Flexibility Assessment Methods

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EPRI

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Overview

- Introduction/Reminder and Approach
- Intra-Hour
- Inter-Hour Method
- Available Thermal and Hydro Flexibility
- Actual Flexibility Required
- Net Unused Flexibility
- Wrap-Up/Next Steps

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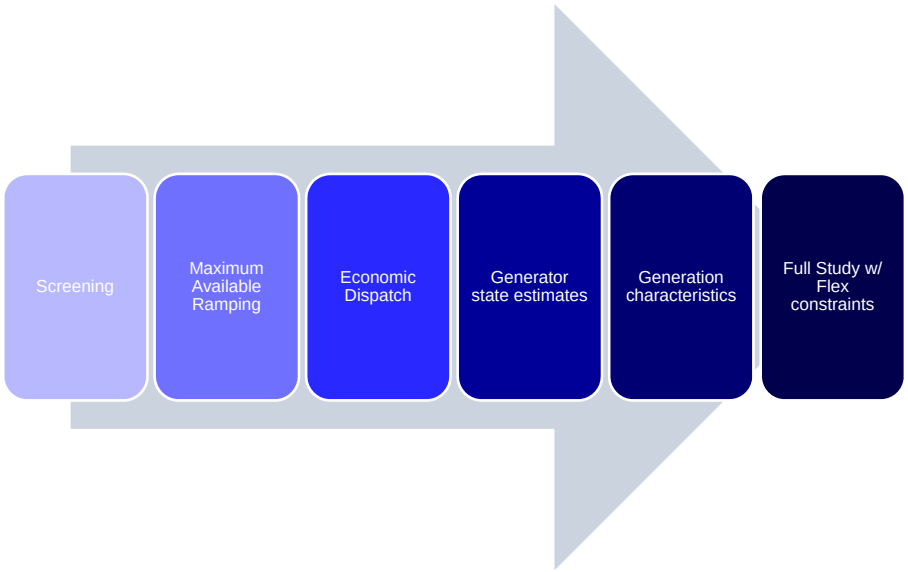
Flexibility Assessment Approaches



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Two level approach Employed Here

- Intra-hour:
  - Examine one minute data from 3 years of wind and load to determine intra-hour requirements
  - Include as constraints in 80 year hydro modeling
  - Track violations and use results of hydro dispatch data in detailed analysis
- Inter-hour:
  - Use 80 years of hourly dispatches
  - Examine a number of time horizons (2 hours up to 14 hours)
  - Determine flexibility of thermal generation using min/max, start time
  - Determine flexibility of hydro based on dispatch
  - Calculate flexibility actually used in each time horizon
  - Calculate unutilized capability → determine how much spare flexibility is available in system

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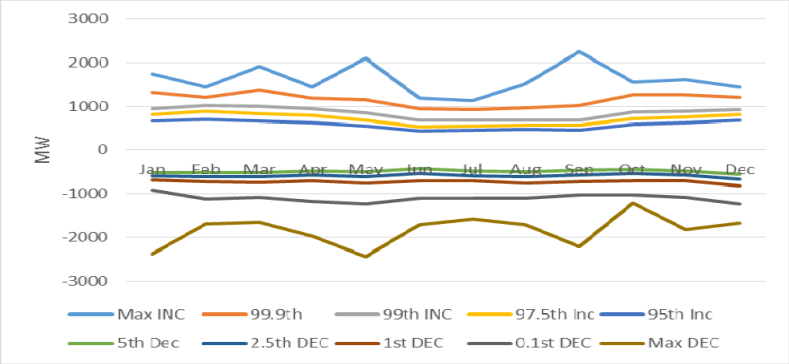
Intra-hour requirements



Hourly	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Max INC	1758	1460	1915	1445	2108	1203	1139	1536	2250	1566	1626	1460
99.9th	1330	1221	1387	1193	1159	949	929	977	1021	1274	1268	1211
99th	956	1030	1005	953	855	693	698	701	696	874	905	940
97.5th	825	898	842	800	704	551	570	583	577	730	776	816
95th	682	717	676	644	565	455	480	496	469	599	645	689
5th	-520	-522	-529	-491	-499	-434	-496	-511	-477	-448	-482	-564
2.5th	-598	-616	-626	-588	-612	-550	-593	-611	-578	-548	-575	-679
1st	-683	-730	-740	-702	-763	-704	-713	-759	-726	-714	-714	-827
0.1st	-920	-1118	-1082	-1167	-1223	-1096	-1094	-1103	-1029	-1024	-1082	-1232
Max DEC	-2376	-1687	-1649	-1974	-2438	-1712	-1587	-1713	-2214	-1209	-1823	-1677

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Inter-Hour Requirements

- 700,800 hours of data available
- Aurora determines thermal and hydro dispatch
- Council determined available hydro flexibility
  - Minimum and maximum output for 14 different periods in the year over all 80 years (two each in April and August)
  - For longer horizons, lower amount of flexibility available
- For each hour, run through and calculate flexibility available, deployed and spare for all thermal units and total hydro (big 4 only were studied)
- MATLAB code available (though needs to be cleaned up)

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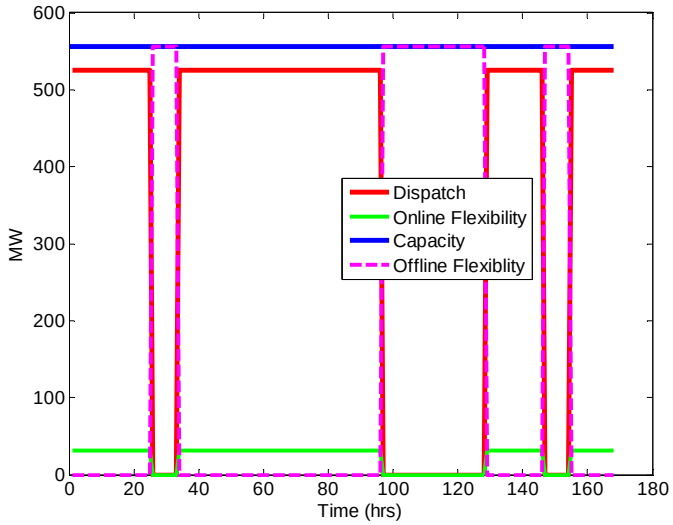
Thermal Upwards Capability – example week of one generator



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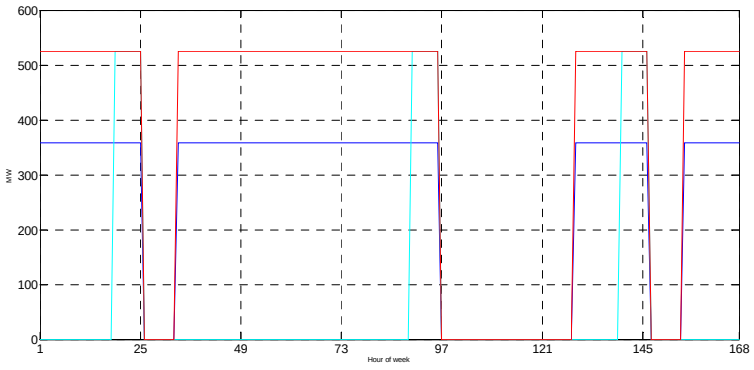
Downwards flexibility example



