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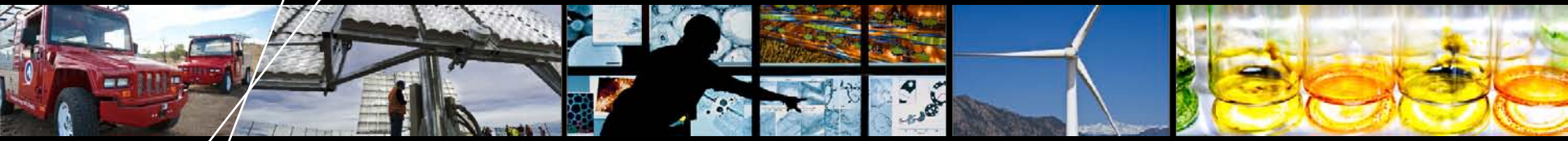
System Operator Scheduling of Storage to Help With Wind Integration



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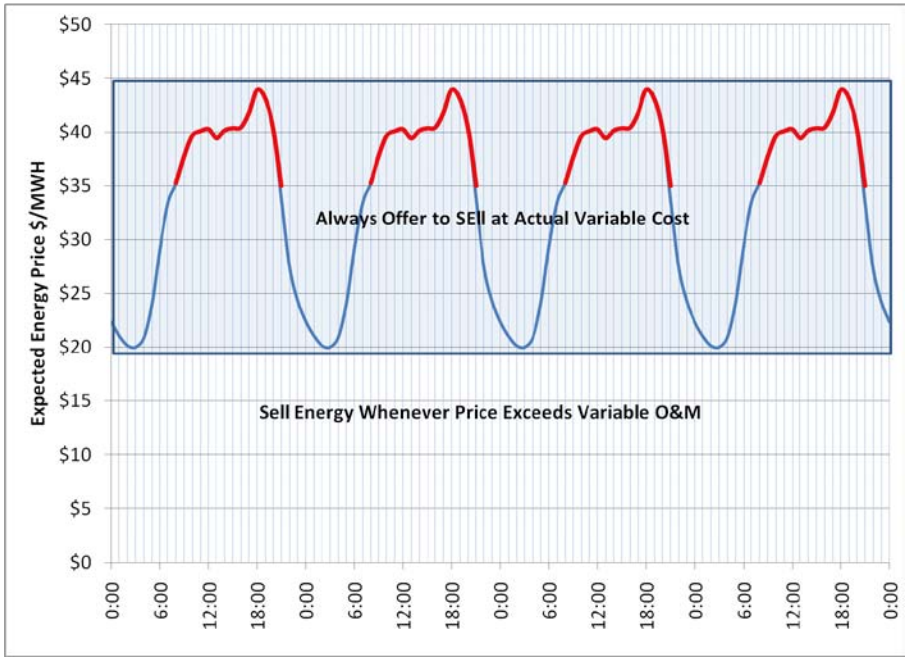
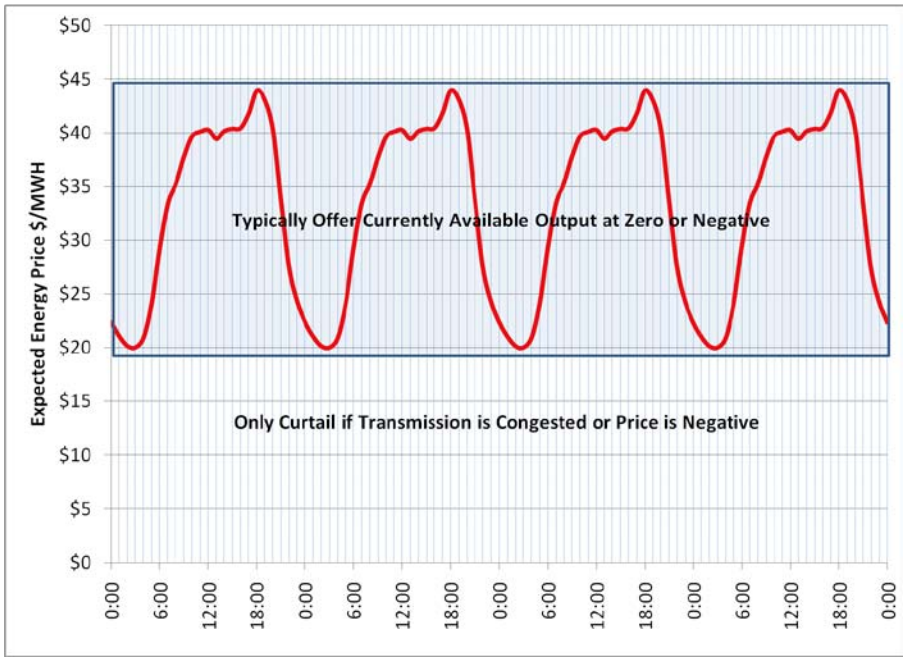
WindPower 2012, Atlanta Georgia, June 4

