

GE Energy

CAISO Planning Reserve Margin (PRM) Study

Phase 1A Summary Report

R. 08-04-012 Planning Reserve Margin Workshop

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imagination at work

Phase 1A Objective

- **Highlight the system data and other study assumptions to which CAISO PRM would be most sensitive**
- **Determine the Base Case PRM for CAISO Controlled Grid for 2010**
 - *Installed reserves required to maintain areas at LOLE of 0.1 days/year*
- **Calculate PRM for sensitivities which consider**
 - *How reserve margins are computed*
 - *Which resources to include in the reserve margins*
 - *Variations in study system data*

Methodology

- Calculate generation system reliability at various levels of installed reserves to determine reserves required to maintain CAISO at LOLE of 0.1 days/year
 - Reserves based on monthly peak load and available capacity
 - Imports and demand response NOT included
- Use GE's Multi-Area Reliability Simulation (MARS)
 - Based on a full sequential Monte Carlo simulation
 - Chronological system simulation performed by combining:
 - Randomly generated operating histories of units through time
 - Hourly chronological load cycles
 - Transmission links
 - Year simulated until convergence criterion is met
 - Daily LOLE calculated from all hours in the day

Critical Planning Factors

- **Definition of reserve margin**
- **Treatment of imports**
- **Treatment of demand response**
- **Load forecast uncertainty**
- **Risk design criteria**

Study Data - Sources

- **Working Groups formed to identify and develop data sources**
 - *Separate report detailing their recommendations*
- **Generating units**
 - *Master CAISO Control Area Generating Capability List*
 - *EFORd – NERC GADS 2002-2006 Generating Unit Statistical Brochure – All Units Reporting Data but unit type and size*
 - *Hydro energy – CEC/EIA 906 data from 1994-2005*
 - *Wind, solar, biomass, geothermal, small hydro – historical 2007 hourly output scaled to 2010*

Study Data – CAISO Load and Capacity

2010 “As Found” Installed Capacity and Peak Load for CAISO System

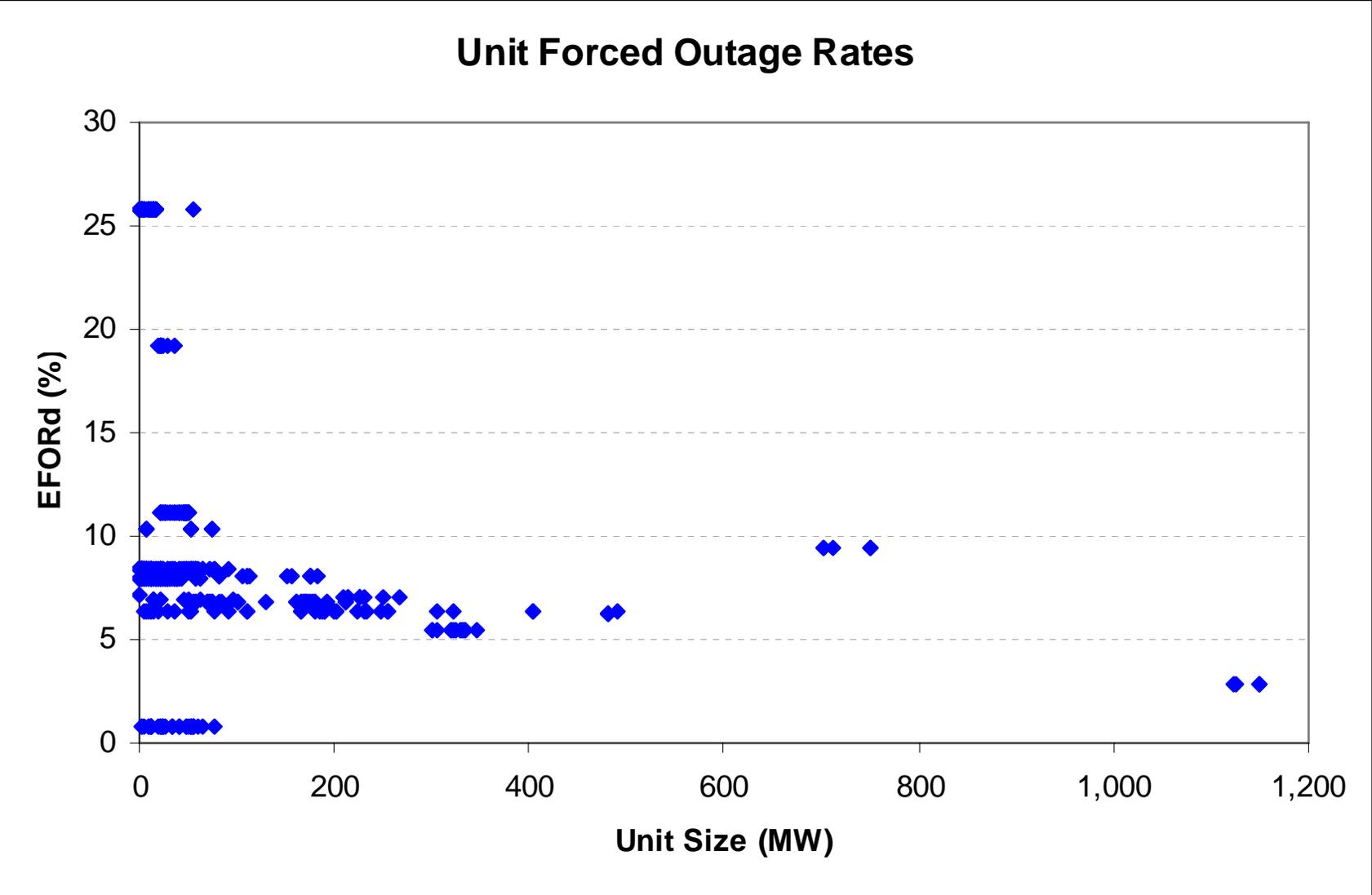
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Nuclear	4,550.00	4,550.00	4,550.00	4,550.00	4,550.00	4,550.00	4,550.00	4,550.00	4,550.00	4,550.00	4,550.00
Fossil	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Fossil-Gas	3,202.57	3,202.57	3,197.56	3,192.56	3,187.56	3,182.56	3,177.56	3,172.56	3,167.56	3,162.56	3,157.56
GT-Oil	156.00	156.00	156.00	156.00	156.00	156.00	156.00	156.00	156.00	156.00	156.00
GT-Gas	11,860.36	11,860.36	11,853.06	11,851.06	11,849.06	11,847.06	11,847.06	12,197.06	12,198.06	12,204.06	12,210.36
C.C.	3,240.31	3,240.31	3,240.31	3,240.31	3,240.31	3,240.31	3,240.31	3,240.31	3,240.31	3,240.31	3,240.31
I.C.	227.12	227.12	227.12	227.12	227.12	227.12	227.12	227.12	227.12	227.12	227.12
Diesel	28.00	28.00	28.00	28.00	28.00	28.00	28.00	28.00	28.00	28.00	28.00
Steam	581.91	604.27	662.61	721.09	771.86	861.34	862.54	862.58	867.46	671.58	599.02
ST-Gas	16,886.43	16,886.43	16,886.43	16,886.43	16,886.43	16,886.43	16,886.43	17,071.43	17,071.43	17,071.43	17,071.43
ST-Other	1,879.91	1,879.91	1,879.91	1,879.91	1,879.91	1,879.91	1,866.91	1,866.91	1,866.91	1,879.91	1,879.91
ST-Coal	254.70	254.70	254.70	254.70	254.70	254.70	254.70	254.70	254.70	254.70	254.70
Other	214.75	214.75	214.75	214.75	214.75	214.75	214.75	214.75	214.75	214.75	214.75
Refuse	903.98	903.98	903.98	903.98	903.98	903.98	903.98	903.98	903.98	903.98	903.98
Hydro	8,101.02	8,101.02	8,101.02	8,101.02	8,101.02	8,101.02	8,101.02	8,101.02	8,101.02	8,101.02	8,101.02
Hydro-RR	800.22	800.22	800.22	800.22	800.22	800.22	800.22	800.22	800.22	800.22	800.22
Hydro-Small	161.62	159.13	166.00	171.68	209.46	163.50	121.79	97.84	79.32	56.08	51.78
Non-RPS	1,804.00	1,804.00	1,804.00	1,804.00	1,804.00	1,804.00	1,804.00	1,804.00	1,804.00	1,804.00	1,804.00
Biomass	666.87	638.49	622.26	605.81	600.47	704.05	702.75	694.34	701.41	727.13	711.91
Geothermal	1,107.78	1,098.48	1,088.80	1,112.53	1,098.20	1,129.35	1,103.53	1,110.14	1,112.61	1,120.04	1,105.31
Solar	129.16	210.99	274.95	302.86	329.82	377.62	370.07	366.82	367.87	234.51	181.16
Wind	1,057.61	1,060.01	1,267.31	1,257.54	1,275.40	1,236.34	1,228.01	1,197.10	1,255.13	1,235.32	988.37
Cogen	172.40	174.50	168.60	170.30	176.20	169.20	171.20	169.80	170.40	167.90	168.30
Adjust	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	57,986.88	58,055.40	58,347.75	58,432.03	58,544.63	58,717.62	58,618.11	59,091.84	59,153.42	58,835.78	58,445.37
Peak	35,247.90	33,168.10	33,957.00	34,456.90	39,669.70	42,331.40	46,495.10	47,470.50	50,710.10	34,765.30	33,740.80
Reserve Margin (%)	64.51	75.03	71.83	69.58	47.58	38.71	26.07	24.48	16.65	69.24	73.22
Other Resources											
Demand Response	81.30	81.30	81.30	81.30	2,101.36	2,886.56	3,007.13	2,841.47	2,920.61	1,959.51	81.30
Out-of-State	1,565.00	1,565.00	1,565.00	1,565.00	1,565.00	1,565.00	1,565.00	1,565.00	1,565.00	1,565.00	1,565.00
Avg. Historical Imports	9,076.00	9,319.00	10,617.00	10,879.00	10,699.00	11,615.00	12,229.00	11,173.00	9,415.00	10,519.00	9,901.00

Study Data – Outage Rates

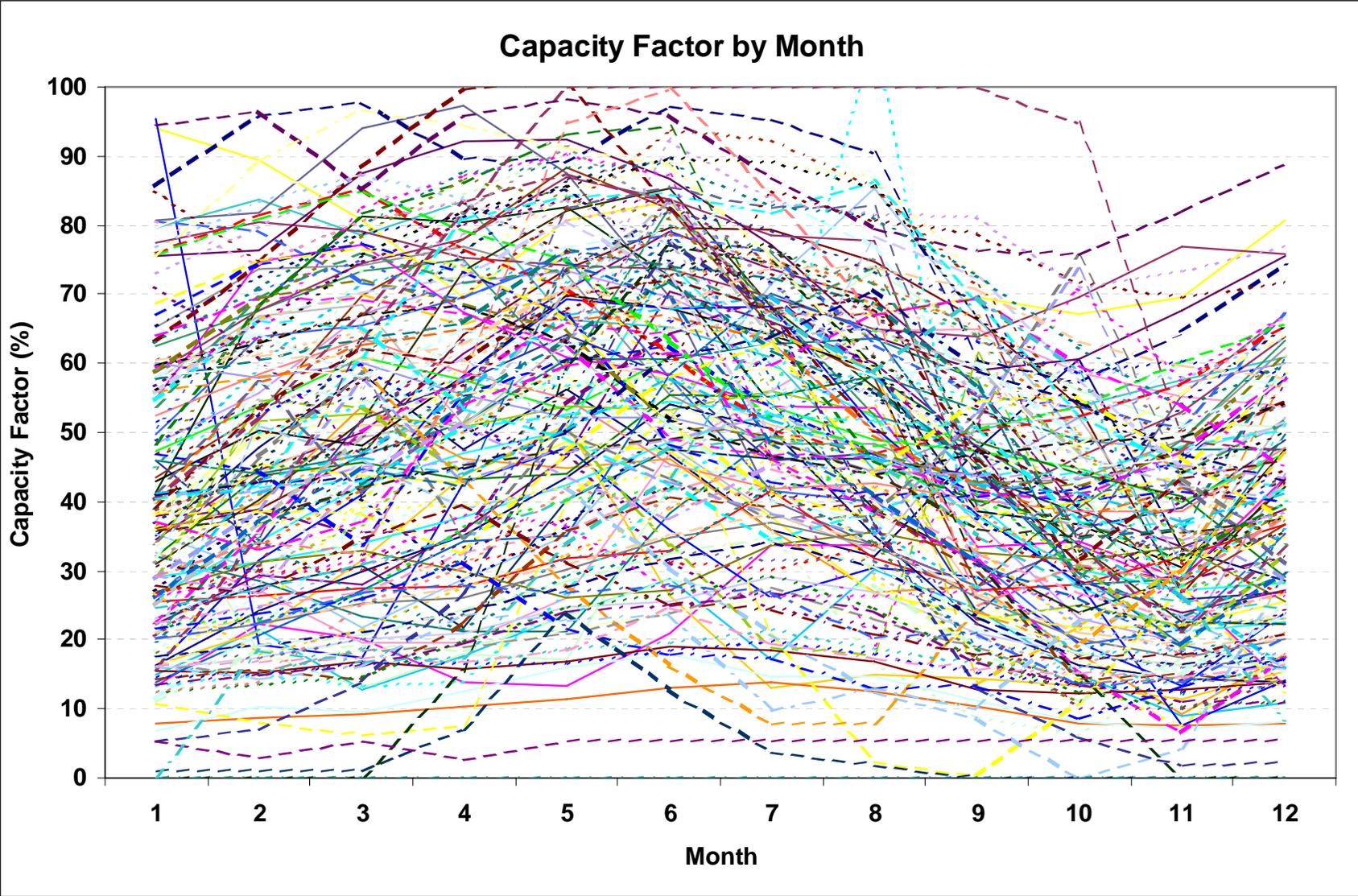
MW-Weighted Average Outage Rates

	No. Cal.		So. Cal.		San Diego		CAISO	
	P.O.R.	F.O.R.	P.O.R.	F.O.R.	P.O.R.	F.O.R.	P.O.R.	F.O.R.
Nuclear	4.25	2.87	6.66	2.87			5.44	2.87
Fossil				7.95				7.95
Fossil-Gas	3.25	8.46	2.93	8.64	3.00	8.39	3.20	8.49
GT-Oil	1.09	10.30					1.09	10.30
GT-Gas	2.32	8.39	2.42	8.63	2.27	11.55	2.36	8.92
C.C.	4.89	6.33	4.89	6.33			4.89	6.33
I.C.	2.70	16.70	3.04	8.39	3.07	8.39	2.72	16.13
Diesel			1.09	10.30			1.09	10.30
Steam			4.06	6.91			4.06	6.91
ST-Gas	7.96	7.22	7.74	6.95	6.93	6.91	7.71	7.04
ST-Other	2.21	3.36	3.12	5.49			2.45	3.91
ST-Coal	5.39	6.96	5.39	6.96			5.39	6.96
Other	4.72	7.95	4.51	7.55			4.52	7.58
Refuse	4.55	8.08	3.36	11.95	2.73	15.52	4.12	9.54