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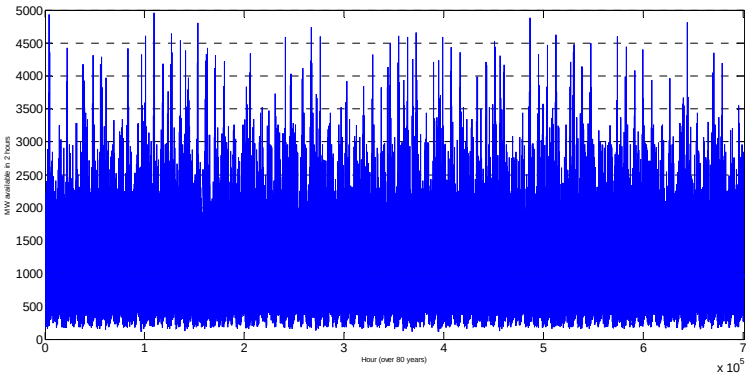
Hourly upwards flexibility over all years



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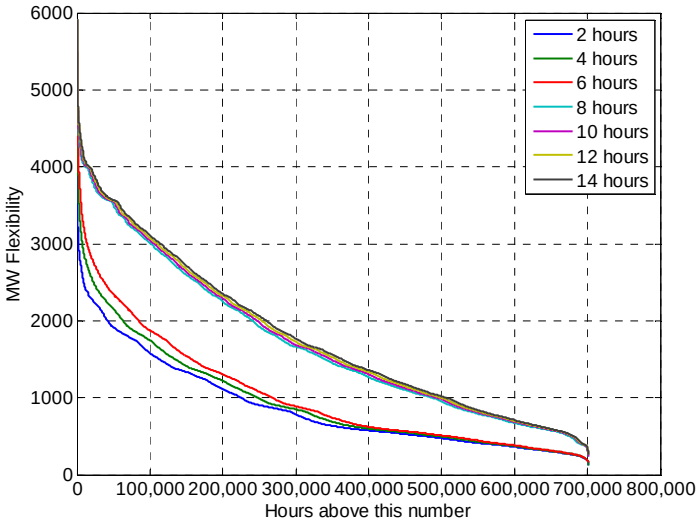
Thermal Upwards available flexibility duration curve



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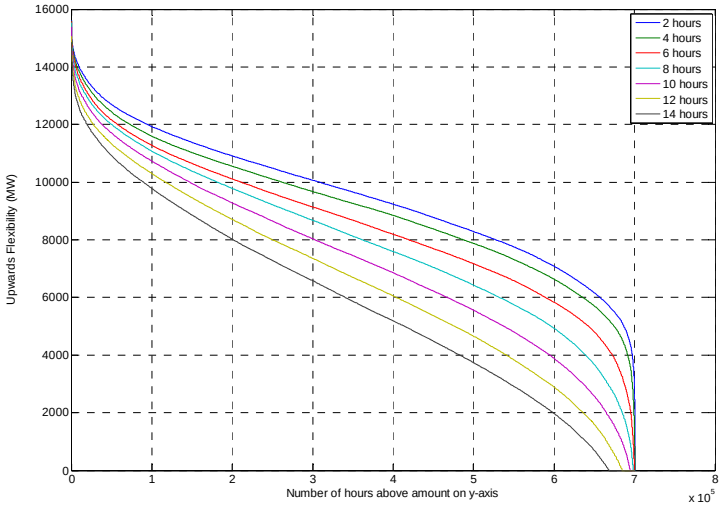
Hydro Upwards Available Flexibility



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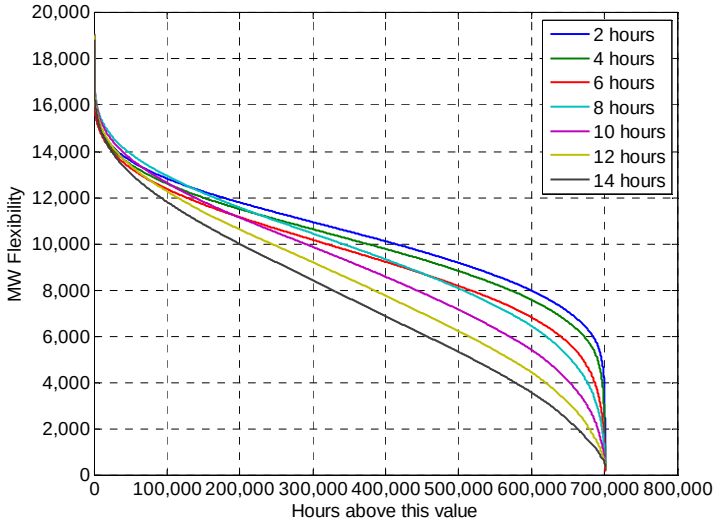
Total Available Upwards Flexibility



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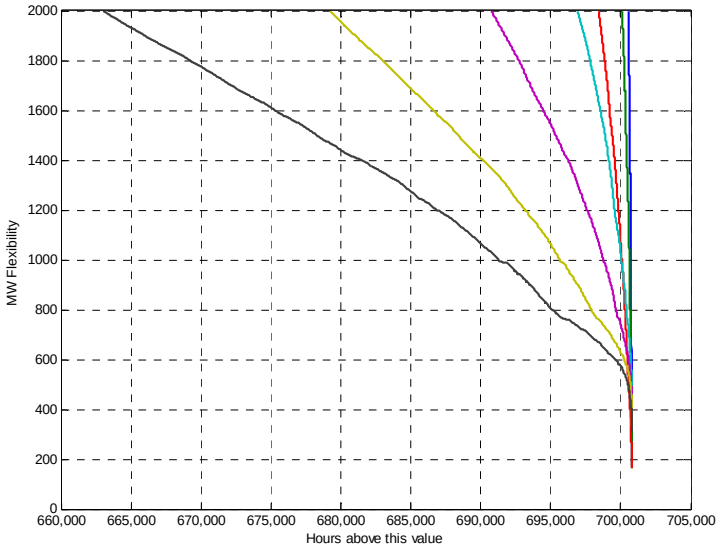
Less than 1, 000 MW



