



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



www.FractalBA.com



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?

Which chemistry is best?

Are we allowed to own it?

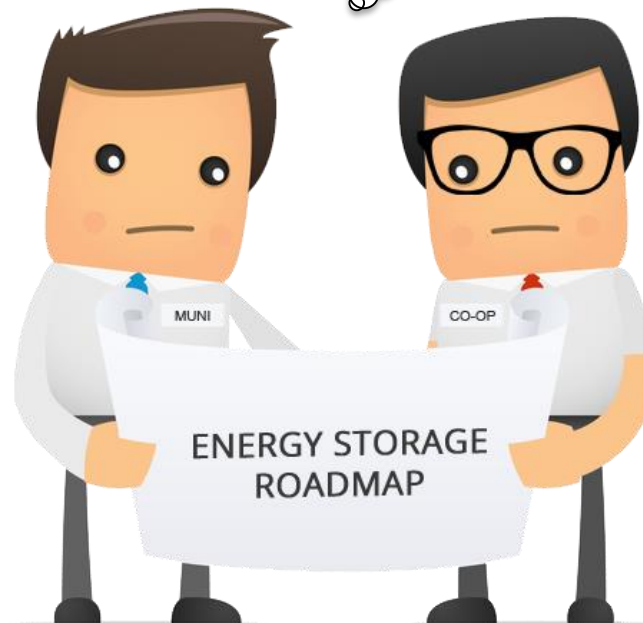
Where do we put it?

**What size system do
we need?**

What are the risks?

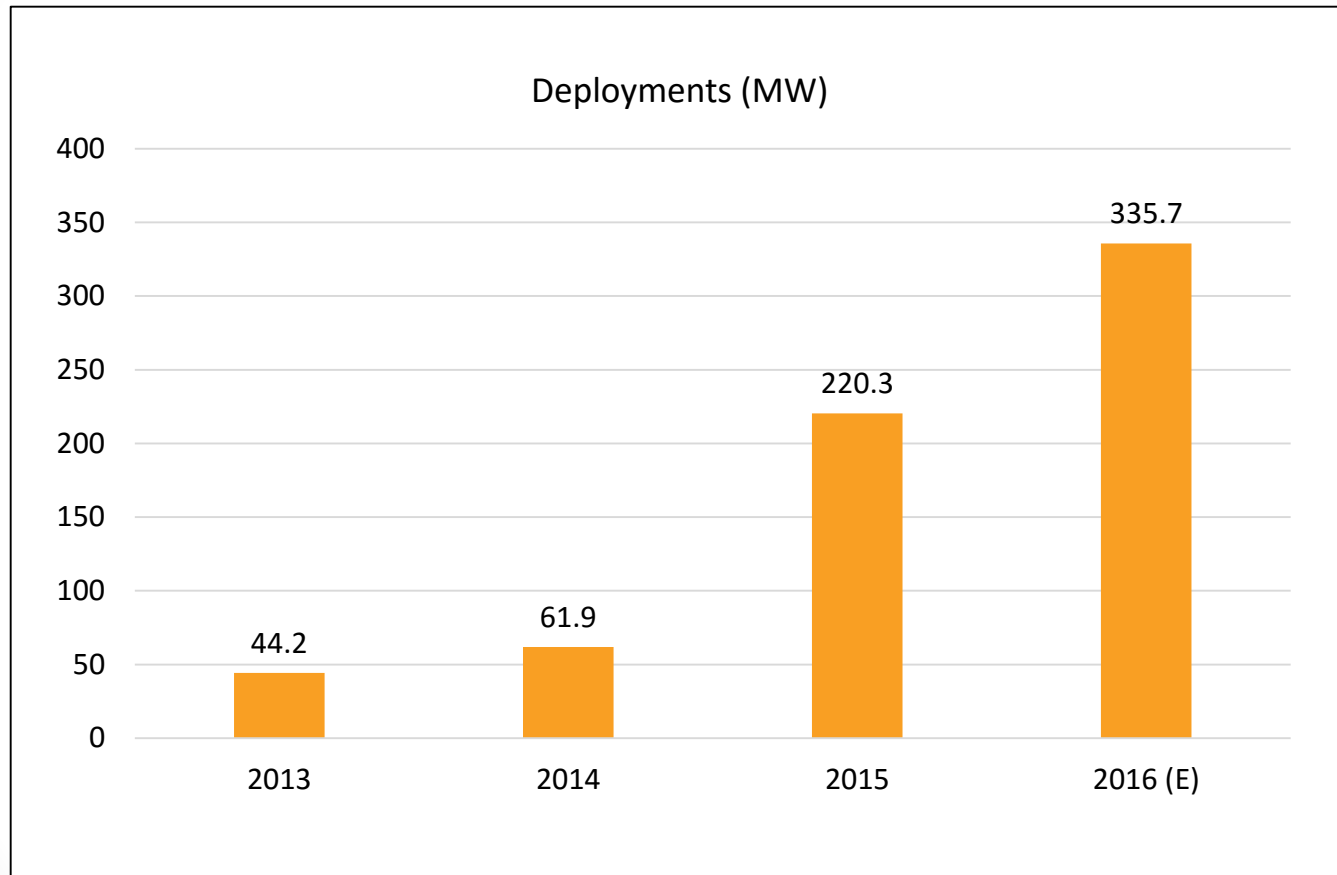
Is storage cost-effective yet?

