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U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Integrated Hydropower and Energy Storage Systems

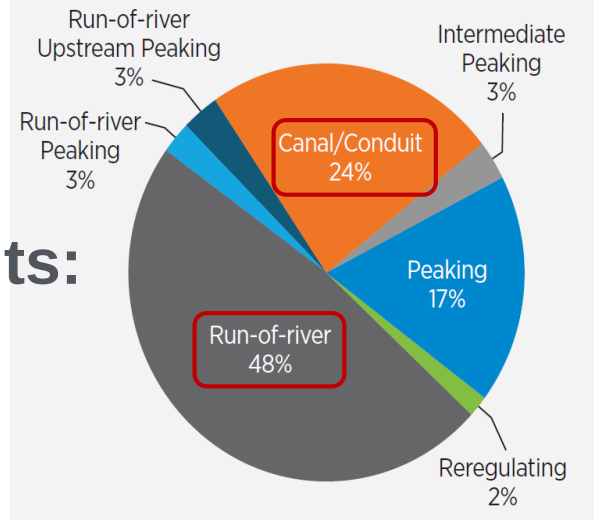
waterpower@INL.gov

Over 31% of U.S. hydropower fleet's capacity has very limited flexibility

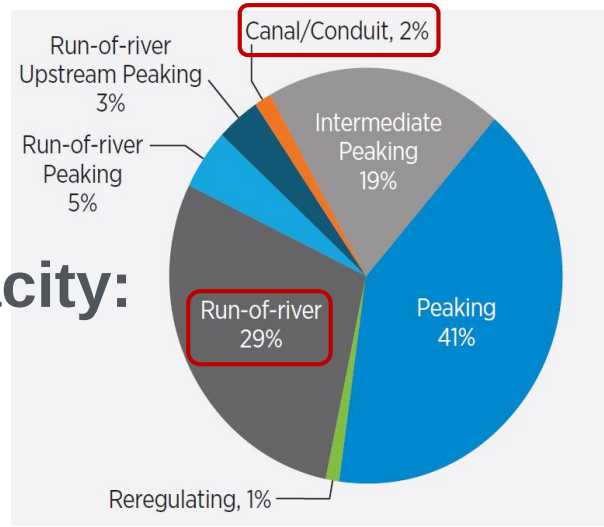
Run-of-river + canal/conduit:

- Have little to no active water storage (in = out)
- Without storage cannot provide peaking power or essential reliability services
- Limited revenue streams