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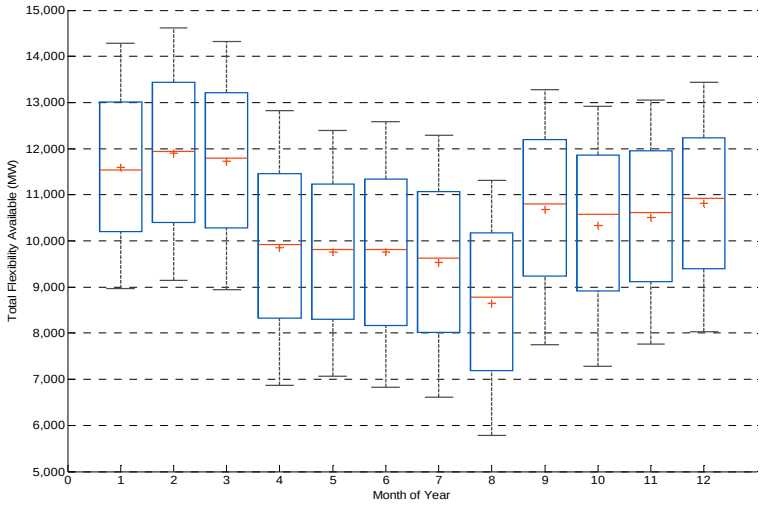
Available upwards Flexibility by month – 2 hour



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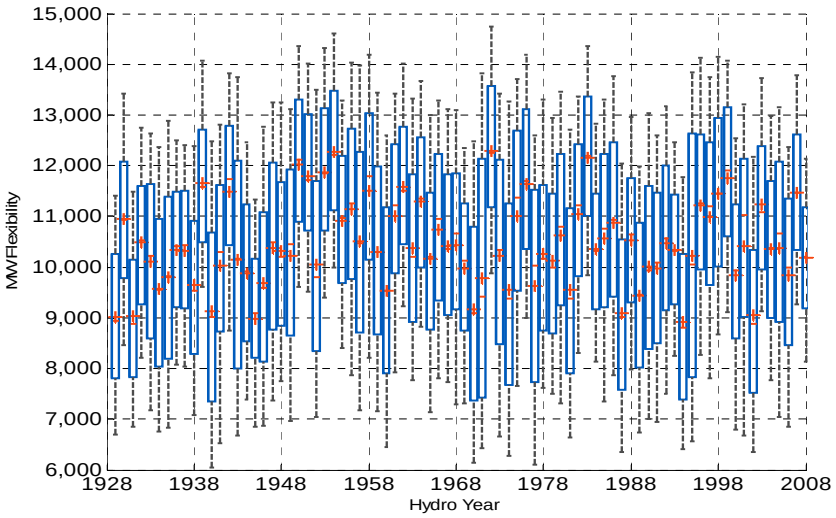
2 hour available Upwards flexibility by hydro year



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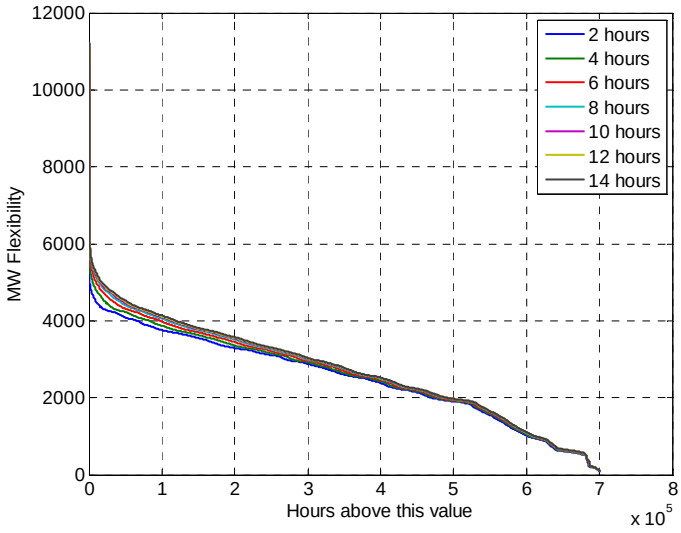
Downwards Thermal Flexibility Available



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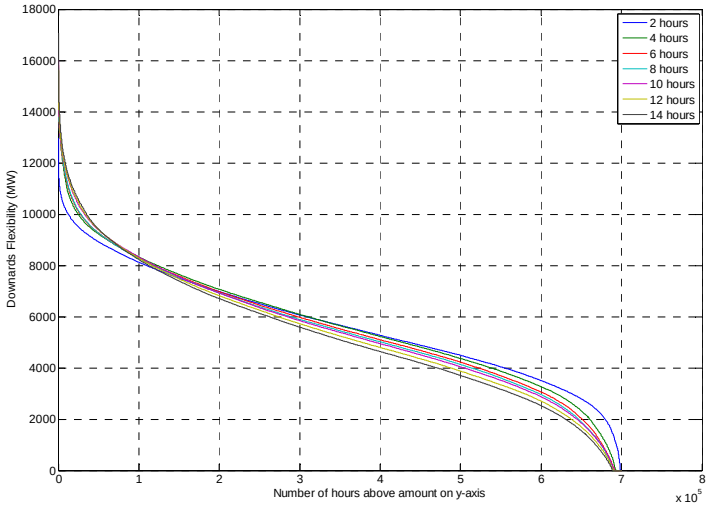
Hydro Downwards Available Flexibility



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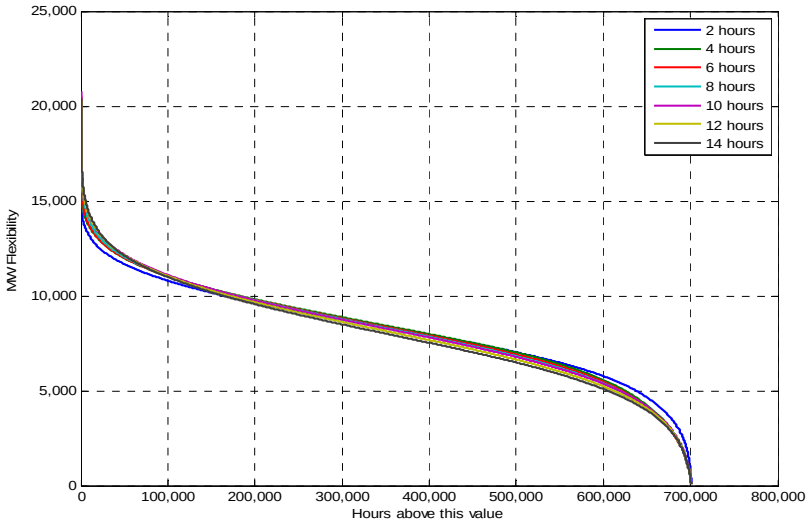
Total Downwards Available Flexibility