Scheduling & Co-optimization Works Well For Conventional Generators but not for Storage

- Fuel burning generators and even wind and solar plants specify capabilities and let the system operator optimize plant use
- Energy limited hydro and pumped storage must forecast energy and ancillary service needs and prices and optimize their own schedules
- This underutilizes the storage capability and reduces their ability to facilitate variable renewables

Co-optimization Schedules 1 Interval At a Time





Generators provide capability information

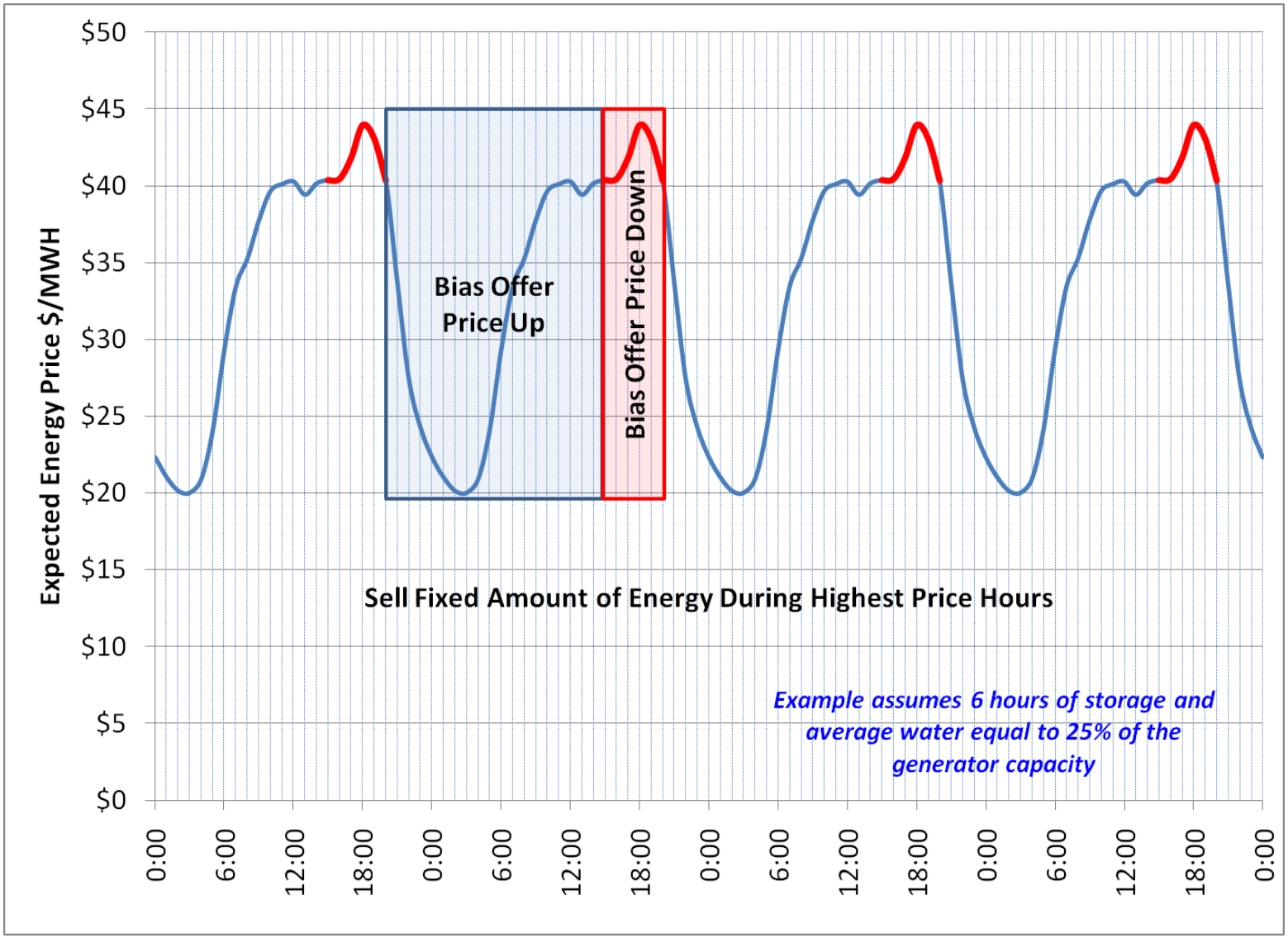
The system operator schedules operation

- **Fuel burning**
  - $35/MWH
  - X MW min, Y MW max
- **Renewable**
  - $0/MWH
  - X MW expected

Scheduling Energy Limited Hydro is Harder

- **Inter-temporal constraints complicate scheduling**
  - 100 MW generator
  - “25 MW” continuous water
  - 6 hours of storage
- **Offering at cost ($0/MWH) would result operating from 00:00 to 06:00 (not useful)**
- **Generator operator must forecast the hours of highest value or price that maximizes usefulness**

