



FRACTAL

VALUE OF ENERGY STORAGE

CEE Annual Meeting

Daniel Crotzer

The Leading Battery Storage Consulting Firm

ENERGY STORAGE AND RENEWABLE ENERGY CONSULTANT



BATTERY STORAGE



SOLAR ENERGY



WIND ENERGY



SOLAR+STORAGE



MICROGRID



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OUR VALUE TO YOU



NEUTRAL & UNBIASED

REAL, HANDS-ON EXPERIENCE

ROBUST ANALYTICS & MODELS



Where is the Value
For Our Utility?

How does it work?

Which technology is best?

Where do we put it?

Which chemistry is best?

What size system do
we need?

Are we allowed to own it?

What are the risks?

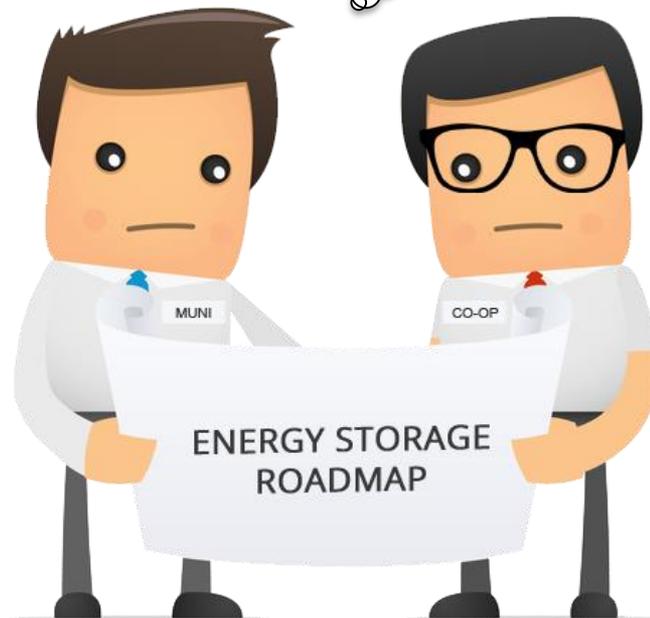
What services would it do?

Is storage cost-effective yet?

What is the O&M?

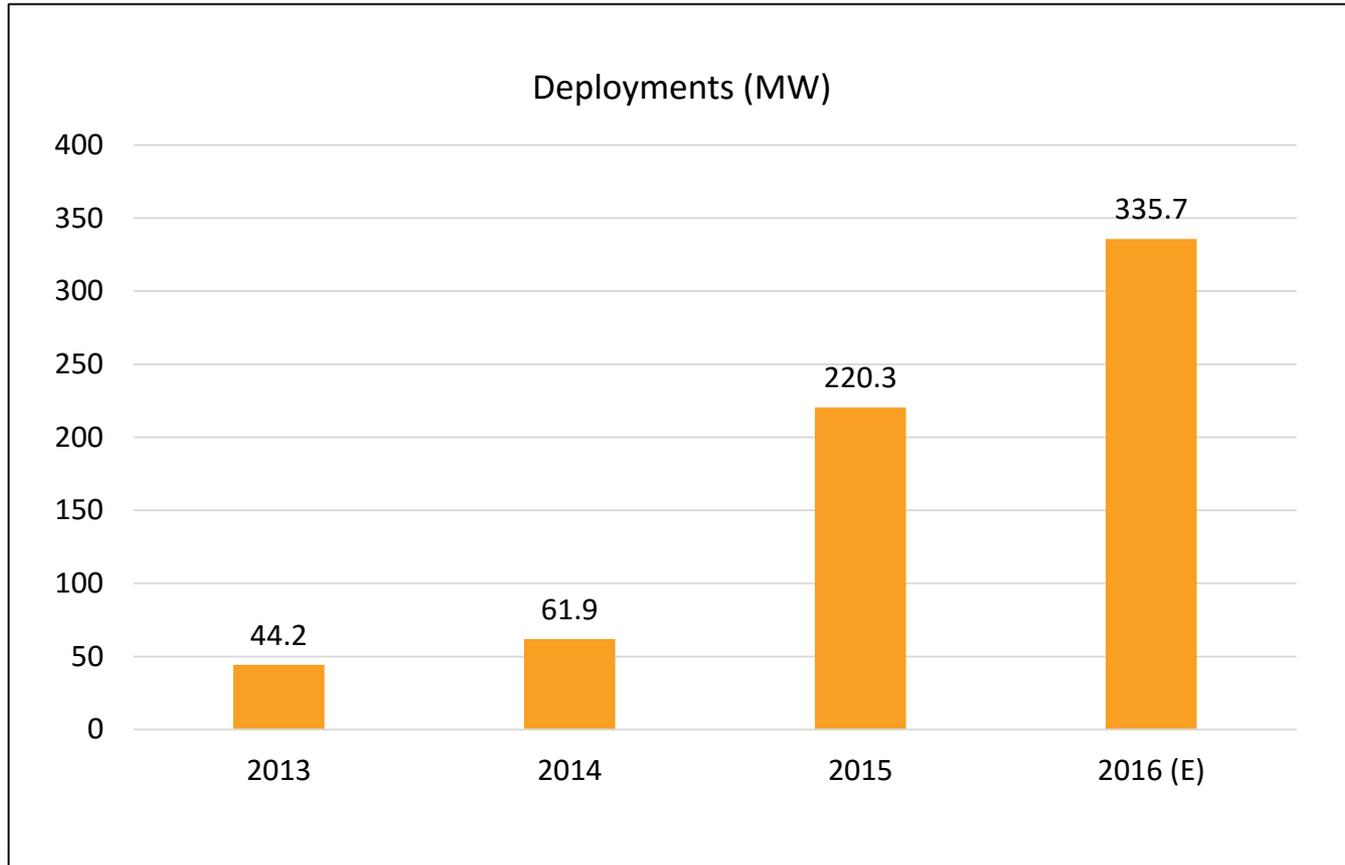
How long does it take?