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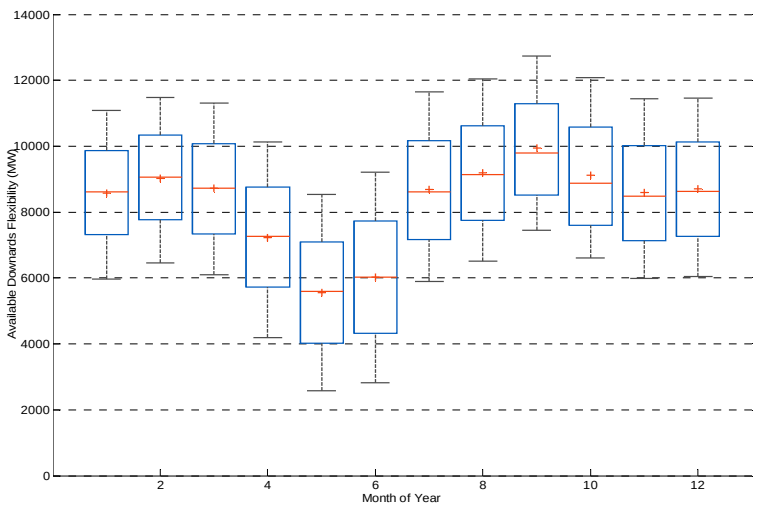
2 hour downwards available flexibility by month



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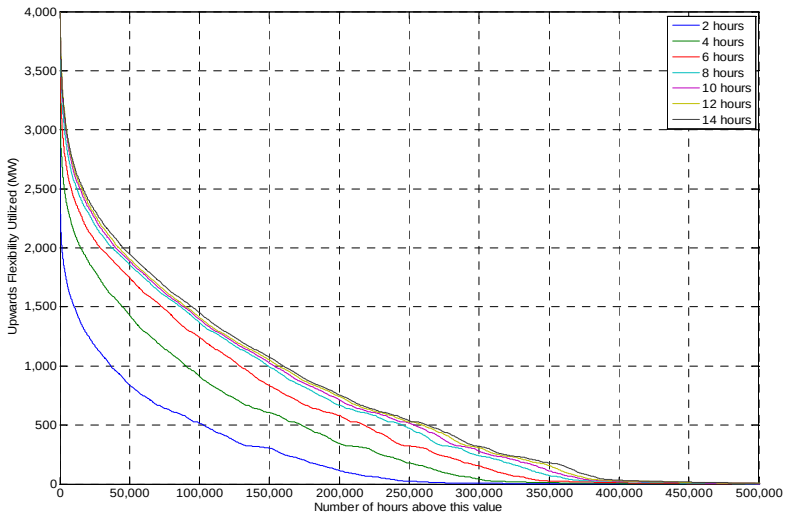
Flexibility Utilized – Thermal Upwards



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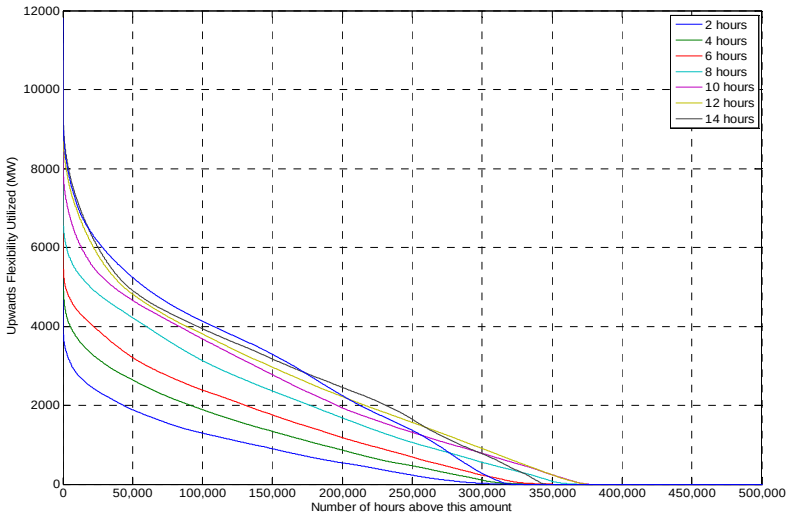
Flexibility Utilized – Hydro Upwards



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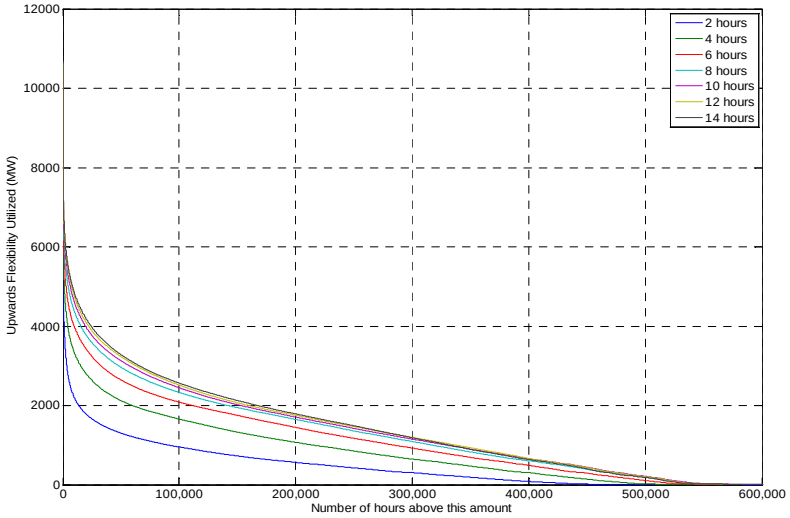
Flexibility Utilized Total Upwards (Downwards is similar)



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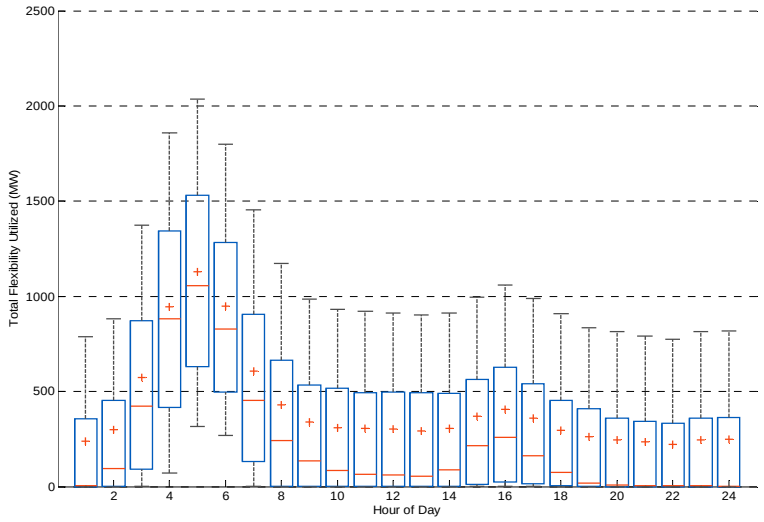
Hourly 2 hour upwards utilized



