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Valuing Pumped Storage

Evaluation Methods and Recent Studies

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Energy Storage Valuation can be Confusing!

Voltage Support

Load Following

Spinning Reserve

Congestion Relief

Arbitrage

Non-spinning Reserve

Renewable Integration

Distribution Deferral

Frequency Regulation

Backup Power

Black Start

Ramping

Reduced GHG?

Asset Utilization

Resource Adequacy

Lower Production Costs

Transmission Deferral

Value sources differ in clarity, and may be direct, secondary, or overlapping.

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Proposed methodology to value storage

1. Grid Services

- Define direct benefit calculation
- Define technical requirements by service

2. Use Cases

- Direct benefits of combined services
- Simulate "1st unit" cost-effectiveness

3. Grid Impacts

- Indirect impacts of storage deployment and operation
- Environmental impacts

4. Business Cases

- Monetizable value to storage owner under real world assumptions

Important to look at all possible realistic sources of value

For future years → simulations required for prices, energy usage, etc.

Study should be aimed at most effective use cases

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Tools, Time, Money – Overall suggested approach to fully capture values

	1. Grid Services	2. Use Cases	3. Grid Impacts	4. Business Cases
Tools	Technical Analysis Tools; Planning Heuristics	Financial Analysis, Valuation Tools	System impacts tools, particularly Production Costing	Financial Analysis
Time	Depends on Service Minutes-Months	**Minutes-Hours**	**Weeks-Months**	Minutes-Hours
Money	Depends on Service $-$$$	**$**	**$$$$**	$

Know what you want to examine before starting studies!

Not all steps will be necessary in all studies → see later results

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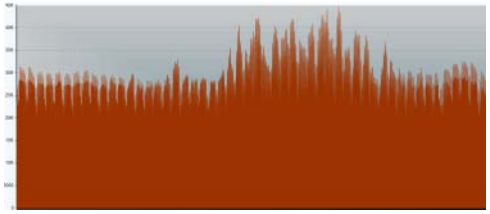
How the ESVT works – Reduced form site-specific dispatch model

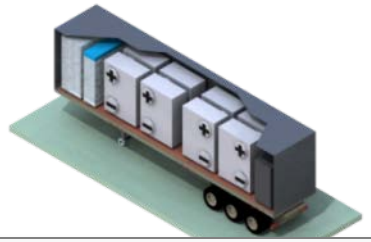
INPUTS

Prices / Loads



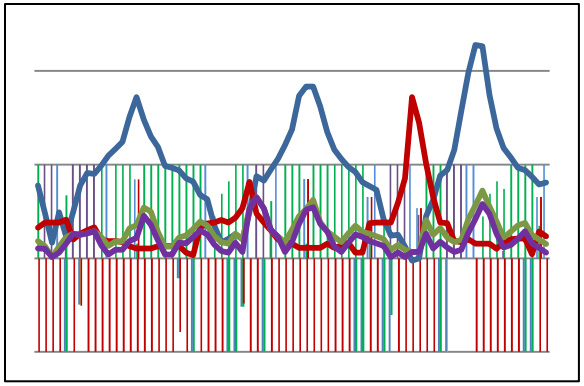
Financial Assumptions

Storage Cost / Performance



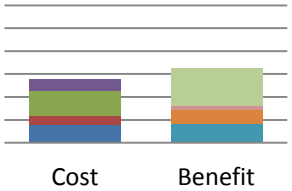
MODEL

Storage Priority / Bid / Dispatch

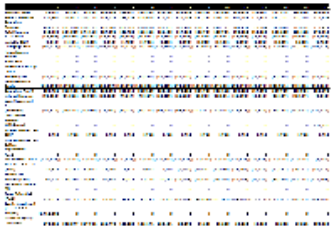


OUTPUTS

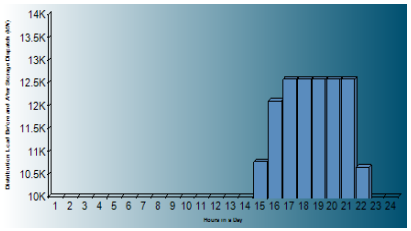
NPV Cost / Benefit



Detailed Financials



Dispatch Information



Informs where storage might make sense, prior to embarking on expensive network modeling exercises.