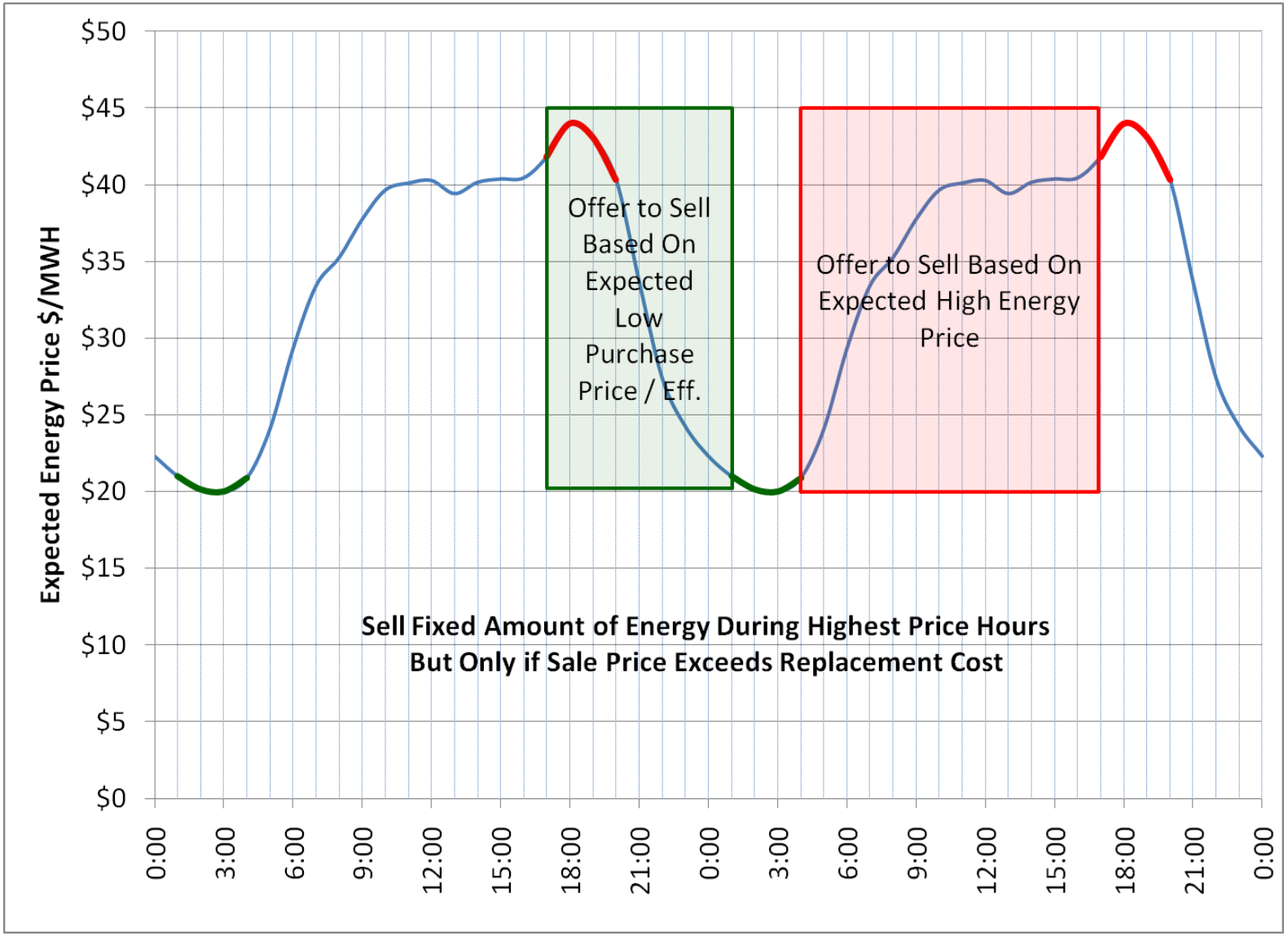
Scheduling Energy Limited Hydro



Pumped Storage is Tougher Still

- **Generator operator has to forecast pumping and generating times**
  - Prices and/or hours for pumping and generating must be forecast
  - Hours are easier to forecast than prices
  - Fixed schedules prevent response to changed situations
  - Plant efficiency determines if a transaction can happen
    - Assumed 75% round-trip efficiency

Pumped Storage Scheduling



Generator Operator Forecasting Is Inefficient

- **Forcing the generator operator to forecast (guess) at system prices and conditions results in suboptimal resource utilization**
  - Hurts the generator
  - Hurts system reliability
  - Hurts variable renewables integration
  - Hurts all power system customers
- **Offering capabilities and allowing the system operator to optimize the resource use is more efficient**
  - Conceptually similar to co-optimization of conventional generation
  - Extends co-optimization over multiple hours