By plants: 72%



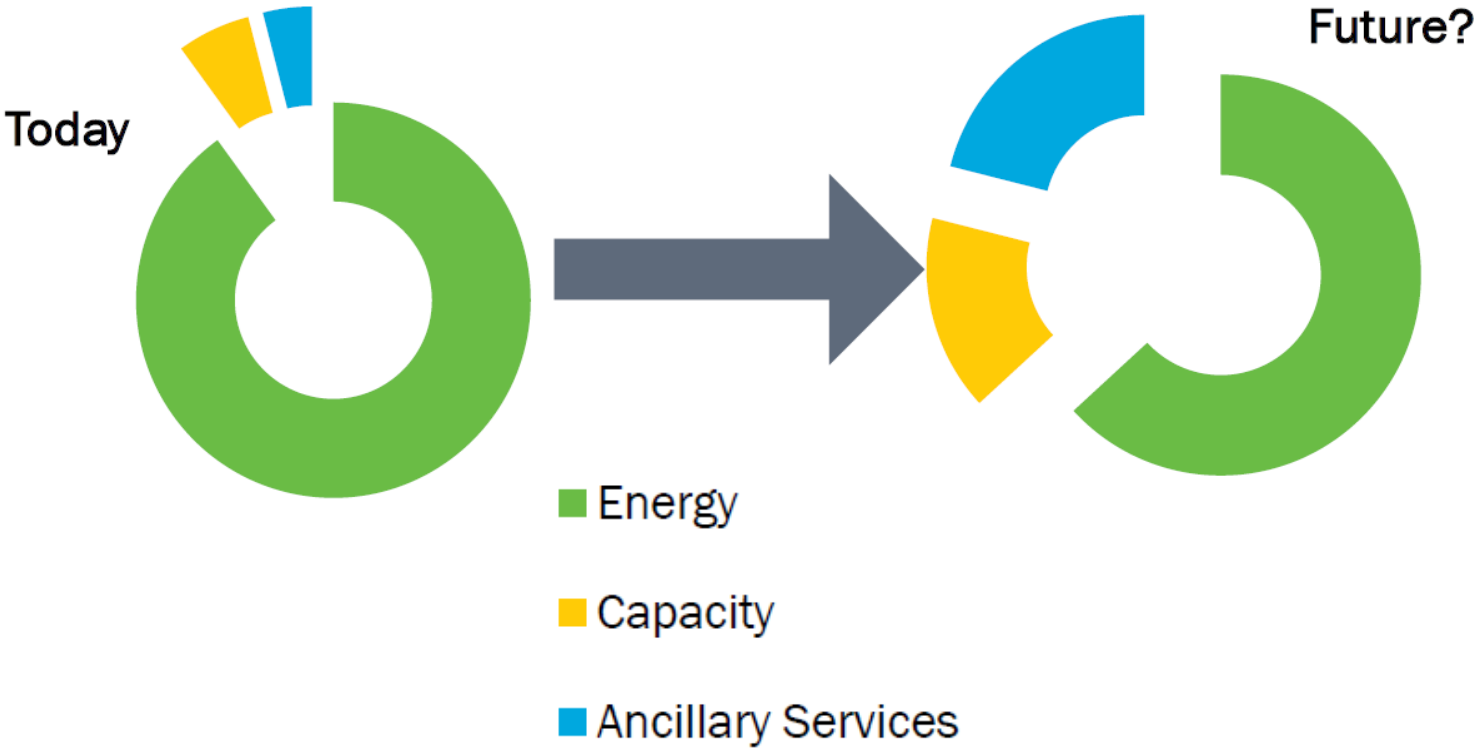
By capacity: 31%



Source: DOE, Hydropower Vision Report, 2016

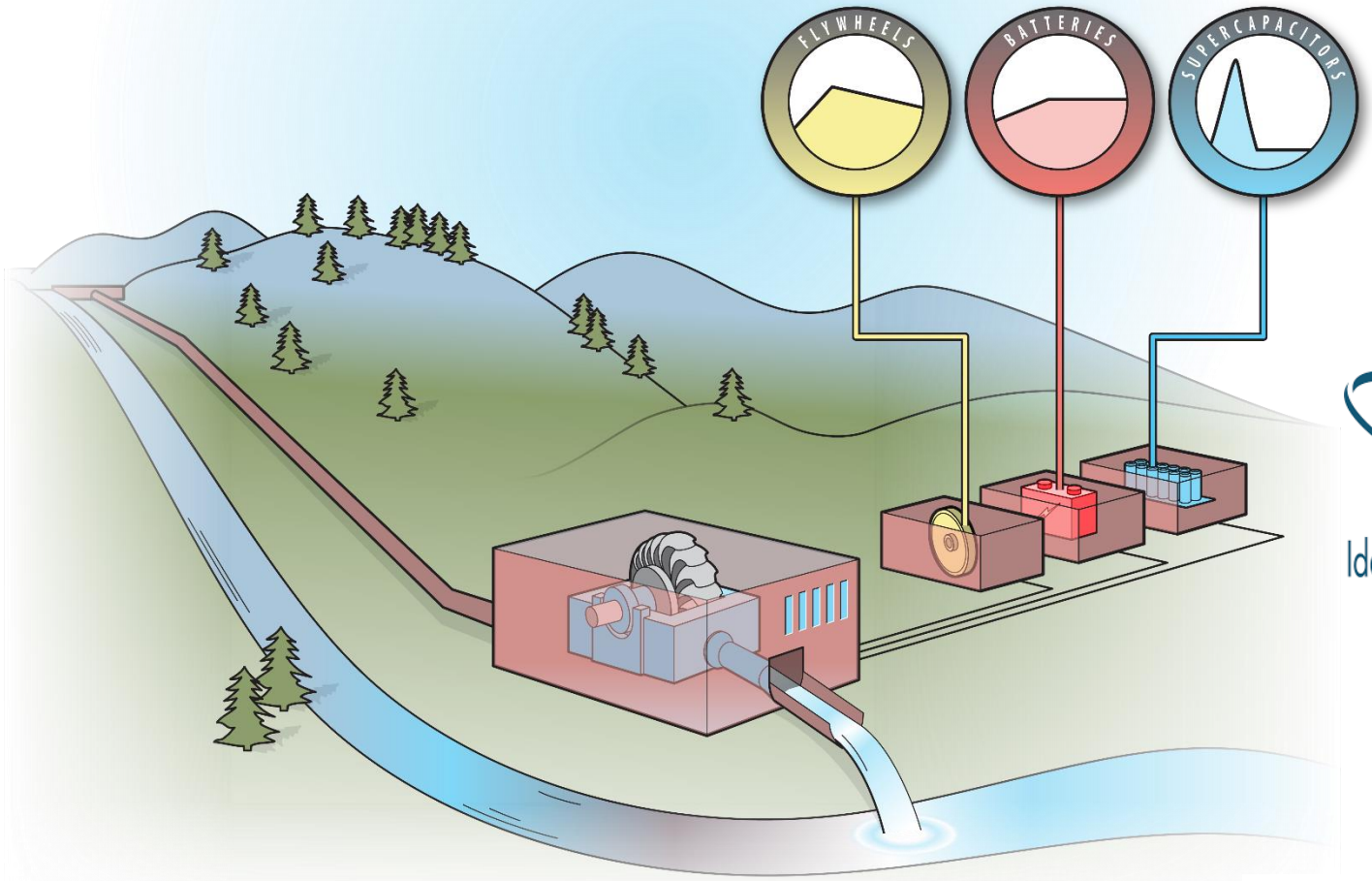
The relative value of services in the electrical grid is increasing