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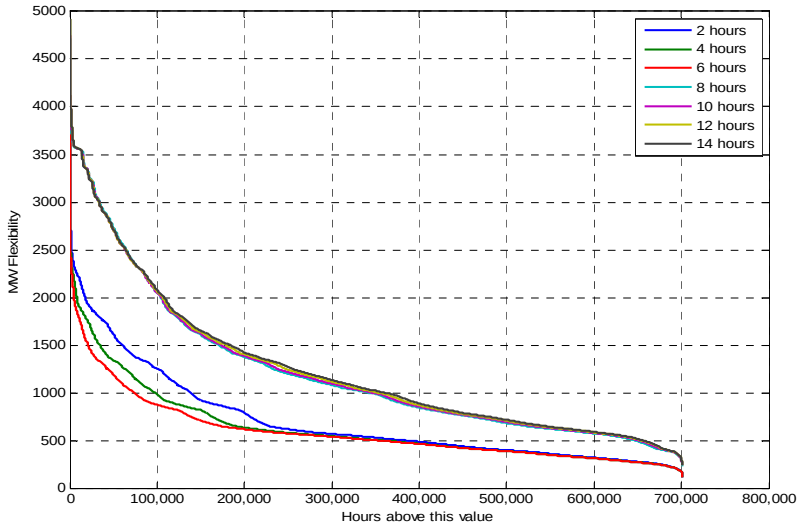
Spare Thermal Capability - Upwards



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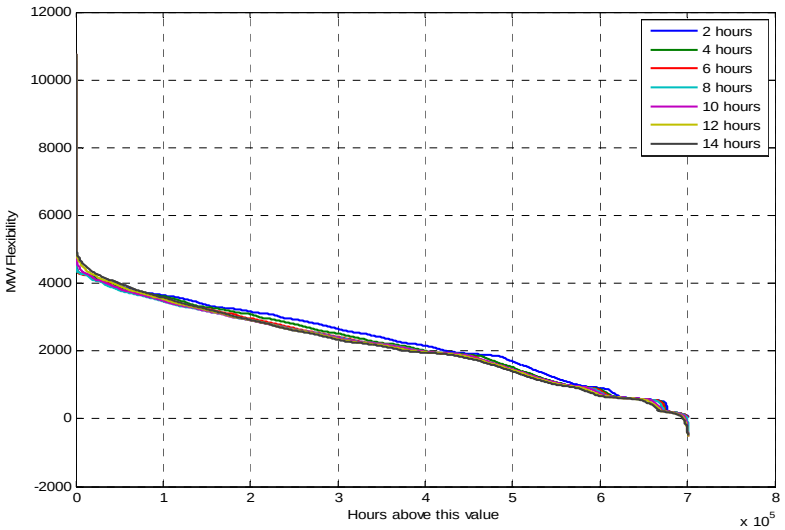
Spare Thermal Capability - Downwards



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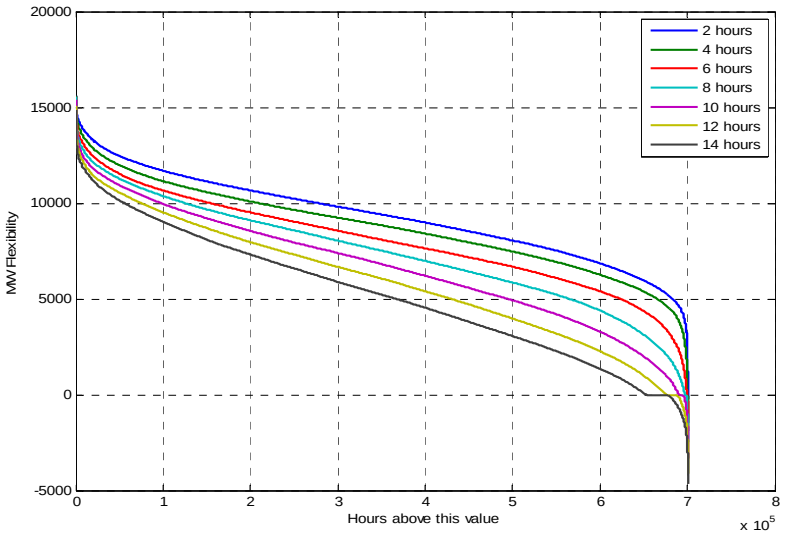
Spare Hydro Capability - Upwards



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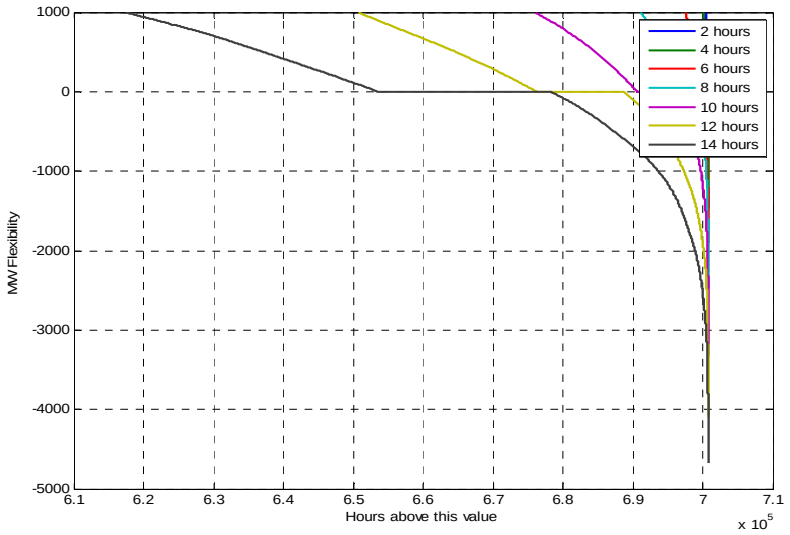
Spare Hydro Capability – Upwards less than 1000MW



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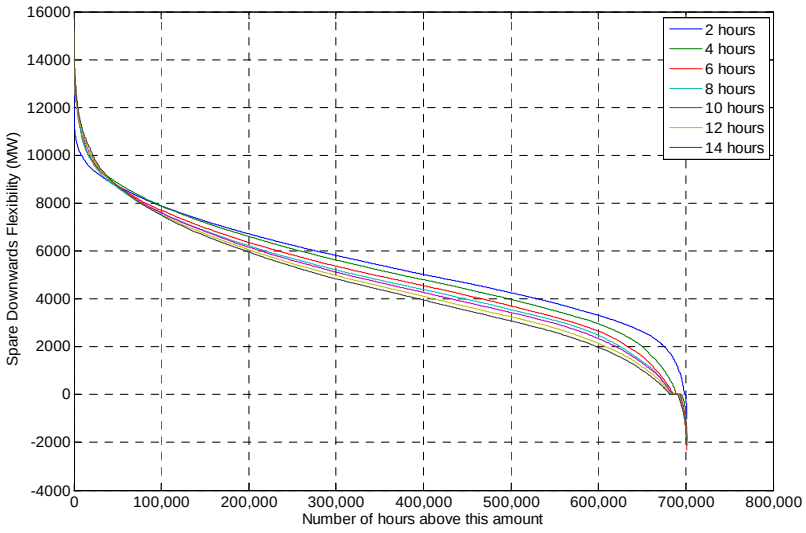
Spare Hydro Capability - Downwards



