Joint Integrated Resource Plan (IRP) Stakeholder Presentation

February 3, 2016

7 RESOURCE MODELING (I&M/AEP)

Resource Modeling

Agenda

- Objective: Provide a basic overview of resource modeling and how it is used in developing an IRP
    - List software criteria necessary for resource modeling
    - Identify and describe resource modeling inputs
    - Provide examples of model output
    - Describe risk modeling options and provide examples
    - Development of a preferred plan

Resource Modeling

- Role of Resource Modeling in Developing an IRP
  - Utilities must select among a variety of resource options (supply and demand-side) to meet their customers' energy needs
  - Each resource option has a different cost and energy profile
  - The optimal suite of resources will vary based on the modeling input assumptions (scenarios/sensitivities)
  - Goal of resource modeling is to identify the suite of resources that meets customer requirements at the lowest reasonable cost
  - Model outputs are used to inform utility decision makers in developing a preferred portfolio of resources

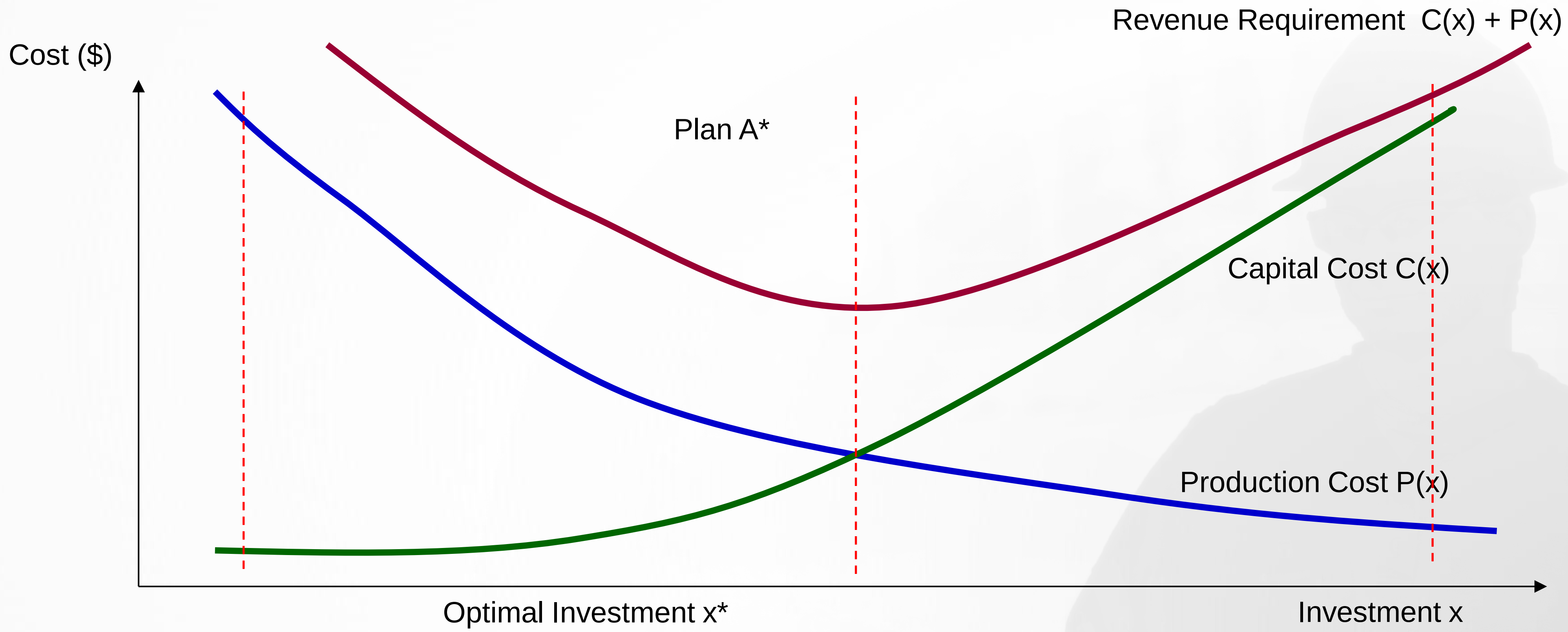
Resource Modeling

- Production Costing Function
  - Production Costing accounts for the costs of converting fuel and other variable and fixed costs in order to produce electrical energy to meet customers' load

