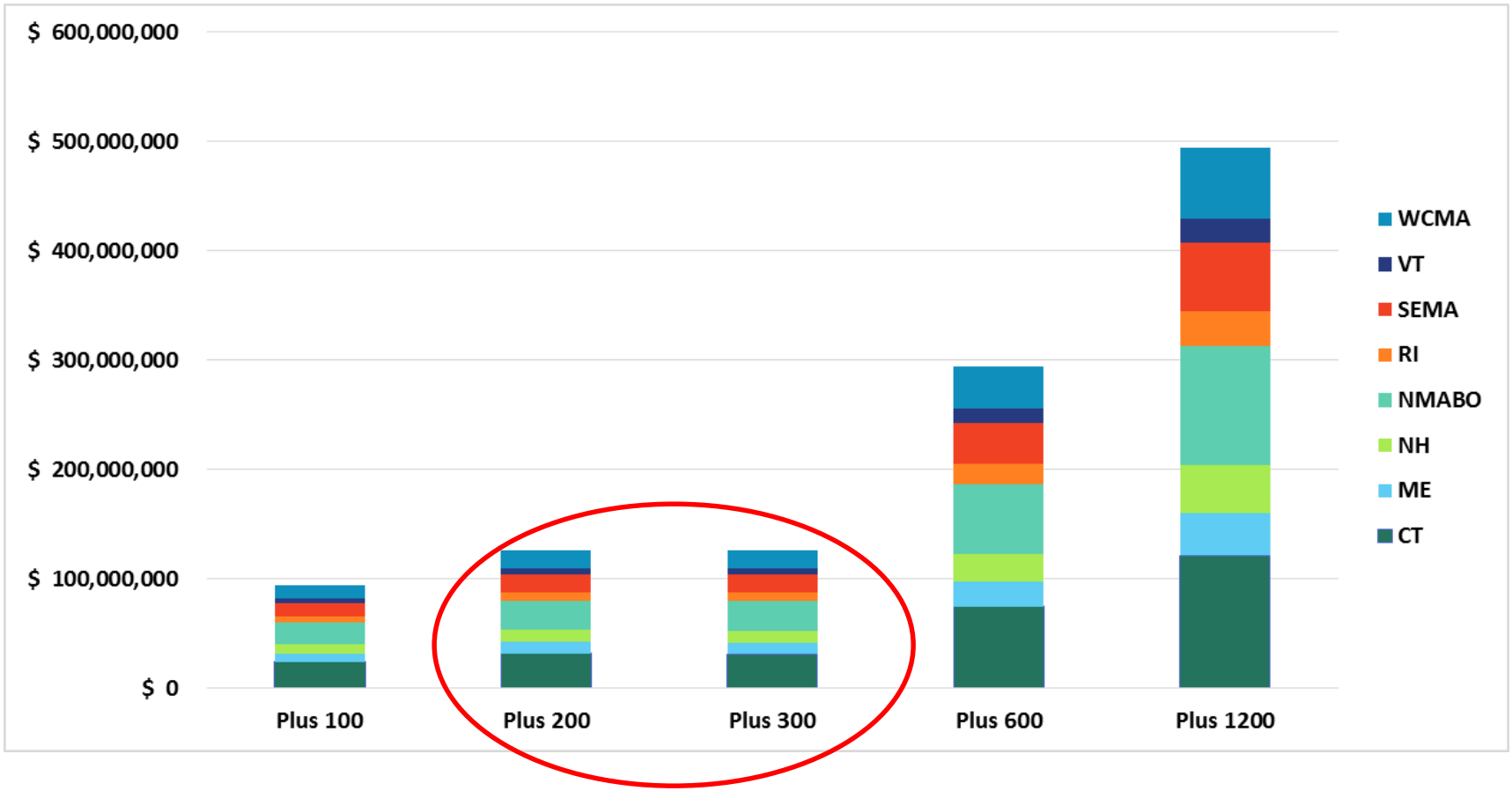


ISO NE Savings Relative to Base Case by Zone



Use of cloud computing really pays off in exploring results

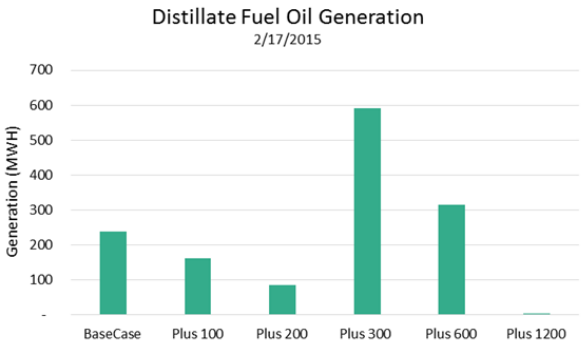


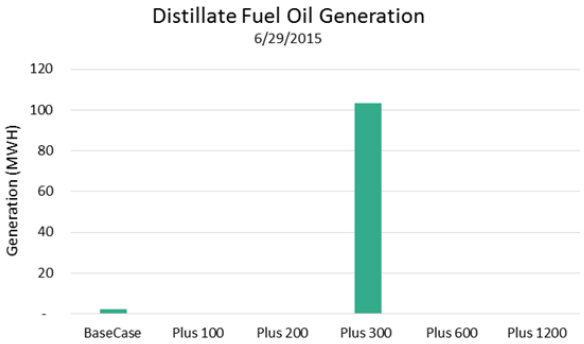
Why additional 100 MW of wind yield no additional price suppression?

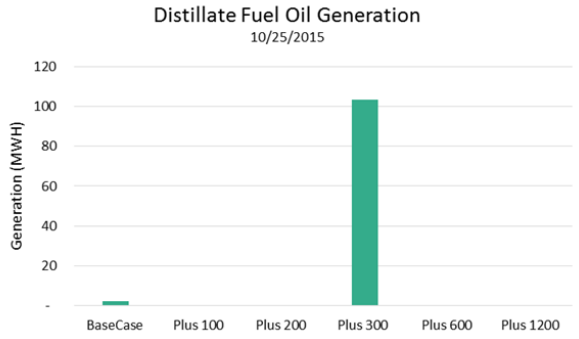
Use of cloud computing really pays off in exploring results (cont'd)

- An experienced modeler knows that such effects are possible due to the non-convexity of unit commitment
- However, even an experienced modeler has to be sure that this is the case indeed and not a data input error…
- … and then the modeler must explain the result to the "customer"
- This typically requires performing additional model runs and drilling down the result
- Being able to rapidly obtain additional runs is very important
- Accessing results of all scenarios at once is also very important

Use of cloud computing really pays off in exploring results (cont'd)







- The plus 300 MW wind scenario shows an unusually high usage of flexible capacity burning distillate fuel oil and setting very high prices
- With advanced data analytics (cube models) exploration of results can be performed very efficiently and requires no special scripting

Compute Resources and Performance

- Partition method: monthly
- Number of virtual machines used: 72
- Total VM time: ~40 hours
- Actual time to complete the study < 40 min

Conclusions

- On-going advancements of the power industry and of power markets create new applications for power market simulators

… and new challenges

- Commercially available cloud infrastructures such as Amazon AWS or Windows Azure provide logical and practical solutions to these challenges

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