How long does it take?

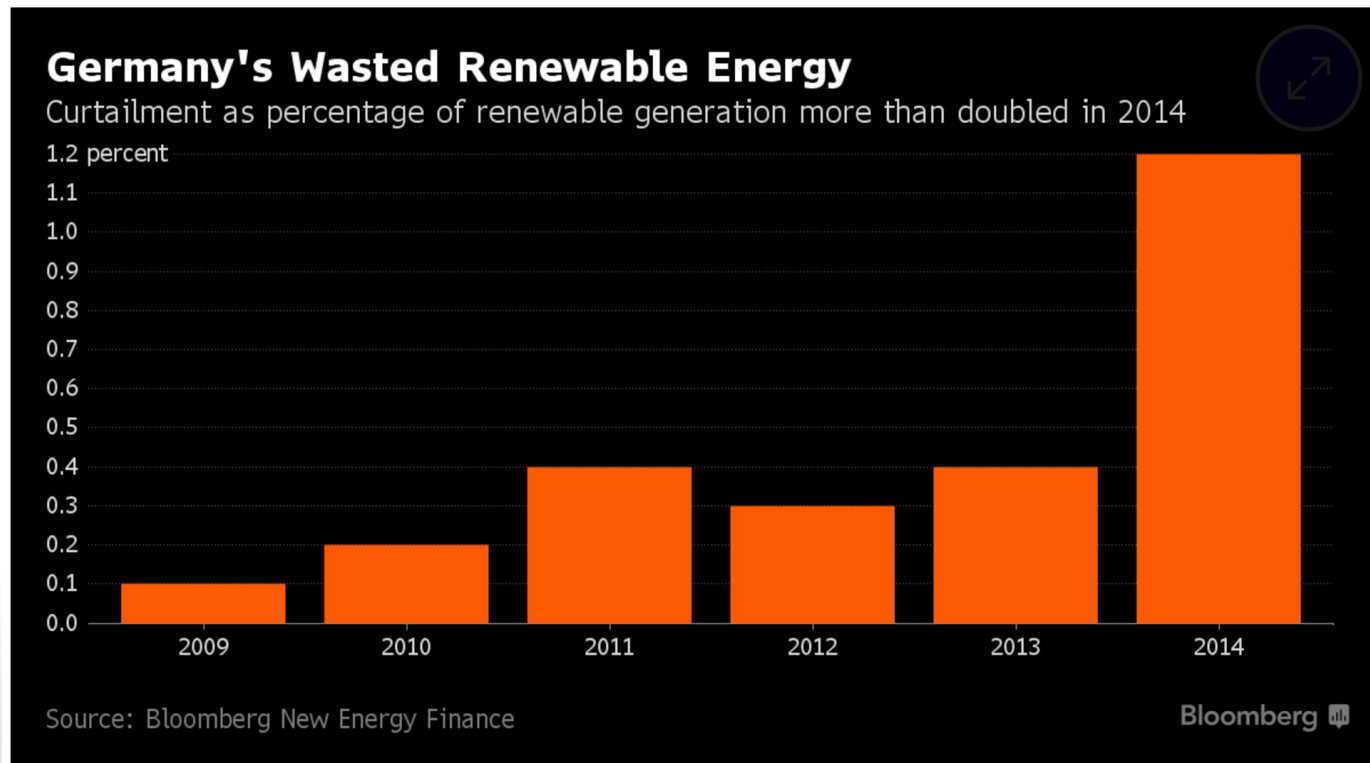


What are the economical business models that make sense for us?