How do we procure it?

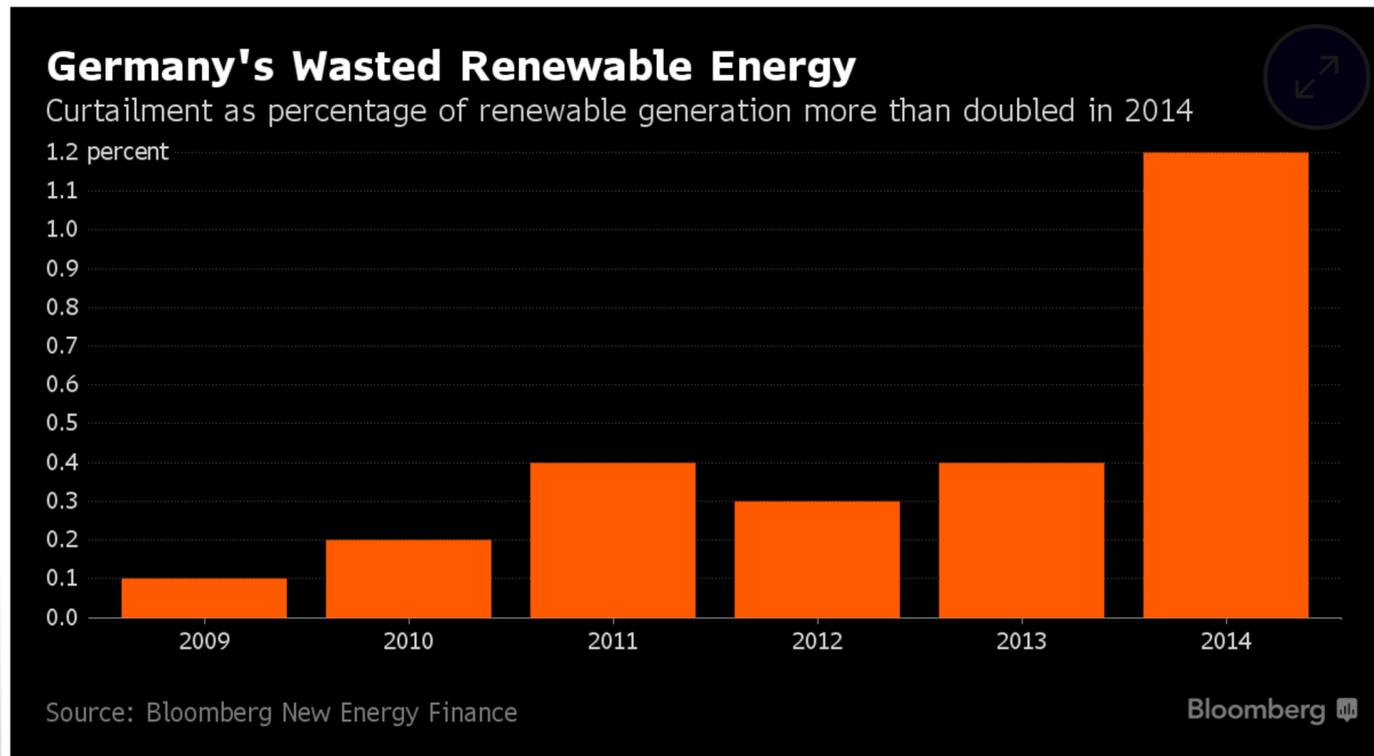


What are the economical business models that make sense for us?