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"Valuing Hydropower Grid Services in the Future Electricity Grid"

- **Purpose:** **Quantify the potential value of increased use of hydropower grid services**
- **Objectives:** **Define the current market structures, asses the economic value based on modeling, and ID opportunities to potentially increase the value of hydropower in the future (operational changes, technology upgrades & market changes)**
- **Participants:**
  - **Researchers: EPRI, ORNL, SNL**
  - **Consultants: HDR, HPPi, LCG Consulting, Kirby Consulting**
  - **Industry sponsors: Ameren, Duke Energy, Exelon Chelan County PUD, TVA, NYPA, Voith Hydro, Manitoba Hydro, Brookfield**

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Strategic Approach to Valuing Hydropower

Economic value of hydro	• Hourly economic dispatch model of WECC with sub-hourly reserve requirements
Market Structure	• Market comparison gaps & recommendations to rules
Operational Realities	• Hydrological Constraints • Operational Opportunities
New Technologies & Costs	• New Technologies for Future Plants and Cost of Technologies

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"Valuing Hydropower Grid Services in the Future Electricity Grid"

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For existing pumped storage → already know use cases

Purpose was overall societal case → step 4 not carried out

Key aspects were the value storage provides the grid, particularly w/high renewables

Study performed before methodology finalized and ESVT released

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Tools to value energy storage

- **Resource Adequacy / Expansion (Weak for Valuing Storage)**
  - Long-term capacity and A/S procurement needs based on load growth and retirements = Future gen mix
  - Examples: NESSIE, RETScreen, NEMS, HOMER
- **Production Cost Models (Relatively Strong for Storage Valuation, excl. Capacity, Dist, Cust)**
  - Simulate hourly scheduling and dispatch of energy and A/S in a balancing area or region (w/ or w/o trans req's)
  - Examples: PLEXOS, UPLAN, PROMOD
- **Load Flow / Dynamics (Limited to Grid Impact, Reliability analysis)**
  - Simulate physical grid (T&D) short duration time steps to assess system stability and reliability
  - Examples: PSS/E, PSLF, CYMDIST, OpenDSS
- **Project Financial Analysis (Project-specific focus with all stakeholder benefits – excl. societal)**
  - Model grid asset as a price-taker and simulate future revenues and cost for asset NPV
  - Examples: **ESVT**, KERMIT
- **Technology Screening / Survey (Provides initial guidance)**
  - Utilize estimates and heuristics to screen technology and applications for high potential combinations
  - Examples: ES-SELECT

Other aspects somewhat captured or not relevant to this study

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Findings relative to pumped storage