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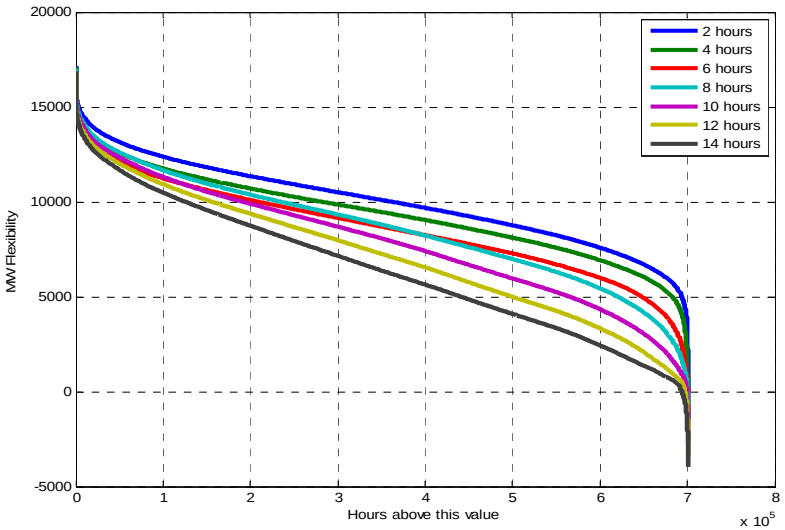
Total Spare Capability - Upwards



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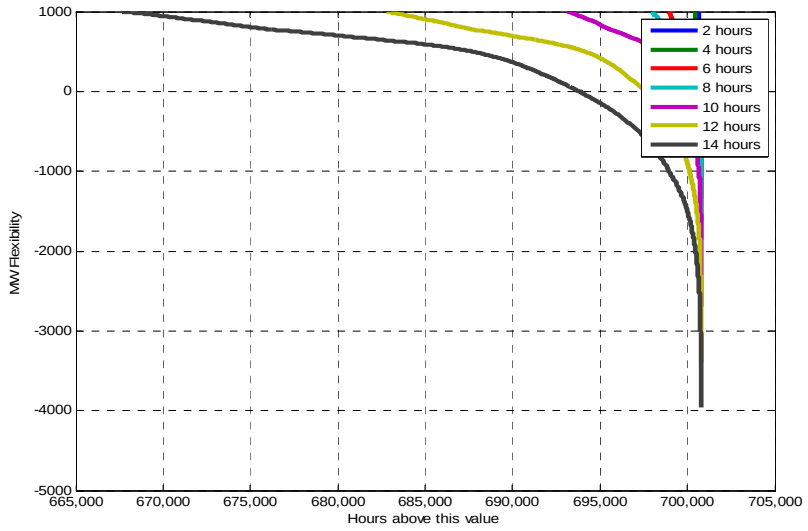
Total Spare Capability – Upwards less than 1000MW



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Total Spare Capability – Upwards less than 1000MW

	2 hour	4 hour	6 hour	8 hour	10 hour	12 hour	14 hour
<1000 MW	118	356	1,851	2,870	7,655	18,043	33,174
% of time	.02%	0.05%	0.3%	0.4%	1.1%	2.6%	4.7%
<500 MW	53	167	765	844	2,477	6,638	13,097
% of time	~0%	0.03%	0.11%	0.12%	0.4%	1%	1.9%
<0MW	1	49	190	292	1,081	3,202	6,957
% of time	~0%	~0%	0.03%	0.04%	0.15%	0.5%	1%

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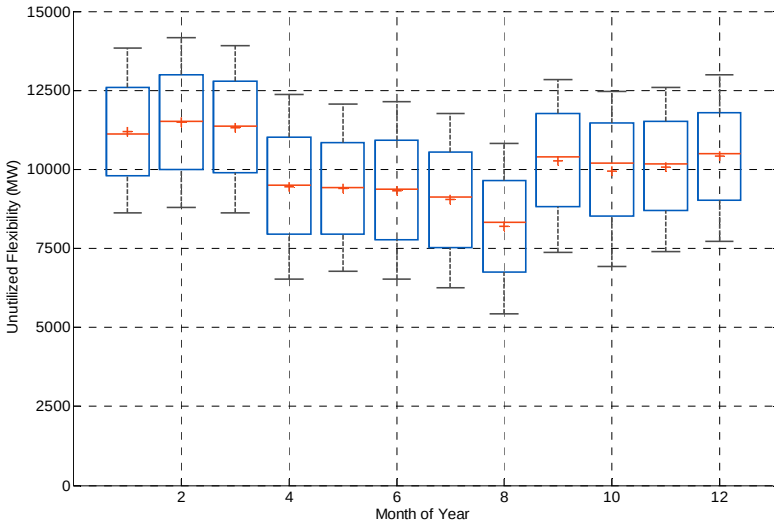
2 hour spare capacity by month



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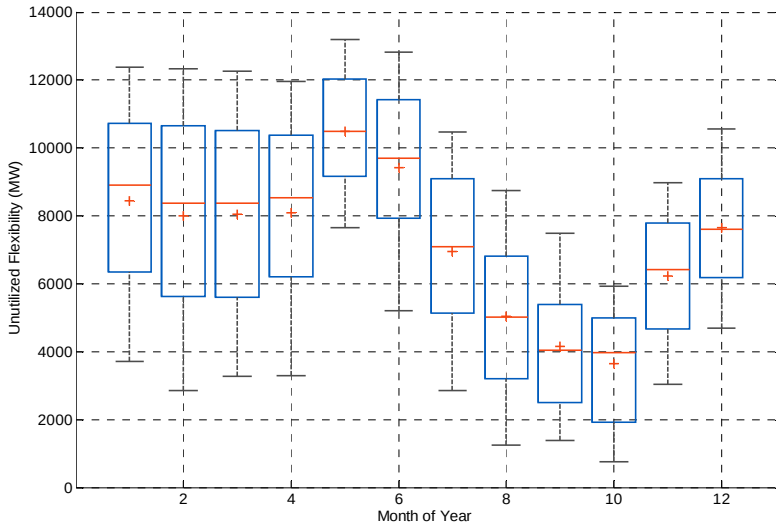
12 hour spare capacity by month