- *The cost of energy is decreasing*
- *The relative value of services is increasing*



Source: EPRI, Capacity and Energy in the Integrated Grid (2015)

Increasing hydropower's flexibility through "virtual reservoirs"



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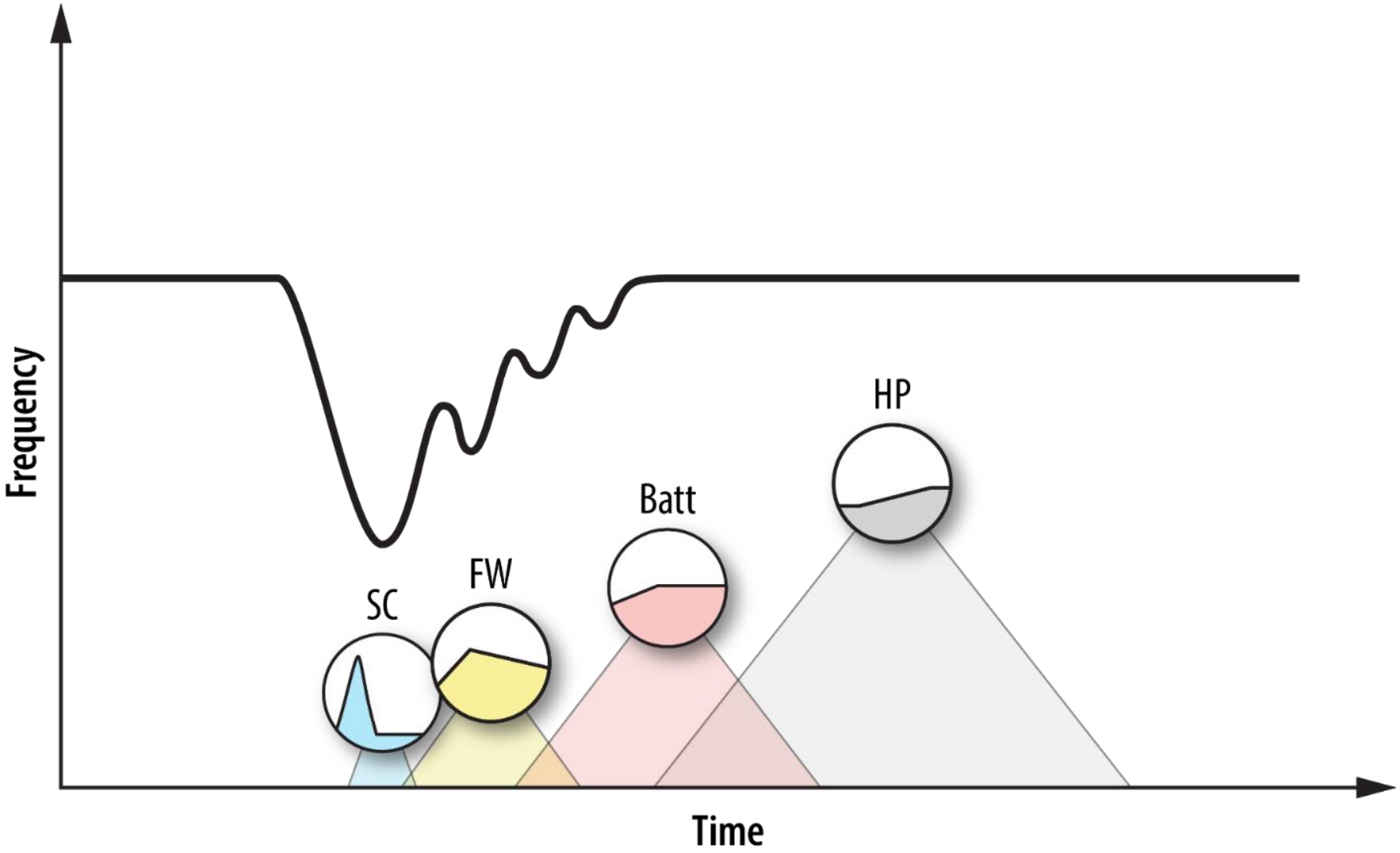
Hybrid energy storage systems: utilizing strengths of multiple technologies