- Resource Planning Function
  - Long-Term resource optimization is the development of a system resource expansion plan that balances "least-cost" objectives with planning flexibility, asset mix considerations, adaptability to risk, and conforms with applicable NERC and RTO criteria

Resource Modeling

- The "Objective Function" is to minimize net present value of forward-looking costs (i.e. capital and production costs)



Resource Modeling

- Software tools used in resource modeling functions (Production Costing and Resource Planning)

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Strategist

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Resource Modeling

- Criteria for selecting Resource Planning Software
  - Market-based commitment & dispatch
  - Easily model emission-limited dispatch
  - User-friendly input/output interface
  - Responsive user support

Resource Modeling

- **Inputs used in the modeling**
  - Existing System
  - Resource Options
  - Scenario Drivers
  - Financial Rate Inputs

Resource Modeling

Inputs : **Existing System** → Resource Options → Scenario Drivers → Financial Inputs

- **Existing system operating characteristics**
  - Heat rates
  - Load points (MW)
  - Start cost
  - Start cost times (hours)
  - Rating (firm, max, min)
  - Min up Min down times
  - Ramp rates (MW/min)
  - Variable O&M ($/MWh)
  - Fixed O&M ($/kW/year)
  - Capital expenditures
  - On-going capital
  - Maintenance schedule (dates)
  - Forced outage rates (%)
  - Outage ratings (MW)
  - Mean, min, max repair times (hours)
  - Transmission interconnection

Resource Modeling

Inputs : Existing System → **Resource Options** → Scenario Drivers → Financial Inputs

- **Resource Options**
  - Thermal
    - Base load, Intermediate, and Peaking
  - Energy efficiency
    - Commercial and Residential
  - Wind
  - Solar
    - Utility and customer owned
  - Grid optimization

- Build costs ($/kW)
- Construction profiles
- Economic life
- Technical life
- Min and max units built (by horizon or year)
- Operating characteristics
- Generation profiles (wind/solar)

1 2 3 4 5 6 7 8

Resource Modeling

Inputs : Existing System → Resource Options → **Scenario Drivers** → Financial Inputs

- **Scenario drivers**
  - Load forecast (base)
    - Load sensitivities (high, low)
  - Commodity prices (base)
    - Coal, Gas, Market energy price
    - Price sensitivities (high, low)
  - Environmental Regulation
    - Water, CO_2, Coal Combustion Residuals

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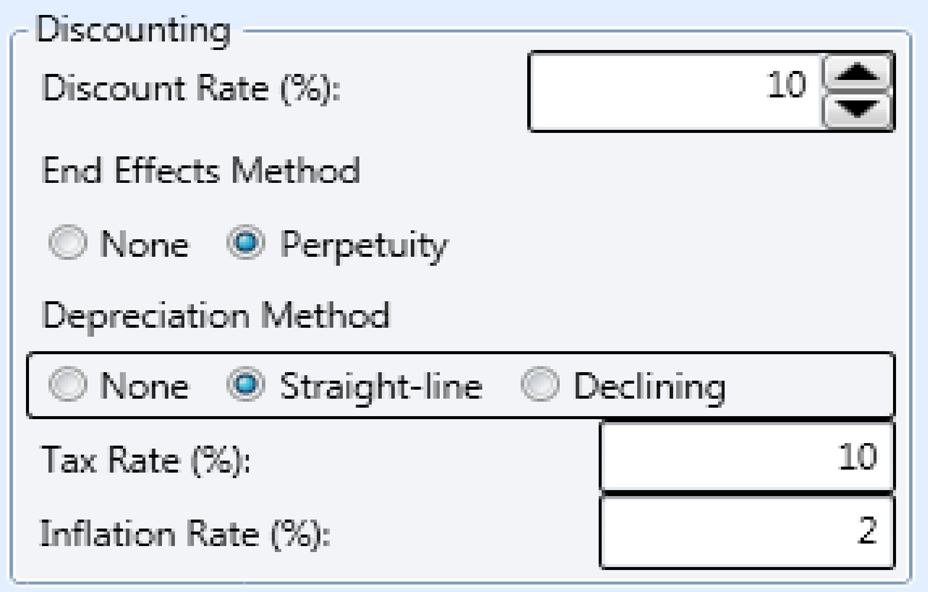
Resource Modeling

Inputs : Existing System → Resource Options → Scenario Drivers → **Financial Inputs**