Ancillary Services Important for Storage

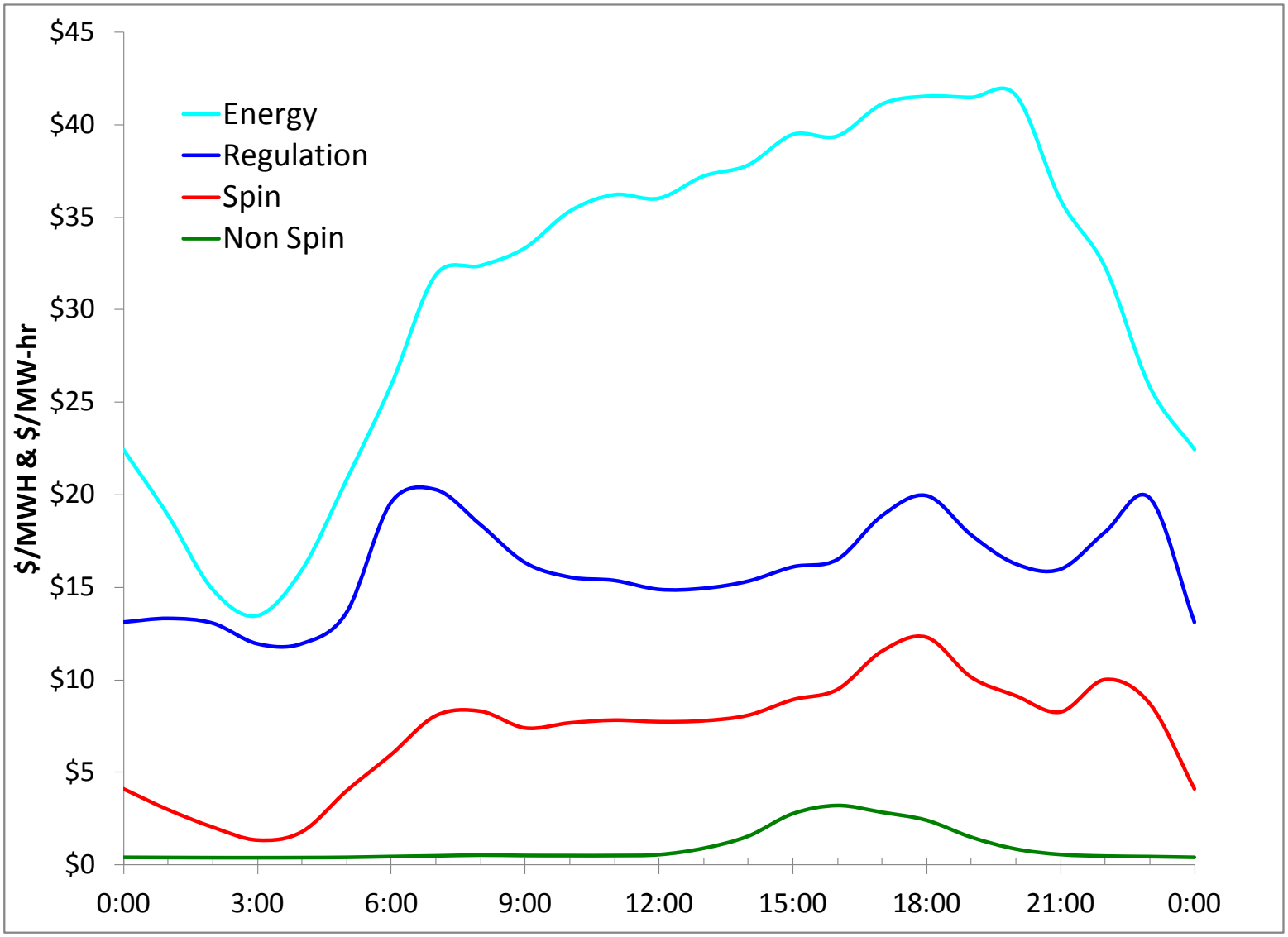
- **Simplified price taker model**
  - Studying concepts
- **1 year of energy and AS price data**
  - CAISO 2011
- **Assumes:**
  - Perfect forecasting
    - Over states benefits
    - Forecasting *time* of AS prices not that difficult
  - Inelastic prices
    - Plant too small to impact prices & no congestion

AS Prices Recovering

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
	CAISO Annual **Average** and Maximum Ancillary Service Prices ($/MW-hr)									
Regulation	**26.9**	**35.5**	**28.7**	**35.2**	**38.5**	**26.1**	**33.4**	**12.6**	**10.6**	**16.1**
(up+down)	111	164	166	188	399	421	618	500	124	120
Spin	**4.3**	**6.4**	**7.9**	**9.9**	**8.4**	**4.5**	**6.0**	**3.9**	**4.1**	**7.2**
	250	92	125	110	225	400	400	416	66	48
Non-Spin	**1.8**	**3.6**	**4.7**	**3.2**	**2.5**	**2.8**	**1.3**	**1.4**	**0.6**	**1.0**
	92	92	129	125	110	400	399	416	66	35
Replacement	**0.90**	**2.9**	**2.5**	**1.9**	**1.5**	**2.0**	**1.4**			
	80	55	90	36	70	175	244			

- **Regulation is the most expensive, followed by spinning reserve and non-spin**

