

Value and Risks of Pumped Storage Plants



John C. Parker
Vice President
HDR|Decision Economics

Value and Risks of Pumped Storage Plants

- Decision Support for Feasibility Studies
 - There is a high demand for hydro pumped storage feasibility studies – need for economic model of value of storage
- Sources of risk
 - Costs, externalities, revenue, bidding process, market liquidity
- Sources of value
 - Arbitrage - Make hay when the sun shines
 - Ancillary services - When the wind blows the load goes
 - Optionality -Make money when the ISO says so



Decision Support for Feasibility Studies

- The need was to develop an economic model of costs and benefits taking into account risk
 - For a screening/feasibility study it had to be high level
 - But it had to be a useful abstraction from reality
- Cost side is uncertain
 - Should be able to take the engineering and technical risk ranges into account to reflect what is known and what is not
- Revenue side has risk
 - Should be able to point the model at representative energy and ancillary services prices from a balancing area to determine revenue (and risks thereof)
- Market itself has risk
 - Risk of new market entrant, or change in ISO rules

Decision Economics

- When we do Cost Benefit Analysis it is usually to support:
 - What gets built?
 - When?
 - How big?
- Usually out of scope is:
 - How will it be operated?
- Even if the operation decision and capacity decision are linked the next wrinkle is not usually included:
 - What will be the (hourly) market conditions that will determine how it will be run, and therefore how much money it will make, and consequently whether it should be built at all?
- Pumped storage valuation has it all!

Sources of Risk

- Before building - Costs and schedule are never certain
 - At the feasibility stage costs have huge variances
- External costs usually are subject to uncertainty and differences of opinion
 - Sustainable Return on Investment (SROI) handles costs (internal and external) as well as risk
- Once running - since plant needs to exploit market opportunities reliability risk is also important
- Revenues from ancillary services hugely volatile. Since this market is dealing with unanticipated changes you expect it to be. But also issues with:
 - Market entrants
 - Existence or Liquidity of the market