U.S. Energy Storage Deployments



- ✓ *California Mandate of 1.325 GW (PG&E, Edison and SDF&E)*
- ✓ *Massachusetts evaluating a mandate*
- ✓ *New York imposed a “No Wires” solution*
- ✓ *Germany ~15% of energy, BUT have times of 100%*



INDOOR / OUTDOOR FACILITY OPTIONS



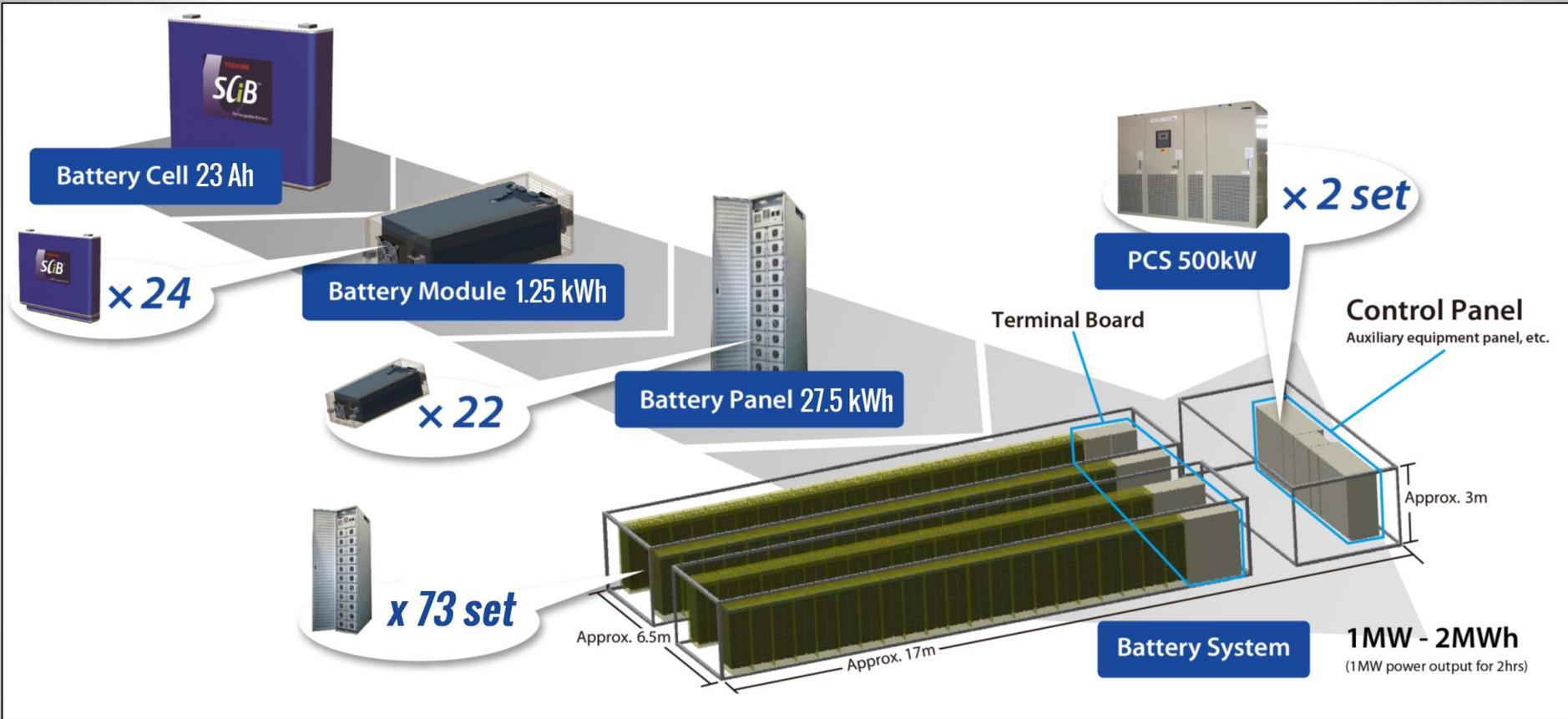
Indoor Facility Advantages:

- *Indoor facility more cost-effective to cool = less fixed Cost*
- *Available indoor space for interactive displays and education*
- *Tourable facility*