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



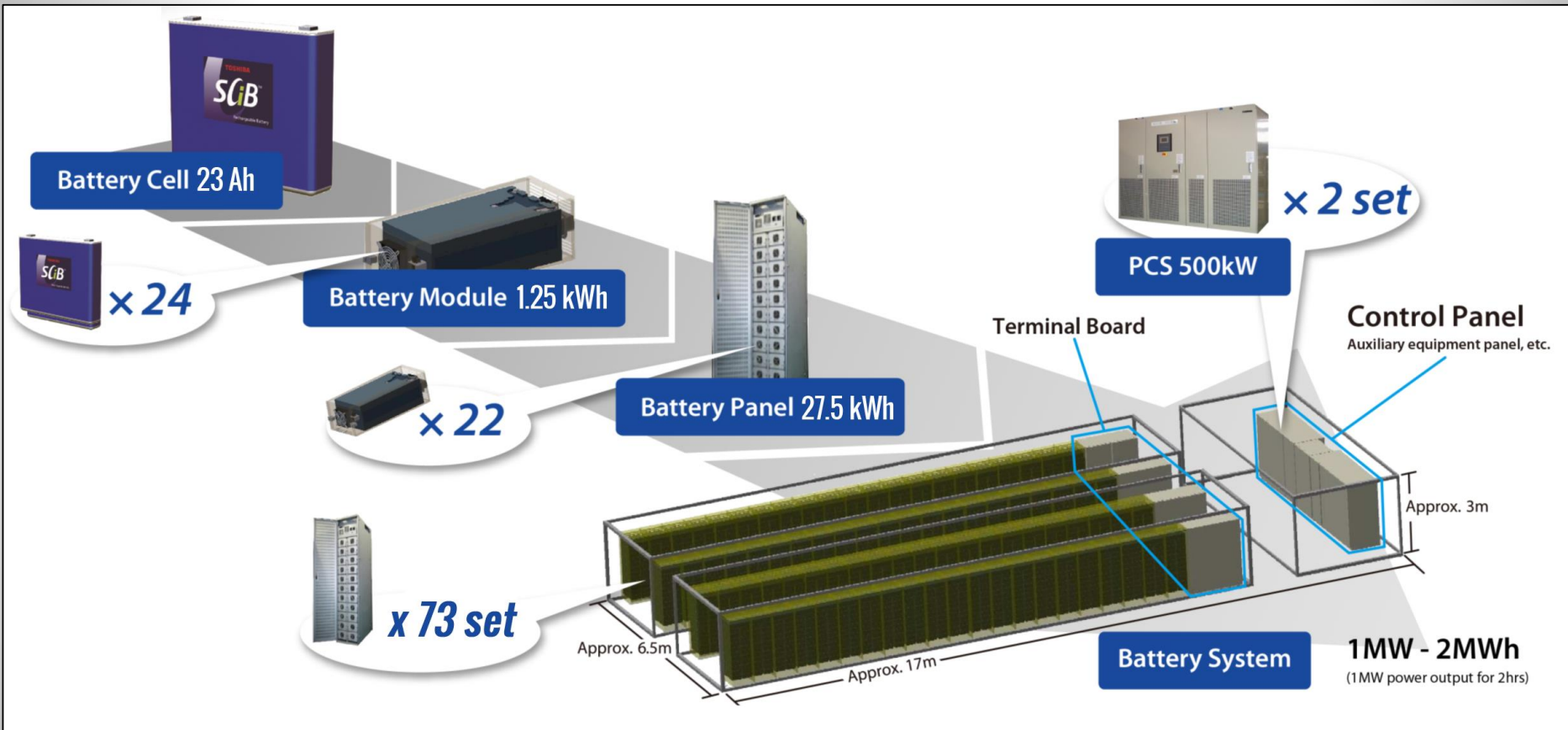
Indoor Facility Advantages:

- *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

\$500



1 Hr

\$500

\$500



2 Hr

\$1000

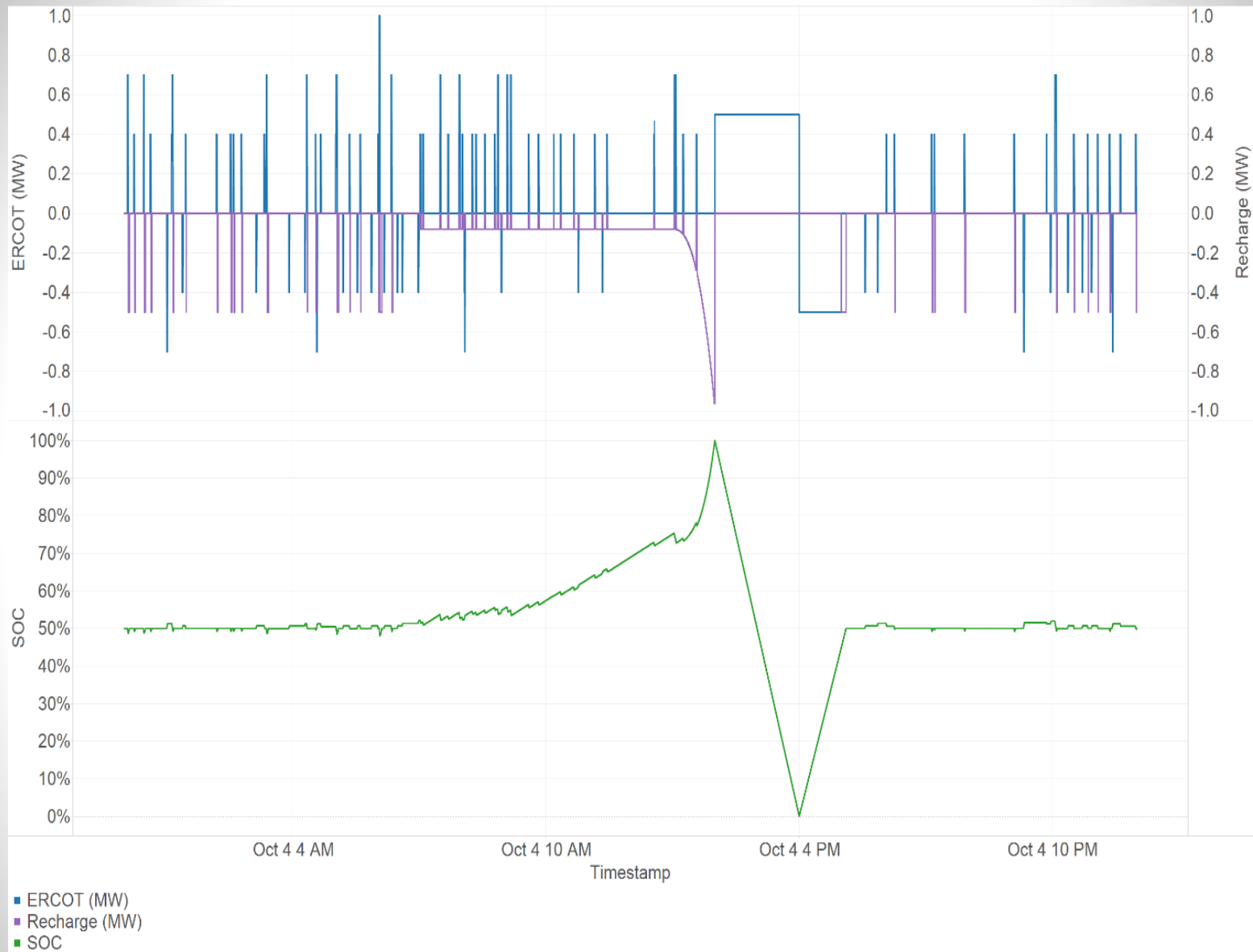
\$500

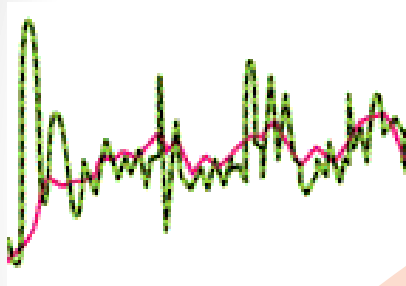
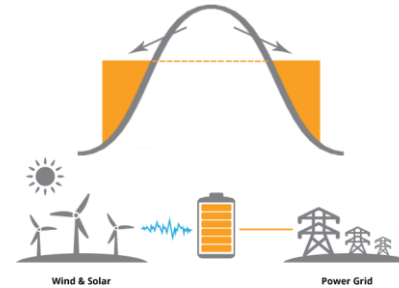
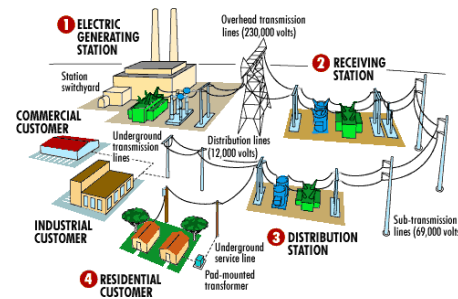