- ## Financial Rate Inputs

1	Composite Tax Rate (%)
2	Customer Discount Rate (%)
3	Debt Service Reserve Percent (%)
4	Federal Income Tax Rate (%)
5	Inflation Rate (%)
6	Real Discount Rate (%)
7	Reserve and Contingency Reserve (%)
8	Utility Discount Rate (%)
9	Weighted Cost of Capital (%)



Resource Modeling

- Long term resource models utilize the objective function described earlier while abiding by the following possible constraints:
  - Minimum and maximum reserve margins
  - Resource addition and retirement candidates (*i.e.*, maximum units built)
  - Age and lifetime of generators
  - Operation constraints such as ramp rates, minimum up/down times, capacity, heat rates, etc.
  - Fuel burn minimum and maximums
  - Emission limits on effluents such as SO_2 and NO_x

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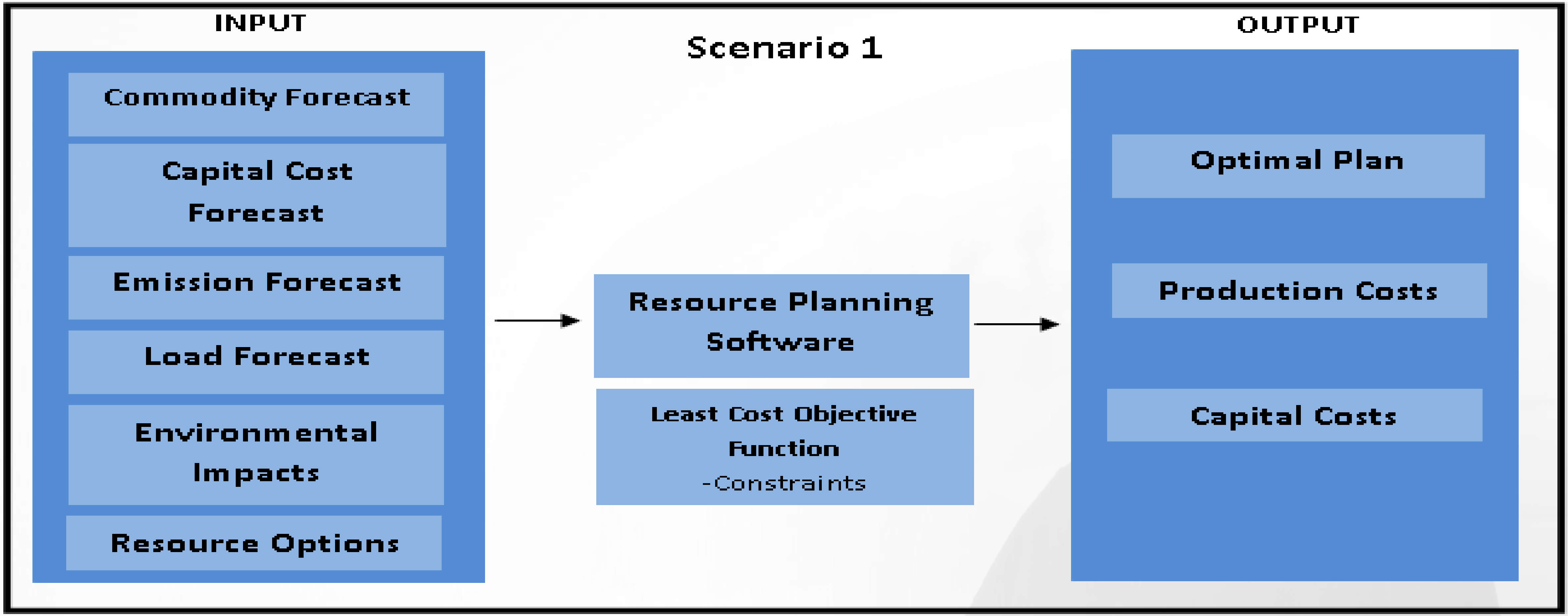
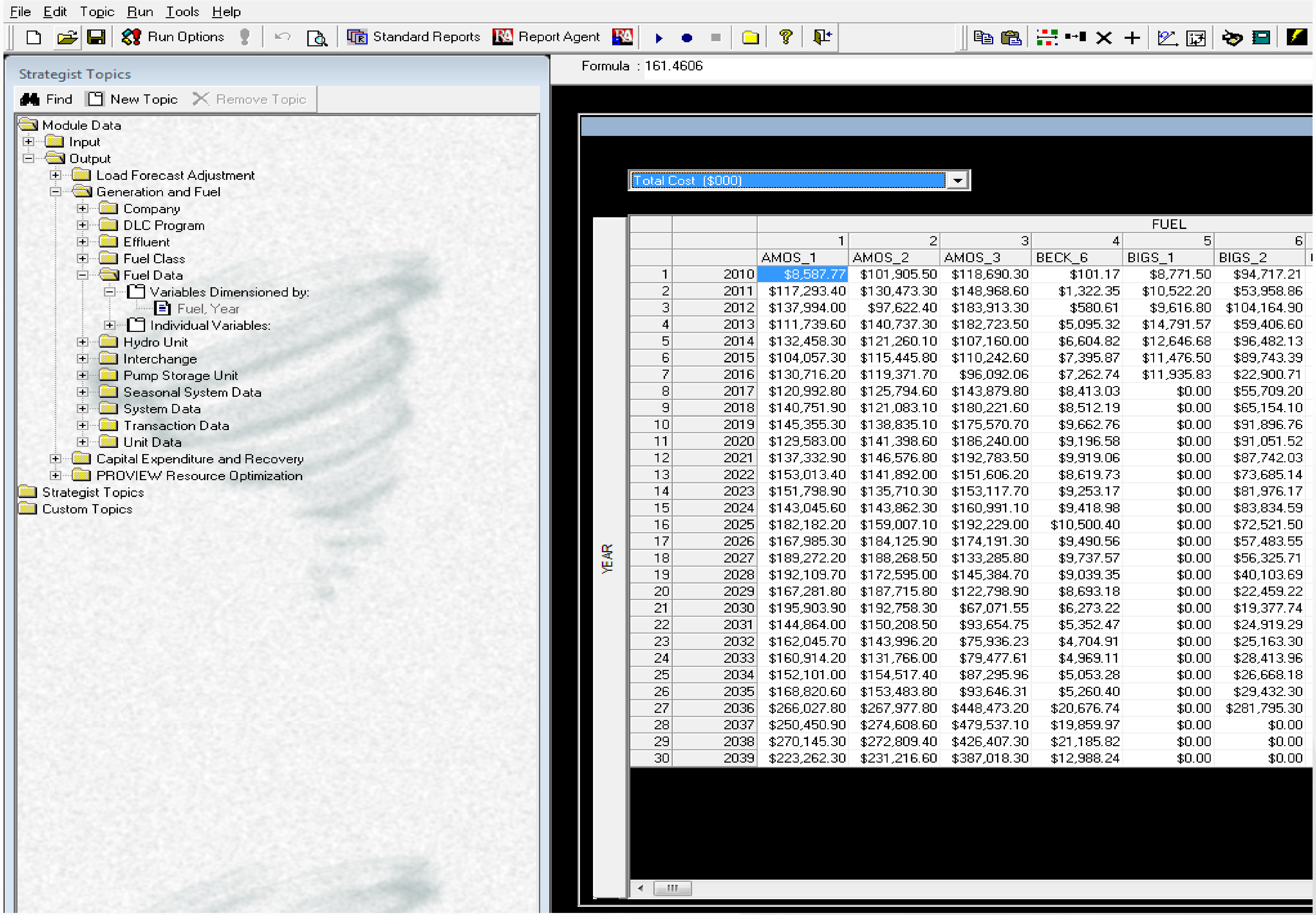
Resource Modeling