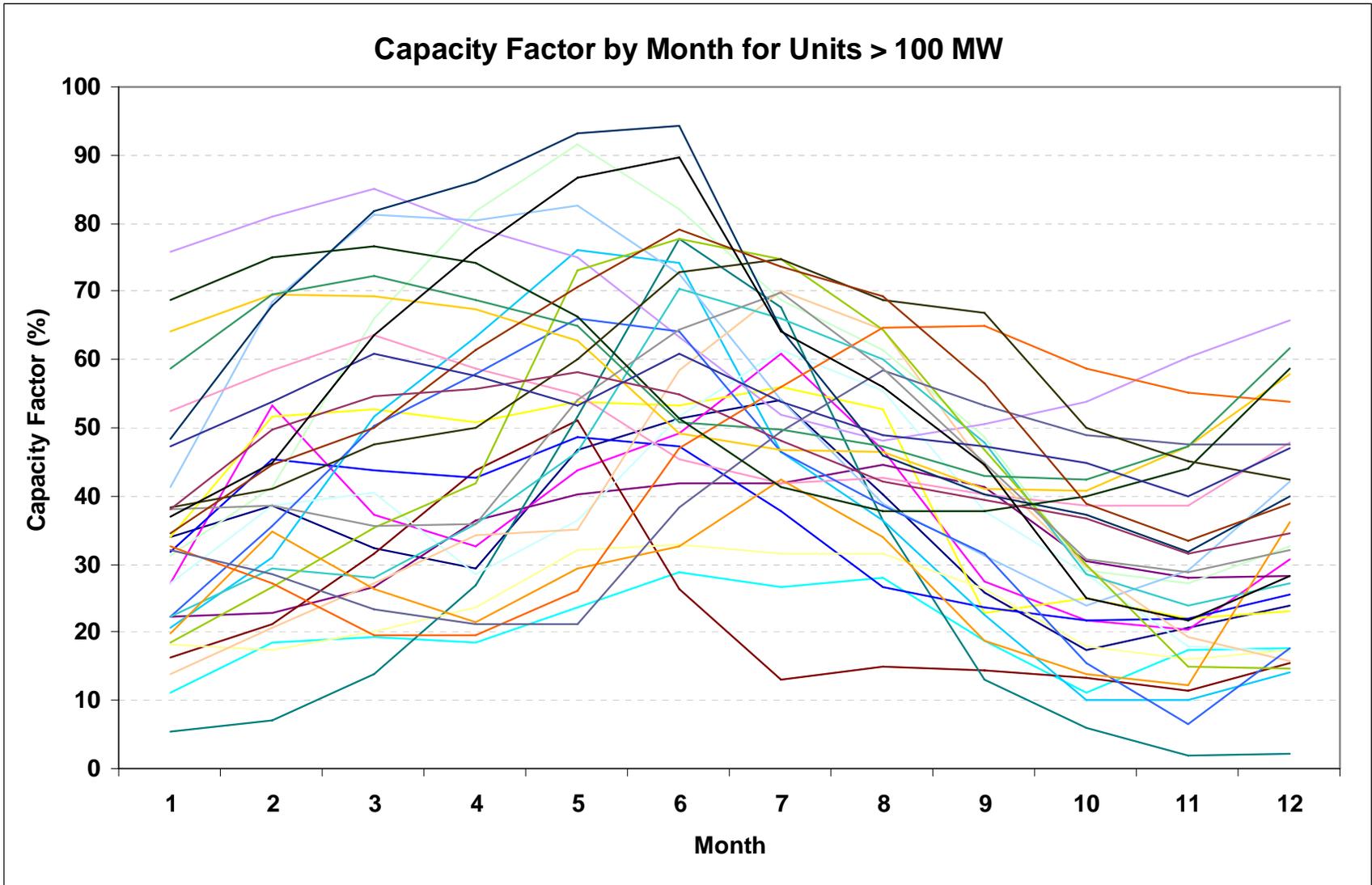
Study Data – Forced Outage Rates



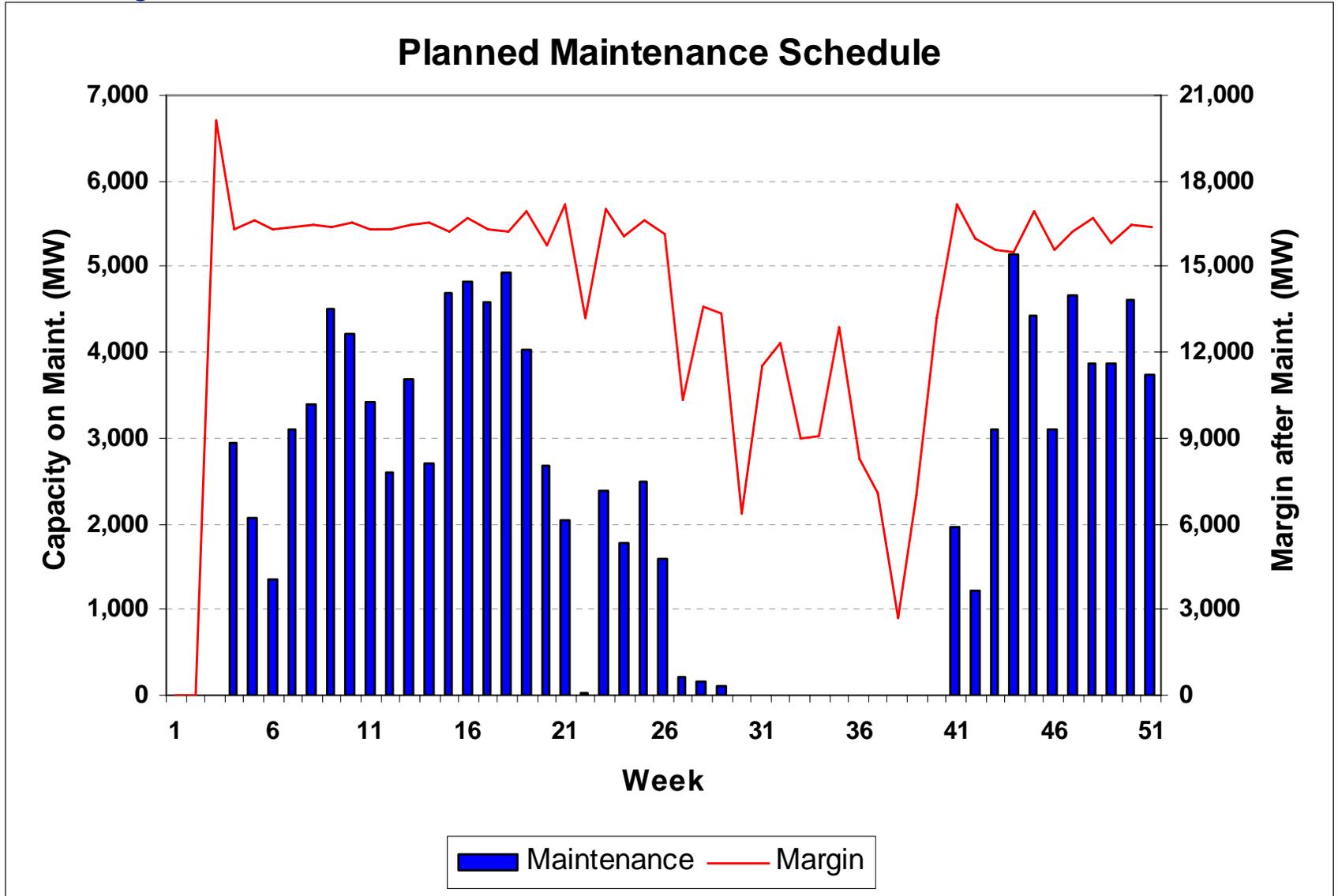
Study Data – Hydro Capacity Factors



Study Data – Hydro Capacity Factors



Study Data – Maintenance Schedule

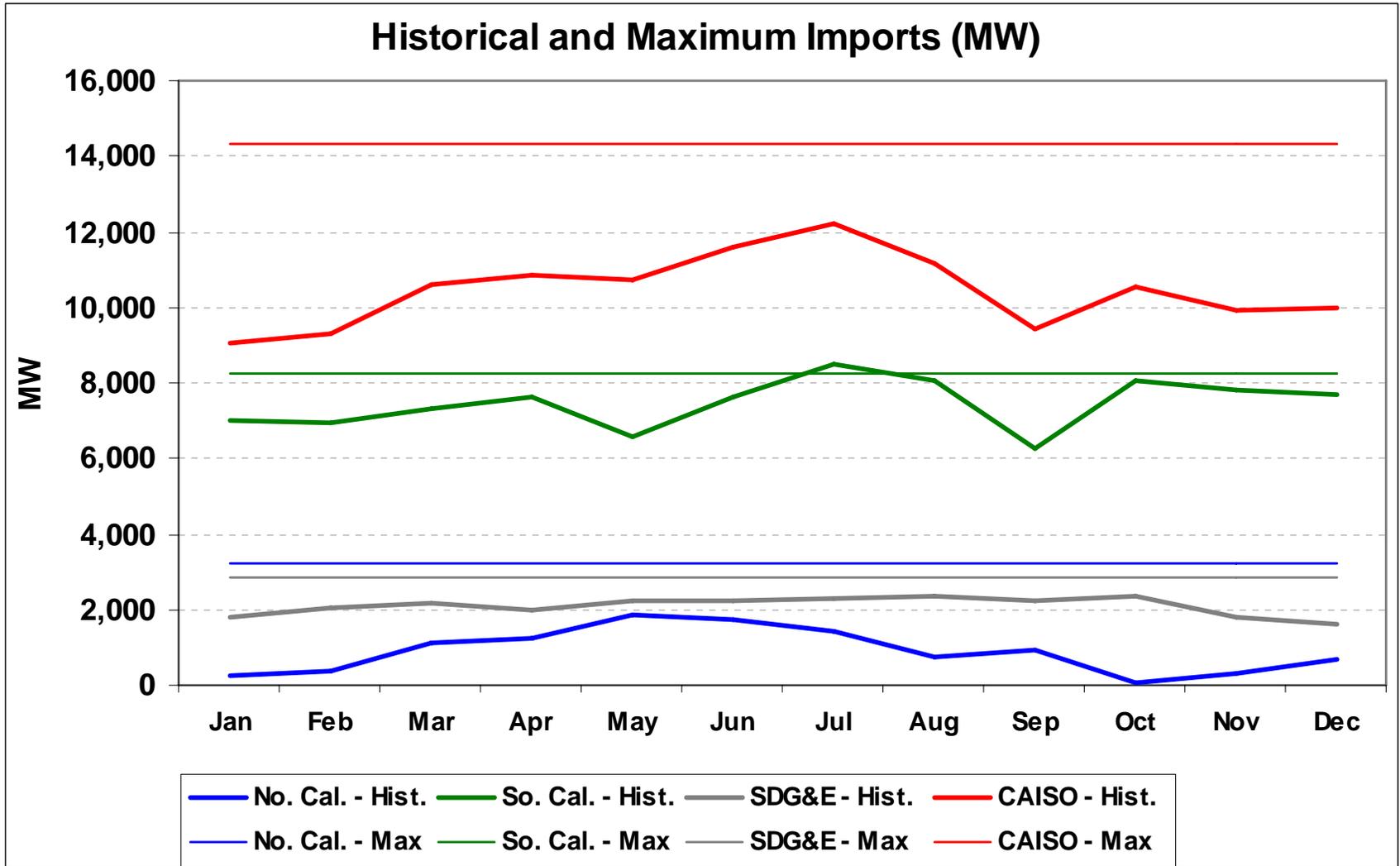


Study Data - Interfaces

- **Internal interface transfer limits**
 - **Northern California to Southern California (Path 26)**
 - 3,750 MW north to south
 - 2,902 MW south to north
 - **Southern California to San Diego (Path 41)**

Status of SONGS Units		Interface Flow Limit (MW)	
Unit 1	Unit 2	North - South	South - North
Available	Available	2,200	236
Unavailable	Available	2,200	1,314
Available	Unavailable	2,200	1,316
Unavailable	Unavailable	2,200	2,440

Study Data - Imports



Study Data - Loads

- **Historical load profiles from 2007**
 - *2006 for extreme load sensitivity*
- **2010 peak projections from 2007 Integrated Energy Policy Report**
- **Load forecast uncertainty**

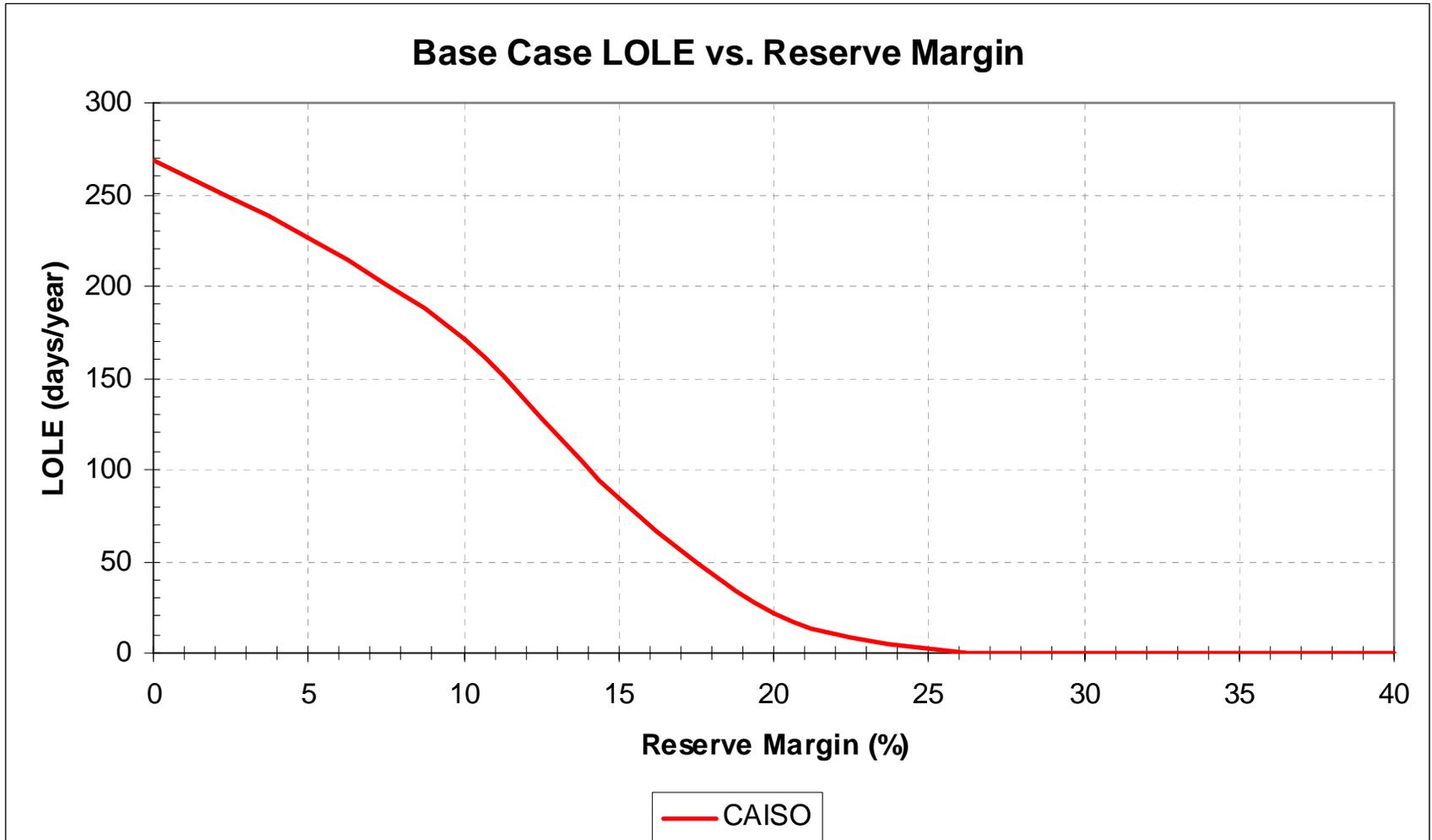
	Load Forecast			
	1-in-2	1-in-5	1-in-10	1-in-20
No. California	1.0000	1.0264	1.0367	1.0777
So. California	1.0000	1.0663	1.0773	1.1070
San Diego	1.0000	1.0680	1.0880	1.1490
Probability	0.5	0.3	0.1	0.1