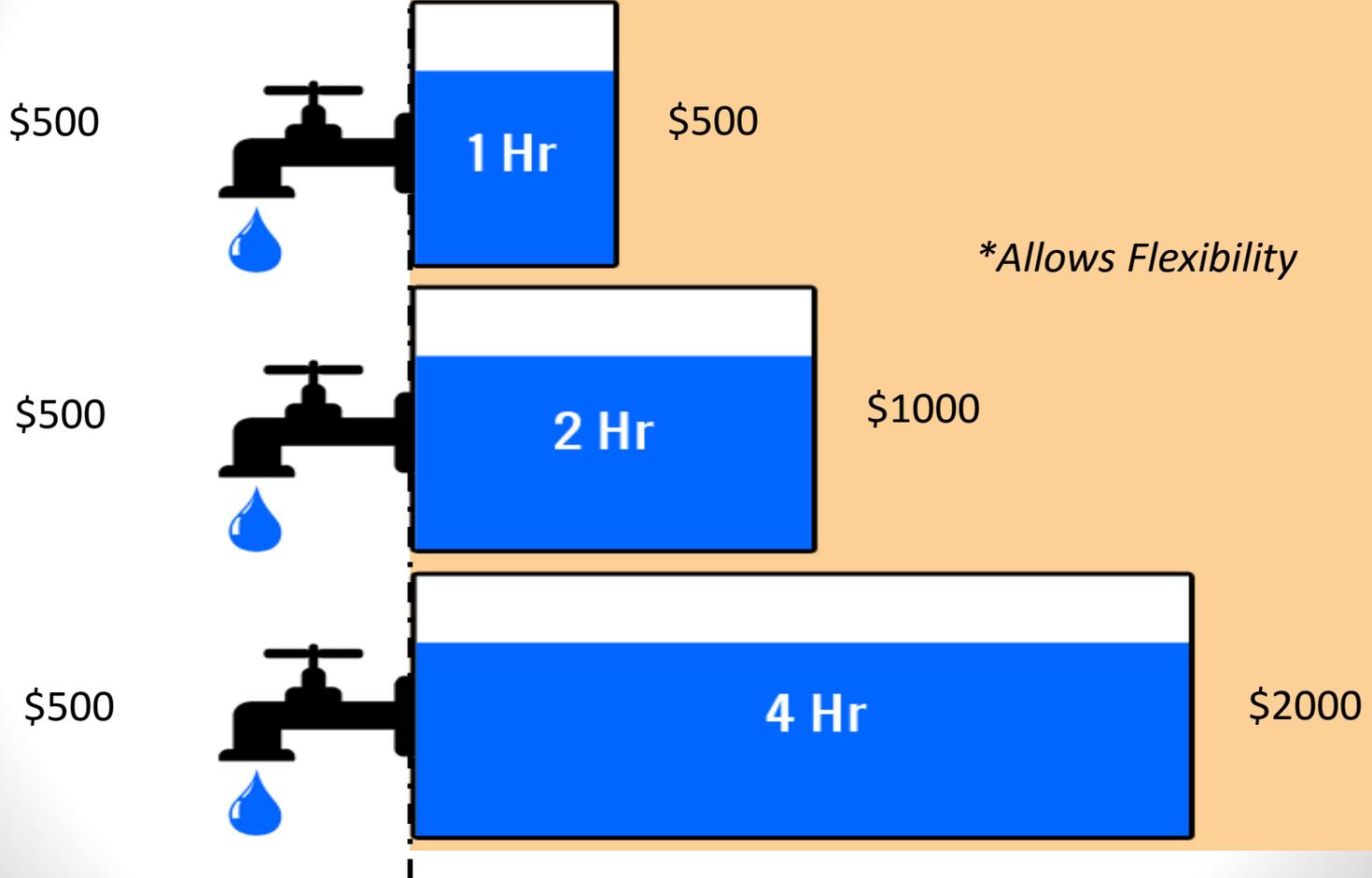
Outdoor Facility Advantages:

- *Faster installation*
- *Mobile*
- *Very modular*

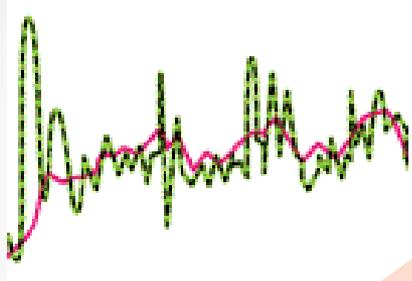
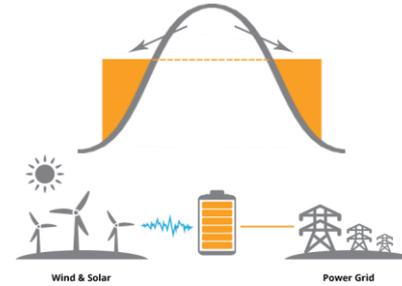
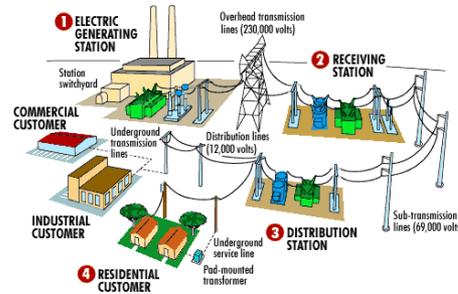


