

Technical Education on Capacity Expansion Software

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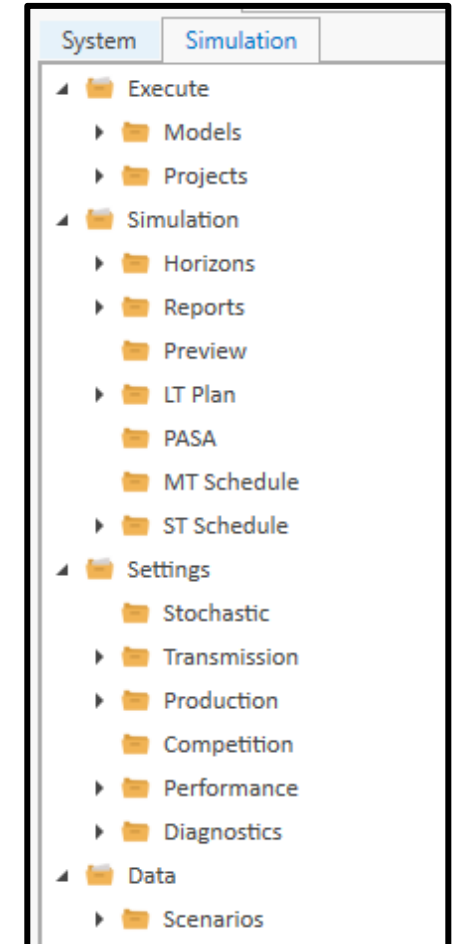
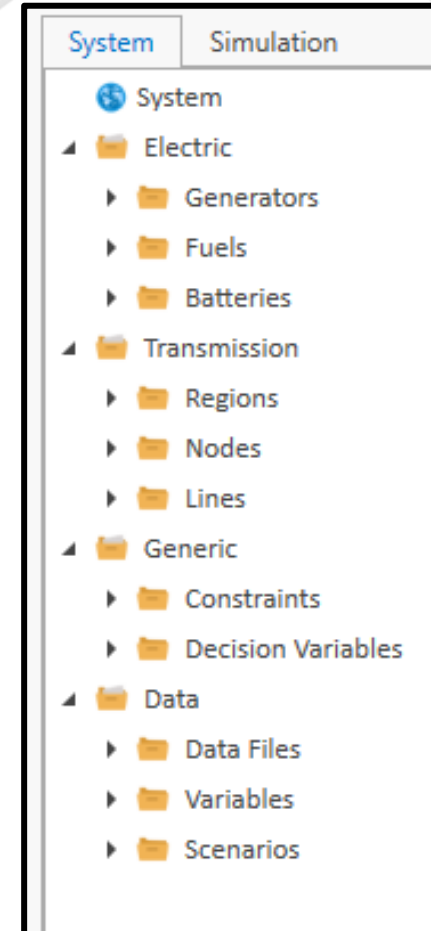
TEAC Special Session - Order 1920

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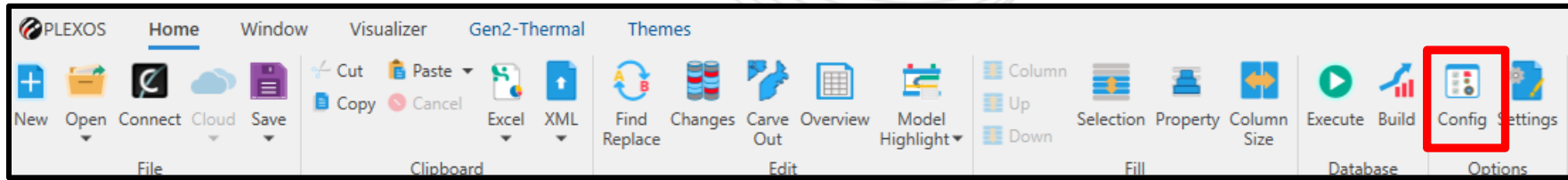
- PJM uses Energy Exemplar's Plexos software for capacity expansion
- This presentation provides high-level education on use of the software using an illustrative example
- Further education on policy and resource adequacy modeling will be provided in a subsequent meeting