4 Hr

\$2000

**Allows Flexibility*





**Peak Management,
Renewable Integration**

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

Frequency Response



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

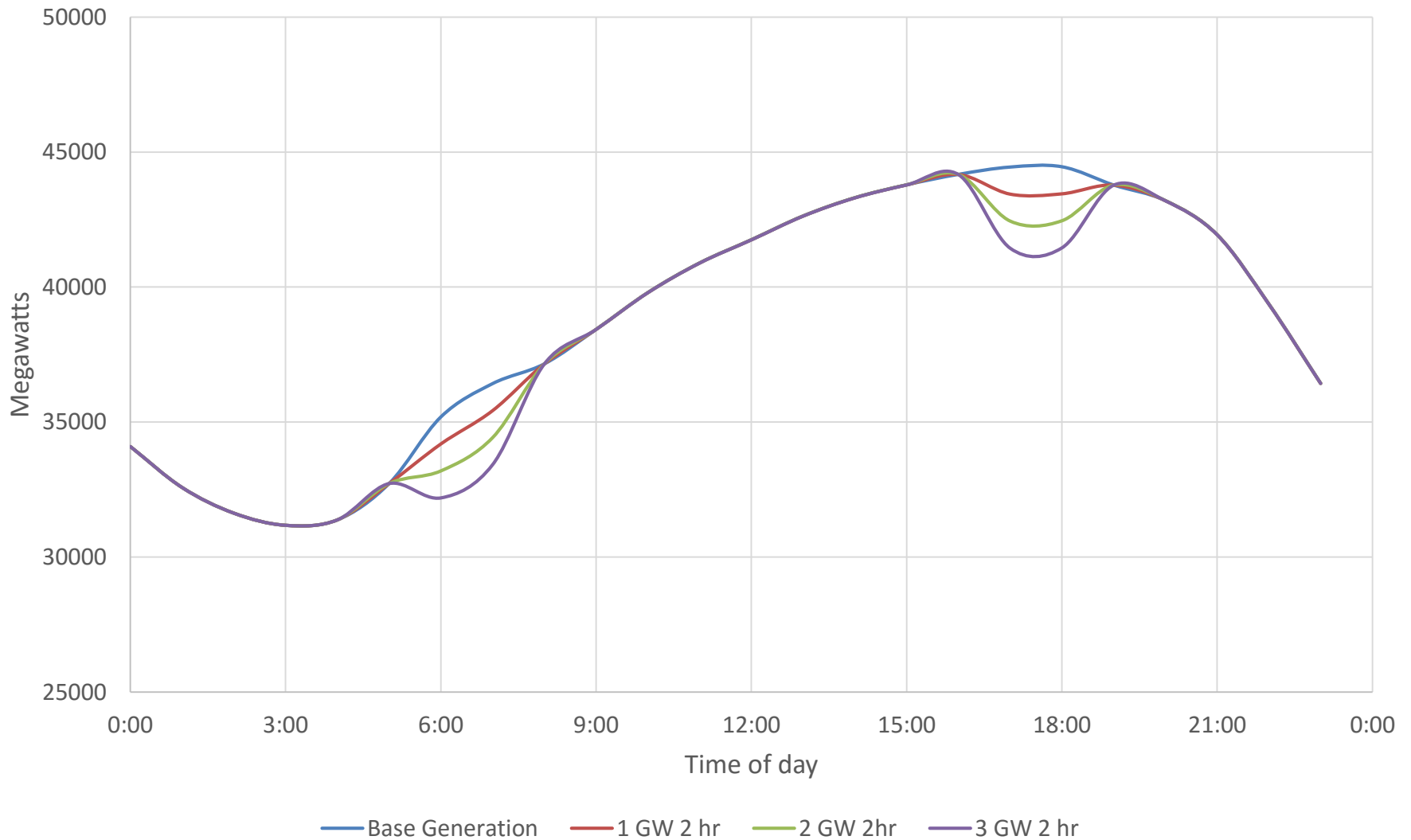


25 - 50 GWh
\$12B-\$25B