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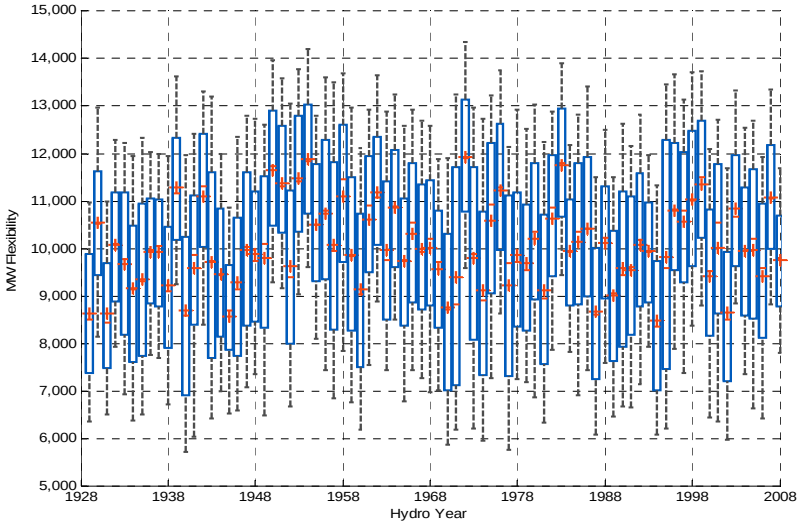
Spare Upwards Capability by Year – 2 hour



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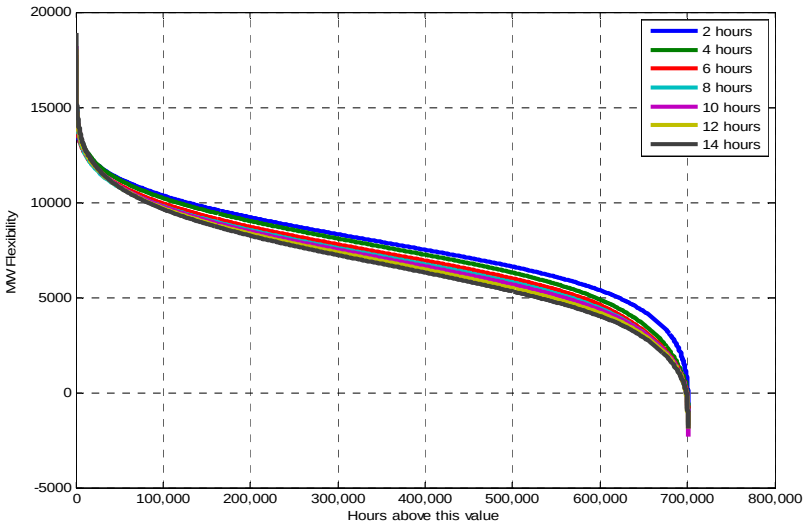
Spare Downwards Capability



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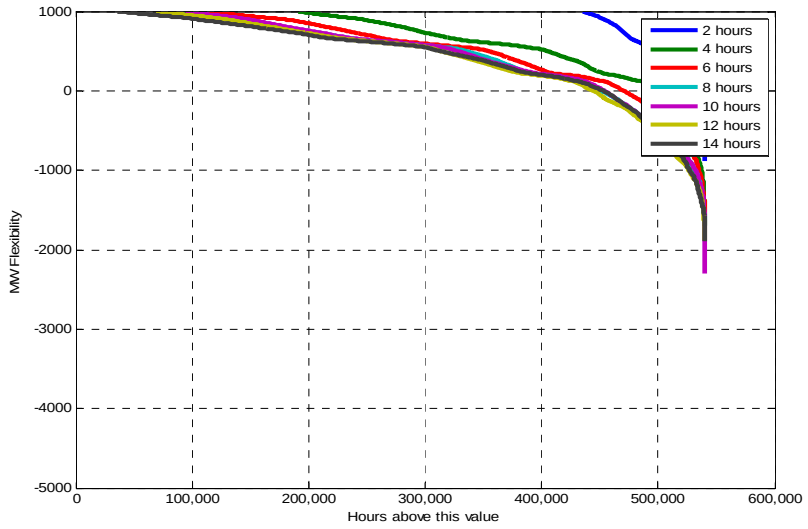
Spare Downwards Capability – less than 1000 MW



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Spare Downwards Capability – periods of low flexibility

	2 hour	4 hour	6 hour	8 hour	10 hour	12 hour	14 hour
<1000 MW	2,098	6,978	8,505	9,416	8,922	9,424	10,077
% of time	0.3%	1%	1.2%	1.3%	1.25%	1.3%	1.4%
<500 MW	716	2,689	3,703	4,076	4,251	4,519	4,526
% of time	0.1%	0.38%	0.53%	0.58%	0.61%	0.64%	0.65%
<0MW	117	761	1,376	1,759	1,702	1,897	1,728
% of time	~0%	0.11%	0.2%	0.25%	0.24%	0.27%	0.25%

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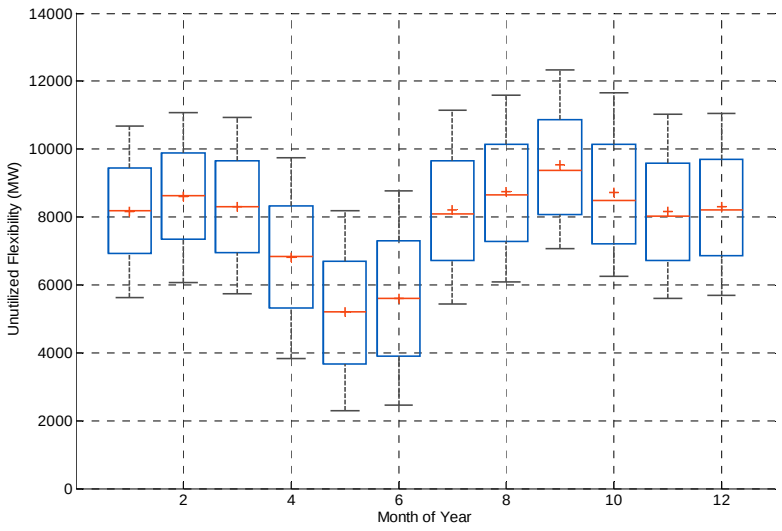
Spare Downwards 2 hour flexibility by month



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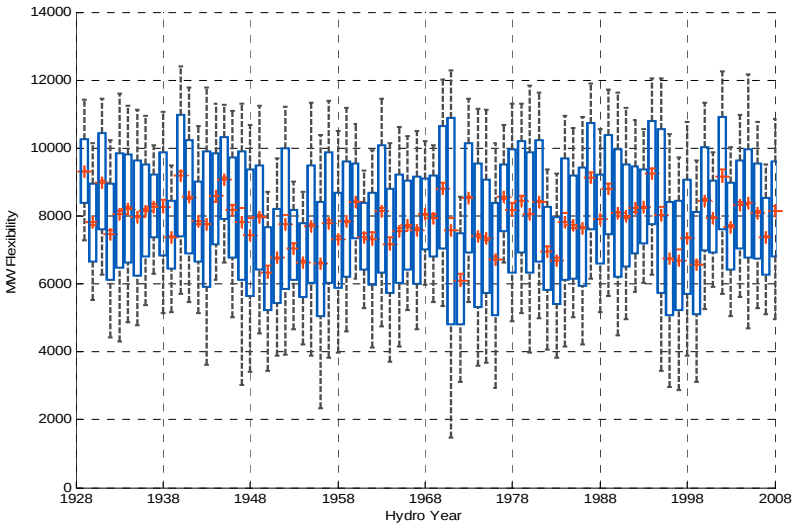
Spare 2 hour downwards capability by year