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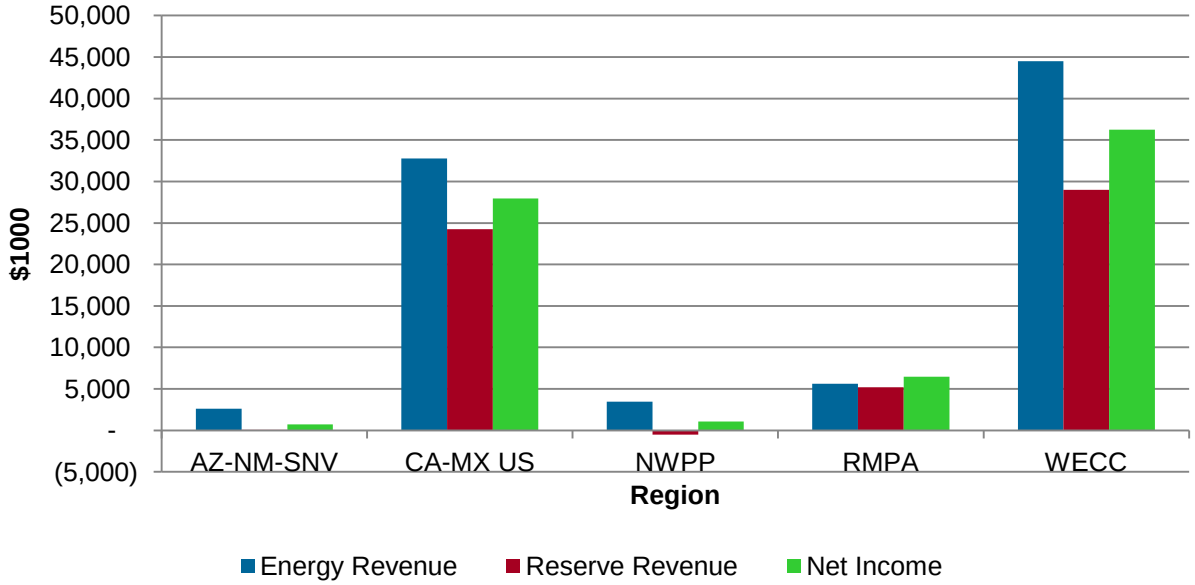
Use hydro to address variability
Modeling Flex Reserve– Pumped Hydro

Region	Capacity (MW)	Generation(GWh)	Energy Revenue ($1000)	Reserve Revenue ($1000)	Net Income ($1000)	Average Income ($/kW)
AZ-NM-SNV	198	356	26,821	5,226	9,464	48
CA-MX US	3,639	5,783	413,929	47,652	80,255	22
NWPP	314	598	44,519	3,815	11,251	36
RMPA	560	1,116	84,294	8,510	19,315	34
WECC	4,711	7,854	569,563	65,202	120,284	26



Significant Increase in both A/S and Energy Revenue

Average Income almost doubles when adding flexible reserve requirement

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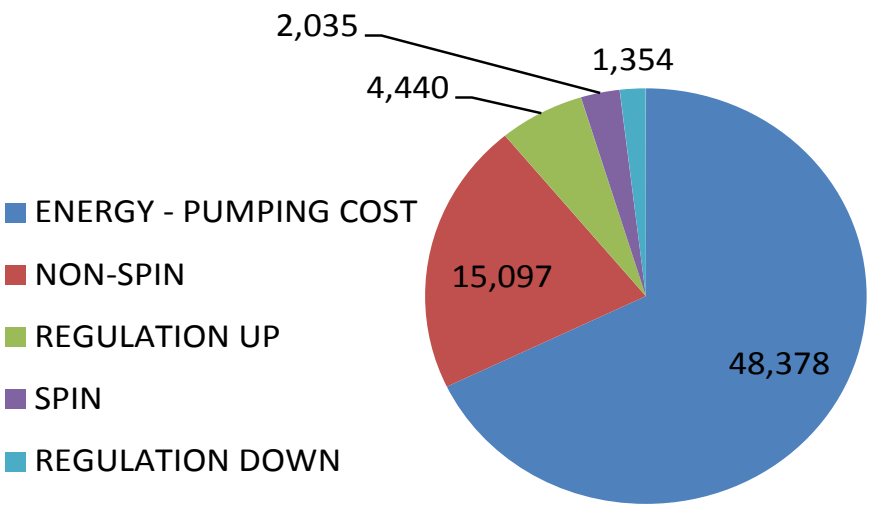
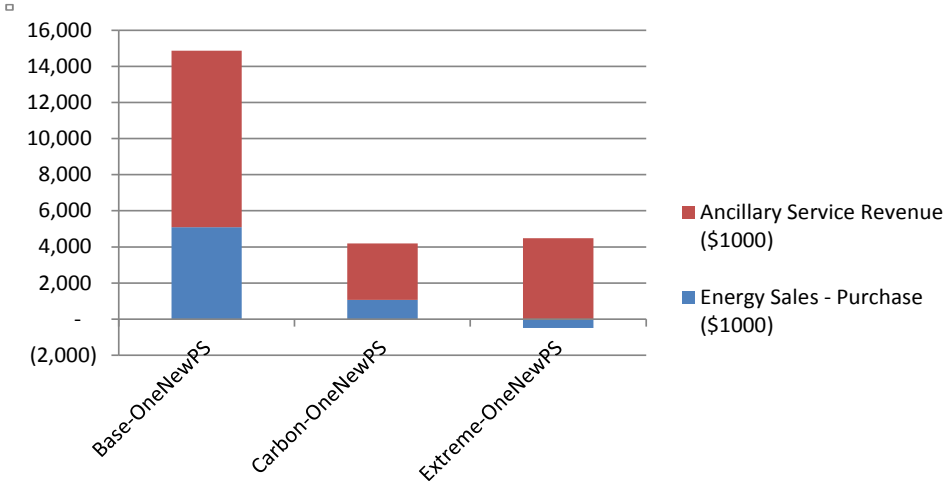
Energy and Ancillary Services