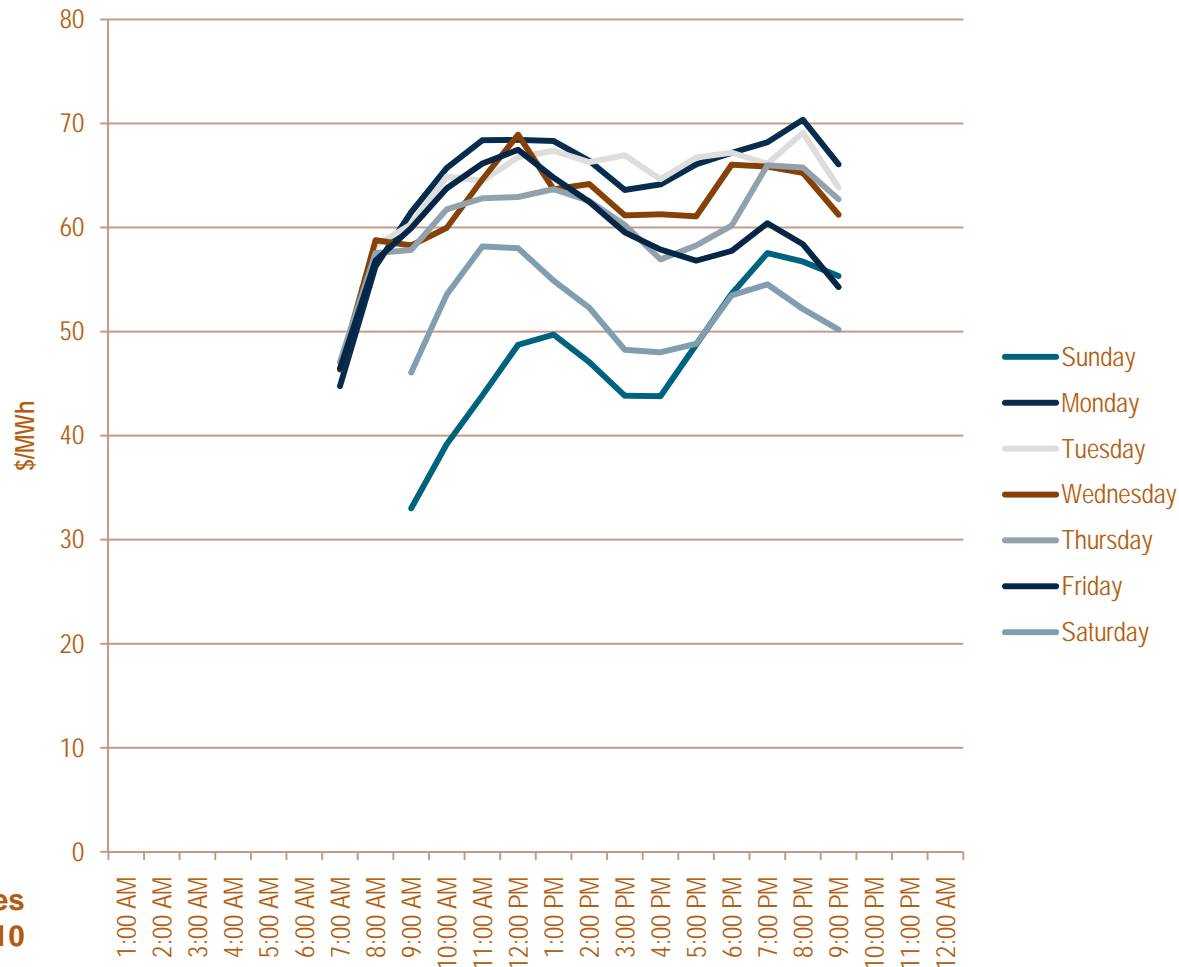
Sources of Value

- A pumped storage plant's value comes from two sources:
 - Arbitrage Revenue - Pump when energy is cheap and generate when it is expensive
 - Ancillary Service Revenue – Provide Regulation Up/Down, Spinning/Non-Spinning Reserves
- The prices that determine value are:
 - Peak/Off-Peak Energy Price Spread
 - Ancillary Services Prices (which are usually quoted as a spread over costs)
- The value of a plant then becomes:
 - Given (uncertain) prices, operate plant to maximize the revenue from five (or so) markets hourly,
 - Subject to operation restrictions ... Easy ... Not!