- Introduction
- Setting up the database
- Simulation setup
- Running capacity expansion
- Reports
- Illustrative East – West example of PJM system
- Next steps

- User Interface
 - System elements consist of various classes
 - Classes can be enabled/disabled using Config menu settings
 - Simulation elements consist of models and settings for running the models



- Config menu on Home ribbon



- Includes all classes and their properties

	Property	Dynamic	Bands	Default	Validation	Units
Electric						
Generator						
Generators						
Units		<input type="checkbox"/>		0	>=0	-
Max Capacity		<input type="checkbox"/>		0		MW
Min Stable Level		<input type="checkbox"/>	1	0	>=0	MW
Fuel Price		<input type="checkbox"/>		0		\$/MMBtu
Heat Rate		<input type="checkbox"/>	1	0		Btu/kWh
VO&M Charge		<input type="checkbox"/>		0		\$/MWh
FO&M Charge		<input type="checkbox"/>		0		\$/kW/yr
Rating Factor		<input checked="" type="checkbox"/>		100	>=0	%
Initial Age		<input type="checkbox"/>		0		yr
Power Degradation		<input type="checkbox"/>		0		%
Equity Charge		<input type="checkbox"/>		0		\$/kW/yr
Debt Charge		<input type="checkbox"/>		0		\$/kW/yr
Firm Capacity		<input checked="" type="checkbox"/>	1	0		MW
Firm Capacity Unit Count		<input checked="" type="checkbox"/>	1	0		-
Build Cost		<input type="checkbox"/>	1	0		\$/kW

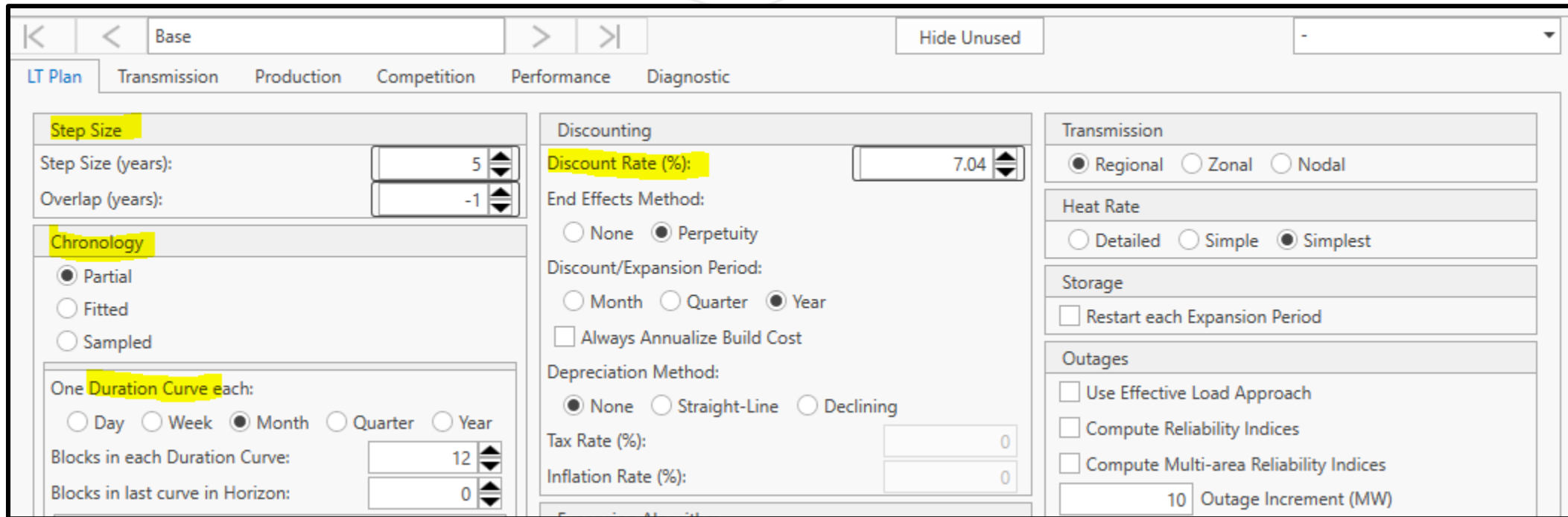
- Each element can have memberships and properties
- Memberships relate classes to one another
 - Example: Emission.Fuels or Emission.Generators
- Each element has a set of properties
 - Example: Generator MaxCap, Fuel price

