The Evolving Role of Energy Storage in Power System Planning and Operations

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2019 FALL TECHNIICAL WORKSHOP

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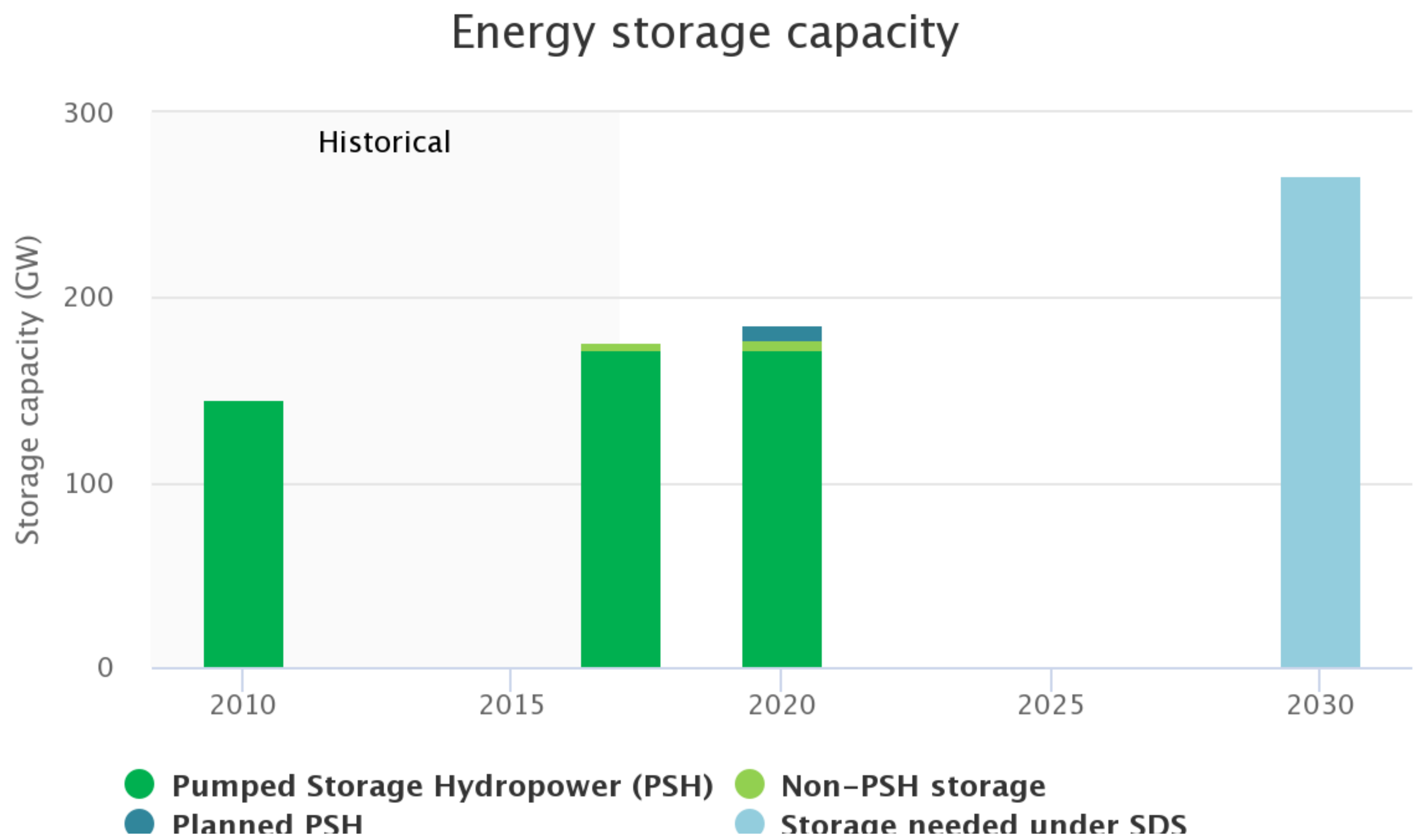
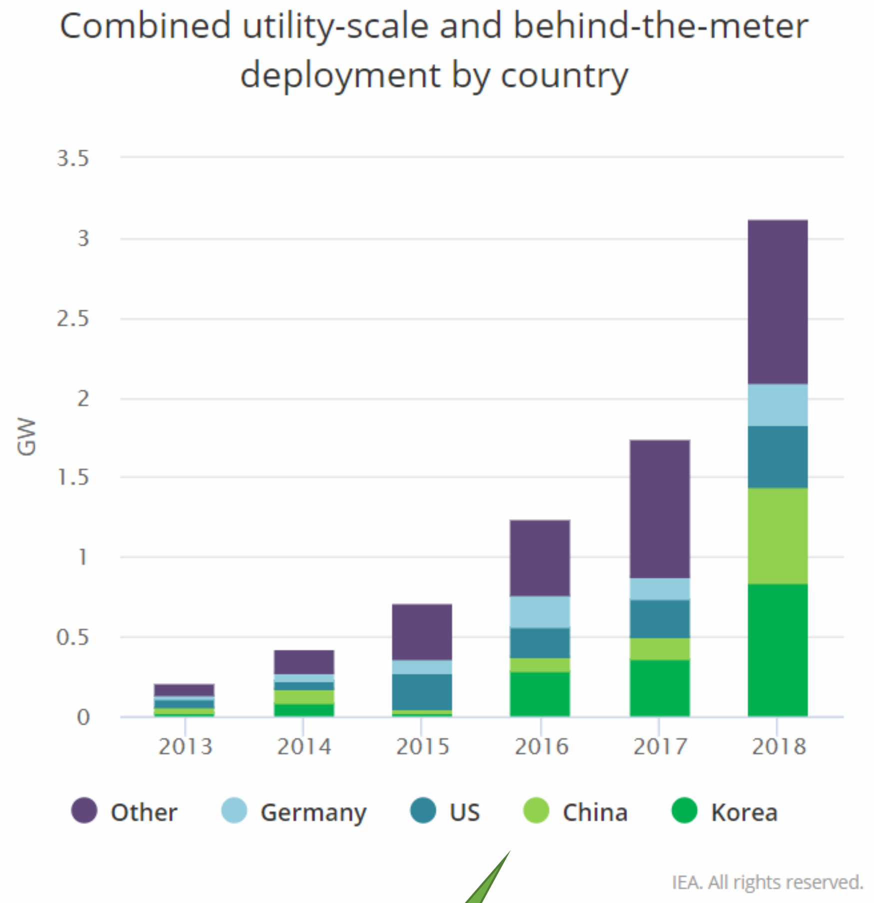
Hilton Charlotte Center City, Charlotte, NC