Arbitrage: Make Hay When the Sun Shines

- Peak/Off Peak Price Arbitrage

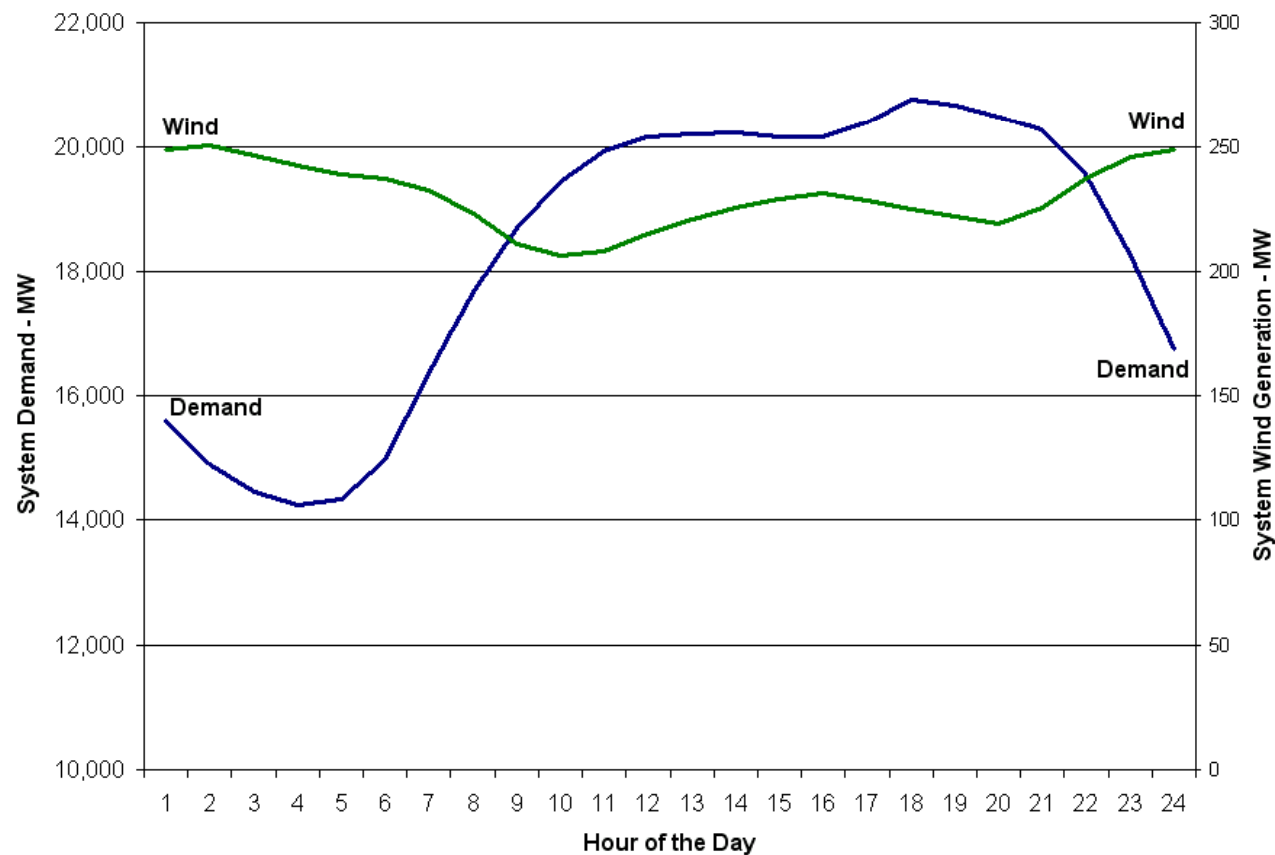
Generate During Peak



Average Hourly
Ontario Energy Prices
May 2002- March 2010

Ancillary Services: When the wind blows the load goes

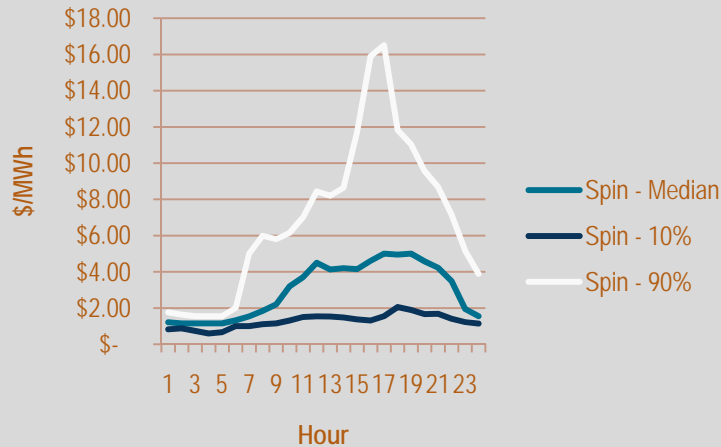
- The diurnal generation pattern does not meet that of load
- Wind generally peaks when demand is lowest
- Non-coincident demand and supply gives storage value



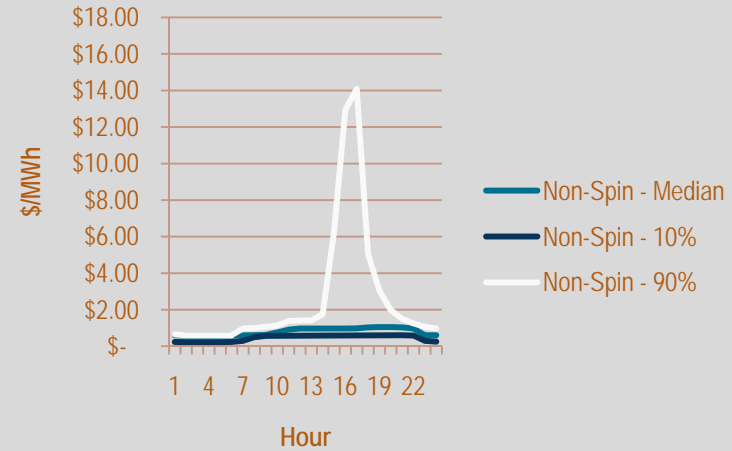
NY Average Hourly Wind Output vs. Demand (2008) "Energy Storage in the New York Electricity Markets" A New York Independent System Operator White Paper, March 2010