- **Supercapacitors:** Less expensive on a capacity basis, tolerant to cycling patterns, don't degrade with cycling
- **Batteries:** Less expensive on an energy basis, degradation depends on use
- **Flywheels:** More expensive, but tolerant to environmental conditions and cycling patterns, don't degrade much with cycling

Parameter	Li-Ion battery	Flywheel	Supercapacitor
Total project cost ($/kW)	1,876 (1,446)	2,880	931 (833)
Total project cost ($/kWh)	469 (362)	11,520	74,480 (66,640)
Round-trip efficiency (%)	86	86	92
Response Time (s)	1	0.25	0.016
Cycles	3,500	200,000	1 million

Balducci, PNNL, 2019, in-press

Energy storage can boost power output quickly, supporting ROR and reservoir-based hydropower

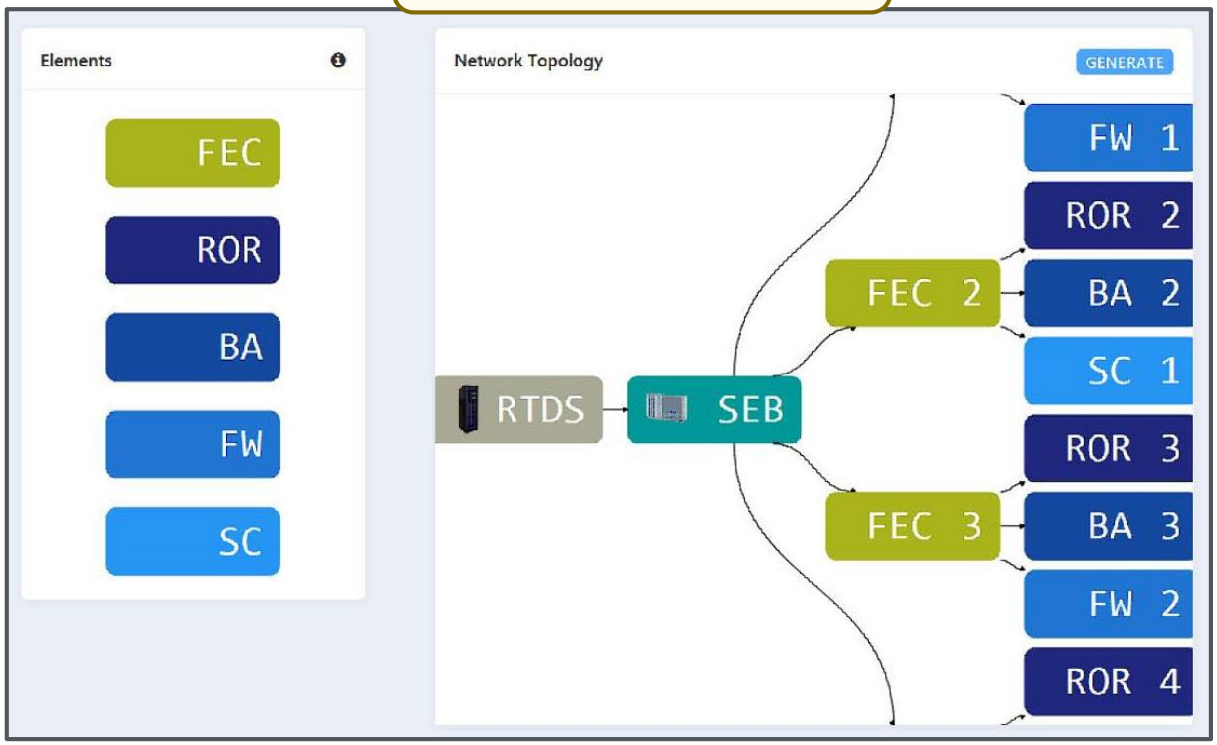


Siemens Smart Energy Box links device-level controls and overall utilization

Siemens Smart Energy Box (SEB)