World Energy Storage: PSH and everything else





No PSH?

U.S.

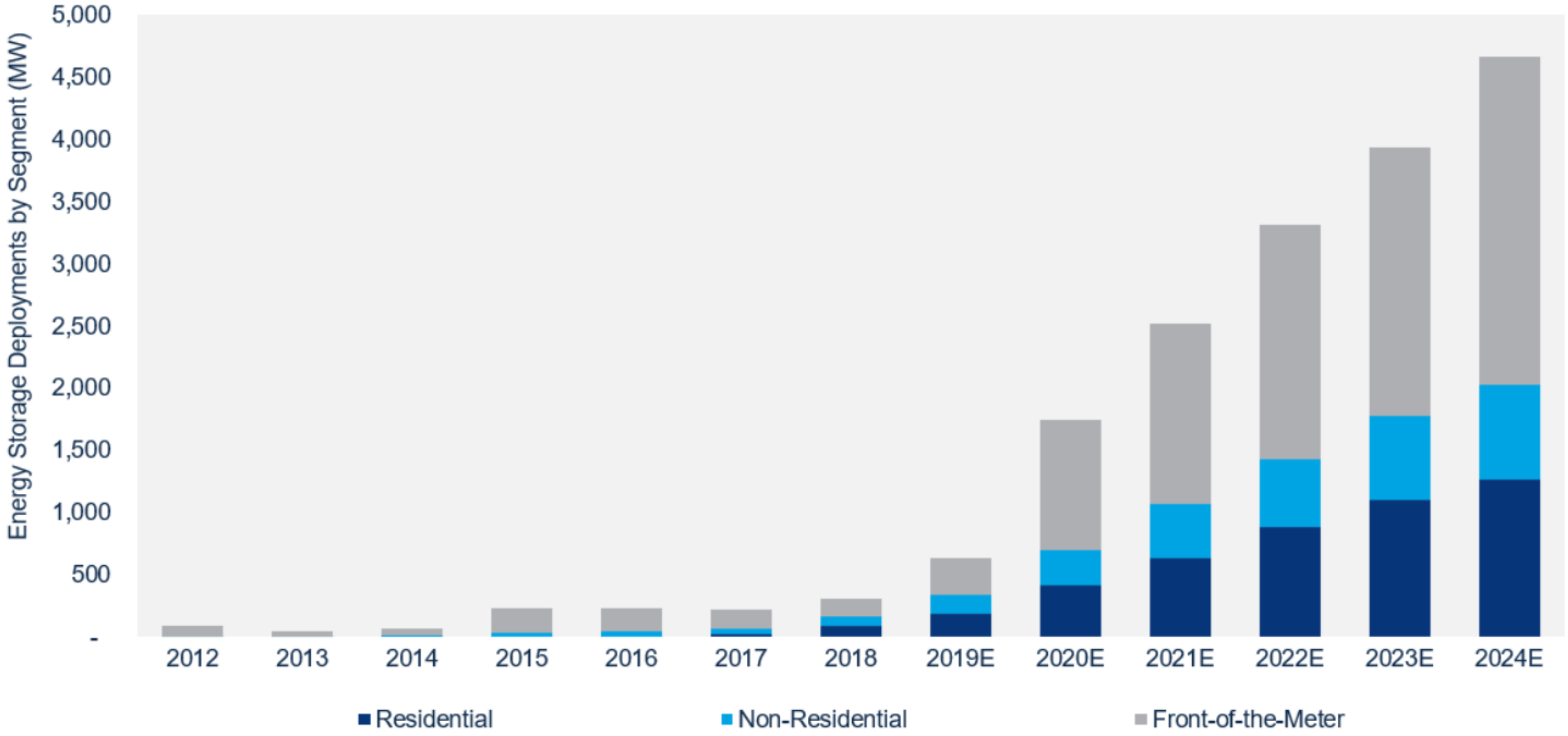
BTM: Residential + other

Projected to be about equal to grid (FTM)

U.S. energy storage annual deployments will reach 4.7 GW by 2024

Utility procurements, changing tariffs and grid service opportunities all drive the market forward

U.S. energy storage annual deployment forecast, 2012-2024E (MW)