- Scenarios
 - Software terminology for tagging data properties
 - Each model consists of base data and data scenarios
 - You can tag data and properties using a scenario. Then use the scenarios to make changes to the base data or create multiple models

	Collection	Parent Object	Child Object	Property	Value	Data File	U.. ▲	Band	Date From	Date To	Timeslice	Action	Expression	Scenario
🔌	Fuels	System	NGHenry	Price		Fuel Price-H	\$/...	1				=		High Fuel
🔌	Fuels	System	NGHenry	Price		Fuel Price-L	\$/...	1				=		Low Fuel

- LT Plan
 - LT Plan phase is used for long term capacity expansion
 - The objective is to minimize system cost
 - Fixed costs (Capital cost of new generation and FOM costs)
 - Production costs (Cost of operating the system given a set of existing generators and cost of unserved energy)
 - Decision variables are whether and when to build a generator candidate
 - Discount factors are used to represent all costs as present values






















- LT Plan



The screenshot displays the PJM software interface for configuring the LT Plan. The interface is divided into several sections:

- Step Size:** Step Size (years) is set to 5, and Overlap (years) is set to -1.
- Chronology:** The 'Partial' option is selected. Under 'One Duration Curve each:', the 'Month' option is selected. Blocks in each Duration Curve is set to 12, and Blocks in last curve in Horizon is set to 0.
- Discounting:** Discount Rate (%) is set to 7.04. End Effects Method is set to 'Perpetuity'. Discount/Expansion Period is set to 'Year'. Depreciation Method is set to 'None'. Tax Rate (%) and Inflation Rate (%) are both set to 0.
- Transmission:** The 'Regional' option is selected.
- Heat Rate:** The 'Simplest' option is selected.
- Storage:** The 'Restart each Expansion Period' checkbox is unchecked.
- Outages:** The 'Use Effective Load Approach', 'Compute Reliability Indices', and 'Compute Multi-area Reliability Indices' checkboxes are unchecked. The Outage Increment (MW) is set to 10.

- Config menu for Generator Expansion

Expansion			
<input checked="" type="checkbox"/>	 Build Cost	Multi Band	\$/kW 0
<input checked="" type="checkbox"/>	 Retirement Cost		\$000 0
<input checked="" type="checkbox"/>	 One-time Cost		\$000 0
<input checked="" type="checkbox"/>	 Lead Time		yr 0
<input checked="" type="checkbox"/>	 Project Start Date		- 1/1/2000
<input checked="" type="checkbox"/>	 Commission Date		- 12/31/1899
<input checked="" type="checkbox"/>	 Technical Life		yr 1E+30
<input checked="" type="checkbox"/>	 WACC		% 10
<input checked="" type="checkbox"/>	 Levelized Capital Carrying Rate		% 0
<input checked="" type="checkbox"/>	 Economic Life		yr 30
<input checked="" type="checkbox"/>	 Max Units Built		- 0
<input checked="" type="checkbox"/>	 Max Units Retired		- 0
<input checked="" type="checkbox"/>	 Min Units Built		- 0
<input checked="" type="checkbox"/>	 Min Units Retired		- 0
<input checked="" type="checkbox"/>	 Max Units Built in Year		- 1E+30
<input checked="" type="checkbox"/>	 Max Units Retired in Year		- 1E+30
<input checked="" type="checkbox"/>	 Min Units Built in Year		- 0
<input checked="" type="checkbox"/>	 Min Units Retired in Year		- 0
<input checked="" type="checkbox"/>	 Build Set Size		- 0
<input type="checkbox"/>	 Hint Units Built		- 0
<input checked="" type="checkbox"/>	 Capacity Price		\$/kW/yr 0

- Capacity expansion candidates

- Units
- Max Capacity
- Build Cost
- Project Start Date
- Levelized Capital Carrying Rate
- Max Units Built/ Max Units Built in Year
- ...