- **Demand response**
 - *Maximum rating with monthly or annual energy based on number of times and hours per time it can be implemented*

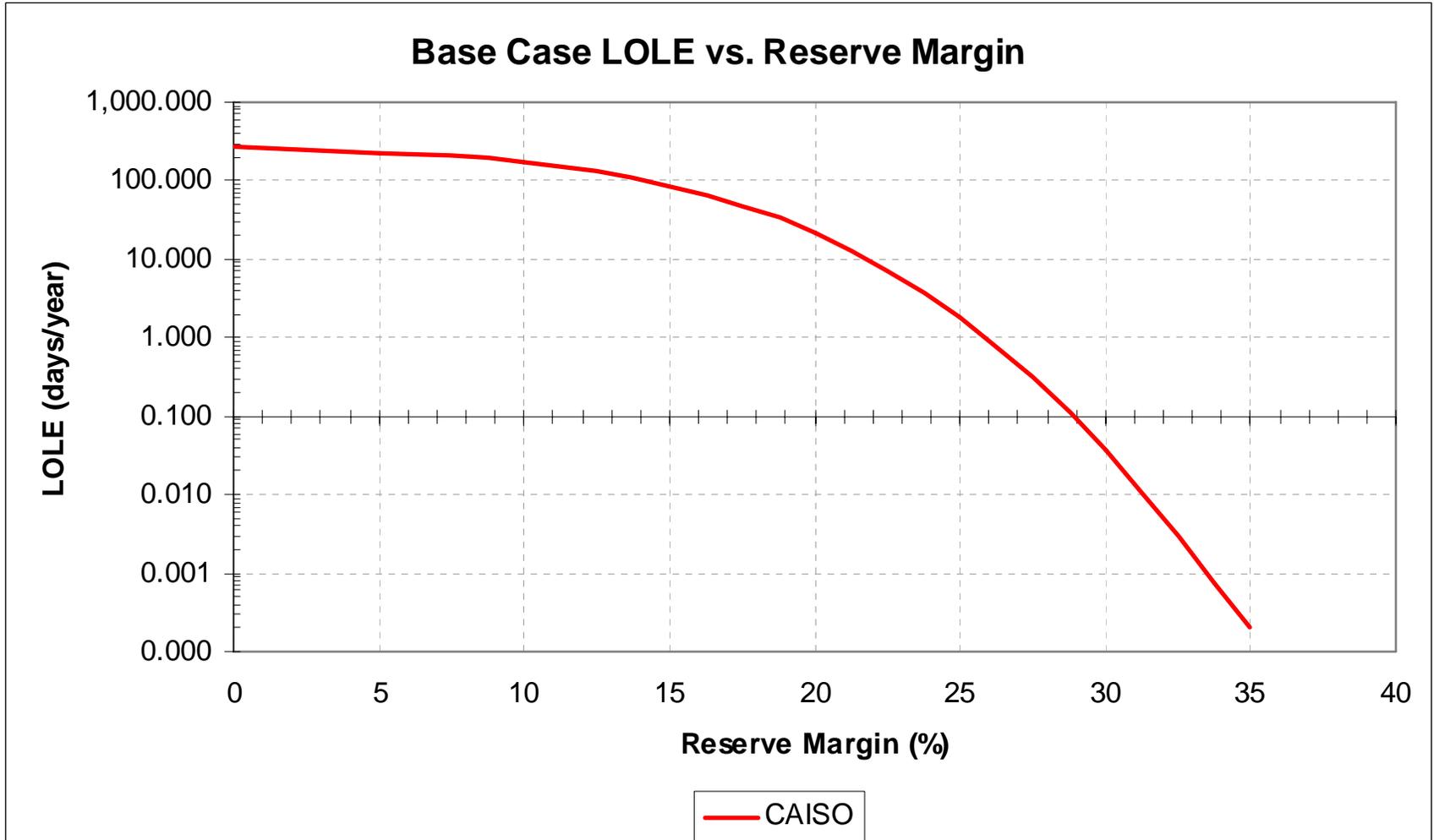
Data Quality Issues

- **Hydro data**
 - *Ratings from CAISO Master List*
 - *Energy from CEC source*
 - *No direct link between sources by unit name*
 - *Different levels of aggregation*
- **Scheduled outage data for 2007**
 - *CAISO Scheduling and Logging for the ISO of California (SLIC) database*
 - *No direct link with other sources by unit name*
 - *Data inconsistencies*
- **PG&E scale factors for wind and other renewables not received by GE in time for simulations**
- **Demand response data specified for summer months only**

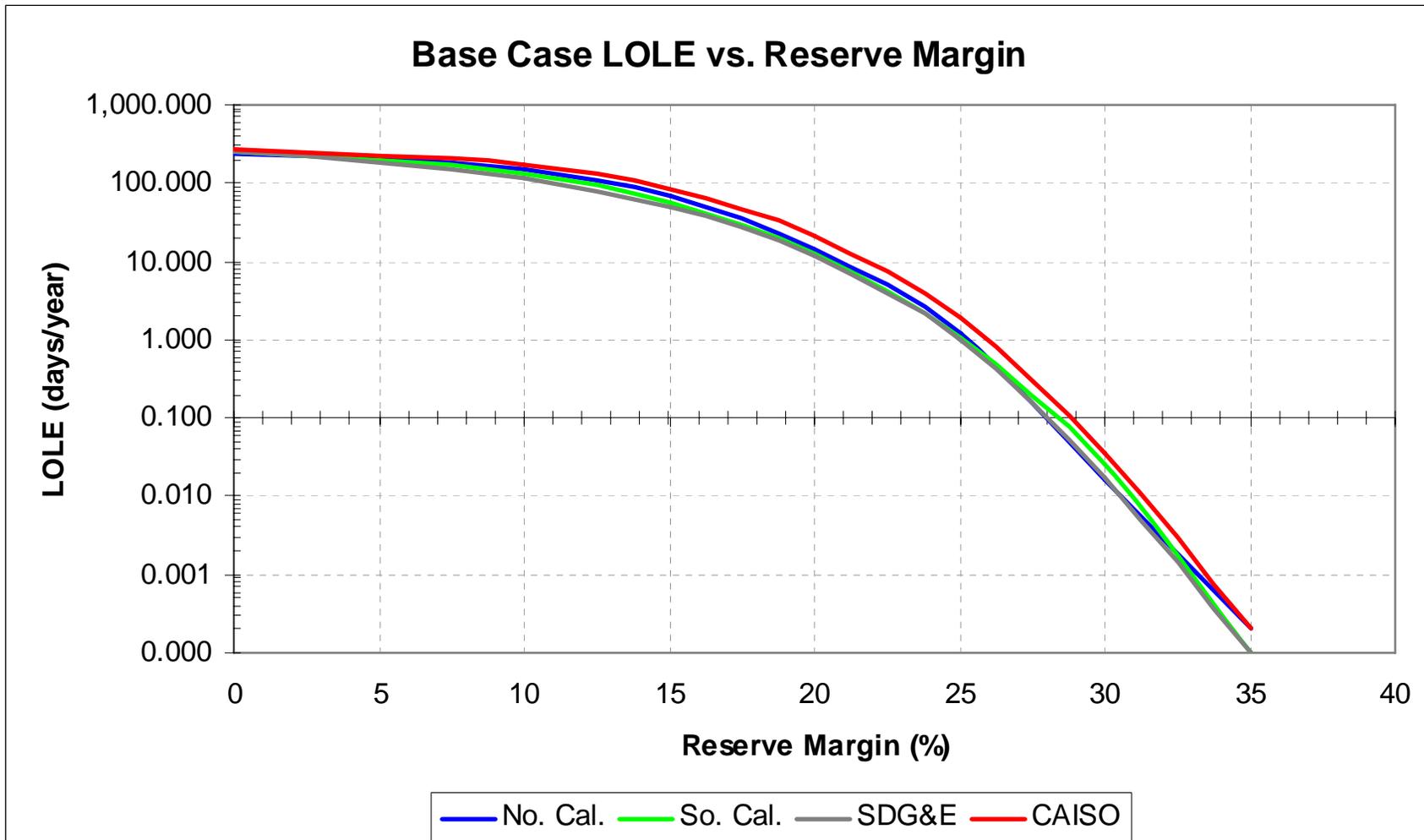
Base Case – Monthly Reserves, Excl. Imports and DR



Base Case – PRM = 28.8%

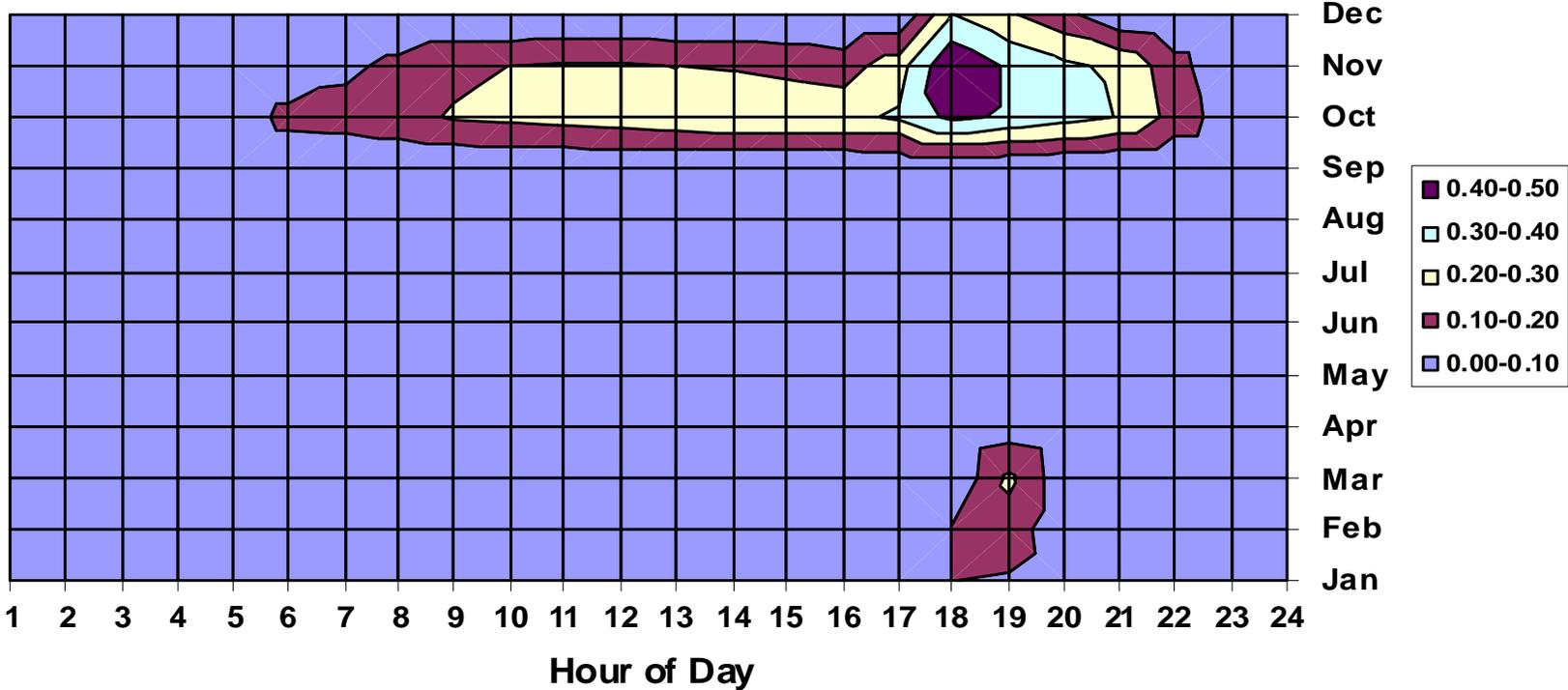


Base Case – Area LOLE



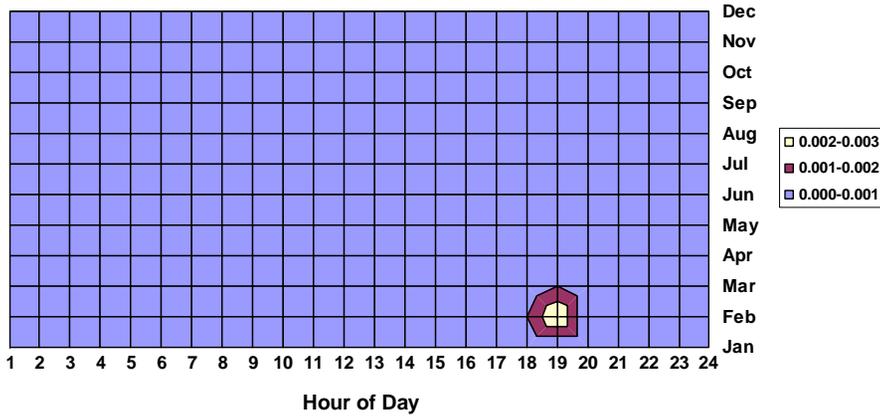
Base Case – Hourly Results

Expected Number of Outages for All Forecast Levels
Base Case with 25% Monthly Reserves