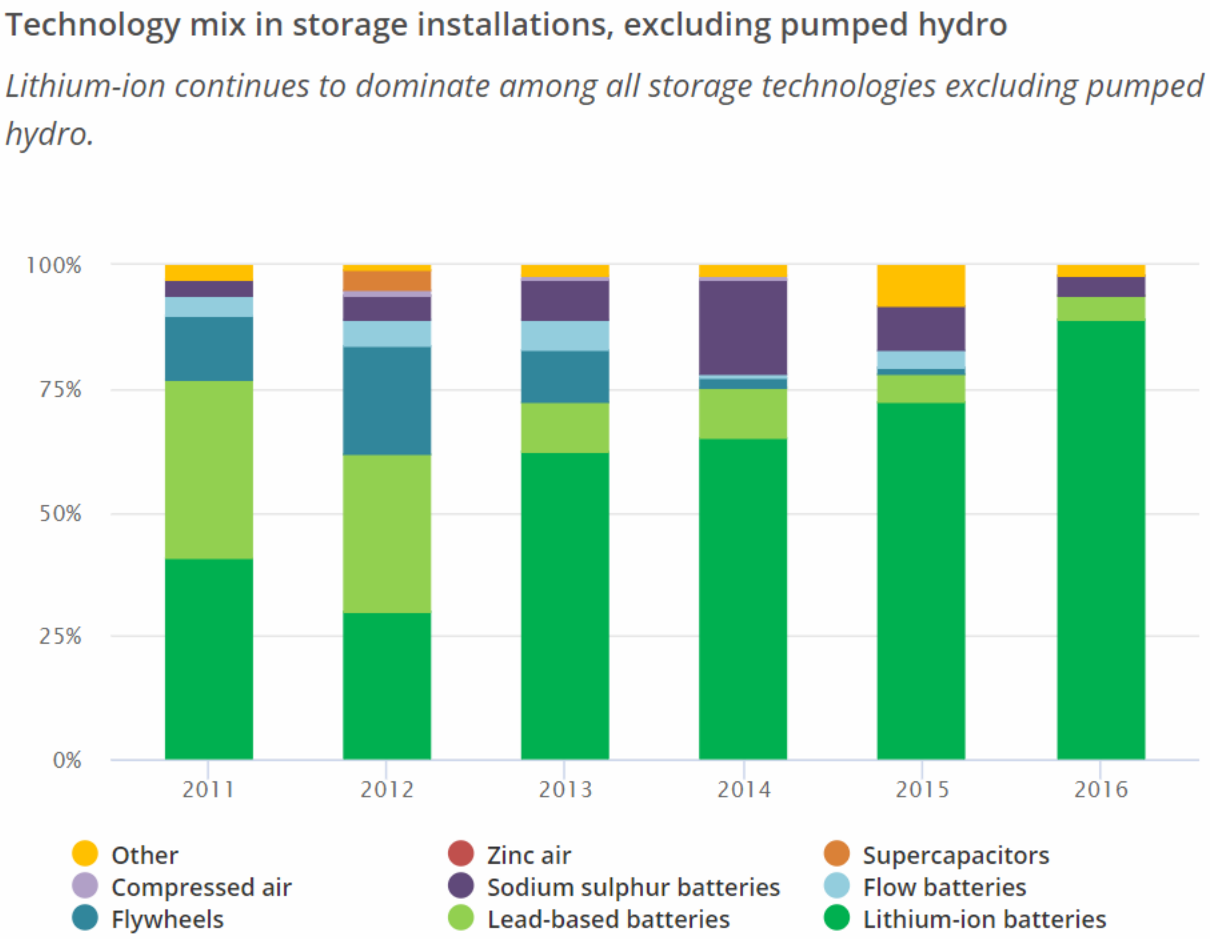
Source: Wood Mackenzie Power & Renewables

A Battery Technology Horse Race?