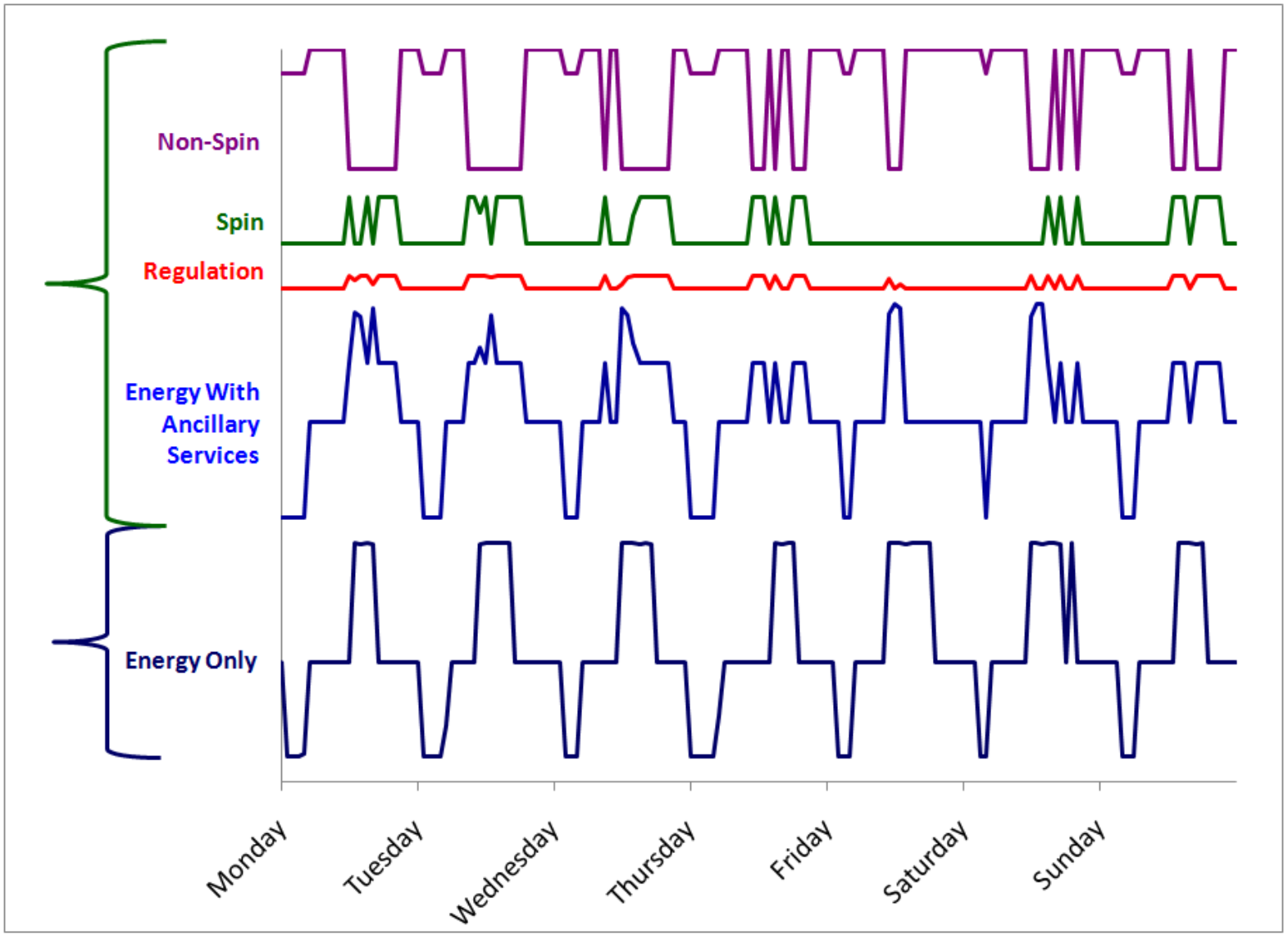
Average Daily Energy & AS Prices



Multiple Operating Modes

- **Sell Energy**
- **Sell Energy & Spin**
  - Make or loose money on energy
- **Sell Energy & Regulation**
  - Make or loose money on energy
- **Plant Capabilities**
  - 100 MW generation & pumping
  - 51 MW minimum load
  - 49 MW spin
  - ±12 MW regulation

1 Week With and WO Ancillary Services



AS Increase Generation Profits

	Profits $M												Gen MW		Ancillary Services		
	Total		Energy		Total A.S.		Reg		Spin		Non		Max	Min	Reg	Spin	Non
Optimized Energy Schedule																	
Energy Only	$4.6		$4.6		$0.0								100	51	0	0	0
Energy & Ancillary Services	$6.2	133%	$3.7	60%	$2.5	40%	$0.9	14%	$1.3	22%	$0.3	4%	100	51	+/-12	49	100
Very Flexible	$7.5	162%	$2.3	30%	$5.2	70%	$2.4	32%	$2.8	37%	$0.1	2%	100	2	+/-49	98	100
Fixed Schedule																	
Energy Only	$2.6	*56%*	$2.6		$0.0								100	51	0	0	0
Energy & Ancillary Services	$3.8	148%	$2.1	55%	$1.7	45%	$0.4	10%	$1.1	29%	$0.2	6%	100	51	+/-12	49	100