Property	Value	Data File	Units
Units	0		-
Max Capacity	150		MW
FO&M Charge	33.41		\$/kW/yr
Rating Factor	1.00	wk_OH-Mansfield_PV_1-Axis_SolarShape	%
Firm Capacity	37.5		MW
Build Cost	0	Build_Cost	\$/kW
Project Start Date	1/1/2024		-
Levelized Capital Carrying Rate	5.68		%
Economic Life	30		yr
Max Units Built	150		-
Max Units Built in Year	5		-

- Load forecast input using data files

Collection	Parent Object	Child Object	Property	Value	Data File	Units	Band	Date From	Date To	Timeslice	Action
Regions	System	East	Load		EAST	MW	1				=
Regions	System	West	Load		WEST	MW	1				=

– Data file

Data File	Property	Value	Filename	Units	Band	Date From	Date To	Timeslice	Action	Expressio
EAST	Filename		Load Forecasts\MH-East_2023-2039-new.csv		1	1/1/2023	12/31/2039		=	
WEST	Filename		Load Forecasts\MH-West_2023-2039-new.csv		1	1/1/2023	12/31/2039		=	

– Source .csv file

Year	Month	Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14
2029	1	1	54792	54564	54396	54716	55630	57724	61010	63883	64529	64566	64186	63173	62232	61242
2029	1	2	54582	53879	53688	53858	54745	56997	60729	63577	63809	63119	62377	61247	60529	59549
2029	1	3	56116	55552	55359	55591	56634	58998	63390	66494	66651	65854	65026	63291	62027	61038
2029	1	4	55530	54802	54662	54901	55879	58348	62836	65950	65962	65173	64157	62884	61922	61034
2029	1	5	55370	54585	54237	54287	55116	57277	60946	64081	64419	63973	63491	62507	61370	60471
2029	1	6	54387	53685	53313	53307	53739	54838	56273	58031	59138	59877	59580	58797	57858	56883
2029	1	7	54102	53466	53274	53398	53725	54612	55712	57419	58470	58659	57980	57102	56390	55504
2029	1	8	55107	54963	54873	55385	56469	58899	63268	66500	67067	66824	66213	65120	64043	63017

- Transmission links between zones

Line	Property	Value	Data File	Units	Band	Date From	Date To	Timeslice	Action	Expression
East to West	Min Flow	-10000		MW	1				=	
East to West	Max Flow	10000		MW	1				=	

- Fuel input using data files

	Collection	Parent Object	Child O...	Property	Value	Data File	Units	Band	Date From	Date To	Timeslice	Action
▶	Fuels	System	NGHenry	Price		MH-Fuel Price	\$/MMBtu	1				=
	Generator.Fuels	Gen1-Thermal	NGHenry	Transport Charge	0		\$/MMBtu	1				=
	Generator.Fuels	Gen2-Thermal	NGHenry	Transport Charge	0		\$/MMBtu	1				=

- Battery expansion candidates

Collection	Parent Object	Child Object	Property	Value	Data File	Units
Batteries	System	BSEx1	Units	0		-
Batteries	System	BSEx1	Capacity	200		MWh
Batteries	System	BSEx1	Max Power	50		MW
Batteries	System	BSEx1	Charge Efficiency	80		%
Batteries	System	BSEx1	Discharge Efficiency	80		%
Batteries	System	BSEx1	FO&M Charge	30		\$/kW/yr
Batteries	System	BSEx1	Max Units Built	5000		-
Batteries	System	BSEx1	Build Cost		build cost	\$/kW
Batteries	System	BSEx1	Economic Life	30		yr