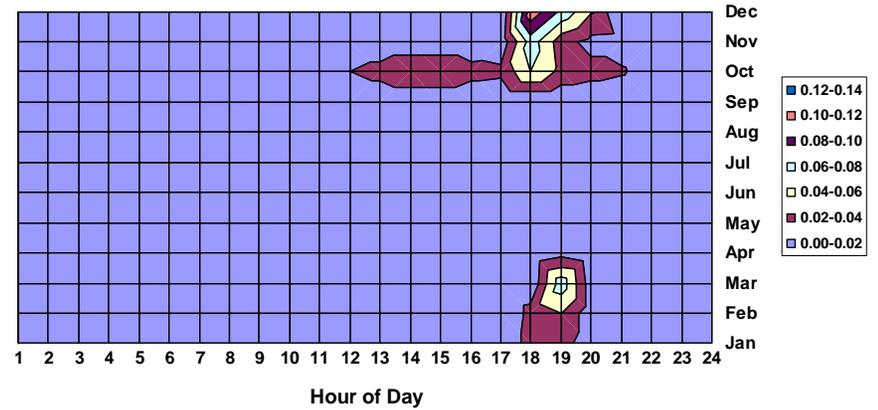


Base Case – Hourly Results

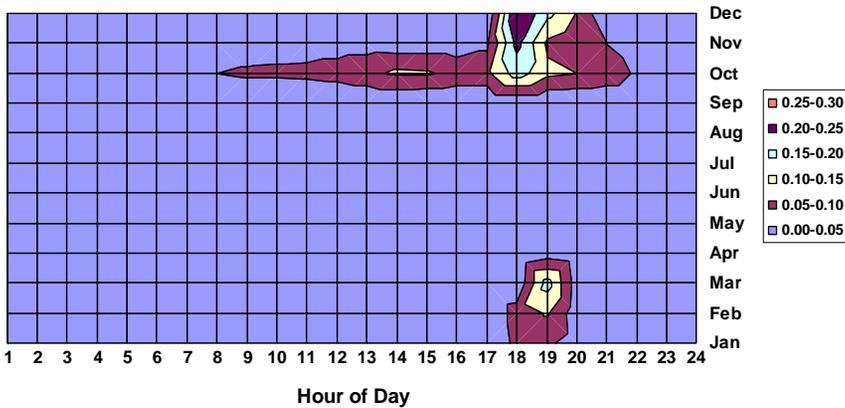
Expected Number of Outages at 1-in-2 Forecast
Base Case with 25% Monthly Reserves



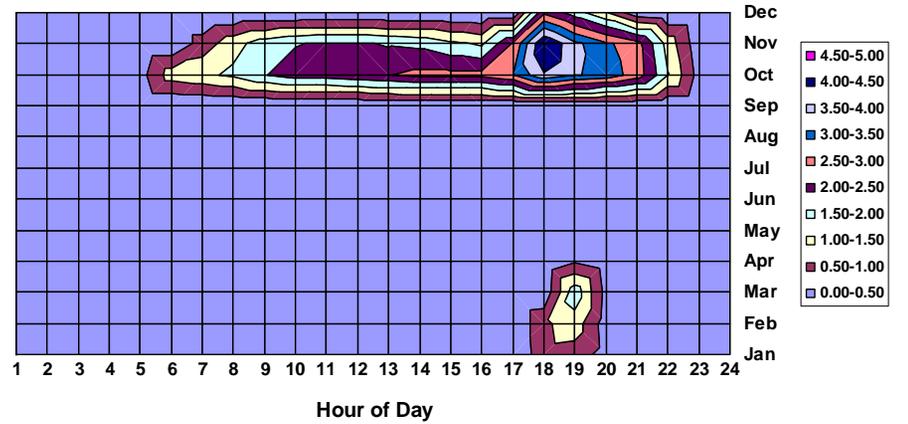
Expected Number of Outages at 1-in-5 Forecast
Base Case with 25% Monthly Reserves



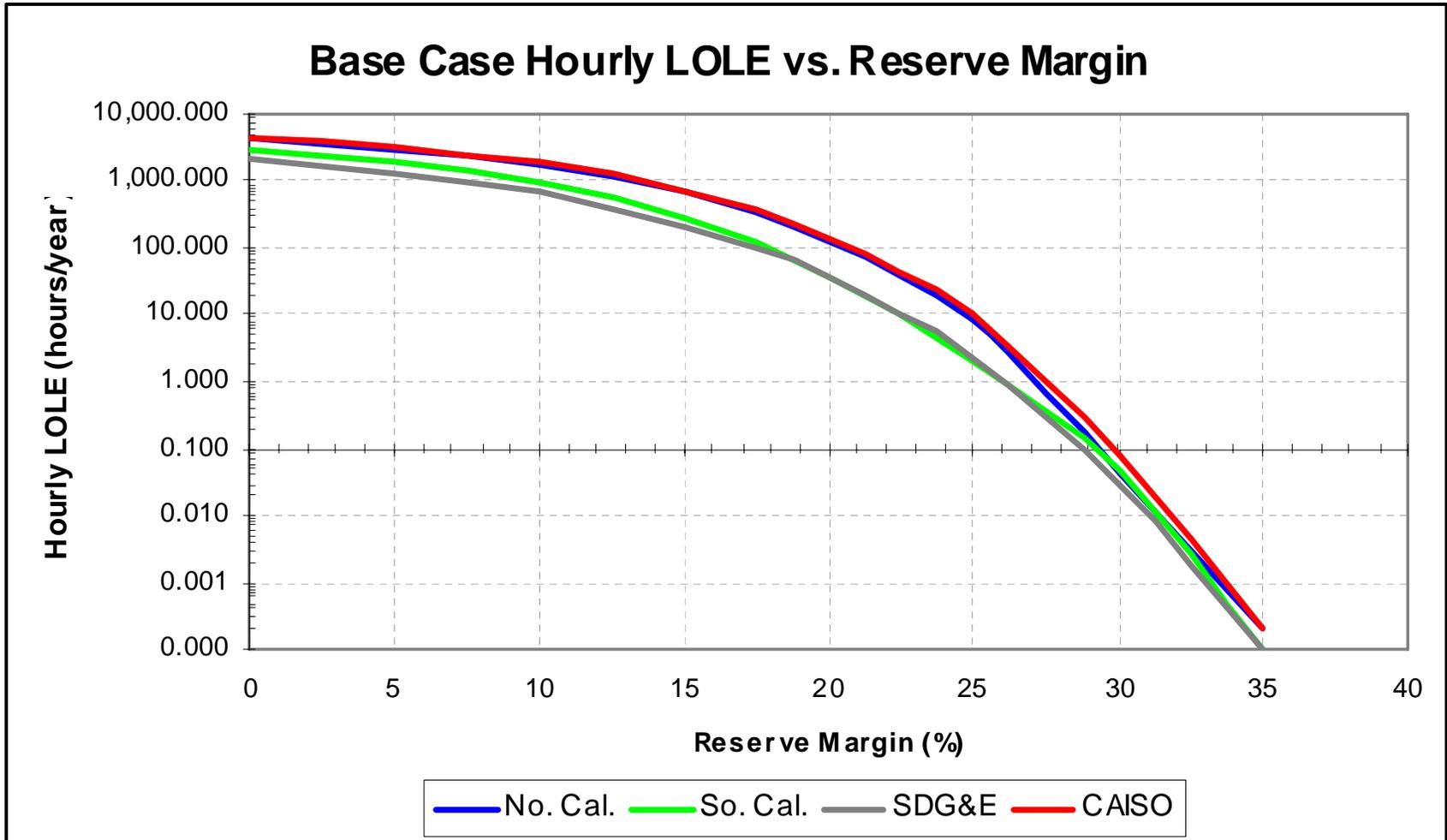
Expected Number of Outages at 1-in-10 Forecast
Base Case with 25% Monthly Reserves



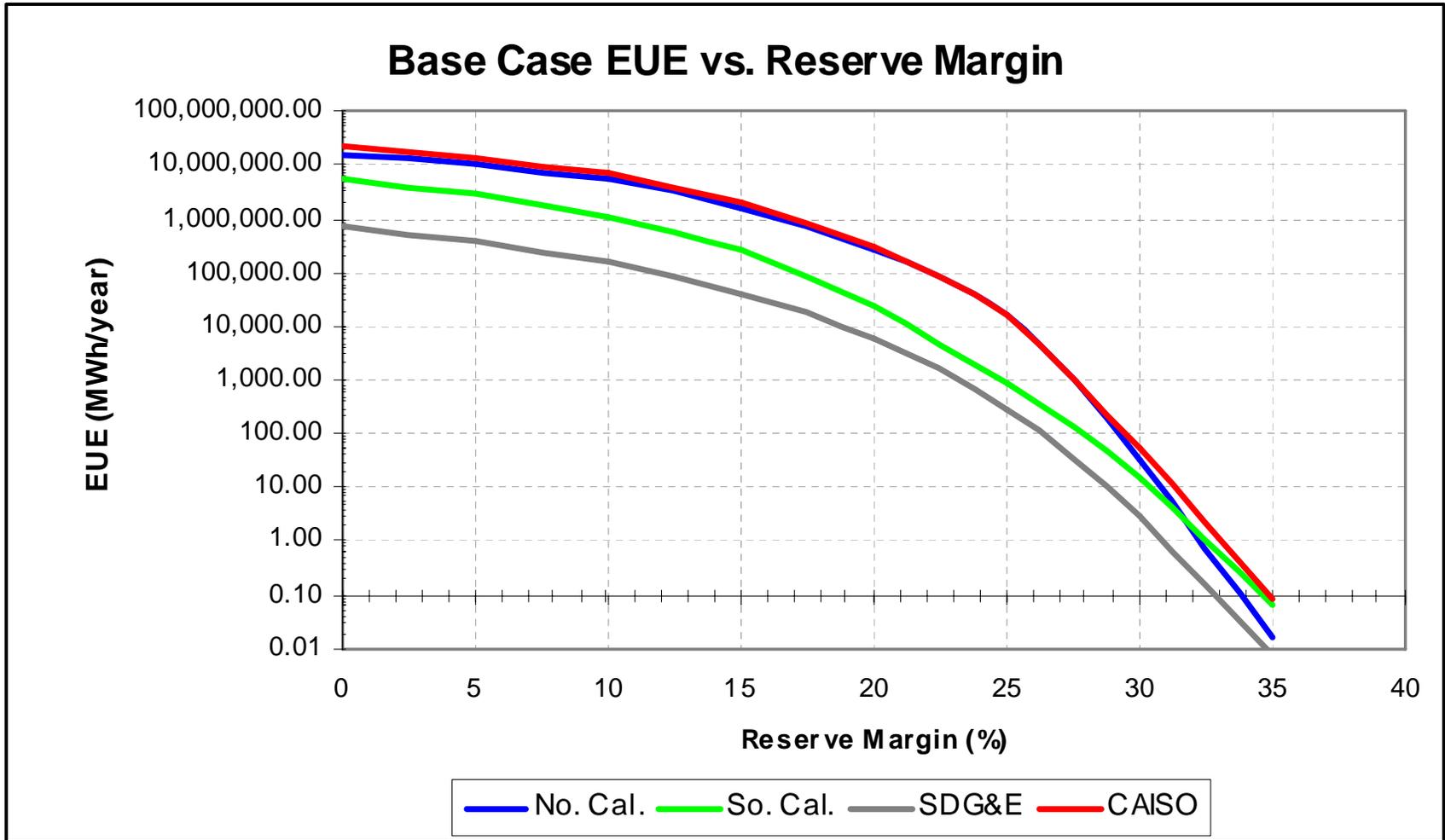
Expected Number of Outages at 1-in-20 Forecast
Base Case with 25% Monthly Reserves



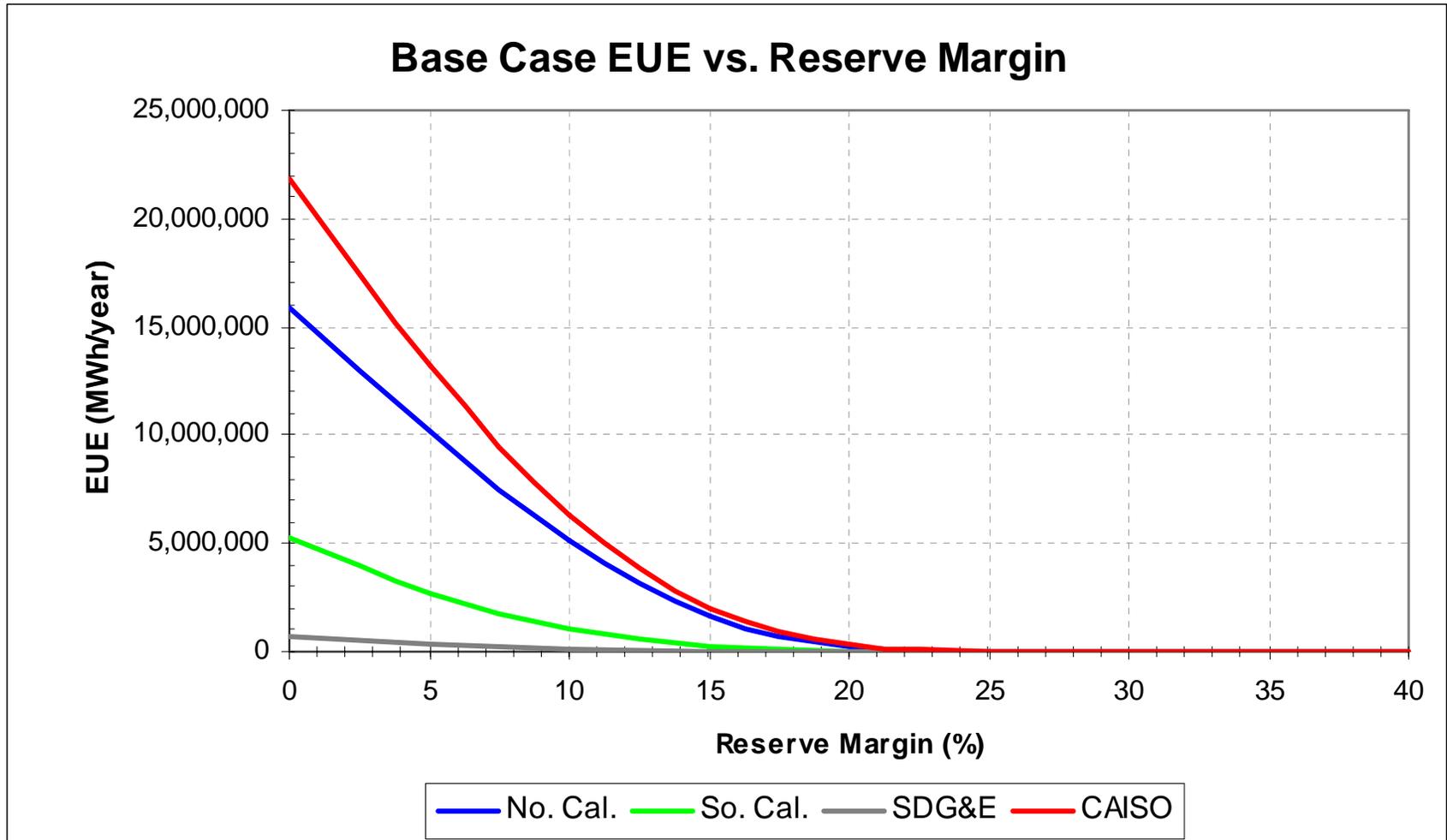
Base Case – Hourly LOLE = 0.2477 hours/year