Resulting in a Need for Reserves and Balancing

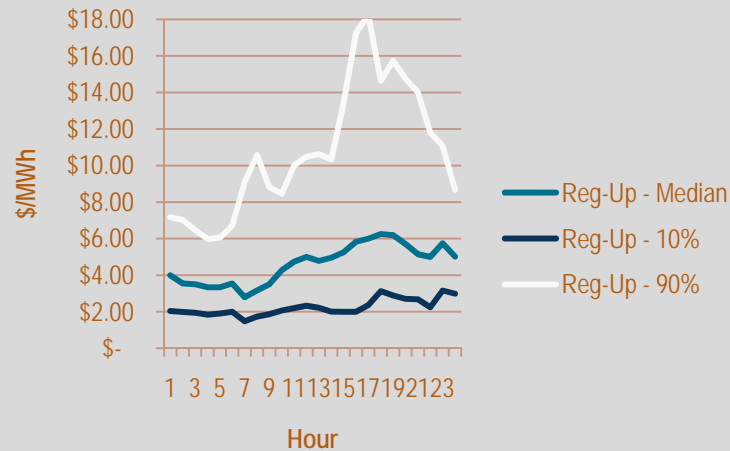
Spinning Reserve



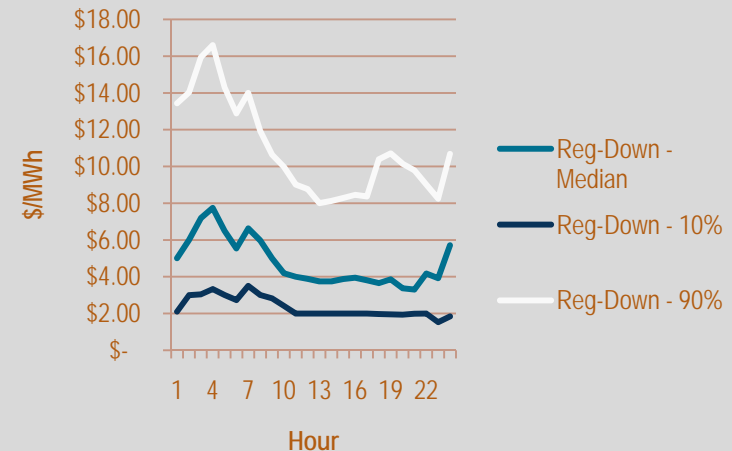
Non-Spinning Reserve



Regulation Up



Regulation Down



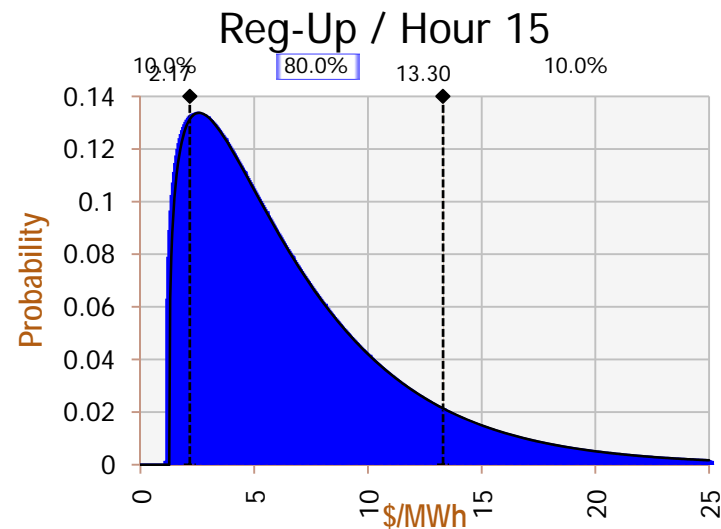
California
Ancillary
Services
(All regions)
Prices April
2009 -
March 2010

Constraints on Value

- When Generating:
 - Can provide reserves. Or Reg-Up. Or Reg-Down (to a maximum of 60% of generating capacity)
- When Pumping:
 - Can provide Reg-Down (to a maximum of 60% of pumping capacity)
- Efficiency of plant
- Single speed (variable speed adds more flexibility)
- May also have minimum flows required for fish or irrigation or constrained at certain times of the year

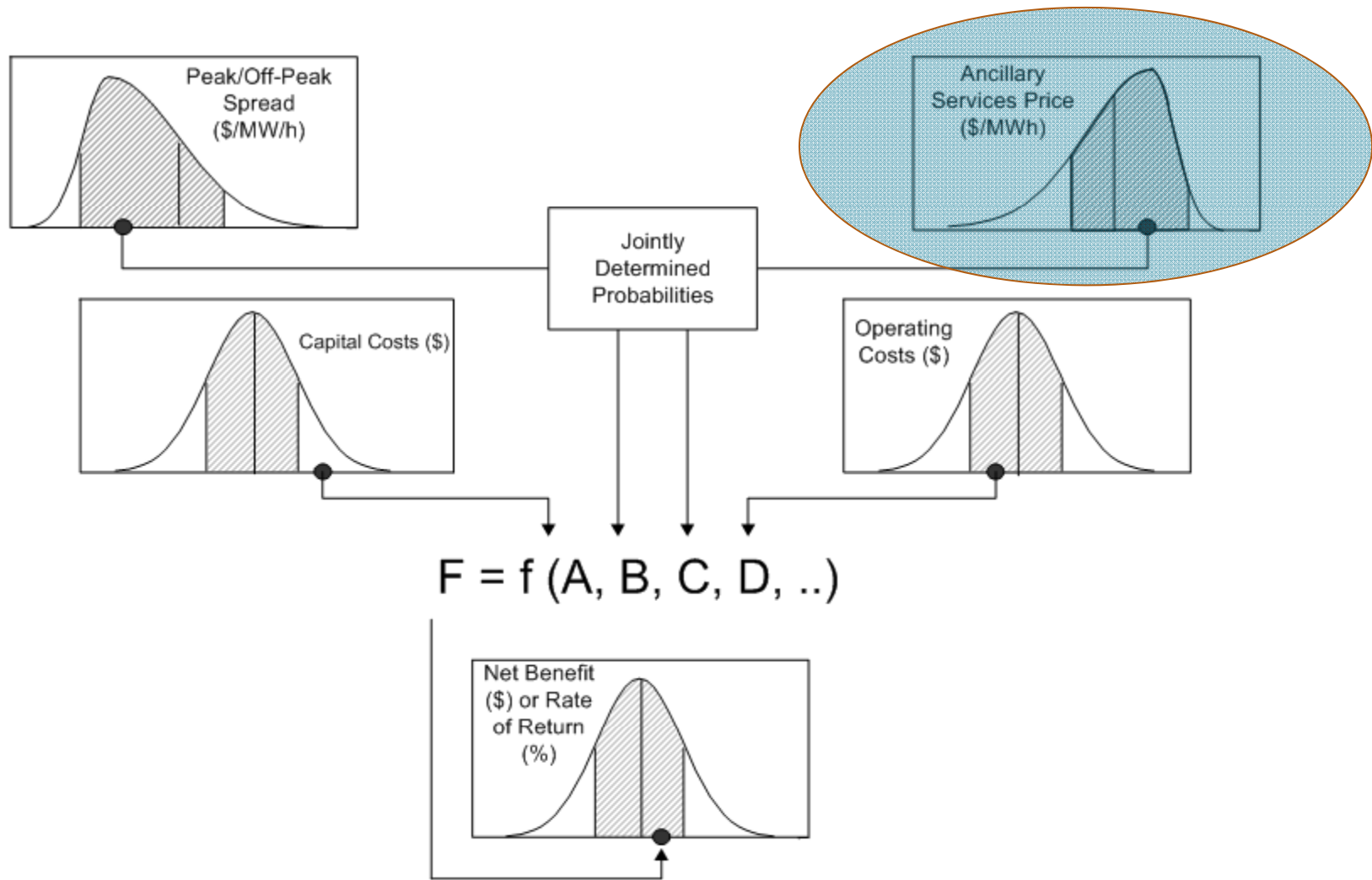
Optionality – Make Money When the ISO Says So