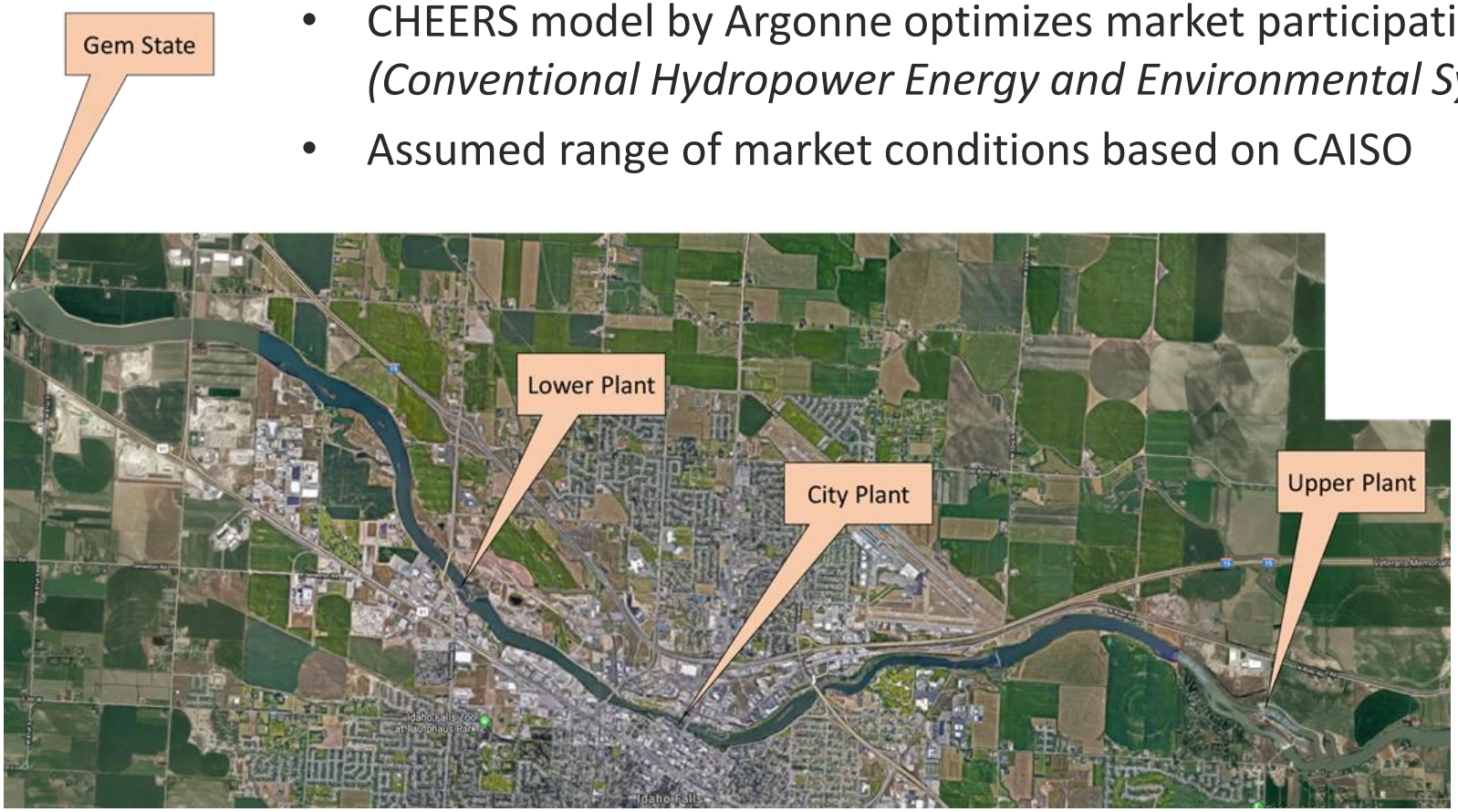
- Receives generation requests
- Tracks state of each device
- Optimizes utilization of each device and sends control signals

SEB Dashboard



Case study on revenue potential: Idaho Falls Power

- IFP has four single-unit ROR hydropower plants:
  - Upper: 7.1 MW - City: 7.3 MW
  - Lower: 6.9 MW - Gem: 22.7 MW
- CHEERS model by Argonne optimizes market participation *(Conventional Hydropower Energy and Environmental Systems)*
- Assumed range of market conditions based on CAISO