Base Case – Expected Unserved Energy = 222.4 MWh/year



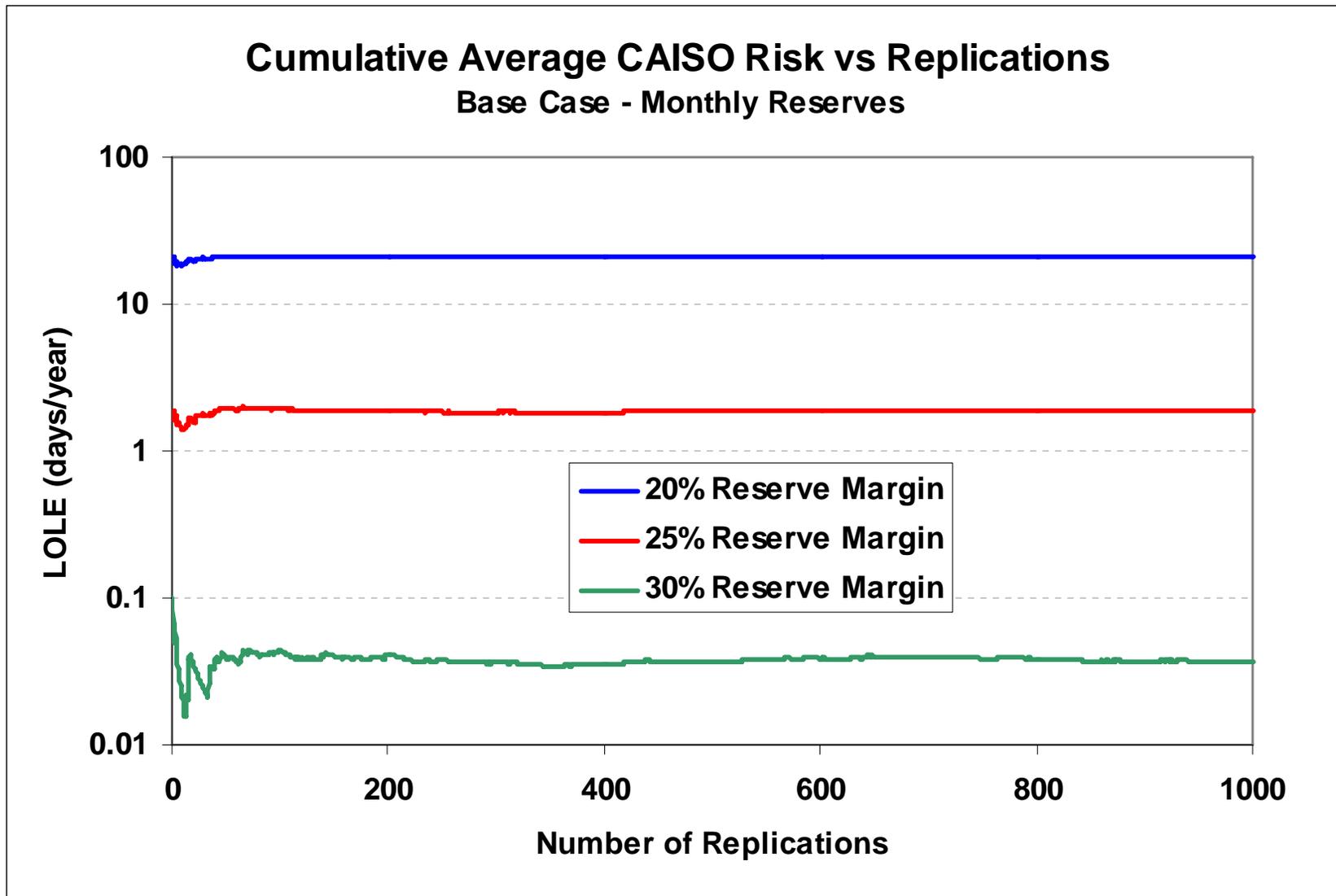
Base Case – Expected Unserved Energy



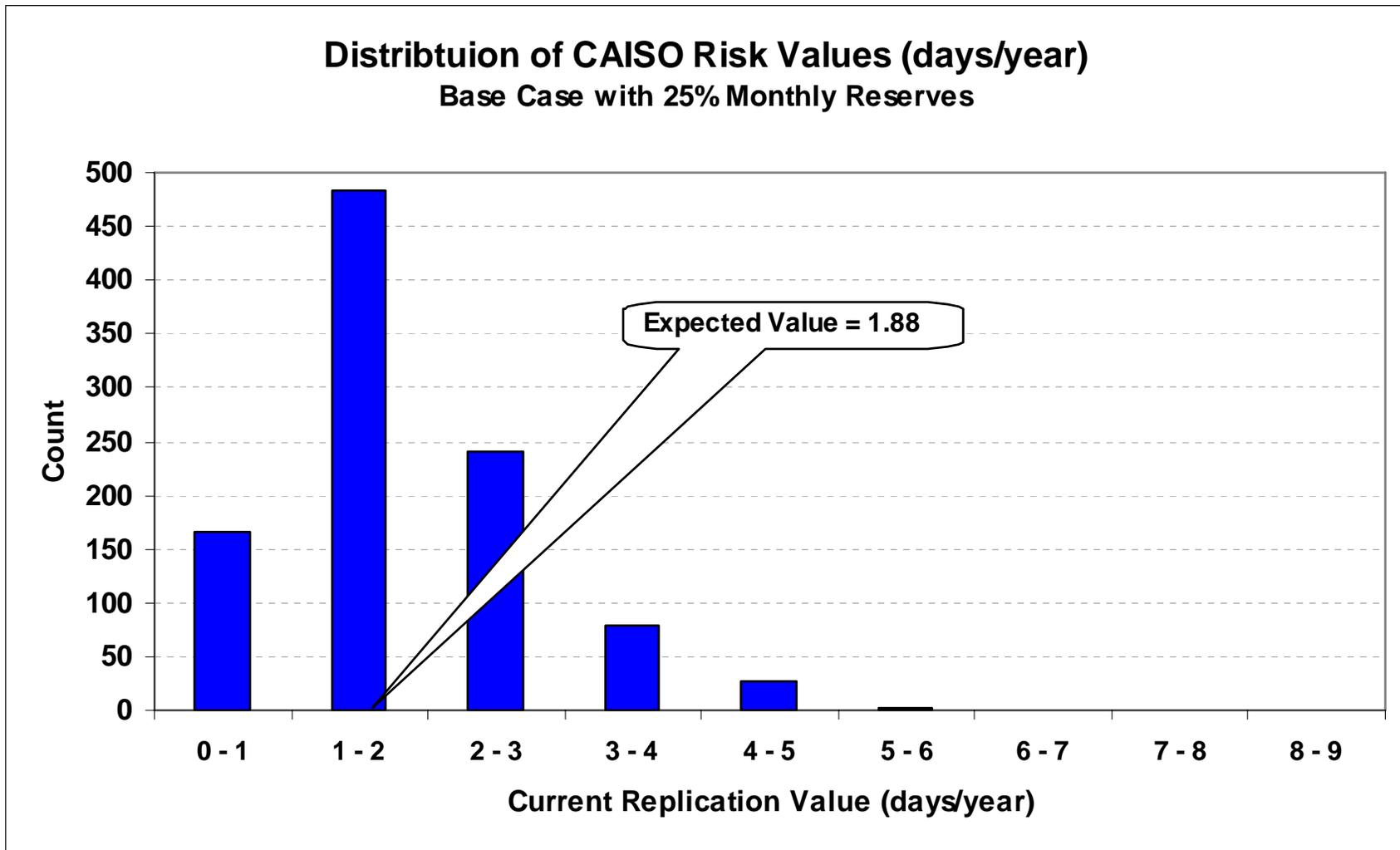
Base Case – Summary at 28.8% Monthly Reserves

Daily LOLE	0.1022 days/year
Hourly LOLE	0.2477 hours/year
EUE	222.4 MWh/year
Total Load Energy	251,108,176 MWh
EUE as % of Load	0.0000886%
Duration of outages	2.42 hours/day of outage
Magnitude of outages	898 MW/hour of outage

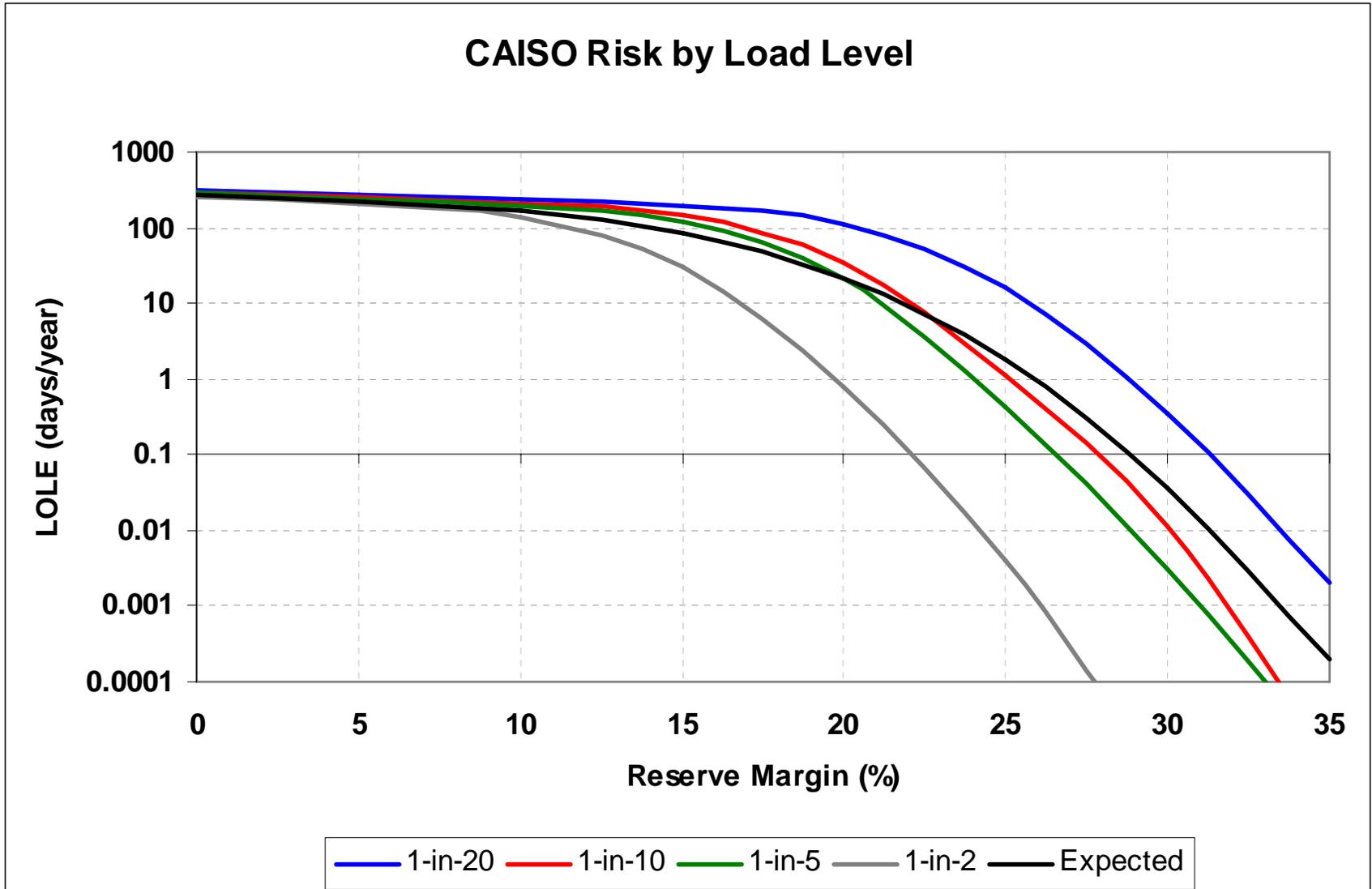
Base Case – Simulation Convergence



Base Case – Distribution of Calculated Indices



Base Case – Risk by Load Forecast



CAISO Risk at 28.8% Monthly Reserves

Load Level	LOLE (days/year)	Probability	Expected Risk Contribution (days/year)	Three Point Probability	Three Point Expected Risk Contribution (days/year)
1 in 20	0.941	0.1	0.0941	0.0	0.0000
1 in 10	0.045	0.1	0.0045	0.2	0.0090
1 in 5	0.012	0.3	0.0036	0.3	0.0036
1 in 2	0.000	0.5	0.0000	0.5	0.0000
Annual total			0.1022		0.0126

System risk is highly dependent upon load uncertainty distribution

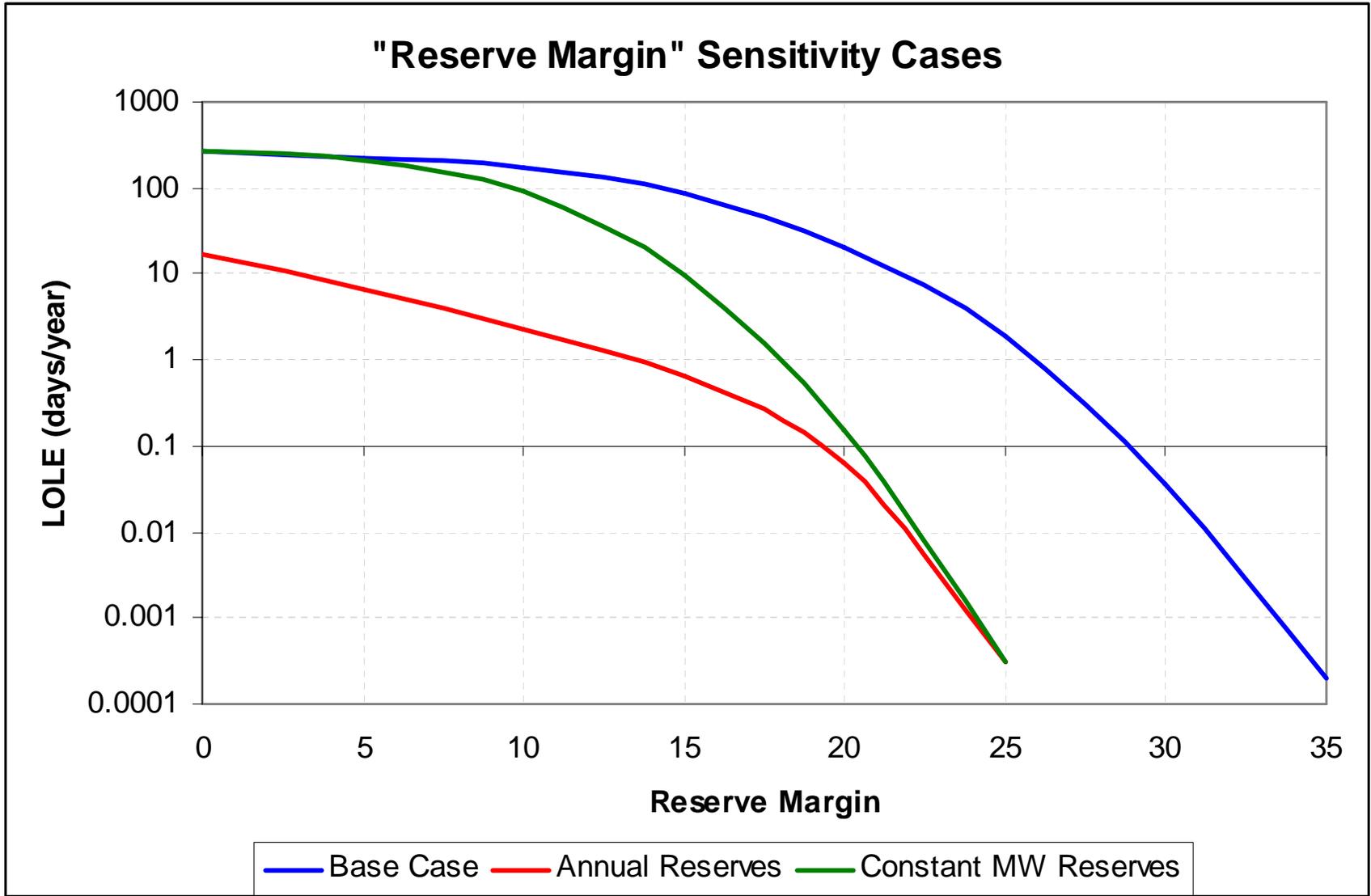
Sensitivity Cases

- **Reserve Margin**
 - *Annual*
 - *Constant MW*
- **Other Resources – Imports and DR**
 - *Imports = historical flows*
 - *Imports = sum of tie limits*
- **Study Data**
 - *Increased EFORd*
 - *Extreme load shape (2006)*
 - *Drought hydro conditions (1992)*
 - *No internal interface limits*
 - *Design criterion (0.2 day/year and 0.05 days/year)*

What is a Reserve Margin?