Fixed Cost
Related to Capacity
\$500/kw

Scalable Cost
Related to Duration
\$500/kWh







**Peak Management,
Renewable Integration**

**Load Management,
CAPEX Deferral,
Voltage & Reliability**

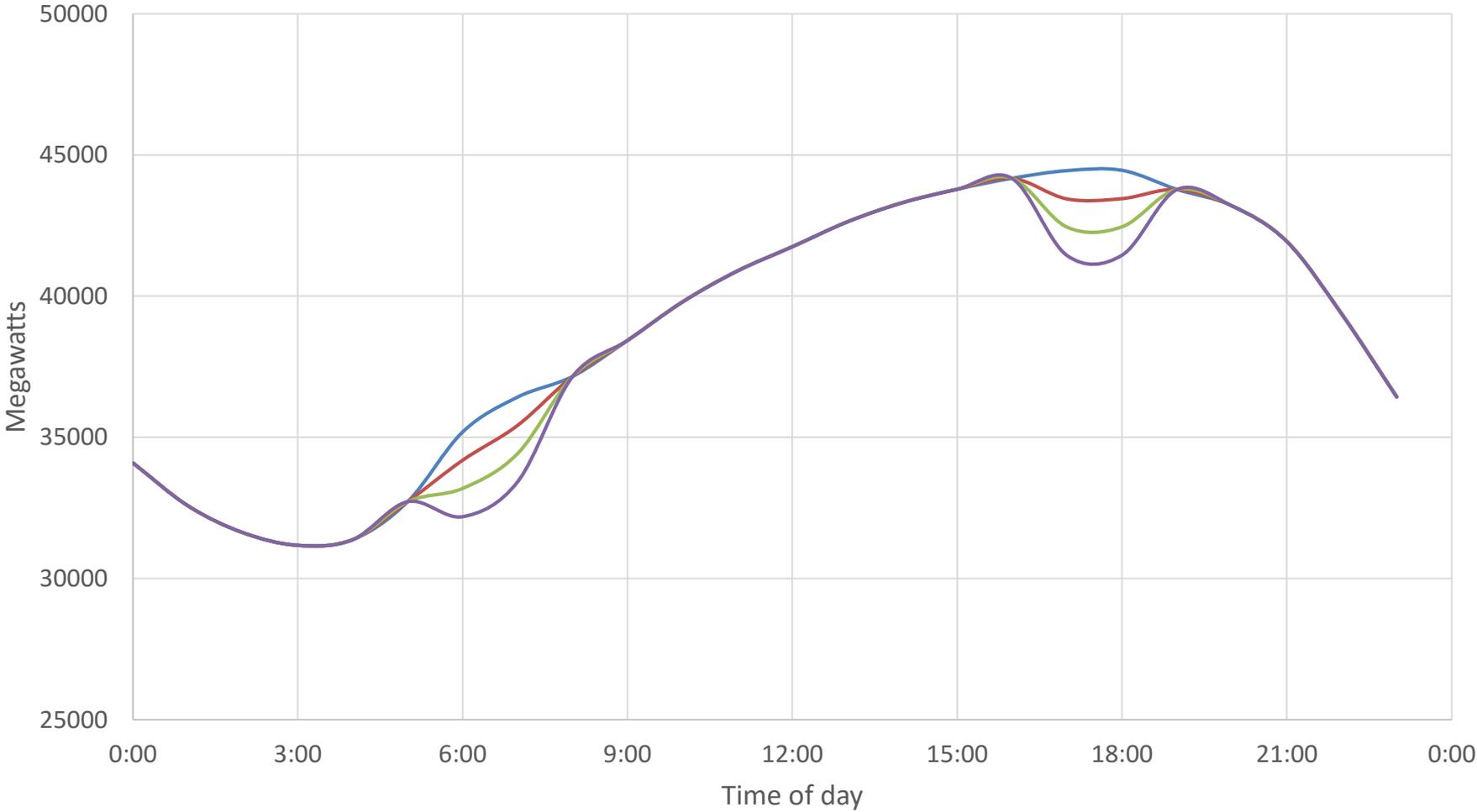
Frequency Response

\$ 3-5 GW
\$3B-\$5B

\$ \$ 25 - 50 GWh
\$12B-\$25B

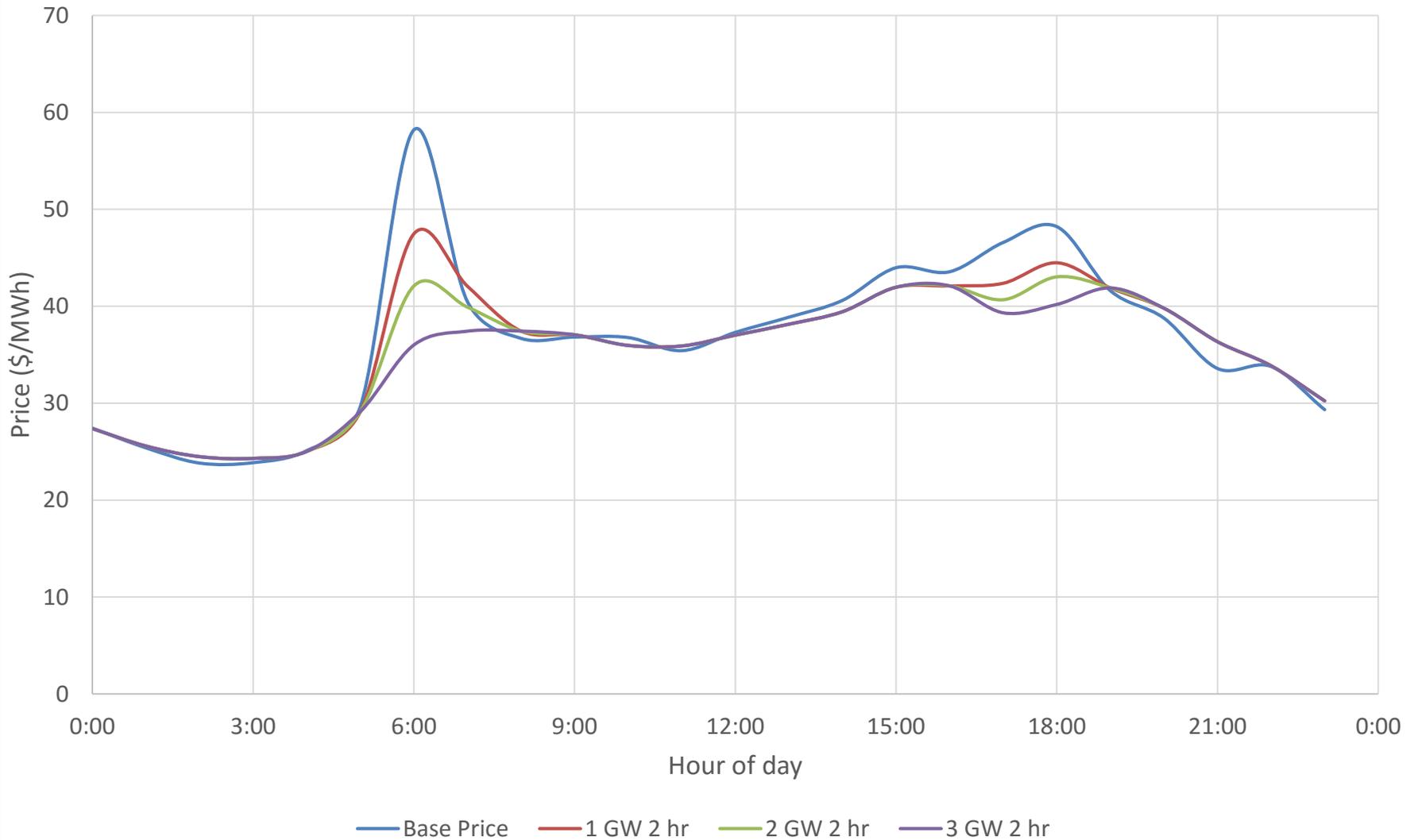
\$ \$ \$ 120 - 240 GWh
\$25B-\$50B