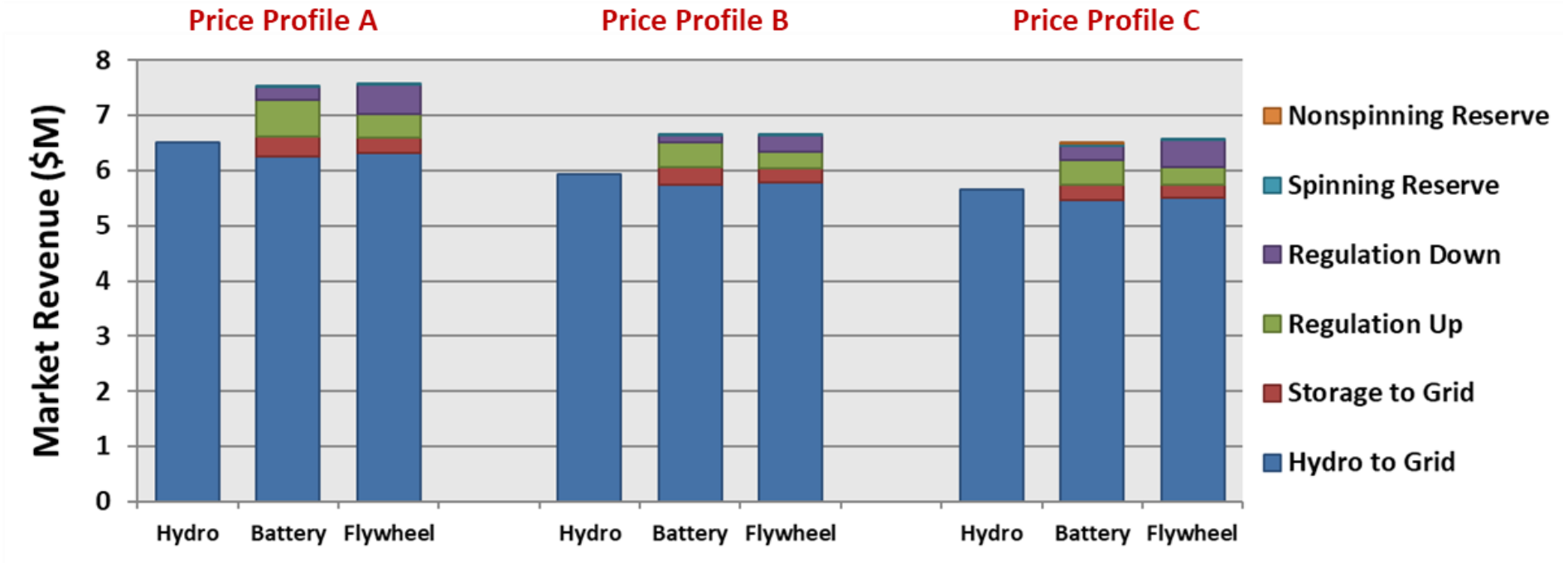


Case study on revenue potential: Idaho Falls Power

Revenue increases due to energy storage

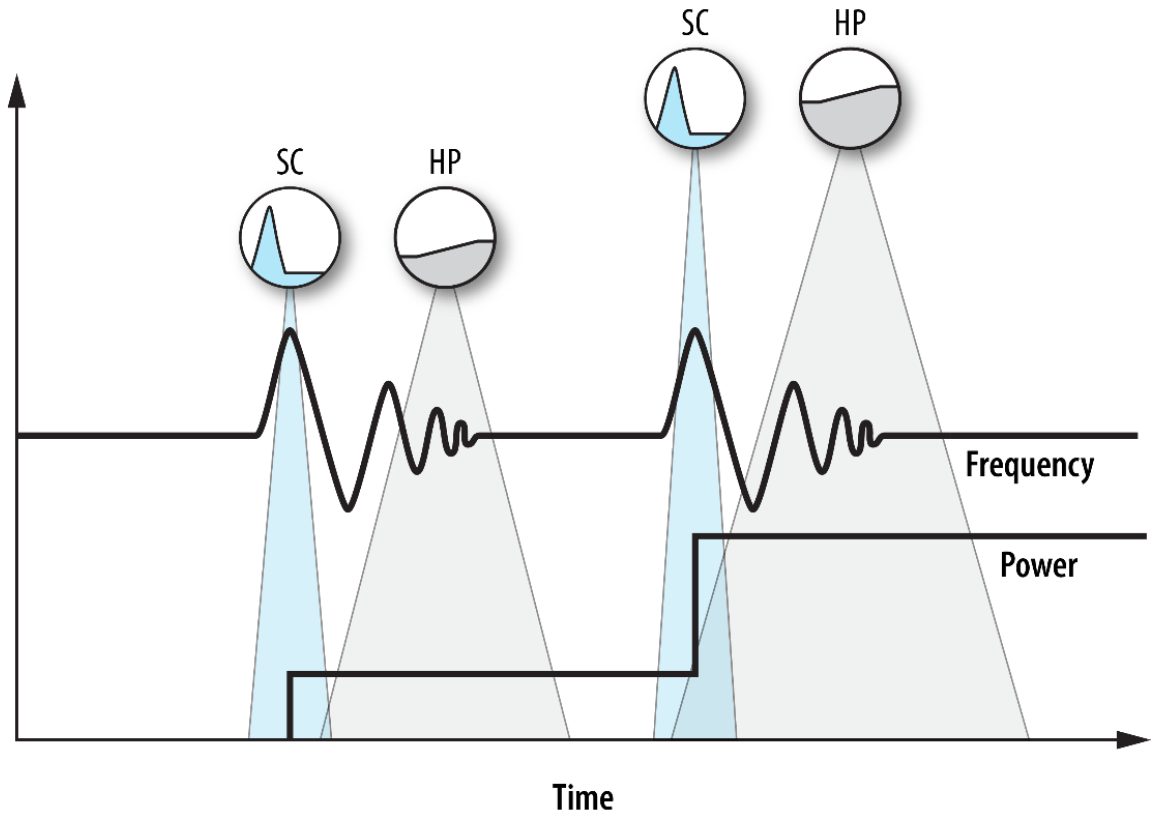