- **Reserve Margin = (Available Capacity / Peak Load) – 1**
- **12,000 MW of Capacity with a 10,000 MW peak load produces a Reserve Margin = 20%**
- **Annual % Reserves**
 - *The reserve margin is measured at the time of annual peak load and the total capacity is maintained throughout the year*
- **Monthly % Reserves**
 - *The reserve margin is measured at the time of each monthly peak*
- **Constant Monthly MW Reserves**
 - *The reserve margin is set at the time of the annual peak load and that amount of MW of reserve is maintained each month*

Sensitivity Cases – Reserve Margins

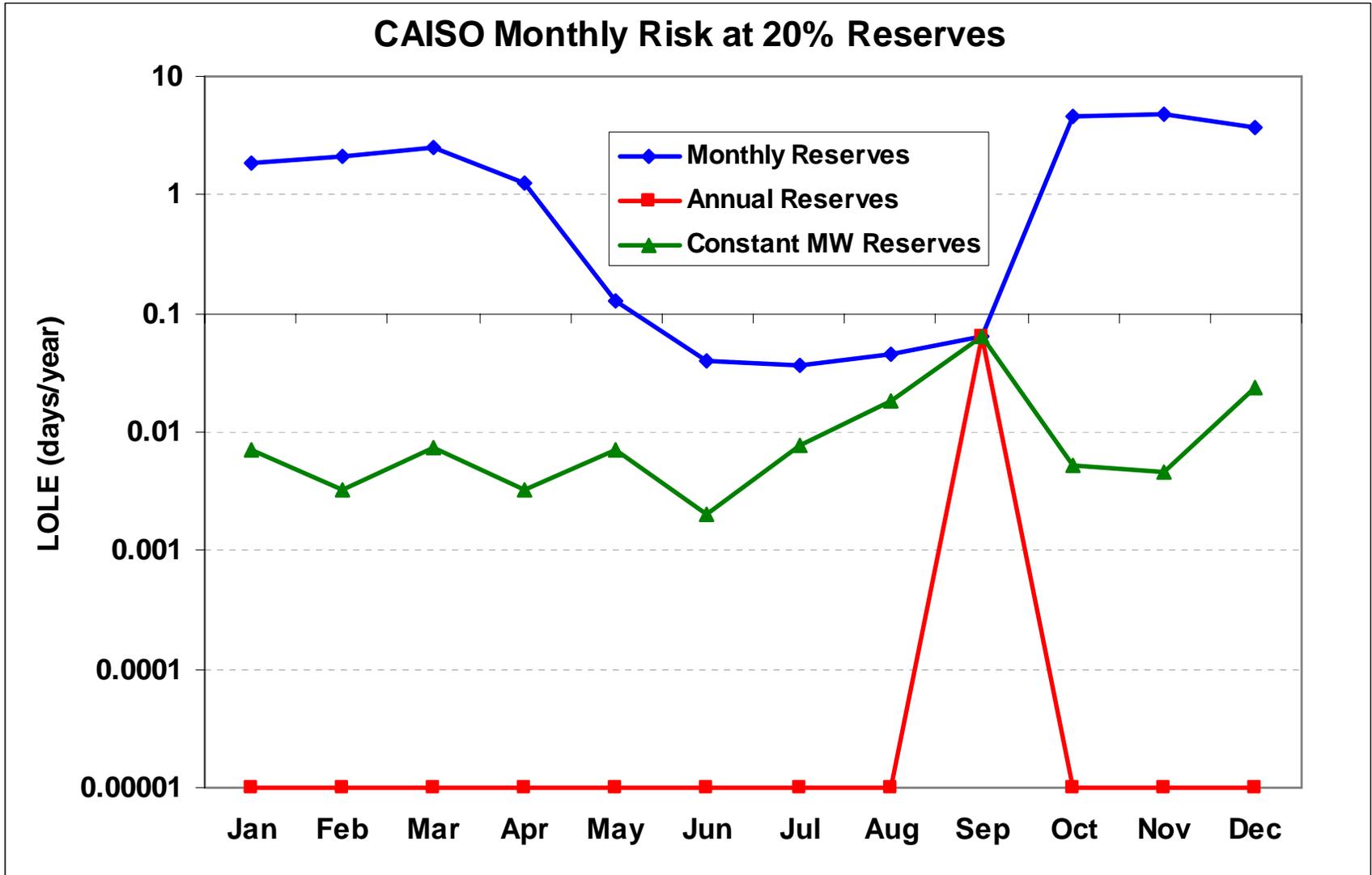


Sensitivity Cases – Reserve Margins

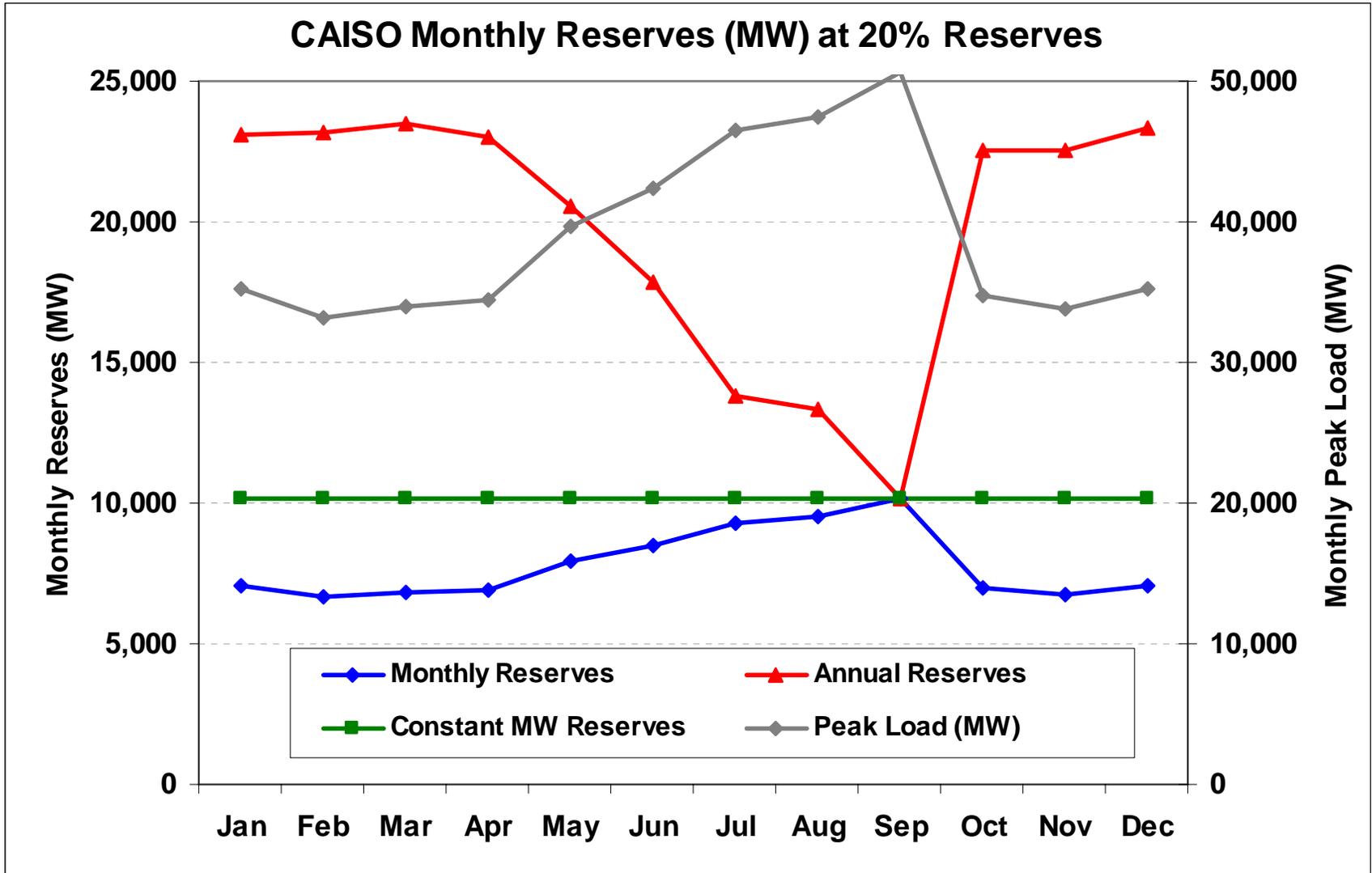
Annual LOLE with 20% reserves

Monthly Reserves	21.099 days/year
Annual Reserves	0.065 days/year
Constant MW Reserves	0.154 days/year