- Received 30-50% of revenue from AS and the remaining from energy arbitrage
- 8 cases show greater than 40% of 2020 revenue from AS
- In extreme case (high demand, renewables, gas prices) higher portion of AS





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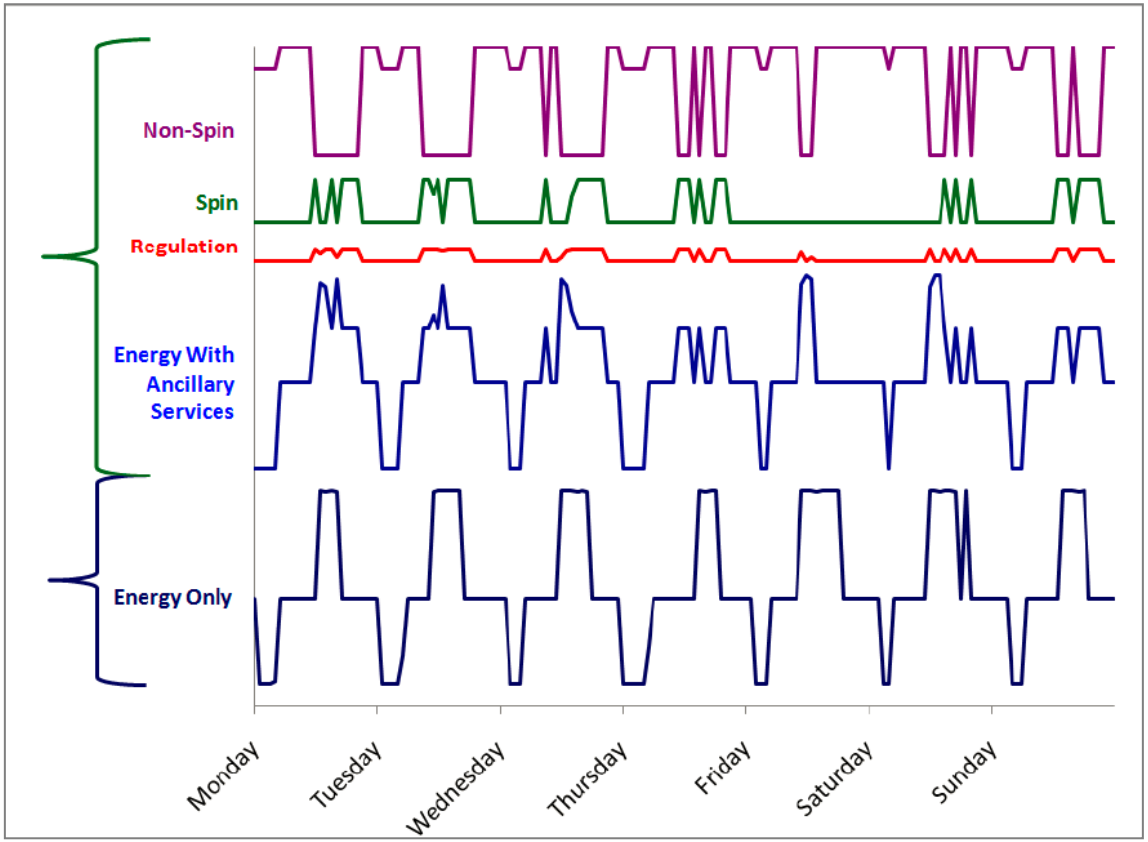
Let ISOs schedule pumped storage