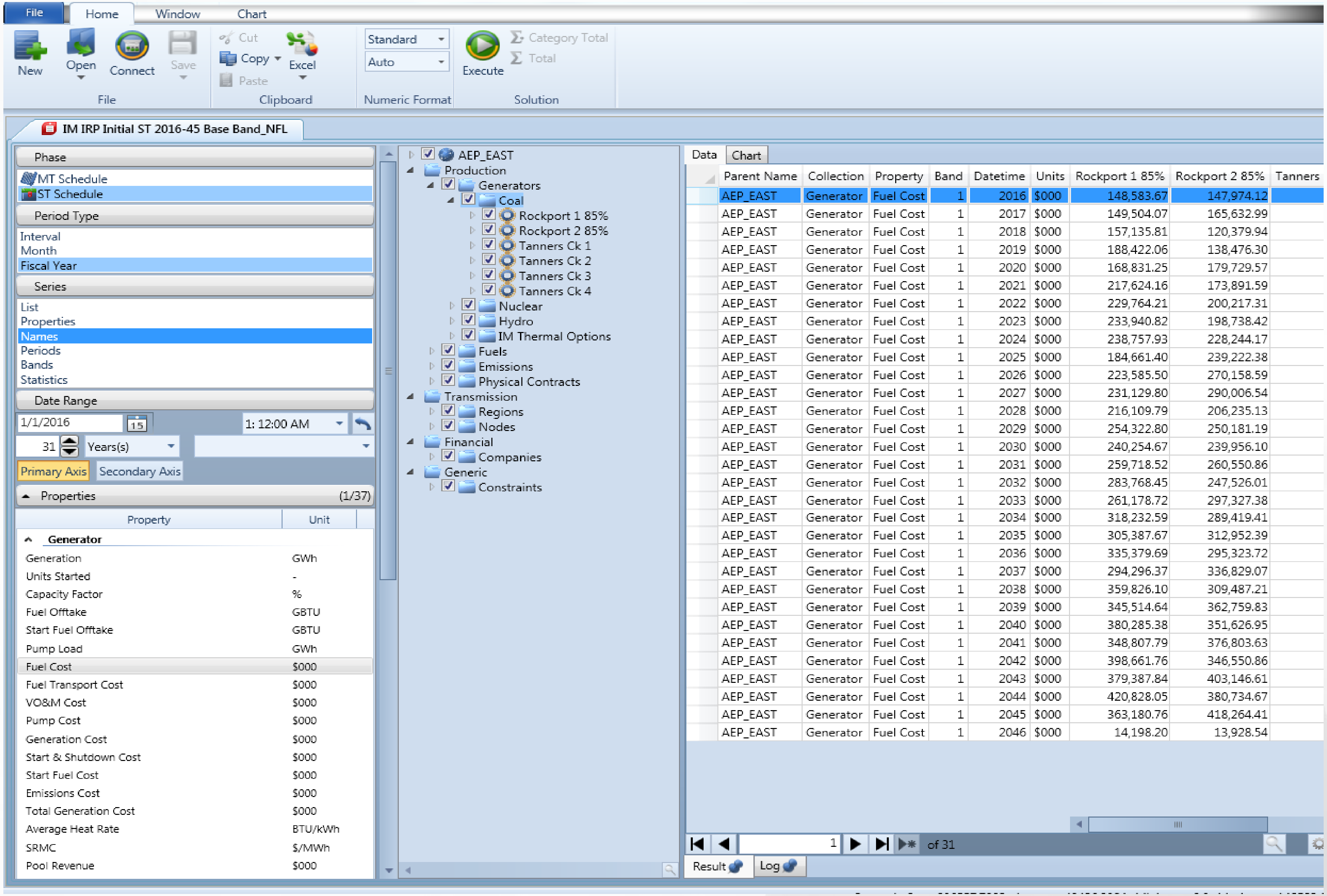
Resource Modeling

- Long term resource models provide multiple plans for each scenario analyzed
  - Cost of plan is represented by the cumulative present worth of revenue requirements (CPW) or present value of revenue requirements (PVRR)
  - Models produce an optimal plans fuel cost, Variable O&M and Fixed O&M cost, start fuel cost, emissions cost, total generation cost, revenues from energy sales to market, recovery of capital investments on generation additions