- Not so much

- ~ 100kg/MWh (0.1MT/MWh)
- 85,000 MT Li produced in 2018
- ~= 850GWH

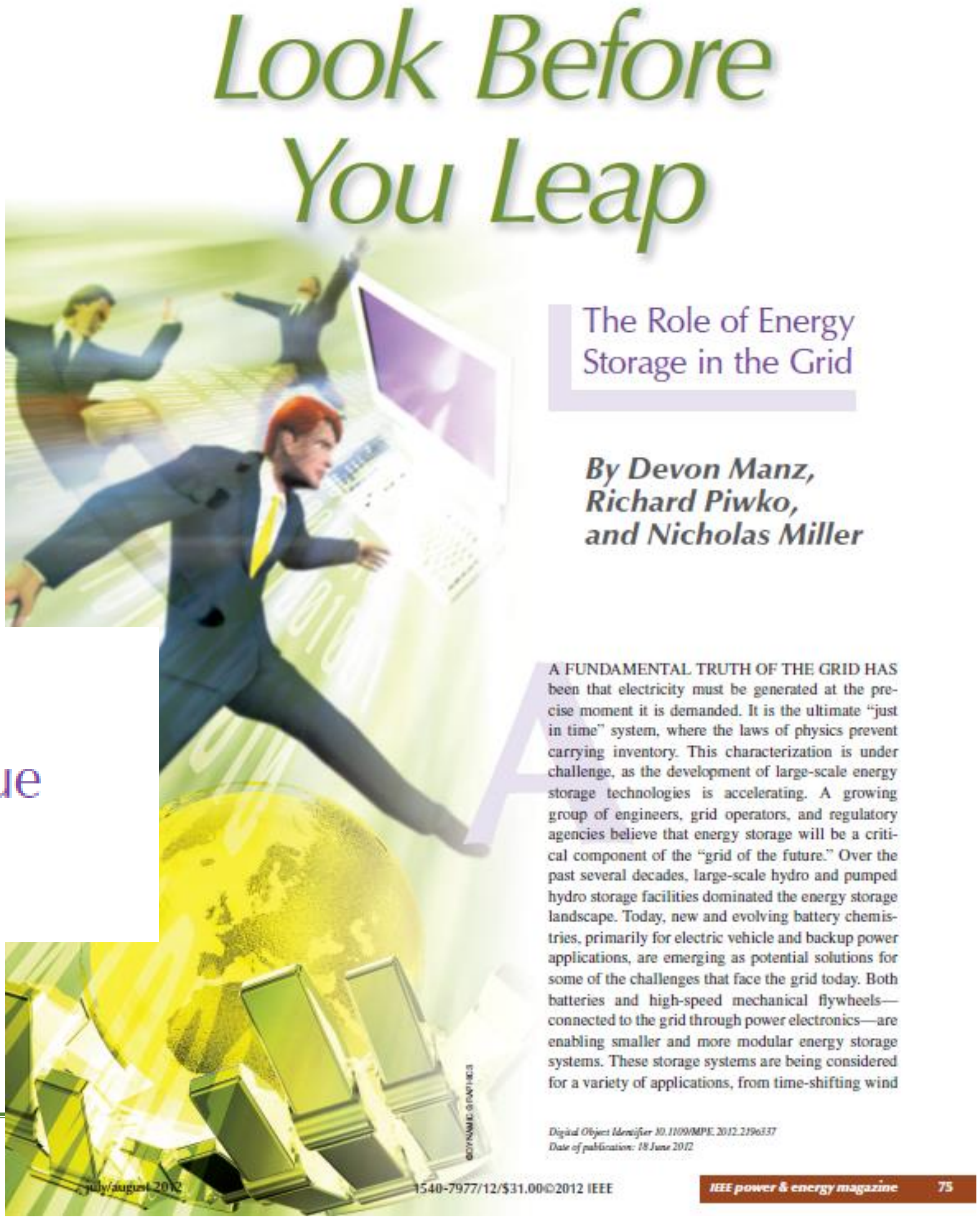
Lithium brine pools in Chile. Image courtesy of Reuters.



Looking Back

- July 2012 IEEE Article
- Be careful of predictions, especially about the future
- We got many things right:

The authors have not yet identified
a single power system operation or performance issue
for which storage is the *only* solution.



Look Before You Leap

The Role of Energy Storage in the Grid

By Devon Manz, Richard Piwko, and Nicholas Miller

A FUNDAMENTAL TRUTH OF THE GRID HAS been that electricity must be generated at the precise moment it is demanded. It is the ultimate "just in time" system, where the laws of physics prevent carrying inventory. This characterization is under challenge, as the development of large-scale energy storage technologies is accelerating. A growing group of engineers, grid operators, and regulatory agencies believe that energy storage will be a critical component of the "grid of the future." Over the past several decades, large-scale hydro and pumped hydro storage facilities dominated the energy storage landscape. Today, new and evolving battery chemistries, primarily for electric vehicle and backup power applications, are emerging as potential solutions for some of the challenges that face the grid today. Both batteries and high-speed mechanical flywheels—connected to the grid through power electronics—are enabling smaller and more modular energy storage systems. These storage systems are being considered for a variety of applications, from time-shifting wind

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Digital Object Identifier 10.1109/MPE.2012.2196337
Date of publication: 18 June 2012

4 hours was “energy applications”

- In 2012, the only function we could really see adding up for BESS was REG
- Resource Adequacy: “ES may offer a competitive alternative to constructing new plants” …
- We missed the retirement angle