- Allow ISOs to co-optimize energy and ancillary service scheduling
  - ISO knows capabilities, limitations and costs of plant as well as forecasting
- Preliminary analysis showed allowing ISO to optimally schedule could increase a PS plant profits 63%-77% compared to a fixed pumping/generating schedule



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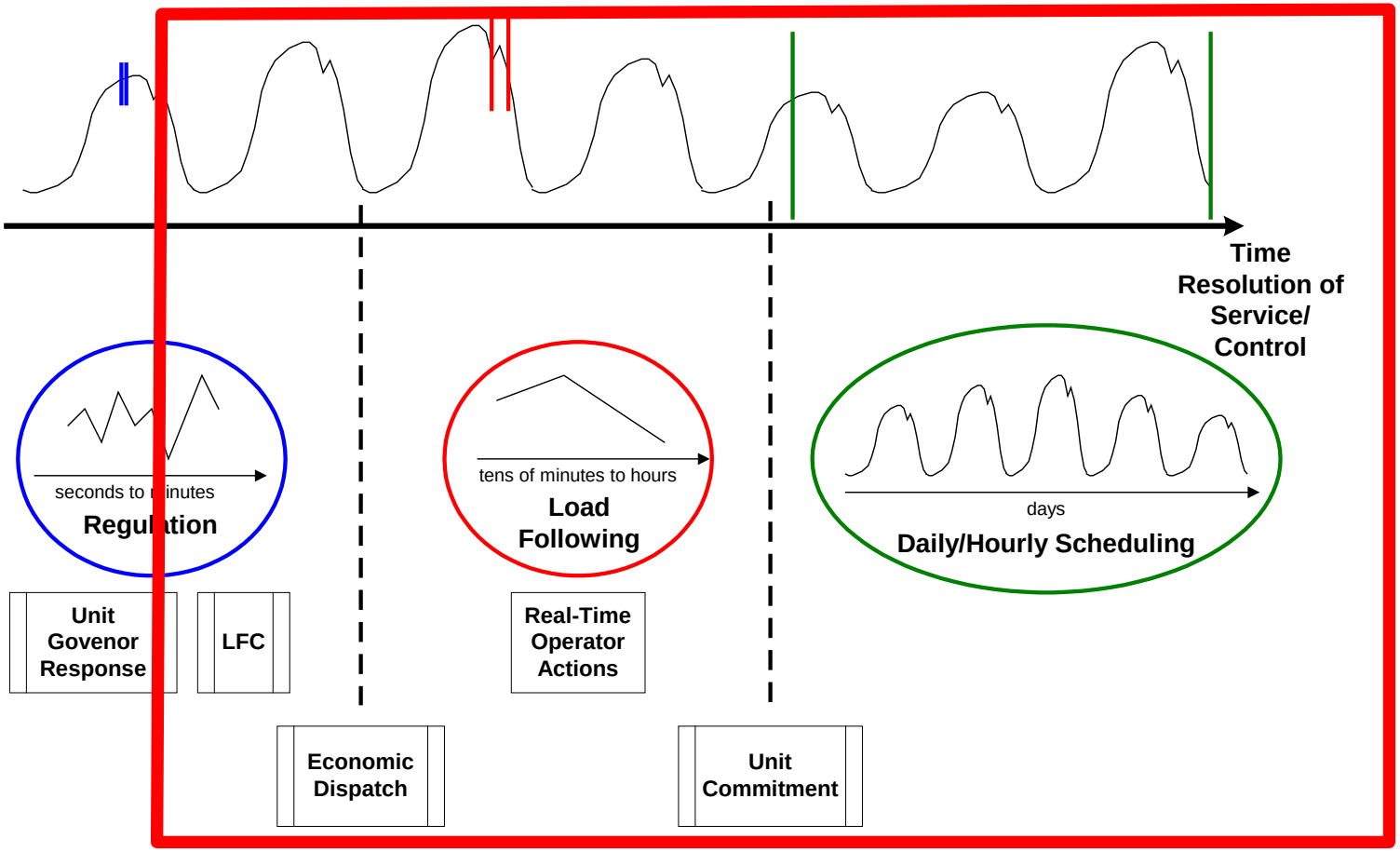
Settle energy markets sub-hourly, increasing arbitrage opportunities