- We fit a distribution to each ancillary service price for each hour
- And we draw from this and then look at what the plant is doing (pumping/generating/idle)
- We then look at what the plant can provide and how much money it will get for doing it



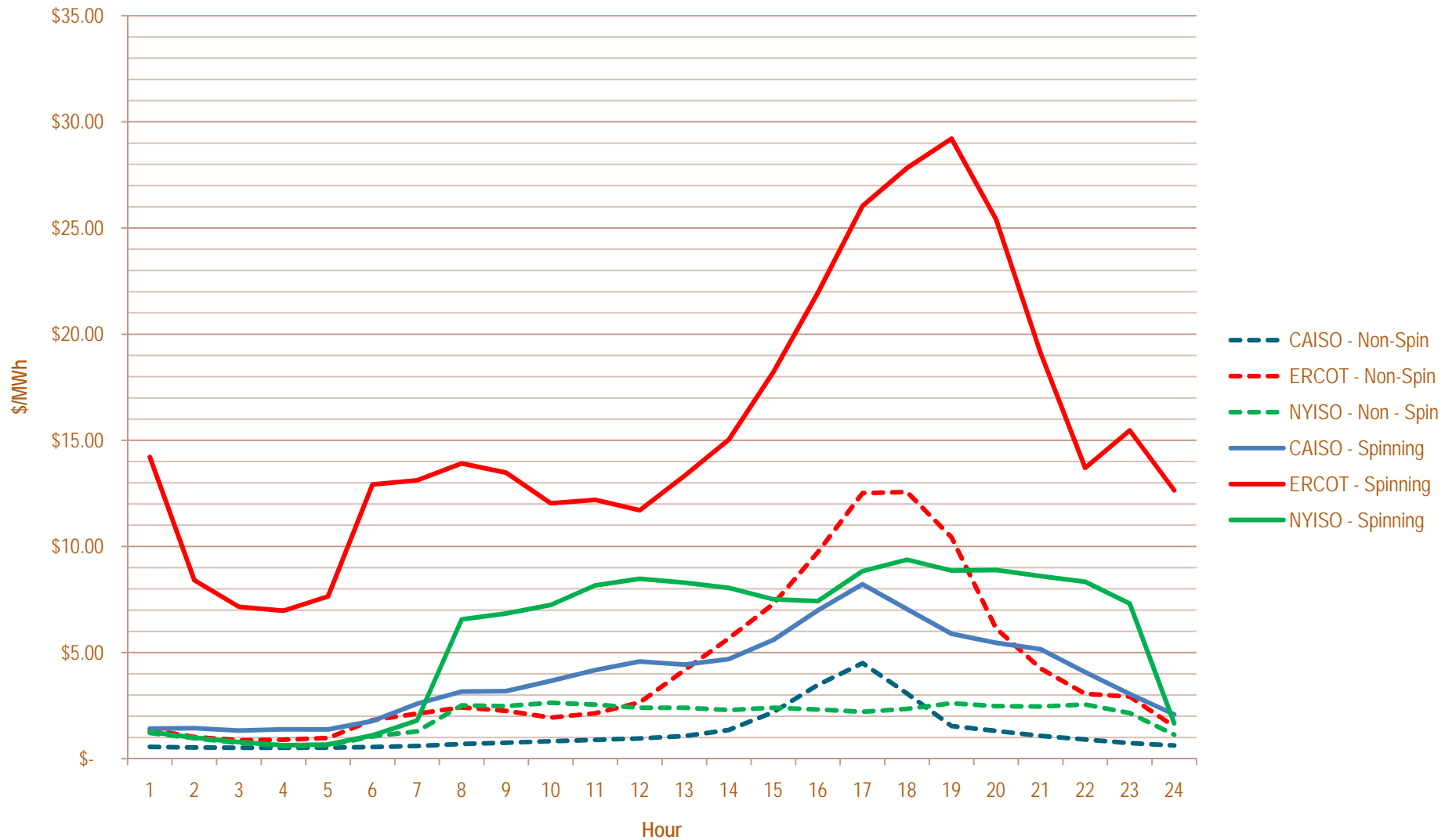
- Then we decide whether to exercise our option (to pump or generate or sell reserves etc.), we pocket the net revenue and move to the next period