- Simulation Horizon

2029-2039 > > Hide Unused

Planning Horizon

Begin On: Monday, January 1, 2029

Run for: 11 + 0 Year

End On: Saturday, December 31, 2039

Interval Length: 1 Hour

Compression: 1

Days Begin: 12:00 AM

Years End: (Automatic)

Weeks Begin: (Automatic)

- Reports

Properties | Field List

Solution File Formats

Flat Files (.csv)

Compressed XML (.zip)

Compact Full

Period Types

Period (hour, 30-min., or 10-min. as in Horizon)

Hour Month

Day Quarter

Week Year

Stochastics

Report Statistics

Save Each Sample

Filters

Filter Objects (Interval)

Filter Objects (Summary)

Whole Years Only

Flat Files

Format: Datetime

Locale: (default)

Date Time Convention

Date Time Convention: Beginning of Period

Base | Hide Unused

Properties | Field List

Sort Ascending | Reset Names

Class

- <All>
- Generator
- Fuel
- Battery
- Region
- Node
- Line
- Constraint

Phase

- LT Plan
- ST Schedule

Synchronize Selections:

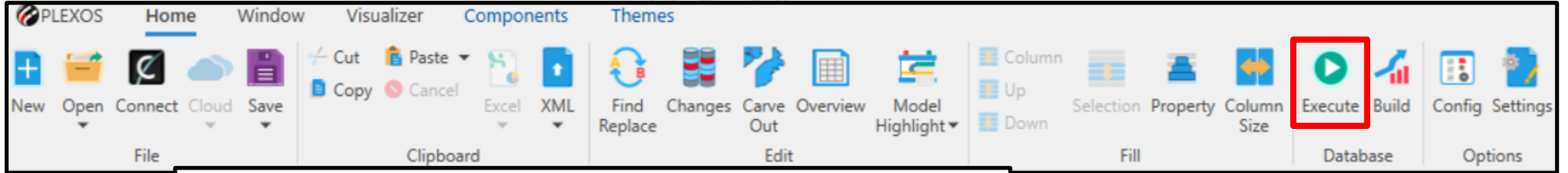
Sync Lock

LT Plan

AND OR

Field	Interval	Summary	Statistics	Files	Description
Generator	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
Production	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
Capacity	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
Max Capacity	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Maximum generating capacity of each unit
Installed Capacity	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Installed capacity (Max Capacity x Units)
Rating	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Rated capacity of units
Raw Rating	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Rated output capacity of units without considering outages
Rated Capacity	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Installed capacity accounting for [Rating] and [Rating Factor]
Rating Violation	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Violation of Rating constraint
Rating Violation Cost	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Cost of Rating violation
Firm Capacity	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Contribution of the generator to capacity reserves
Net Firm Capacity	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Firm Capacity net of maintenance and degradation
Reliability	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
Expansion	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
Units Built	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Number of units built
Units Retired	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Number of units retired
Capacity Built	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Capacity built (Max Capacity x Units Built)
Capacity Retired	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Capacity retired (Max Capacity x Units Retired)
Net New Capacity	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Net Capacity (cumulative Max Capacity x (Units Built - Units Retired))
Capacity Price	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Price received by the generator for capacity
Capacity Revenue	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Revenue from capacity payments
Build Cost	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Cost of building a unit

Select “Execute” from the ribbon



Models and Projects selected for next Execution:

Class	Category	Name	Execution Order	Run Solution Views
Model	-	LT	0	<input type="checkbox"/>
Model	-	LT No ELCC	0	<input type="checkbox"/>
Model	-	LT NoRPS	0	<input type="checkbox"/>

Buttons: Add >, Remove <, Add All >>, Remove All <<

Buttons: Split Execution, Execute in Parallel, Execute in Cloud, Execute in Connect, Execute, Cancel

- Output Interface

The screenshot displays the PLEXOS software interface. The 'Execute' button is highlighted with a red box. The interface shows a project named 'LT No ELCC' with various settings for the 'Generator' block, including a date range from 1/1/2029 to 1:12:00 AM and 11 years. The 'Properties' table for the 'Generator' block is also visible, showing 'Capacity Built' as 1 MW.