Which components do we capture?

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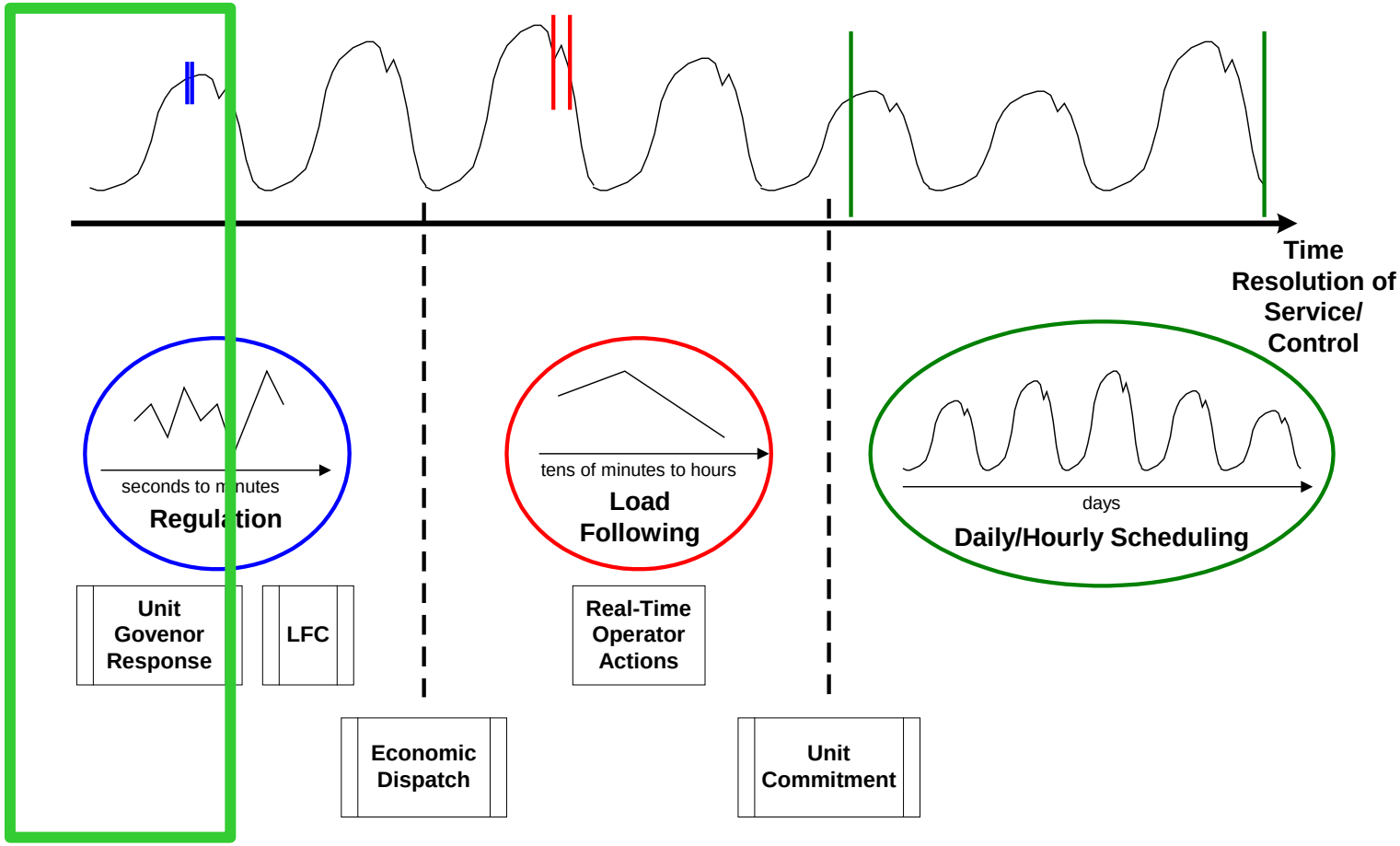
Credit hydro for very fast regulation response