Outputs



		FUEL					
		1	2	3	4	5	6
		AMOS_1	AMOS_2	AMOS_3	BECK_6	BIGS_1	BIGS_2
1	2010	$8,587.77	$101,905.50	$118,690.30	$101.17	$8,771.50	$94,717.21
2	2011	$117,293.40	$130,473.30	$148,968.60	$1,322.35	$10,522.20	$53,958.86
3	2012	$137,994.00	$97,622.40	$183,913.30	$580.61	$9,616.80	$104,164.90
4	2013	$111,739.60	$140,737.30	$182,723.50	$5,095.32	$14,791.57	$59,406.60
5	2014	$132,458.30	$121,260.10	$107,160.00	$6,604.82	$12,646.68	$96,482.13
6	2015	$104,057.30	$115,445.80	$110,242.60	$7,395.87	$11,476.50	$89,743.39
7	2016	$130,716.20	$119,371.70	$96,092.06	$7,262.74	$11,935.83	$22,900.71
8	2017	$120,992.80	$125,794.60	$143,879.80	$8,413.03	$0.00	$55,709.20
9	2018	$140,751.90	$121,083.10	$180,221.60	$8,512.19	$0.00	$65,154.10
10	2019	$145,355.30	$138,835.10	$175,570.70	$9,662.76	$0.00	$91,896.76
11	2020	$129,583.00	$141,398.60	$186,240.00	$9,196.58	$0.00	$91,051.52
12	2021	$137,332.90	$146,576.80	$192,783.50	$9,919.06	$0.00	$87,742.03
13	2022	$153,013.40	$141,892.00	$151,606.20	$8,619.73	$0.00	$73,685.14
14	2023	$151,798.90	$135,710.30	$153,117.70	$9,253.17	$0.00	$81,976.17
15	2024	$143,045.60	$143,862.30	$160,991.10	$9,418.98	$0.00	$83,834.59
16	2025	$182,182.20	$159,007.10	$192,229.00	$10,500.40	$0.00	$72,521.50
17	2026	$167,985.30	$184,125.90	$174,191.30	$9,490.56	$0.00	$57,483.55
18	2027	$189,272.20	$188,268.50	$133,285.80	$9,737.57	$0.00	$56,325.71
19	2028	$192,109.70	$172,595.00	$145,384.70	$9,039.35	$0.00	$40,103.69
20	2029	$167,281.80	$187,715.80	$122,798.90	$8,693.18	$0.00	$22,459.22
21	2030	$195,903.90	$192,758.30	$67,071.55	$6,273.22	$0.00	$19,377.74
22	2031	$144,864.00	$150,208.50	$93,654.75	$5,352.47	$0.00	$24,919.29
23	2032	$162,045.70	$143,996.20	$75,936.23	$4,704.91	$0.00	$25,163.30
24	2033	$160,914.20	$131,766.00	$79,477.61	$4,969.11	$0.00	$28,413.96
25	2034	$152,101.00	$154,517.40	$87,295.96	$5,053.28	$0.00	$26,668.18
26	2035	$168,820.60	$153,483.80	$93,646.31	$5,260.40	$0.00	$29,432.30
27	2036	$266,027.80	$267,977.80	$448,473.20	$20,676.74	$0.00	$281,795.30
28	2037	$250,450.90	$274,608.60	$479,537.10	$19,859.97	$0.00	$0.00
29	2038	$270,145.30	$272,809.40	$426,407.30	$21,185.82	$0.00	$0.00
30	2039	$223,262.30	$231,216.60	$387,018.30	$12,988.24	$0.00	$0.00



Parent Name	Collection	Property	Band	Datetime	Units	Rockport 1 85%	Rockport 2 85%	Tanners
AEP_EAST	Generator	Fuel Cost	1	2016	$000	148,583.67	147,974.12	
AEP_EAST	Generator	Fuel Cost	1	2017	$000	149,504.07	165,632.99	
AEP_EAST	Generator	Fuel Cost	1	2018	$000	157,135.81	120,379.94	
AEP_EAST	Generator	Fuel Cost	1	2019	$000	188,422.06	138,476.30	
AEP_EAST	Generator	Fuel Cost	1	2020	$000	168,831.25	179,729.57	
AEP_EAST	Generator	Fuel Cost	1	2021	$000	217,624.16	173,891.59	
AEP_EAST	Generator	Fuel Cost	1	2022	$000	229,764.21	200,217.31	
AEP_EAST	Generator	Fuel Cost	1	2023	$000	233,940.82	198,738.42	
AEP_EAST	Generator	Fuel Cost	1	2024	$000	238,757.93	228,244.17	
AEP_EAST	Generator	Fuel Cost	1	2025	$000	184,661.40	239,222.38	
AEP_EAST	Generator	Fuel Cost	1	2026	$000	223,585.50	270,158.59	
AEP_EAST	Generator	Fuel Cost	1	2027	$000	231,129.80	290,006.54	
AEP_EAST	Generator	Fuel Cost	1	2028	$000	216,109.79	206,235.13	
AEP_EAST	Generator	Fuel Cost	1	2029	$000	254,322.80	250,181.19	
AEP_EAST	Generator	Fuel Cost	1	2030	$000	240,254.67	239,956.10	
AEP_EAST	Generator	Fuel Cost	1	2031	$000	259,718.52	260,550.86	
AEP_EAST	Generator	Fuel Cost	1	2032	$000	283,768.45	247,526.01	
AEP_EAST	Generator	Fuel Cost	1	2033	$000	261,178.72	297,327.38	
AEP_EAST	Generator	Fuel Cost	1	2034	$000	318,232.59	289,419.41	
AEP_EAST	Generator	Fuel Cost	1	2035	$000	305,387.67	312,952.39	
AEP_EAST	Generator	Fuel Cost	1	2036	$000	335,379.69	295,323.72	
AEP_EAST	Generator	Fuel Cost	1	2037	$000	294,296.37	336,829.07	
AEP_EAST	Generator	Fuel Cost	1	2038	$000	359,826.10	309,487.21	
AEP_EAST	Generator	Fuel Cost	1	2039	$000	345,514.64	362,759.83	
AEP_EAST	Generator	Fuel Cost	1	2040	$000	380,285.38	351,626.95	
AEP_EAST	Generator	Fuel Cost	1	2041	$000	348,807.79	376,803.63	
AEP_EAST	Generator	Fuel Cost	1	2042	$000	398,661.76	346,550.86	
AEP_EAST	Generator	Fuel Cost	1	2043	$000	379,387.84	403,146.61	
AEP_EAST	Generator	Fuel Cost	1	2044	$000	420,828.05	380,734.67	
AEP_EAST	Generator	Fuel Cost	1	2045	$000	363,180.76	418,264.41	
AEP_EAST	Generator	Fuel Cost	1	2046	$000	14,198.20	13,928.54	