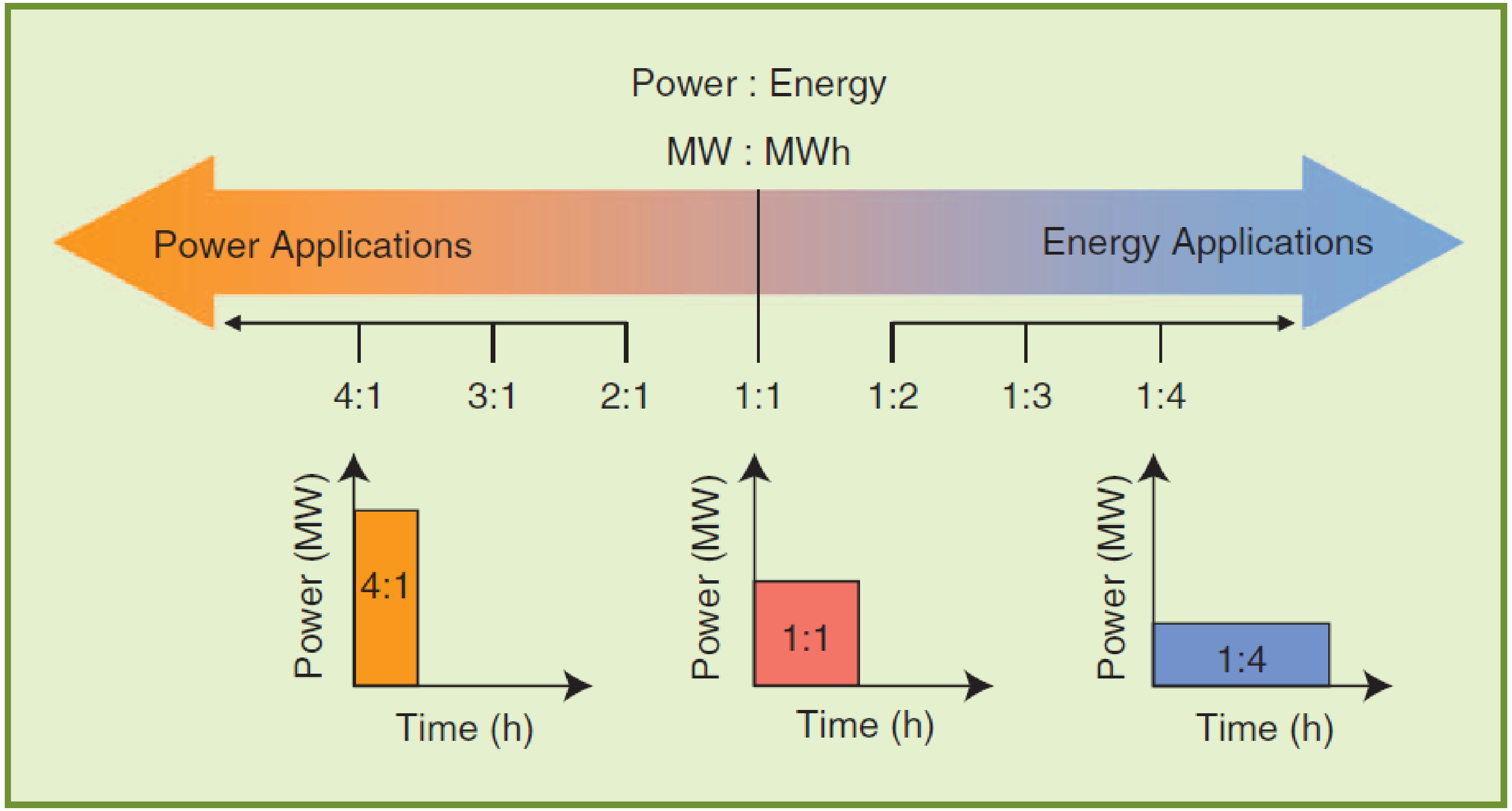


figure 1. The continuum of energy storage applications and technologies.