Property	Unit	Bands	-1x
Units	-	1	<input type="checkbox"/>
Generation	GWh	1	<input type="checkbox"/>
Max Capacity	MW	1	<input type="checkbox"/>
Installed Capacity	MW	1	<input type="checkbox"/>
Units Built	-	1	<input type="checkbox"/>
Units Retired	-	1	<input type="checkbox"/>
Capacity Built	MW	1	<input type="checkbox"/>
Capacity Retired	MW	1	<input type="checkbox"/>

Parent Name	Collection	Child Name	Category	Property	Band	Fiscal Year	Value	Units
System	Generator	GenEx1-PV	Expansion	Capacity Built	1	2029	0.00	MW
System	Generator	GenEx1-PV	Expansion	Capacity Built	1	2030	0.00	MW
System	Generator	GenEx1-PV	Expansion	Capacity Built	1	2031	0.00	MW
System	Generator	GenEx1-PV	Expansion	Capacity Built	1	2032	0.00	MW
System	Generator	GenEx1-PV	Expansion	Capacity Built	1	2033	0.00	MW
System	Generator	GenEx1-PV	Expansion	Capacity Built	1	2034	0.00	MW
System	Generator	GenEx1-PV	Expansion	Capacity Built	1	2035	10,050.00	MW
System	Generator	GenEx1-PV	Expansion	Capacity Built	1	2036	1,350.00	MW
System	Generator	GenEx1-PV	Expansion	Capacity Built	1	2037	0.00	MW
System	Generator	GenEx1-PV	Expansion	Capacity Built	1	2038	0.00	MW
System	Generator	GenEx1-PV	Expansion	Capacity Built	1	2039	0.00	MW
System	Generator	GenEx1-W	Expansion	Capacity Built	1	2029	0.00	MW
System	Generator	GenEx1-W	Expansion	Capacity Built	1	2030	0.00	MW
System	Generator	GenEx1-W	Expansion	Capacity Built	1	2031	0.00	MW
System	Generator	GenEx1-W	Expansion	Capacity Built	1	2032	0.00	MW
System	Generator	GenEx1-W	Expansion	Capacity Built	1	2033	0.00	MW
System	Generator	GenEx1-W	Expansion	Capacity Built	1	2034	0.00	MW
System	Generator	GenEx1-W	Expansion	Capacity Built	1	2035	0.00	MW



Illustrative East – West example of PJM system

- Demo in Software

- Technical Education
 - Modeling Policies
 - Modeling Resource Adequacy

Presenter:

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Sources for Techno-Economic Inputs



Member Hotline

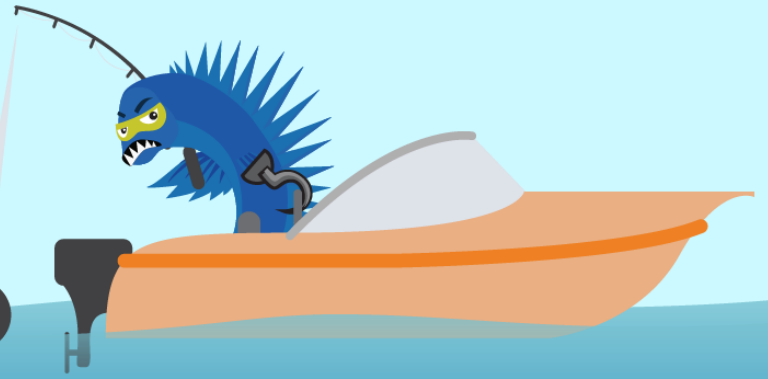
(610) 666-8980

(866) 400-8980

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