Resource Modeling

- Sample output for one resource plan

	Plan A						
Year	Fuel Cost ($000)	VOM Cost ($000)	Emission Cost ($000)	FOM Cost ($000)	Annualized Build Cost ($000)	Pool Revenue ($000)	Revenue Requirement ($000)
2016	104,492	7,652	12,500	5,854	107,357	161,562	76,293
2017	111,806	8,188	13,375	6,264	107,357	172,871	74,119
2018	119,633	8,761	14,311	6,702	107,357	184,972	71,792
2019	128,007	9,374	15,313	7,171	107,357	197,920	69,302
2020	136,968	10,030	16,385	7,673	107,357	211,775	66,638
2021	146,555	10,732	17,532	8,211	107,357	226,599	63,788
2022	156,814	11,484	18,759	8,785	107,357	242,461	60,738
2023	167,791	12,287	20,072	9,400	107,357	259,433	57,475
2024	179,537	13,148	21,477	10,058	107,357	277,594	53,983
2025	359,073	26,295	42,955	20,117	322,071	555,187	215,324
2026	384,209	28,136	45,961	21,525	322,071	594,050	207,851
2027	411,103	30,105	49,179	23,031	322,071	635,634	199,856
2028	439,880	32,213	52,621	24,644	322,071	680,128	191,301
2029	470,672	34,468	56,305	26,369	322,071	727,737	182,147
2030	503,619	36,880	60,246	28,214	322,071	778,679	172,352

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Resource Modeling

- Sample output for multiple resource plans

INDIANA MICHIGAN POWER COMPANY I&M Capacity Resource Optimization PRELIMINARY - Summary Comparison Plan A, Plan B, Plan C Under High Band Commodity Pricing									
CPW $000 (2016$)	Load Cost	Fuel Costs	Emission Costs	Fixed O&M+ Var O&M+ On-going Capital	New Build Capital+ New Build Program Costs	Contract (Revenue)/Cost	*Less:* Market Revenue	ICAP Value	Revenue Requirements
Plan A									
Utility Cost Present Worth 2016-2045	18,527,589	8,691,690	2,853,690	3,689,931	5,465,294	(219,164)	28,155,696	185,130	10,668,203
NPV of End Effects beyond 2045									1,402,022
Total Utility Cost, Cumulative Present Worth									12,070,226
Plan B									
Utility Cost Present Worth 2016-2045	18,527,589	8,817,296	1,875,660	2,662,676	6,354,900	(219,164)	27,229,749	262,091	10,527,117
NPV of End Effects beyond 2045									1,571,701
Total Utility Cost, Cumulative Present Worth									12,098,818
Plan C									
Utility Cost Present Worth 2016-2045	18,527,589	5,922,547	734,031	2,045,270	5,903,289	(219,164)	22,033,360	139,263	10,740,938
NPV of End Effects beyond 2045									1,872,035
Total Utility Cost, Cumulative Present Worth									12,612,972

Resource Modeling

- Risk Modeling Options

- Deterministic
  - Subject specified plan through a variety of commodity price assumptions and load sensitivities.
  - Present value of revenue requirements (PVRR) created for a band of scenarios and sensitivities.