Net Demand with Storage

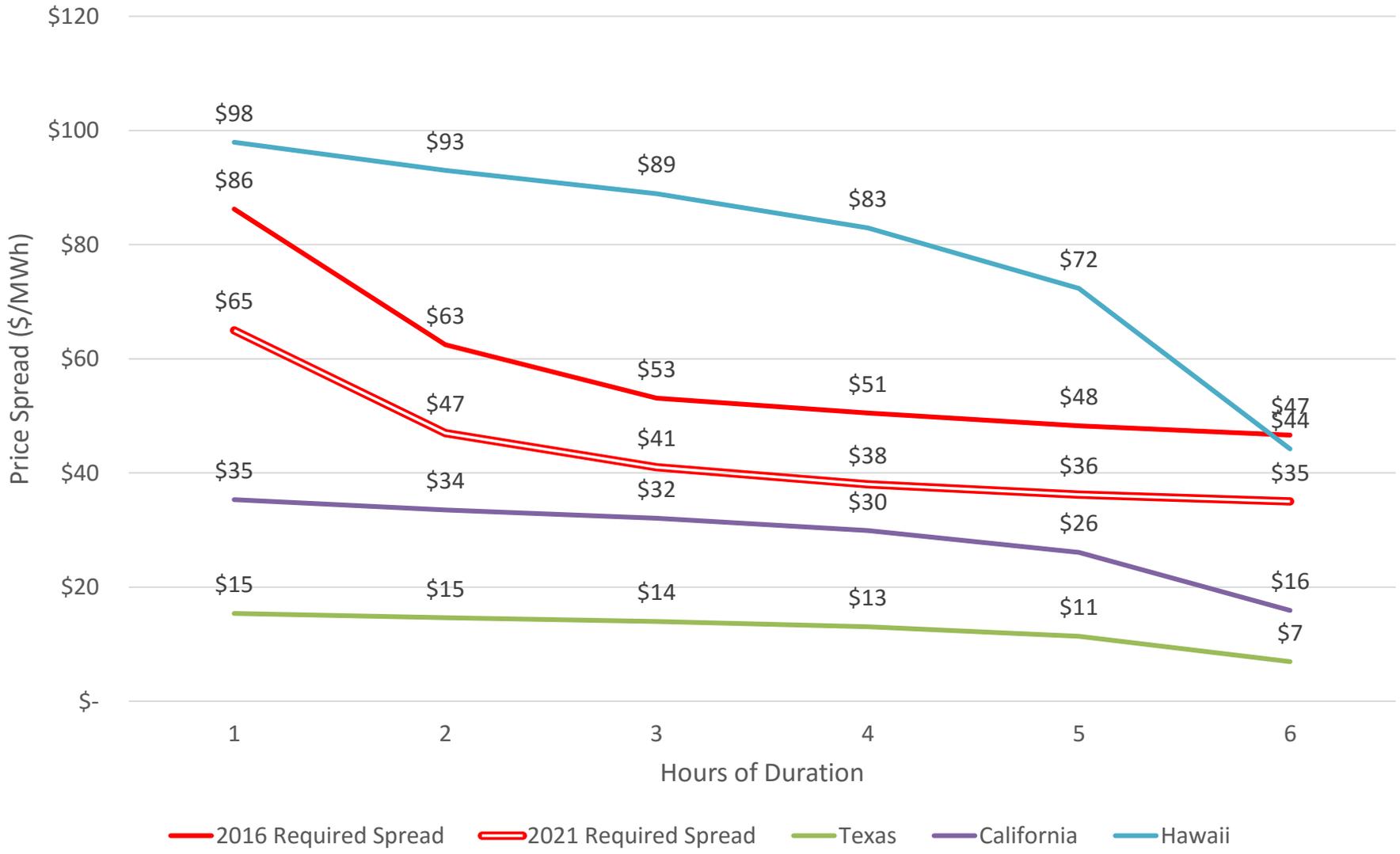


— Base Generation — 1 GW 2 hr — 2 GW 2 hr — 3 GW 2 hr

2014 Hourly Prices with Storage



Price Spreads for Load Shifting



GRID SERVICES

FRRS-Up / FRRS-Down

Non-Spinning Reserves

Reg-Up / Reg-Down

Responsive Reserves

Ramp Support

GRID SERVICES

Emergency Response Services (ERS)

Black Start

Uninterrupted Power Supply (UPS)