Modelling



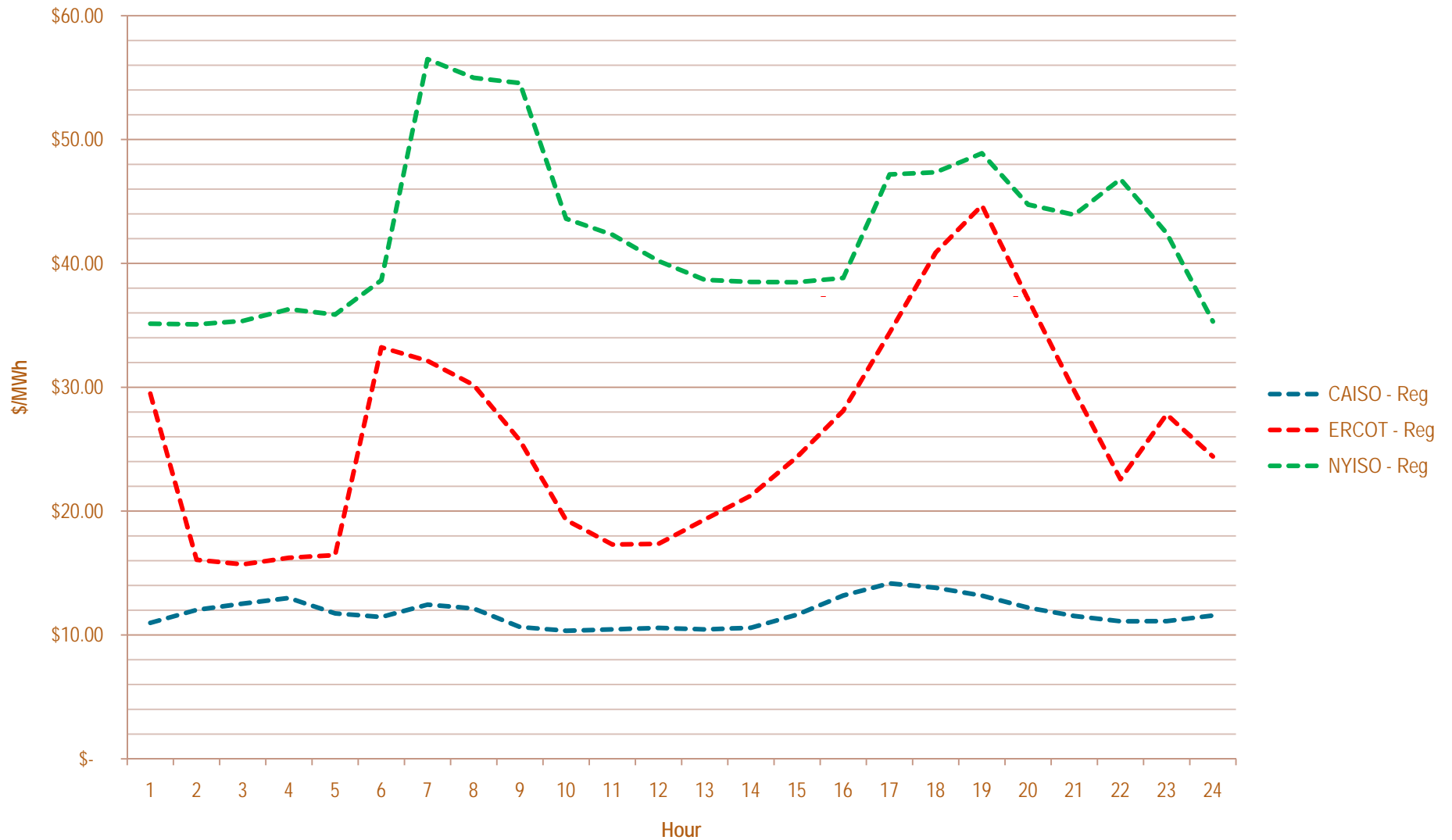
Geographical Price Trends

Average Hourly Reserve Prices



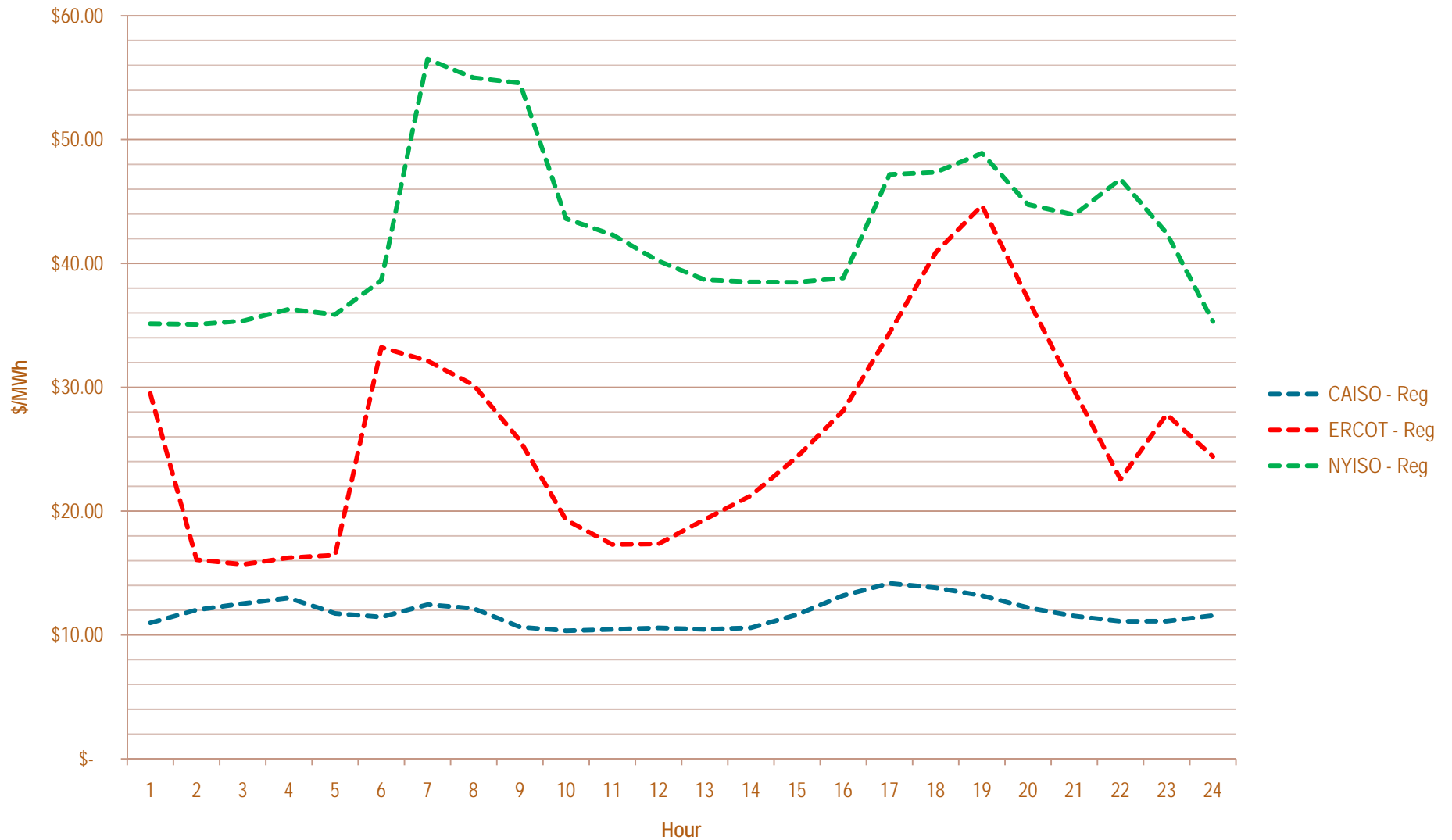
Geographical Price Trends

Average Hourly Regulation Prices



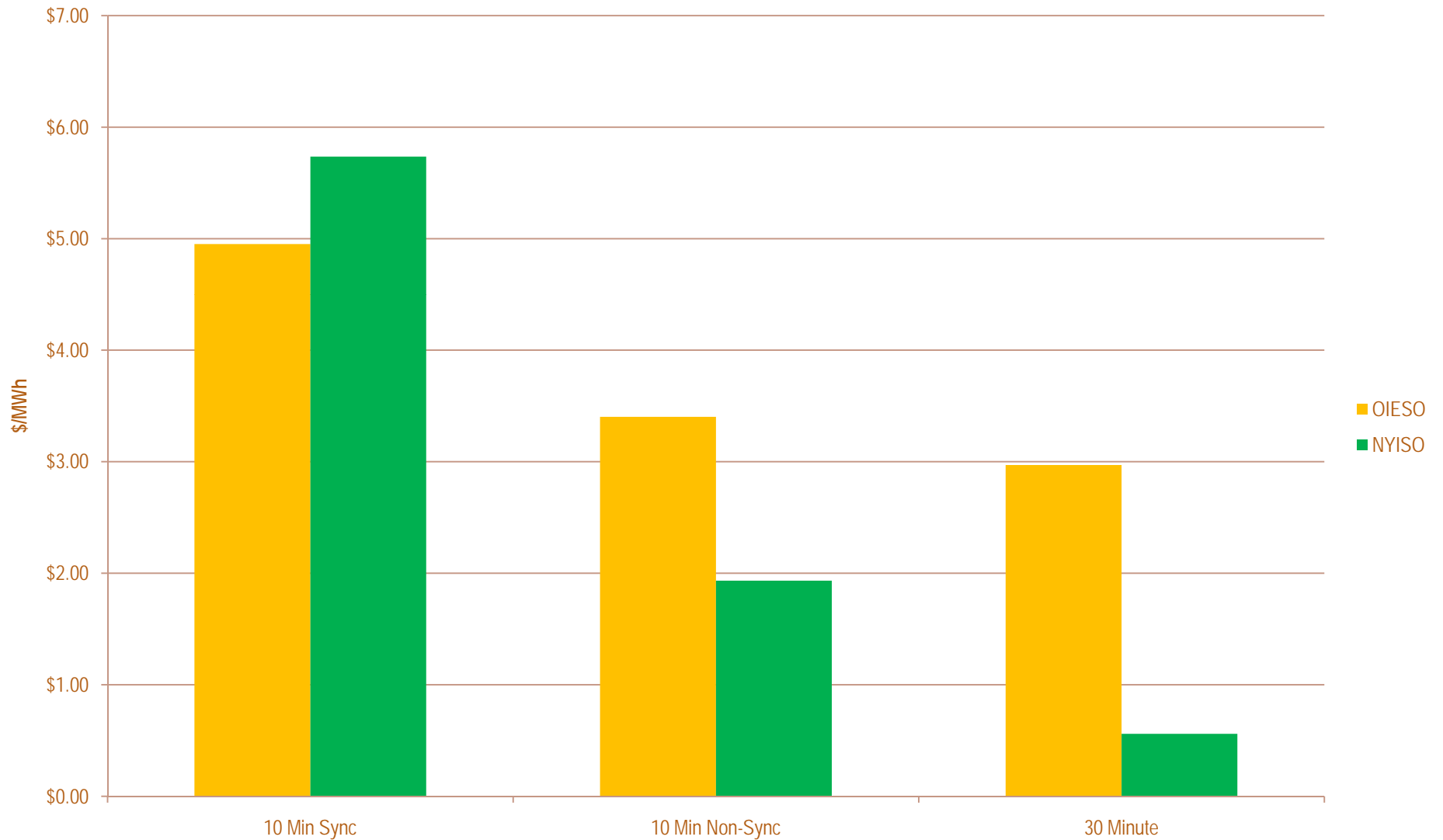
Geographical Price Trends

Average Hourly Regulation Prices



Geographical Price Trends

Daily Average Reserve Prices



Flexibility - Real Options Example

- Flexibility options, where plants are designed to produce alternative outputs depending on market conditions, are also important.
- For example, suppose ABC is considering a new pumped storage plant with a cost of \$5 million.
- There is a 50% probability of strong demand (reliable peak and off-peak prices), in which case the project will provide annual cash flows of \$2.5 million for 3 years, and a 50% probability of weak demand resulting in cash flows of only \$1.5 million per year.