Which components are left to capture?

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Apply adjustable speed drives in pumped storage plants

- Adding variable speed results in 85% increase in income

Pmin=40%,
Round Trip efficiency= 80%
Range of Operation= 60%

Scenario	Unit Size (MW)	Capacity Factor (%)	Energy Revenue ($1000)	Ancillary Service Revenue	Fuel Cost ($1000)	Net Income ($1000)	Average Revenue ($/KW)	Average Income ($/KW)
Base	132	15.9	9,790	605	8,465	1,745	79	13
Base_GenUp	132	19.6	11,995	1,989	10,983	2,774	106	21
Base_PumpUp	132	20.5	11,988	2,863	11,483	3,131	113	24

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Items of unfinished business for research

Operations

3. How to put a monetary value on hydro's role in energy security and increased grid reliability, including capacity value, transmission deferral, stability, etc.

Technology

6. Monetize environmental benefits …. Potential for closed loop/low profile pumped storage, underground, etc.

Markets

9. Treat pumped storage as a storage asset
10. *DOE Argonne Lab project on Advanced Pumped Storage Hydropower in the U.S.* models to evaluate hydro resources contributions for:
    - dynamic reactive power support,
    - primary frequency response, and
    - within-hour reserve deployment services.

Hydro services study captured many of the important values, but not all!

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Valuation Methods

- Important to stack values up in technically-feasible method
  - Assess likelihood of use case “success” to conserve resources
  - Once some feasible use cases (screened financially and technically) have been identified, more detailed modeling required → sometimes may skip straight to step 3!
- Using a methodology that separates analysis into stages promotes clarity of communication
- Reduced form modeling of use cases may enable more effective use of analytical resources prior to full network modeling (w/ production cost tools)
- EPRI Energy Storage Valuation Tool supports use case modeling to quickly iterate different services, technologies, and locations and inform where storage might make sense
- **Development of transparent tools and methods for storage valuation is critical to clarity within and outside of the storage industry**

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Quantifying the Value of Hydropower Reports

- Role of Hydropower in Existing Markets Sandia Report (Jan 2011)
- Modeling Approach & Base Case Scenario EPRI 1023139 (Nov 2011)
- Plant Cost Elements EPRI 1023140 (Nov 2011)
- Systemic Plant Operating Constraints ORNL Report (May 2012)
- Case Studies on Plant Operations (Sept 2012)
  - Results from Case Studies of Pumped Storage Hydroelectric Plants EPRI 1023142
  - Results from Case Studies of Conventional Hydroelectric Plants EPRI 1023143
- Modeling Results for Future Scenarios EPRI 1023141 (Oct 2012)
- Final Report EPRI 1023144 (Oct 2012)

http://www.epri.com/hydrogrid/

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