PEAK MANAGEMENT

Load Shifting

Resource Adequacy / Capacity

Demand Charge Mitigation

Transmission Fee Mitigation

Real-Time Arbitrage

Generation Deferral

Operating Reserves

Congestion Relief

RENEWABLE INTEGRATION

Firming

Smoothing

Shaping

Curtailement Reduction

Time Shifting

POWER QUALITY / RELIABILITY

Voltage Support

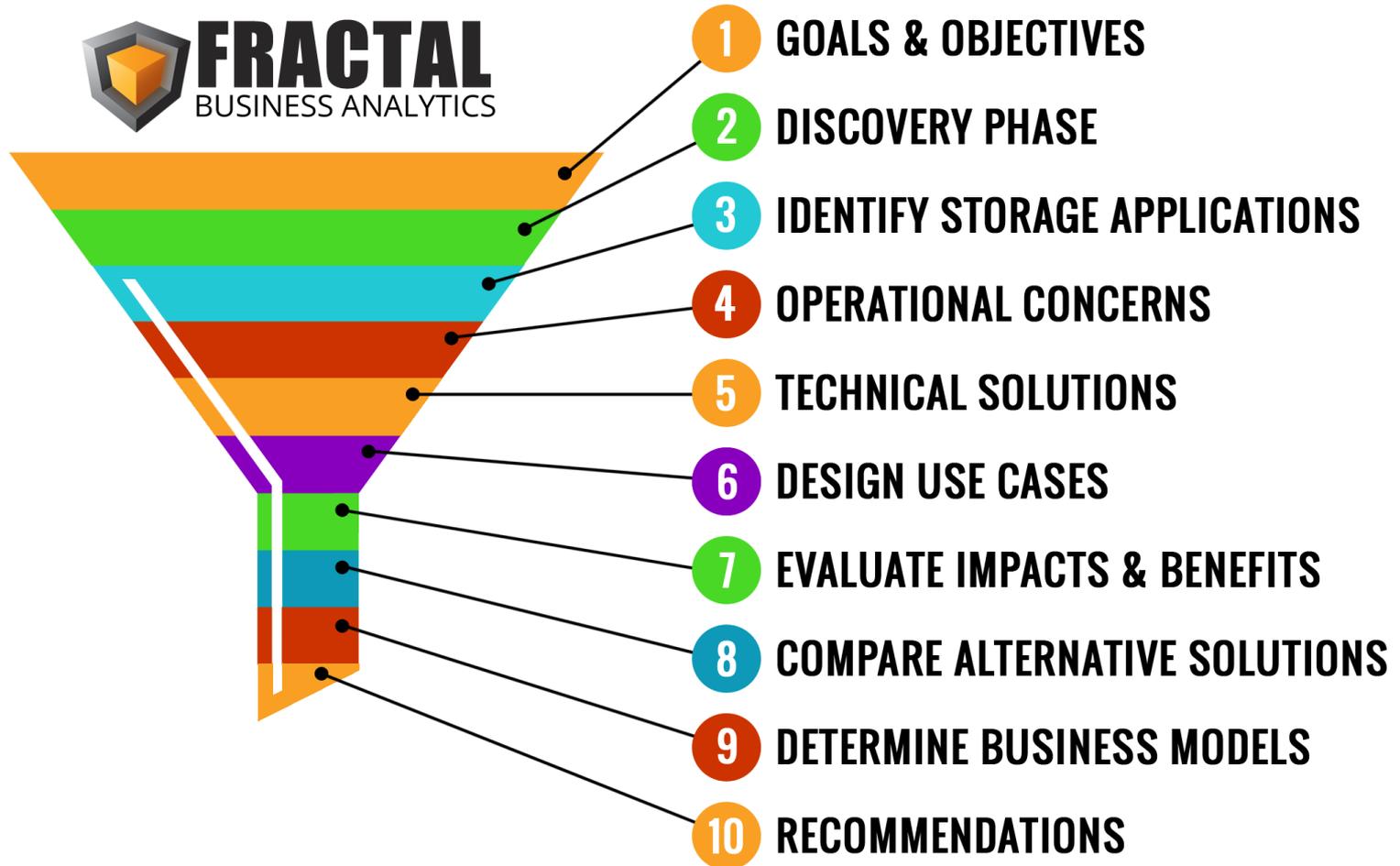
VAR Support

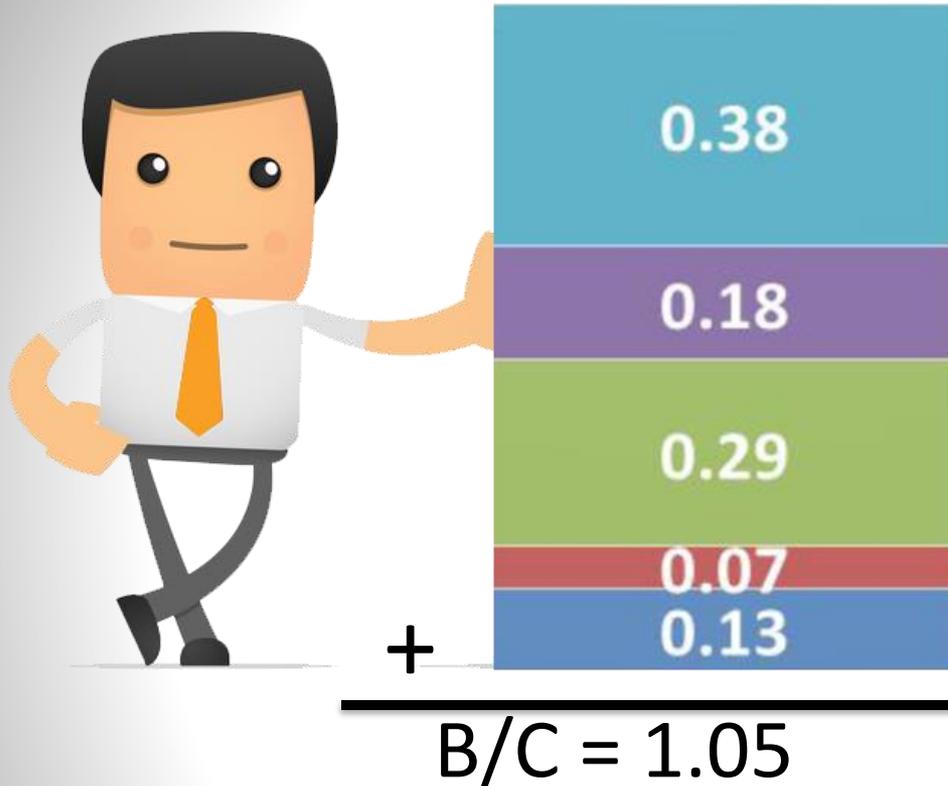
Line Loss Reduction

Outage Mitigation

Power Factor

Applications	Duration	2016
<i>Ancillary Services</i>		
FRRS	30 min	1.65
Reg Up / Reg Dn	2 hour	0.87
Responsive Reserves	2 hour	0.60
Non-Spin	2 hour	0.24
Ramp Support	30 min	0.31
<i>Renewable / DG Integration</i>		
Firming, Smoothing, Shaping	2 hour	0.03
<i>Peak Management</i>		
Demand Charge Mitigation	2 hour	0.72
Real-Time Arbitrage	30 min	0.43
Demand Response	2 hour	0.40
4CP + Arbitrage	1 hour	0.32
Load Shifting (two 4-hr shifts)	4 hour	0.16
Load Shifting (one 2-hr shift)	2 hour	0.08
<i>Emergency Services</i>		
Emergency Response Services (ERS)	2 hour	0.35
Black Start Services	2 hour	0.05
<i>Power Quality / Reliability</i>		
T&D Deferral / Cost Avoidance *	2 hour	0.13
Power Factor	2 hour	0.06
Congestion Relief	2 hour	0.07





Fractal's Objectives:

Determine technically and financially viable energy storage business models:

- ✓ *Generate New Revenue*
- ✓ *Achieve Cost Savings*
- ✓ *Increase Reliability*
- ✓ *Hedge Against Future Risk*
- ✓ *Address Current Operational Challenges*

$$B/C = PV \text{ Benefits} / PV \text{ Costs}$$

BATTERY STORAGE (MW)

077

SOLAR ENERGY (MW)

008

WIND ENERGY (MW)

613



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BUSINESS ANALYTICS



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