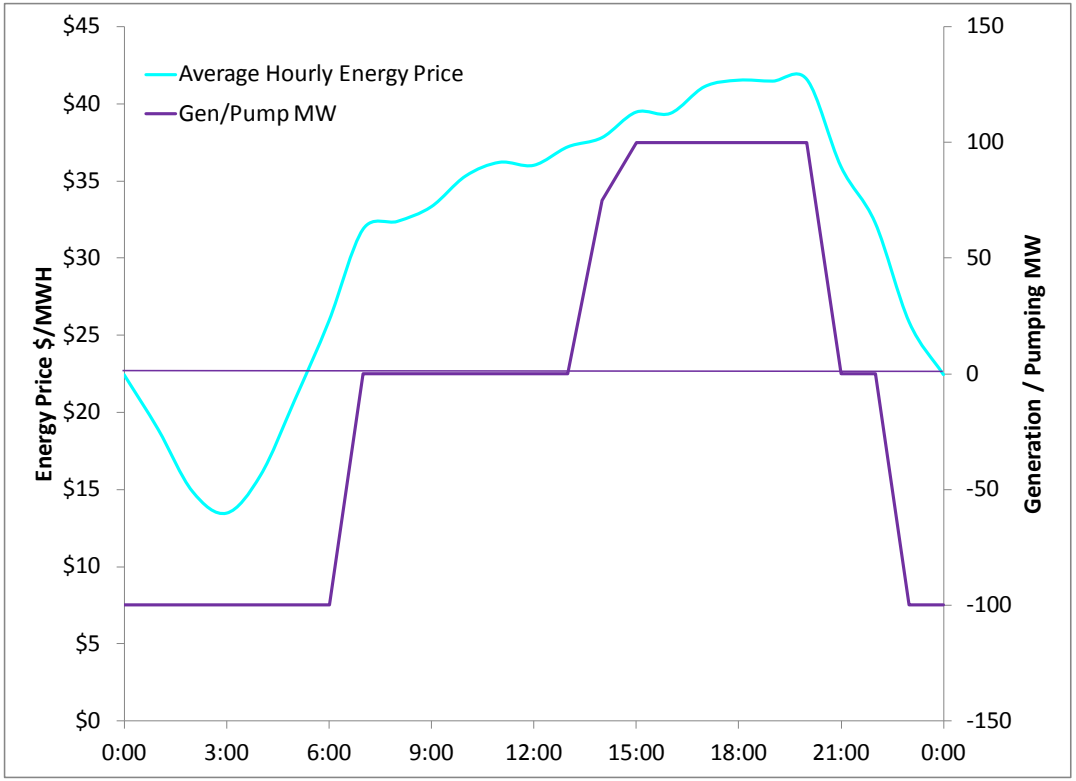
- **Plant profits increase 33%**
  - Energy profits decrease 20%
  - AS account for 40% of total profits
    - 22% Spin, 14% Reg, 4% Non
- **A very flexible plant could increase profits 62%**
  - AS account for 70% of total profits
    - 37% Spin, 32% Reg, 2% Non

System Operator Co-optimization and Scheduling Required

- System operator willing to co-optimize energy and AS each hour
- System operator unwilling to optimize energy over multiple hours

Self Scheduling Pumped Storage

- **Could schedule based on average hourly energy price**
  - Additional sales can be made if prices are particularly attractive



- **Energy-only profits are 56% of the optimized schedule value**
- **AS increases profits by 48%**
  - AS account for 45% of total profits

Conclusions

- **Providing ancillary services is important to pumped storage plant profitability**
  - And energy limited hydro
- **The power system operator is in a much better position than the pumped storage operator to optimize the energy schedule**
- **Optimizing the energy schedule is conceptually similar for the power system operator to co-optimizing energy and ancillary services for conventional generators**
  - The facility offers capabilities and the system operator determines how best to use them

Conclusions Continued

- **System operator optimization benefits:**
  - Power system reliability
  - Pumped storage plant profitability
  - Other power system customers
    - Lower AS and energy costs
  - Variable renewables
    - Increased AS provision
    - Lower energy price volatility
    - Reduced minimum load concerns