- However, if demand is weak, the company can convert the plant and produce an alternative product (ancillary services), and in this case the cash flows in Years 2 and 3 will be \$2.4 million.
- The situation is set forth in the decision tree below. In a conventional NPV analysis, only the top two rows of the tree would be considered, the NPV would be $-\$0.28^*$, so the project would be rejected.
- However, if the flexibility option were considered, the third branch would be considered, the NPV would be $\$0.39$, and the project would be accepted.

WACC 13%

0	End of Period Cash Flows:			NPV this	Conditional	Prob.
	1.0	2.0	3.0	Scenario	Probability	x NPV
\$2.50	\$2.50	\$2.50	\$0.90	50%	\$0.45	
\$1.50	\$1.50	\$1.50	-\$1.46	0%	\$0.00	
\$2.40	\$2.40	-\$0.13	50%	-\$0.06		



*NPV (strong demand) =

$$-5 + 2.5/(1.13) + 2.5/(1.13)^2 + 2.5/(1.13)^3 = \$0.90$$

NPV (weak demand) =

$$-5 + 1.5/(1.13) + 1.5/(1.13)^2 + 1.5/(1.13)^3 = -\$1.46$$

$$\text{Weighted NPV} = 0.5 \cdot 0.9 + 0.5 \cdot -1.46 = -\$0.28$$

Option value NPV =