Battery storage: +12.2% to +15.8%

Flywheel: +12.0% to +16.3%



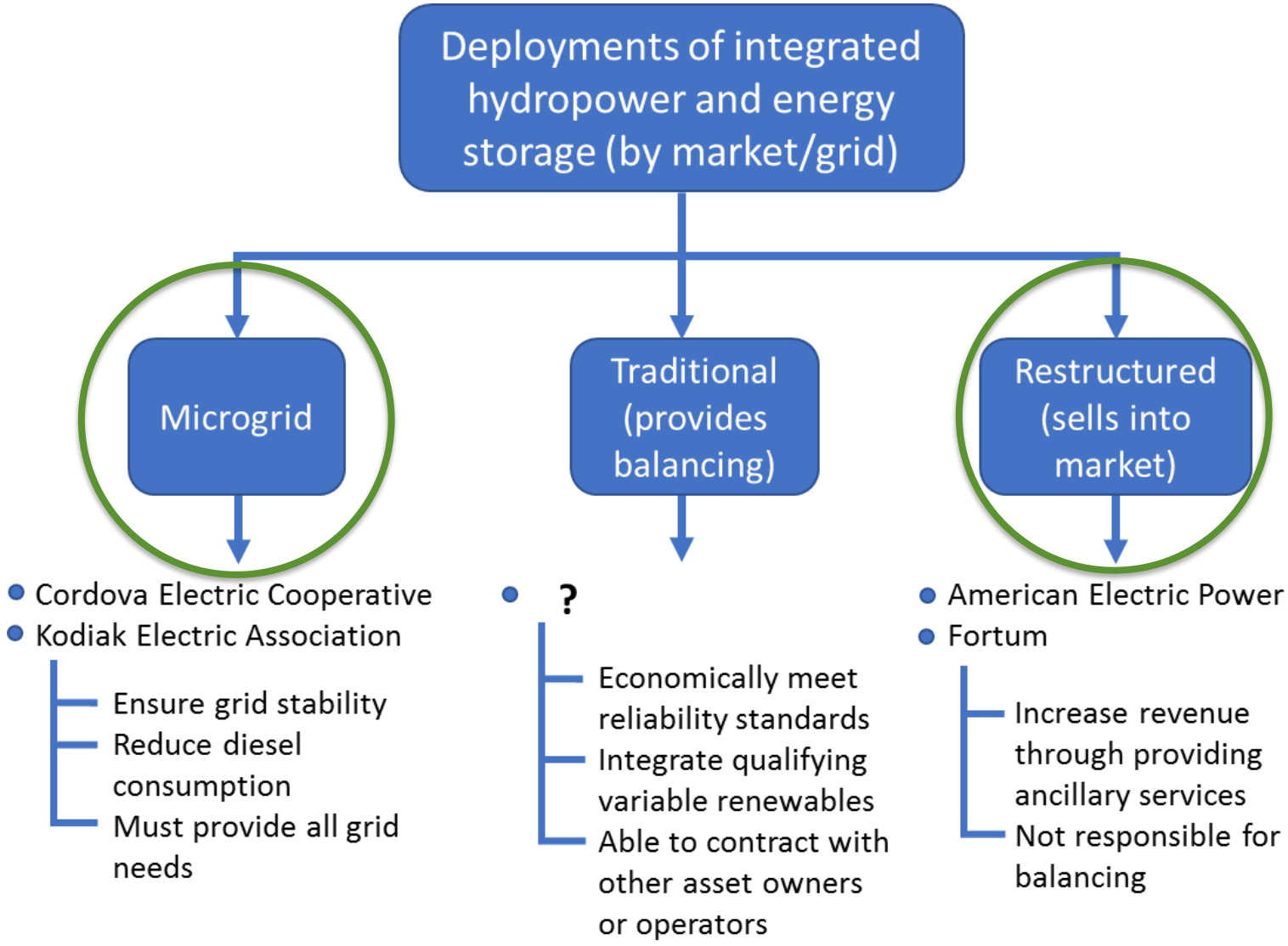
Enabling ROR plants to provide distribution-level black starts