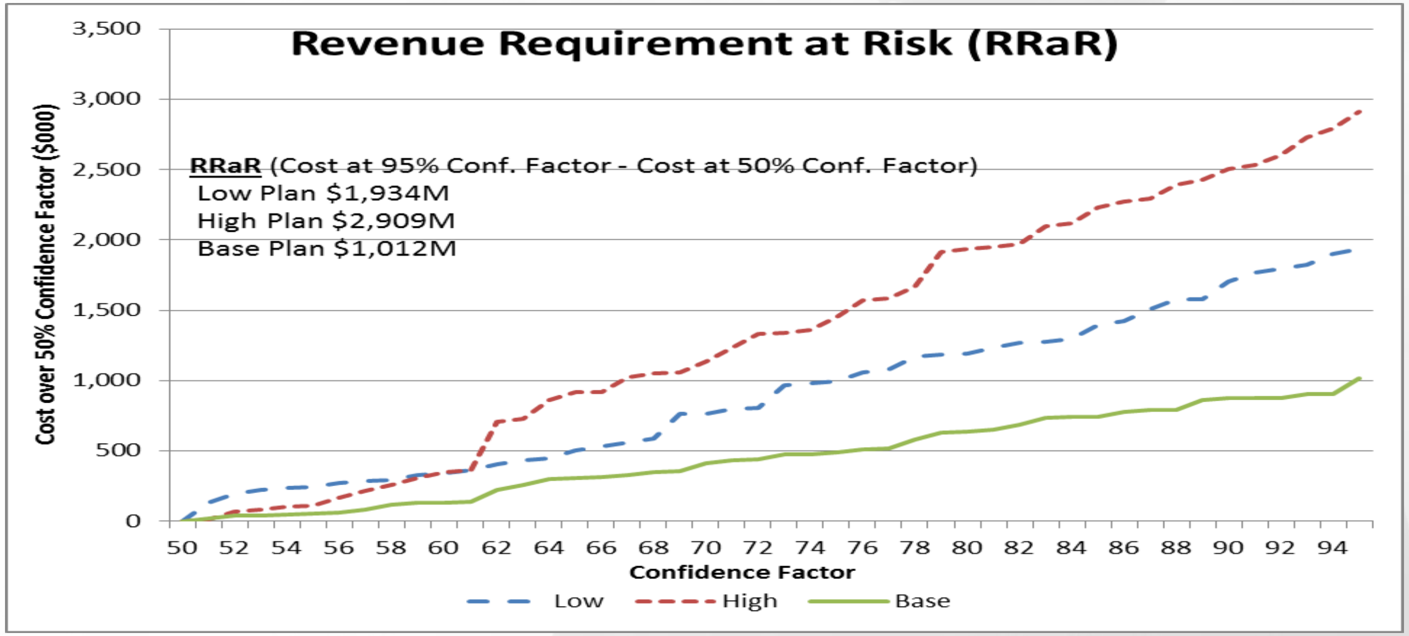
- Probabilistic
  - Identify variables
    - Energy Price, Fuel Price, Emission Price
  - Randomly selected iterations
  - PVRR for each iteration to determine Revenue Requirement at Risk (RRaR)
    - Higher RRaR the “riskier” the plan is.

Resource Modeling

- Risk Modeling Output
  - Deterministic

	Revenue Requirements $		
	Low Plan	Base Plan	High Plan
Low Commodity	6,000,000	7,456,123	8,456,123
Base Commodity	7,894,123	7,000,000	9,456,123
High Commodity	9,456,321	8,456,123	8,000,000

  - Probabilistic



Resource Modeling

- Using Resource Model Results to Determine Preferred Plan
  - Look for similar elements in optimal plans under a variety of input scenarios
    - Quantify impact of modifying resource selection
    - Measure risk characteristics of Preferred Plan to Optimal Plans that are developed under a variety of pricing scenarios
  - Consider variations to existing fleet when constructing portfolios
    - Quantify impact of modifying existing resource assumptions
    - Useful in determining retirement candidates
    - Helpful in determining incremental cost related to policy decisions – for example, increasing renewable energy component of capacity mix to hedge against future CO_2 restrictions