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Next steps

- Additional analysis based on today
- Add one or two screening methods and compare
  - CRDC
  - Other screening Method
- Report out for review

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Together…Shaping the Future of Electricity

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Literature Review

Previously presented

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Assessing Flexibility

- Increased ramping expected:
  - Wind and Solar
  - Potential for uncontrolled DER
- Need to be able to ensure sufficient capability in the system to provide operational flexibility
- Methods need to do some or all of following:
  - Measure requirements for flexibility
  - Assess whether system can meet requirements
  - Complement existing or altered IRP process

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Flexibility Requirements - methods

- 1. Historical or simulated data and a risk preference
  - Cover a certain percentage of historical or simulated data based on risk preference
    - E.g. Cover all historical wind data based on 95th percentile, chosen to represent CPS2 score
  - Sometimes based on expected conditions, e.g. need is higher in mid-point of wind output
  - Can be captured for different datasets relatively easily and well verified with numerous studies
  - Notable examples: NREL, PNNL, Doherty, NERC IVGTF
- 2. Run full unit commitment and economic dispatch study
  - Alter constraints to reflect need for flexibility
  - Use metrics which track violations
  - Examples: Bouffard, E3 REFLEX, Da Silva
  - More detailed simulation needed, but may better reflect reality if system operations known

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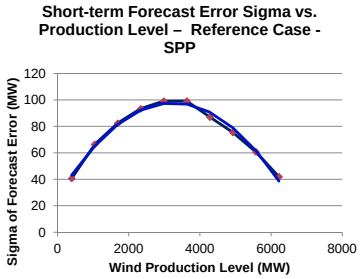
Flexibility Requirements (ctd)

- Methods will examine different time scales
  - <5 mins, 5 mins, 10 mins, 1 hour, 3 hours
- May capture locational aspects if required
- Can be based on dynamic procurement or static number
- Never try to capture 100% of all potential outcomes
  - NERC scores don't require this



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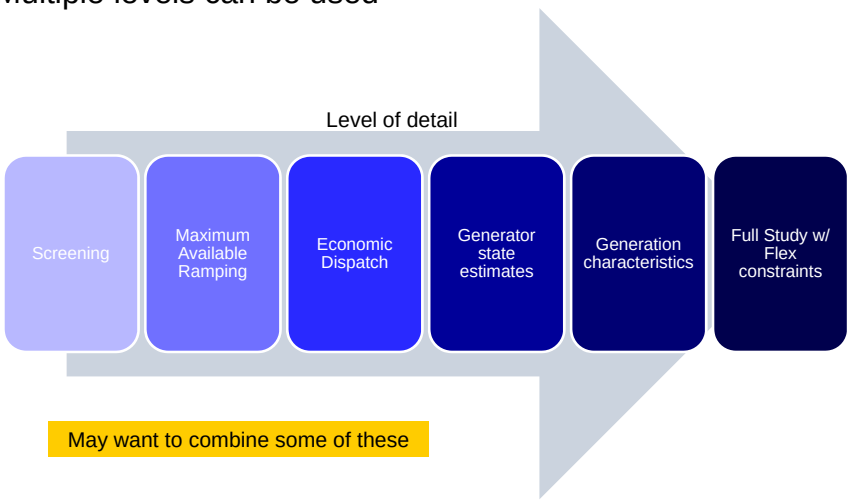
Assessing flexibility adequacy

- Multiple levels can be used



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Screening Methods

- Highest level: Assess ramping capability of system without regard to availability of resources
  - Example: IEA FAST1 – assess ramping capability against a number of snapshot points in time
  - Overly simplistic and misses generation limitations
- More detail: PGE IRP
  - Quantify required flexibility up to one hour
  - Examine available by turning on all capacity and moving to max capacity as soon as possible
  - Compare with required capacity
- Kirschen/Ma
  - Dependent on start time, ramp rate and operating range
  - Flexibility index presented for units and system
  - A means to measure and compare flexibility across resources

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Intermediate assessment

- Schillmoeller/NWPCC: Requirement for and provision of imbalance reserves
  - Calculates cumulative ramp duration curve
  - Orders resource over different time scales
  - Ability of capacity to recover over the course of a net deployment is then described →path
  - Requirement → minimum resource required meeting all of the paths
- IEA FAST v2: Basic dispatch stack
  - Examines optimistic and pessimistic assumptions
    - Optimistic: Commit excessive capacity
    - Pessimistic: Do not account for various constraints
  - Examine 1 year and compare requirements and available resources
  - Calculate number of periods when flexibility is short
  - Extensive data required, but not computation
- EPRI (2013)
  - Levels 1 and 2 of InFLEXion flexibility assessment tool
  - Level 1: Variability based on historical analysis (similar to other methods)
  - Level 2: Ramping capability, standing start of fleet, etc – similar to other methods above
  - Min gen available per hour of year (curtailment)
  - Up ramping similar to PGE methods

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Detailed Assessment

- Insufficient Ramp Resource Expectation (Lannoye)
  - Similar to LOLE, but for ramps
  - Probabilistic method to calculate frequency of deficits
  - Dependent on production cost modeling
  - Applied to up and down in multiple time intervals
- EPRI methods - extension of IRRE
  - Probability of flexibility deficit and expected unserved ramping: Deterministic metrics looking over 1+ year at various percentiles
  - Well being analysis combining these metrics
- E3 REFLEX tool: Detailed Monte Carlo simulation under a range of operating conditions
  - Availability of resources determined using conventional production simulation tools
  - Large number of 3-day scenarios simulated, energy and reserve violations tracked
  - Shapes determined to be used with tools based on flexibility required with penalties for not meeting energy or reserve

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Detailed Assessment (ctd)

- Menemenlis: Effect which operational processes have on the deliverability of the flexibility available from generators
  - Not the technical capability of a system's resources
  - More suited to operations than planning
- Studarus: Operational flexibility of hydro fleet
  - Time series of flexibility available
  - Compares deterministic representation of flex available based on confidence intervals with deterministic representation of requirements
  - Can be used to visualize time periods into the future
  - Detailed operational flexibility assessment
- SERVM/EPRI study: Resource adequacy/production cost tool
  - Adopted to assess ability to meet uncertainty
  - Large number of draws of system operations
  - Can quantify impacts of variability and uncertainty on LOLE

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Conclusions

- Range of methods is quite large
  - Categorized here based on detail
- Need to base method used on goal of study
  - Detailed operational or resource planning?
  - New resources, or check for reliability of system?
- Levels used should also be based on data and resources available to do study

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