1. Excite system; set controls and protections to black start mode
2. Add load in steps; as load added, discharge supercapacitors and ramp hydropower to stabilize circuit
3. Charge supercapacitors
4. Repeat until hydropower plant at desired generation state



Preparing for field demonstration with Idaho Falls Power (spring 2020)

Integrated hydropower and energy storage being built in some markets



Next steps: moving from lab to real-world

- ✓ Distribution-level black start: Idaho Falls Power, Spring 2020
- ○ Other integrated hydropower and energy storage use cases: ?

Digital simulation
- Use digital model of system (either component-level or aggregated)
- Adequate for testing overall system characteristics

Hardware testing
- Integrate digital and physical hardware components
- Most accurate method for lab-based assessment and validation

Field demonstration
- Most realistic
- Necessary to ensure system reliability

Project risk

Cost of evaluation

Send inquiries to:

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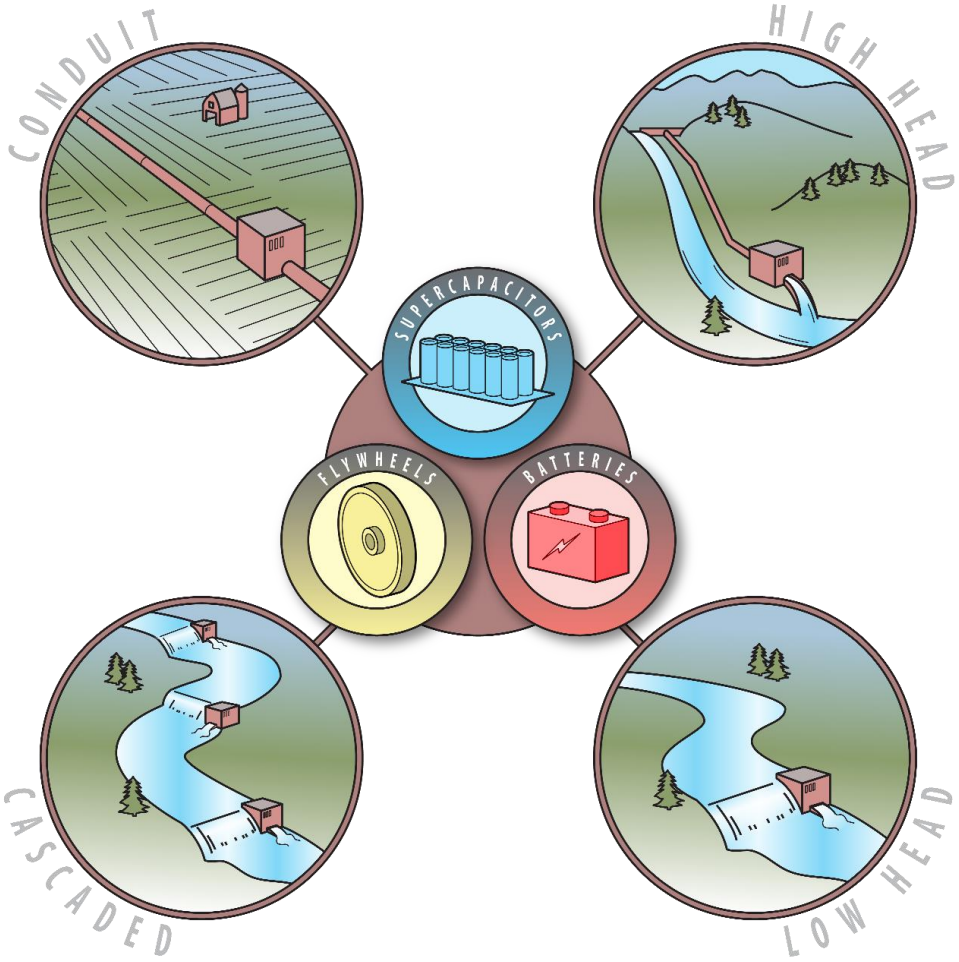

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