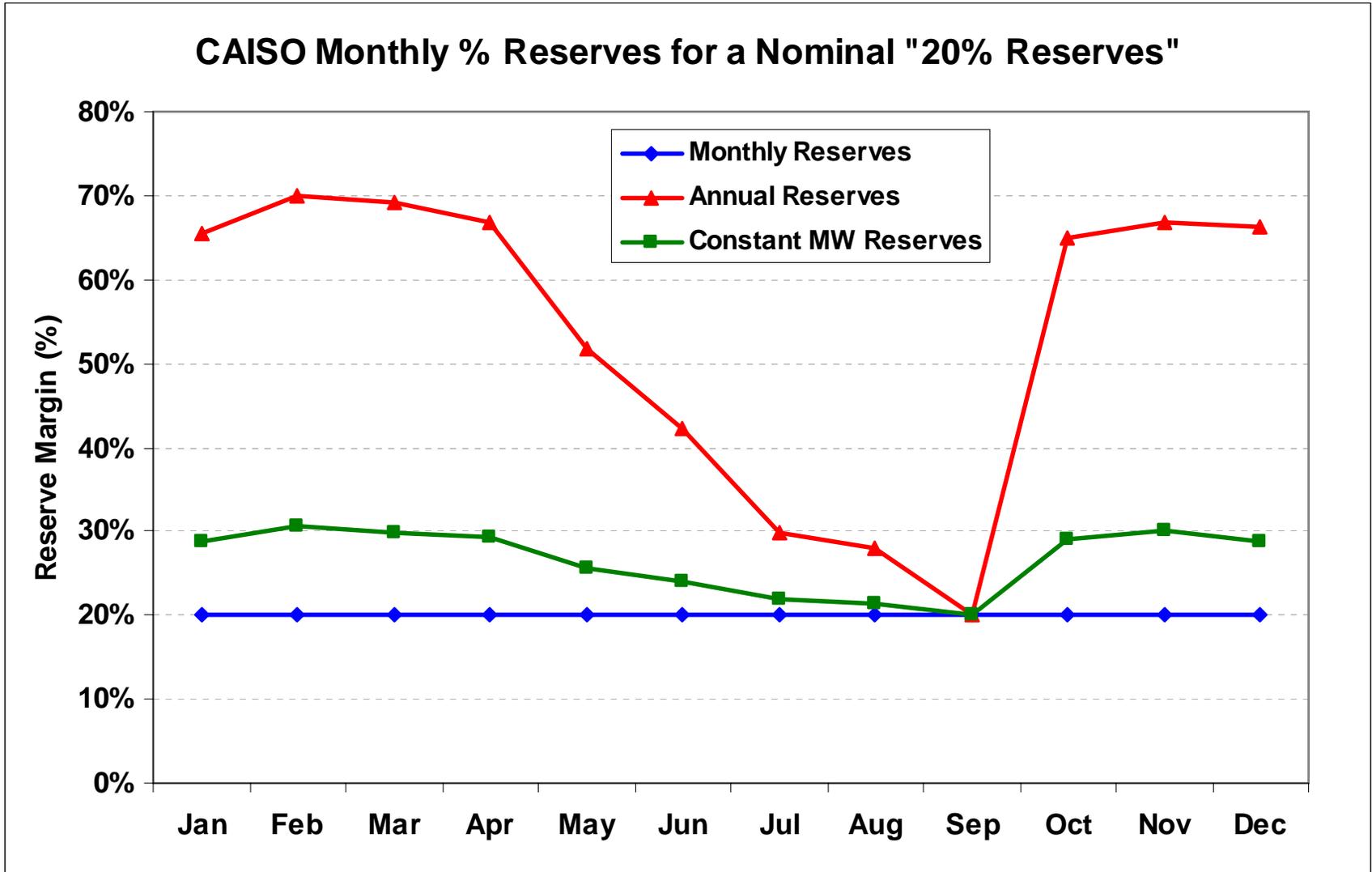
Sensitivity Cases – Reserve Margins



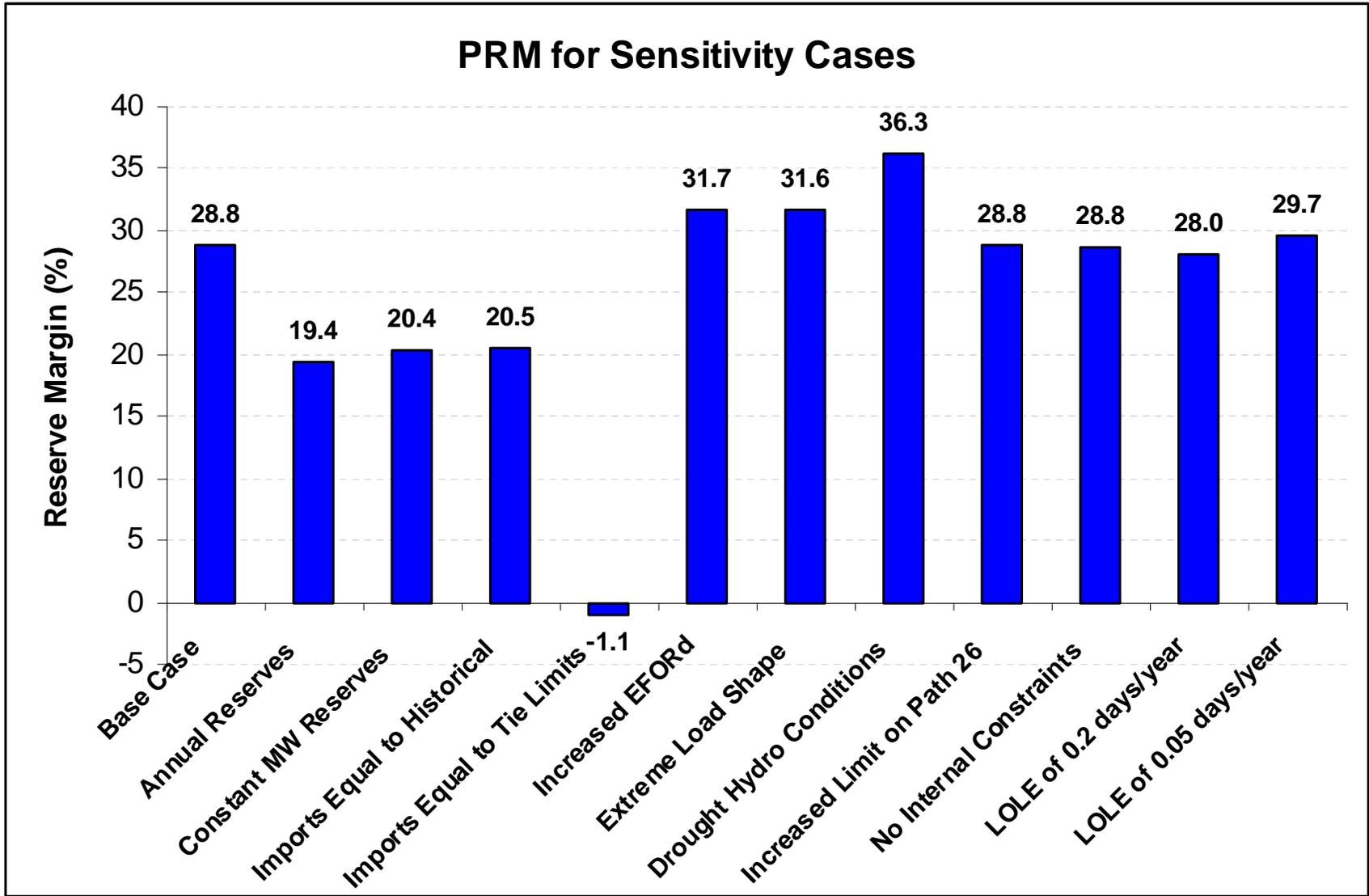
Sensitivity Cases – Reserve Margins



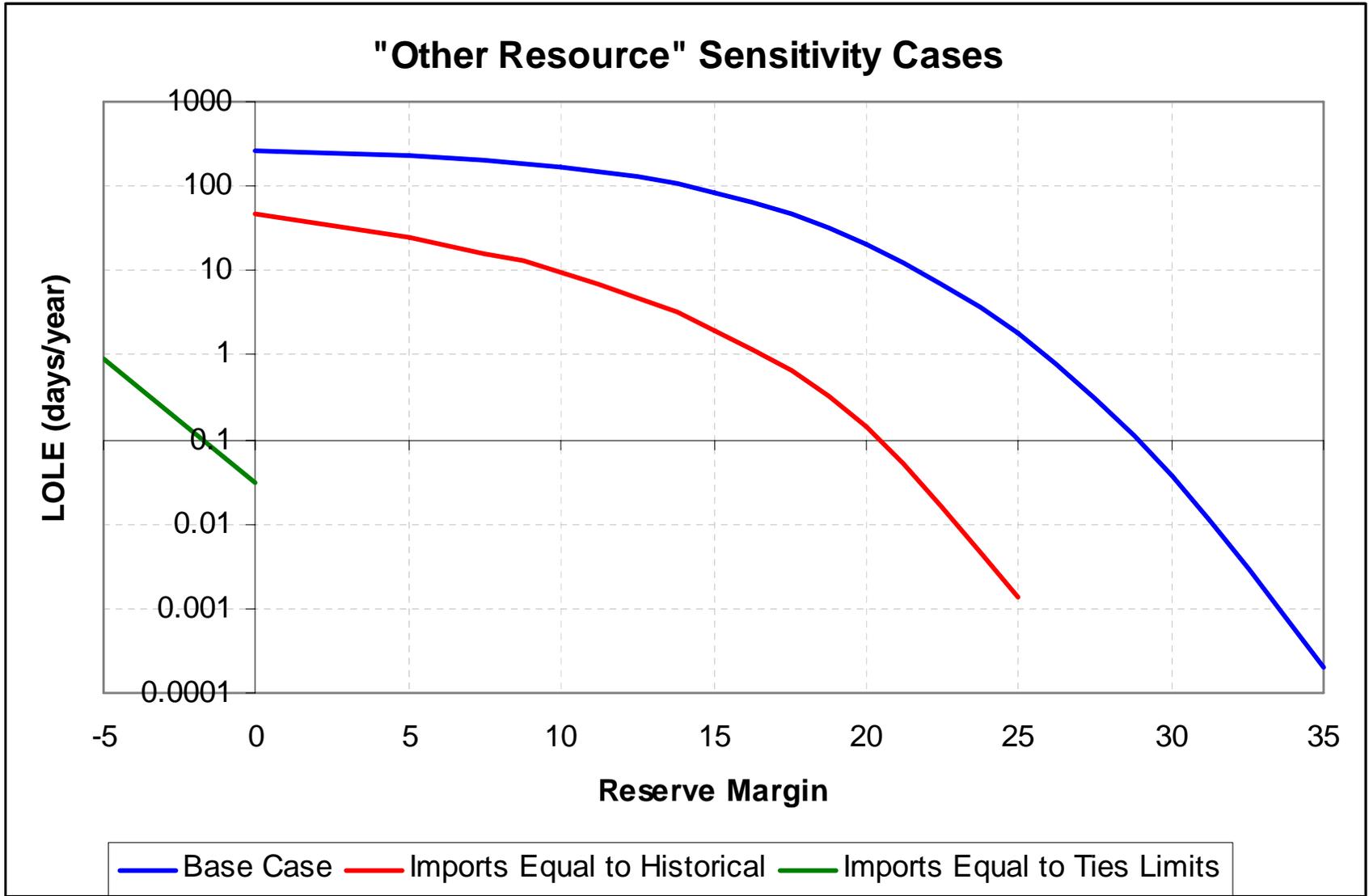
Sensitivity Cases – Reserve Margins



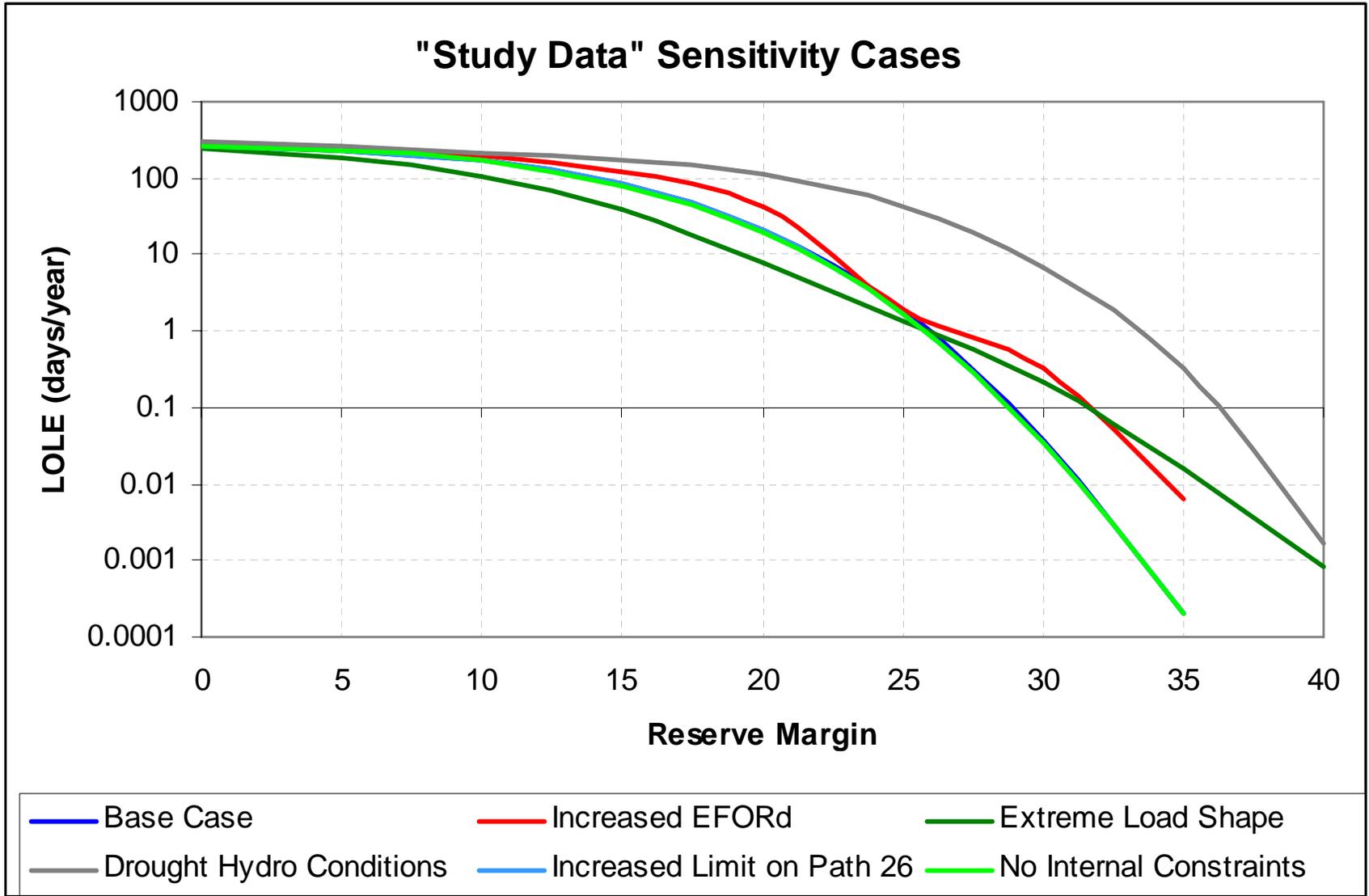
Sensitivity Cases – PRMs



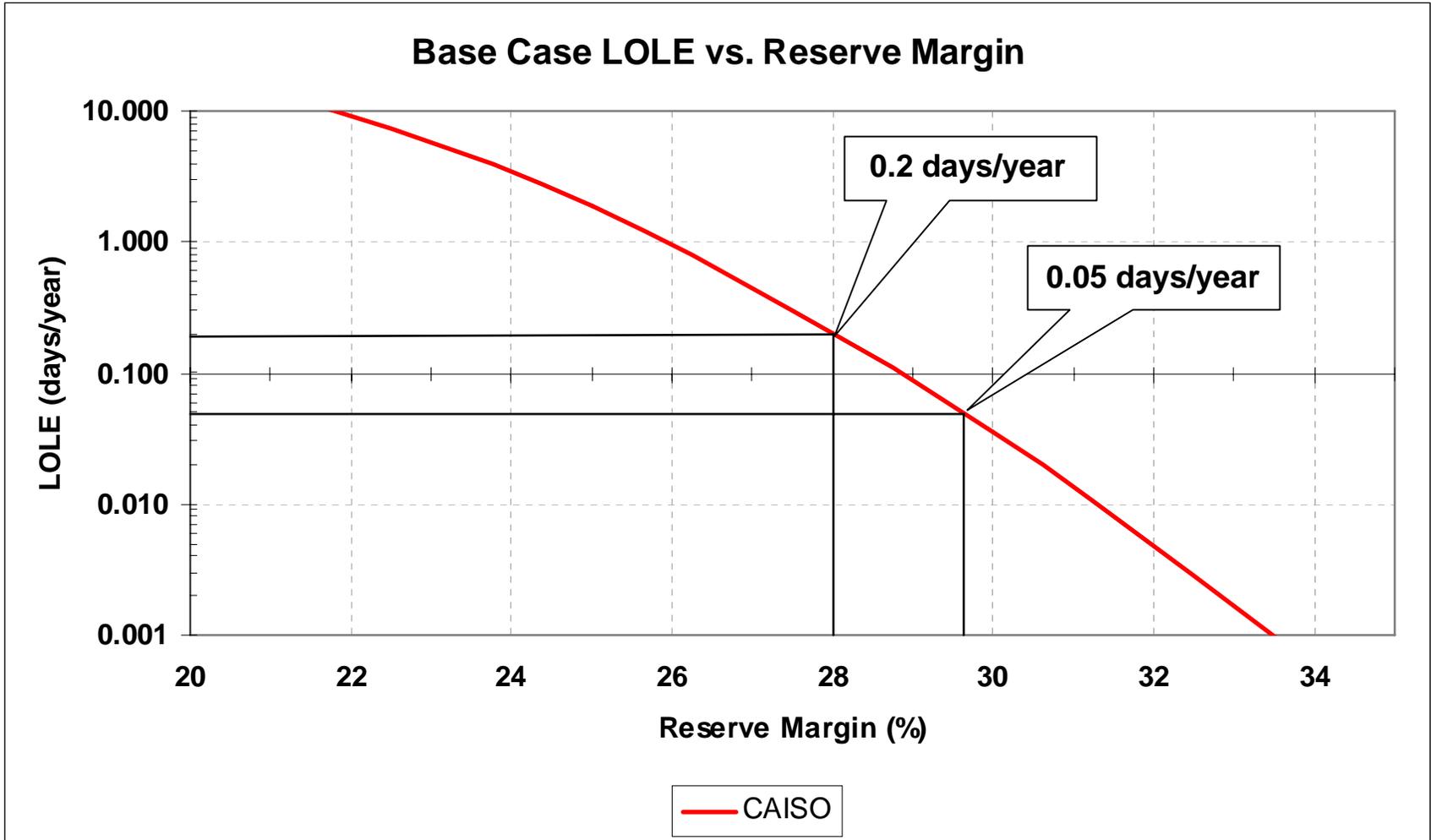
Sensitivity Cases – Other Resources



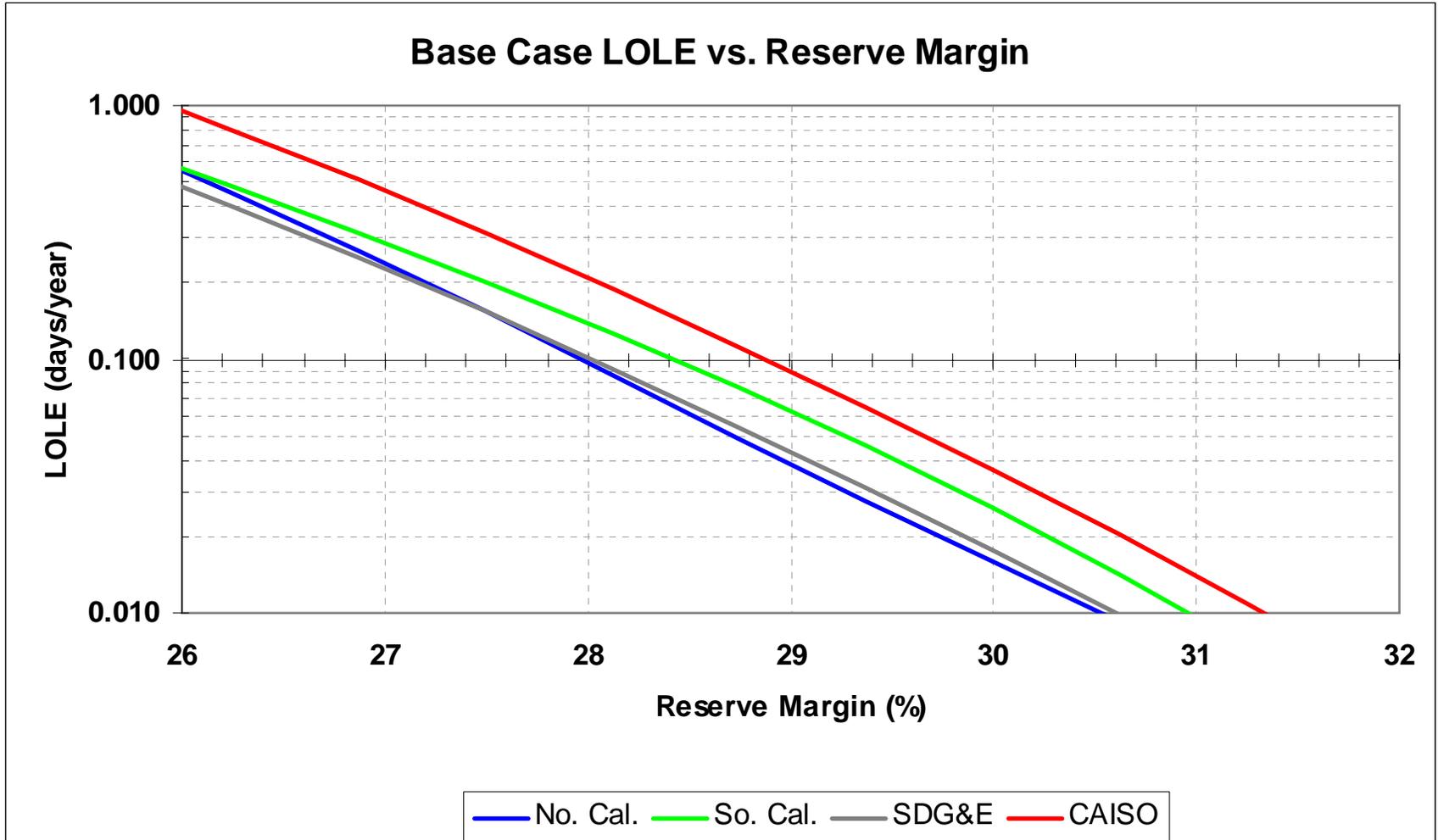
Sensitivity Cases – Study Data



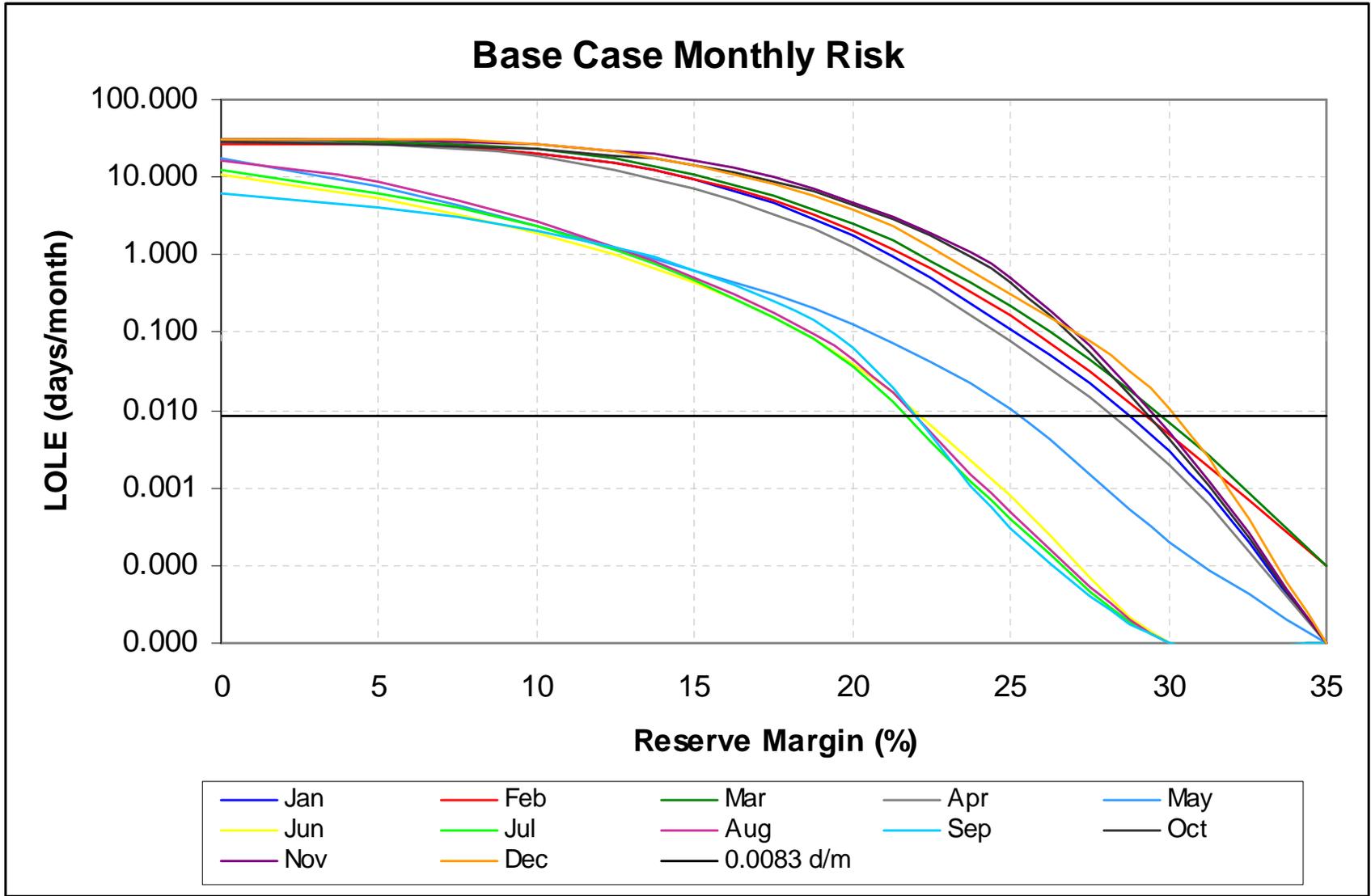
Sensitivity Cases – Design Criterion



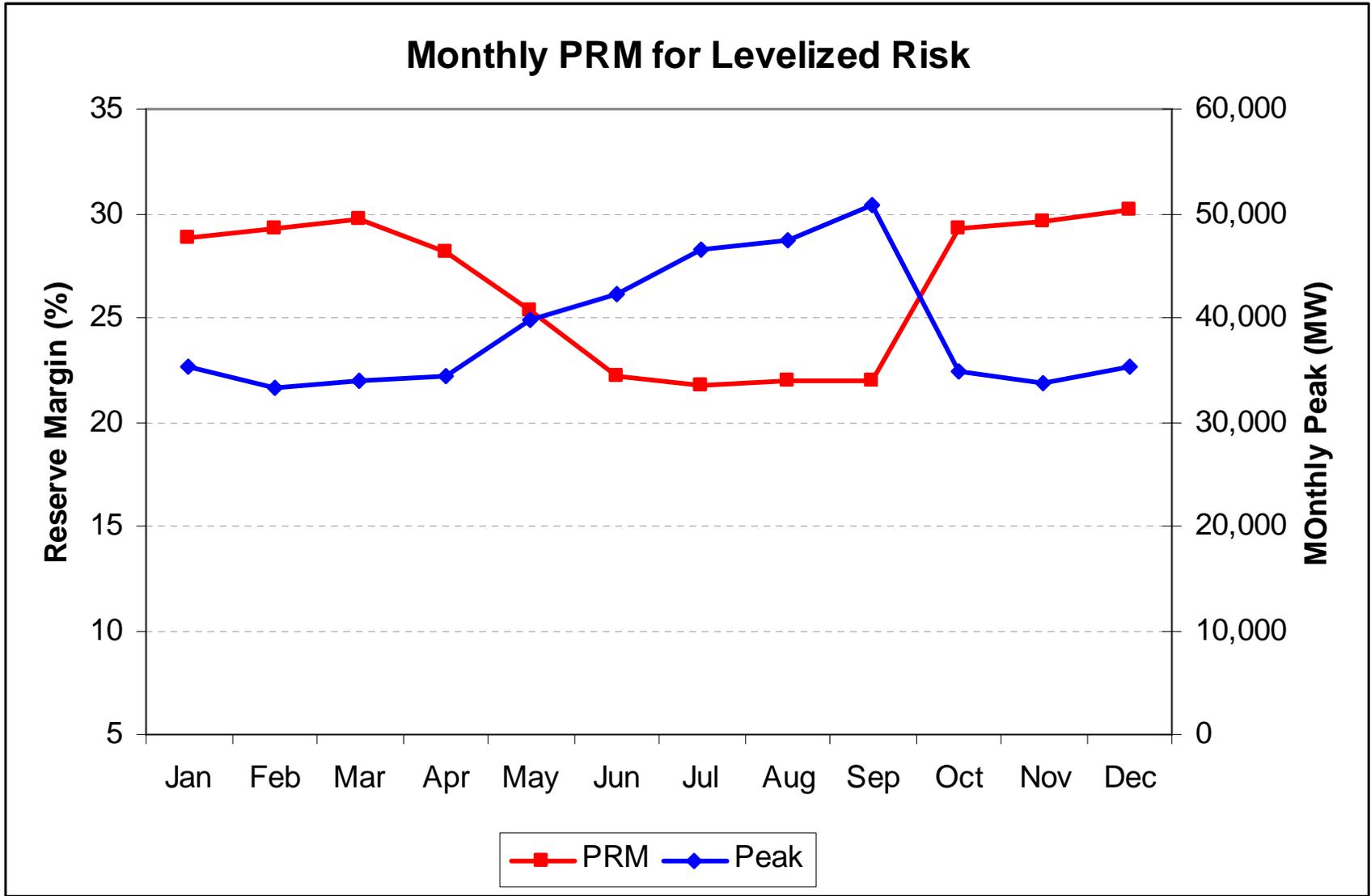
Sensitivity Cases – Separate Area PRM



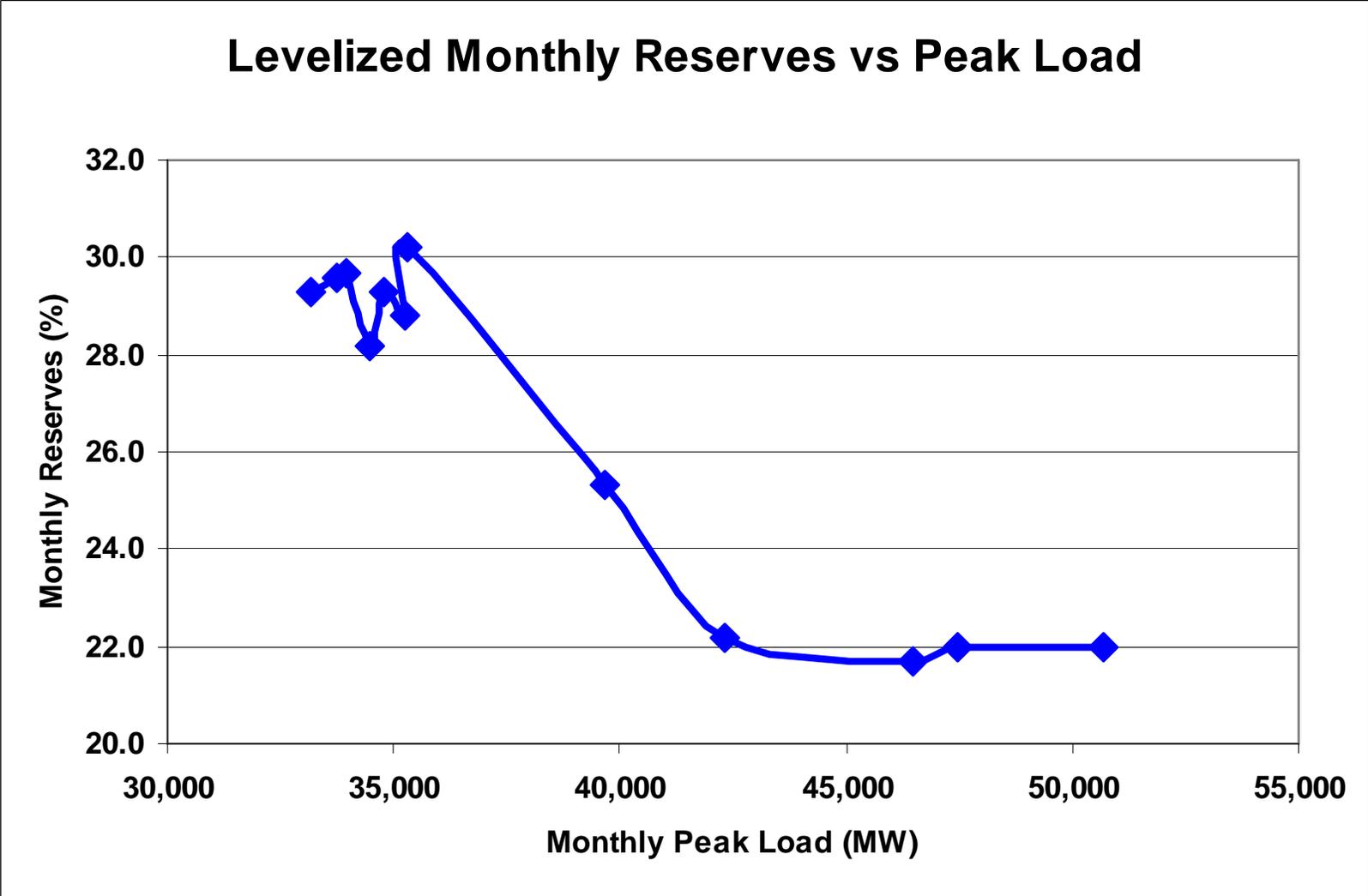
Sensitivity Cases – Levelized Monthly Risk



Sensitivity Cases – Levelized Monthly Risk



Sensitivity Cases – Levelized Monthly Risk



Conclusions – Critical Planning Factors

- **Definition of reserve margin**
 - *Annual % reserve*
 - *Monthly % reserve*
 - *Constant MW reserve*
- **Treatment of imports**
 - *How much of import capability is considered “firm” and therefore adds to the reserve margin, and how much is “emergency support”?*
- **Treatment of Demand Response**
 - *Depends on whether the risk is measured before or after Demand Response actions*
- **Load forecast uncertainty**
 - *How much is enough?*
- **Risk design criteria**
 - *0.1 days/year or higher or lower?*
 - *If other measures are desired, what is the design criteria?*