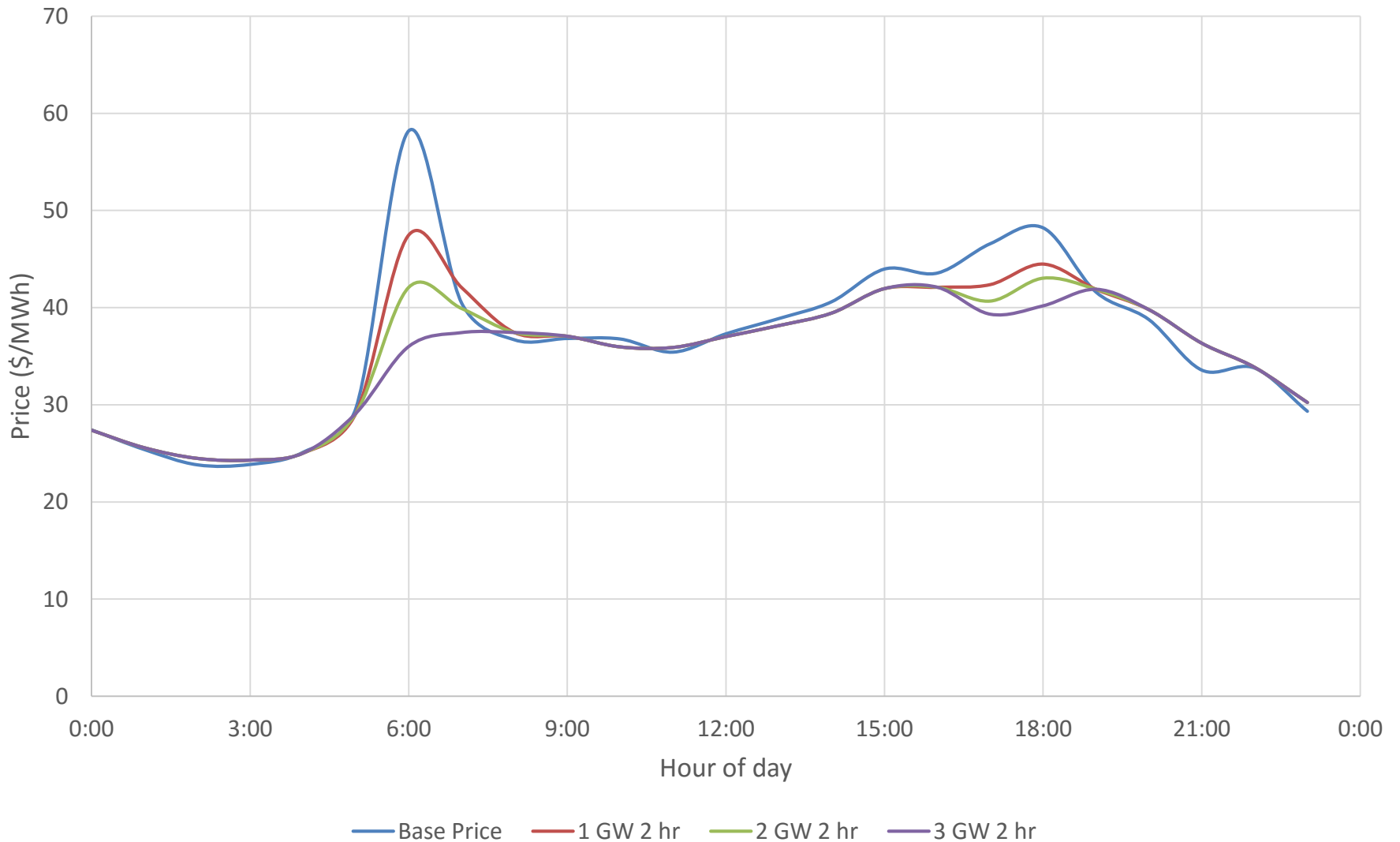


120 - 240 GWh
\$25B-\$50B

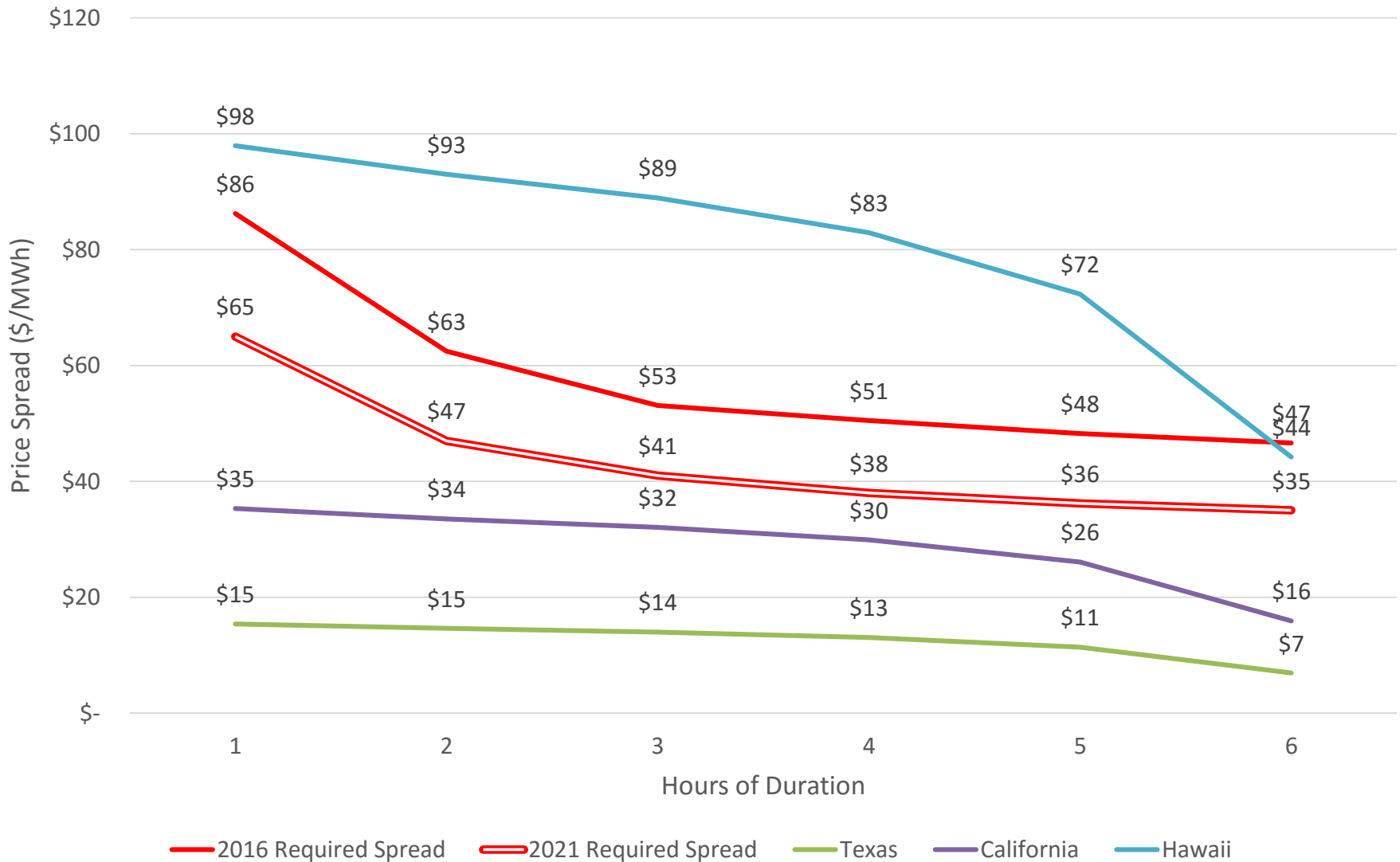
Net Demand with Storage



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

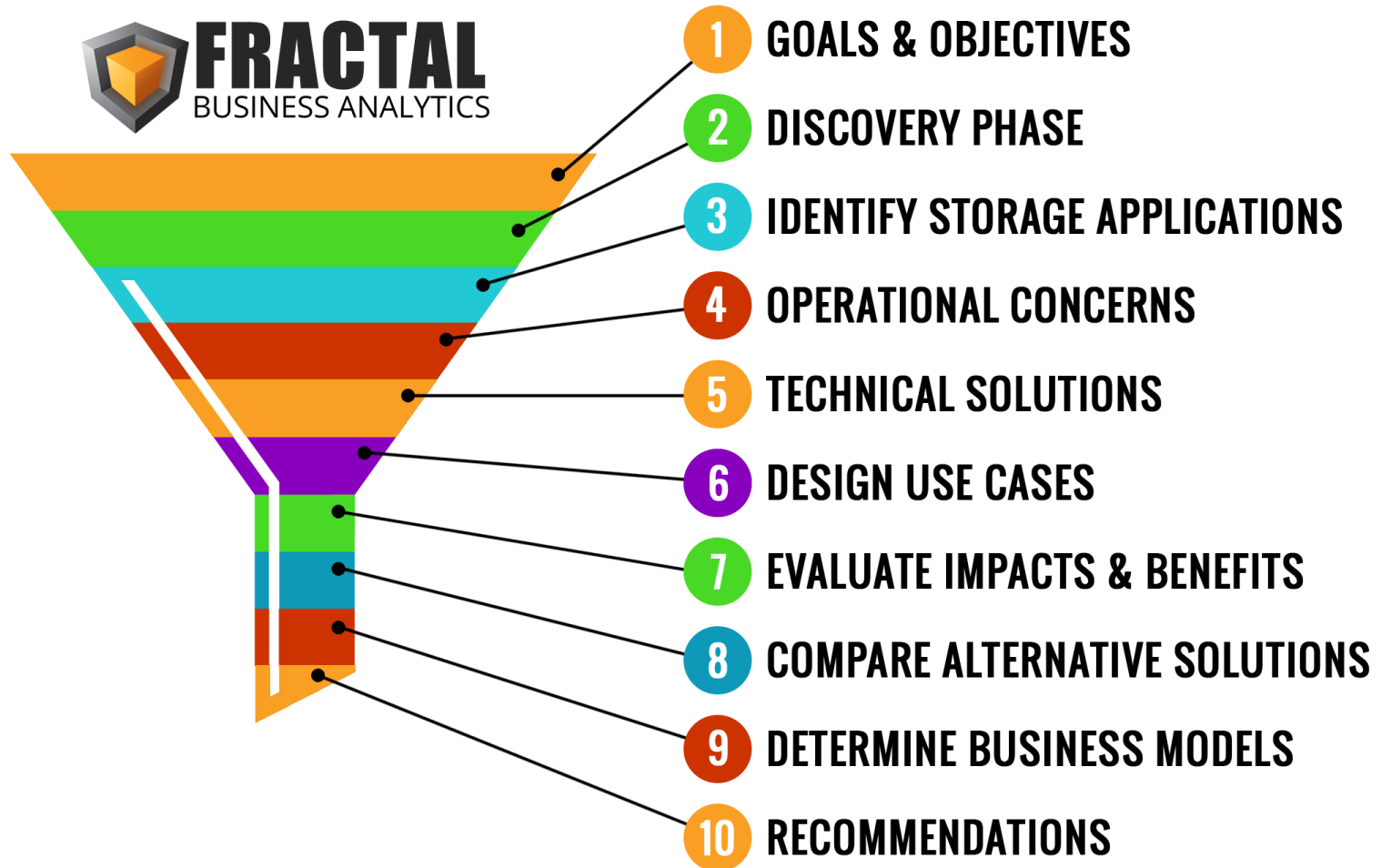
VAR Support

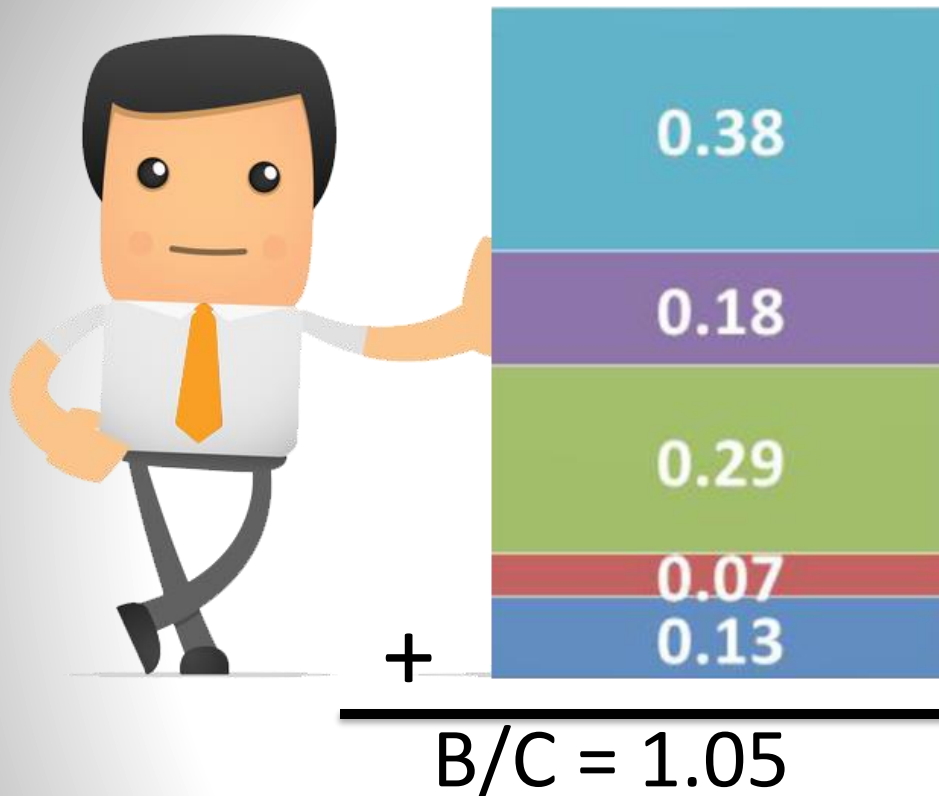
Line Loss Reduction

Outage Mitigation

Power Factor

Applications	Duration	2016
Ancillary Services		
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
Renewable / DG Integration		
Firming, Smoothing, Shaping	2 hour	0.03
Peak Management		
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
Emergency Services		
Emergency Response Services (ERS)	2 hour	0.35
Black Start Services	2 hour	0.05
Power Quality / Reliability		
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



FRACTAL
BUSINESS ANALYTICS



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