$$-5 + 1.5/(1.13) + 2.4/(1.13)^2 + 2.4/(1.13)^3 = -\$0.06$$

$$\text{Weighted Option Value NPV} = 0.5 \cdot 0.9 + 0.5 \cdot -0.06 = \$0.39$$

Standard NPV = sum, prob times NPV (top two rows)

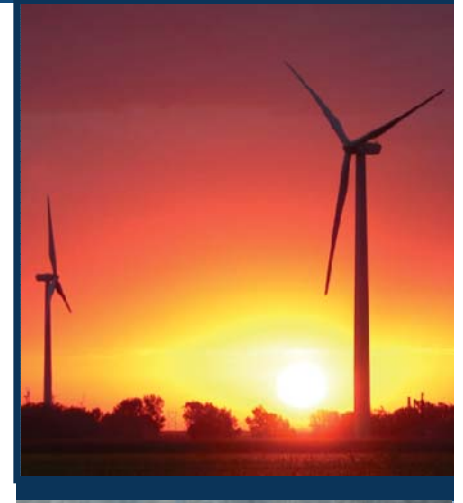
-\$0.28

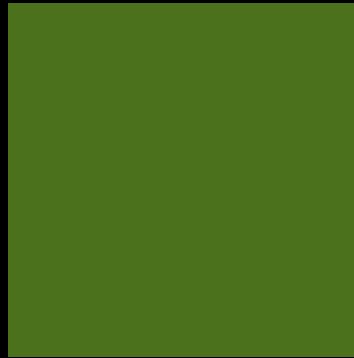
Expected NPV = sum, prob times NPV

\$0.39

Value and Risks of Pumped Storage Plants

- Arbitrage Revenue
 - After efficiency is taken into account this is not a huge money spinner at some market prices
 - However price forecasts may not capture the effect that more renewable generation will have on peak/off-peak prices, so make sure spreads capture generation mix
- Ancillary services value
 - The value of these benefits can be a significant portion of total value of the resource
- There is a real option value that may not be captured unless risk is explicitly identified and quantified. Also plant operations decisions must incorporate these risks





Integrated

listen first. solve second.