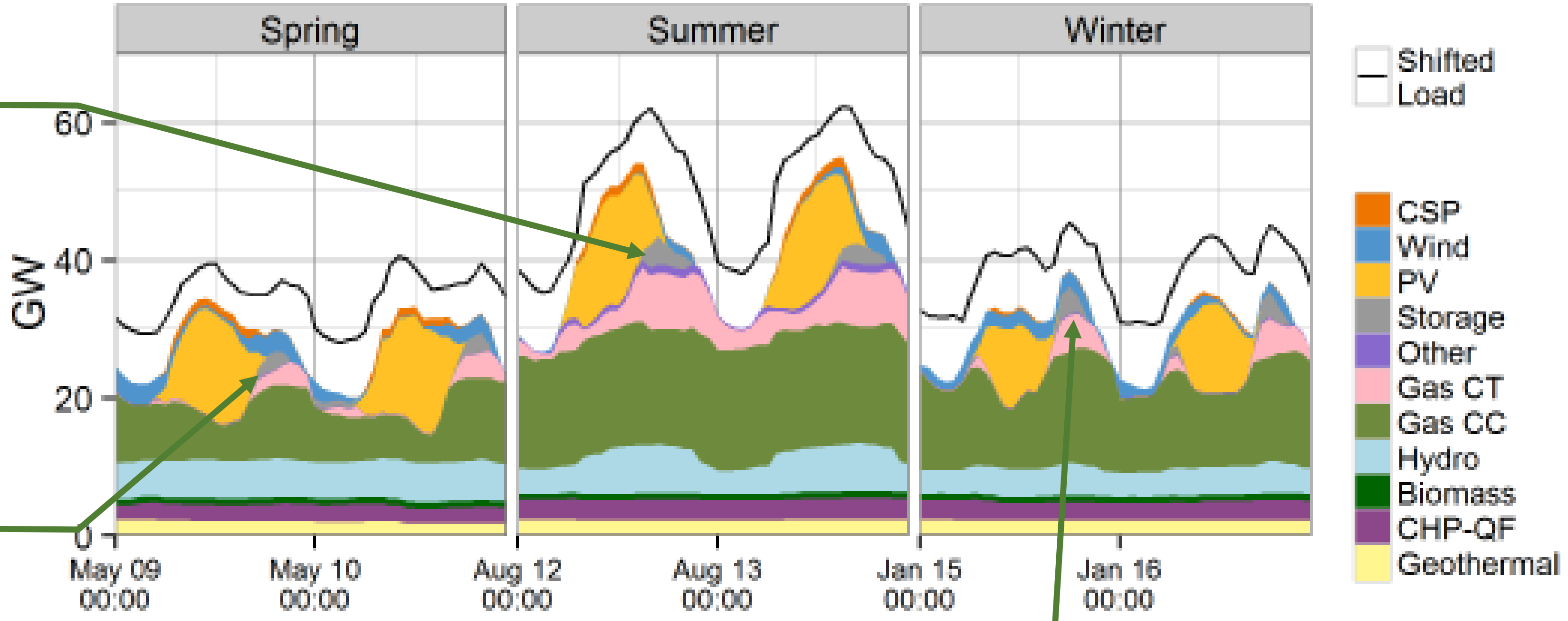
Source: Manz, Piwko, Miller “Look Before You Leap: The role of Energy Storage in the Grid” IEEE P&E Magazine 2012

Storage Operations produce Holistic Benefits:

System VOC, Avoided Curtailment and Carbon Reduction are key metrics in a compliant low carbon future:

Fill-in during Duck (sunset) ramps

Reduced curtailment at low/min load



Agility during spiky winter peaks

Source: CEERTS Low Carbon Grid Study 2014

But how to get $ to the investor?   Arbitrage

- Everybody expects it
- “buy low, sell high. What’s not to like?”
- *It doesn’t add up*
- Necessary, but not sufficient
- *Arbitrage eats its own lunch*
- In 2012, we thought $1000/kw was the floor…for 8 hours…. Not far off, eh?
- With cheap gas, often on the margin, arbitrage is going to remain a challenge

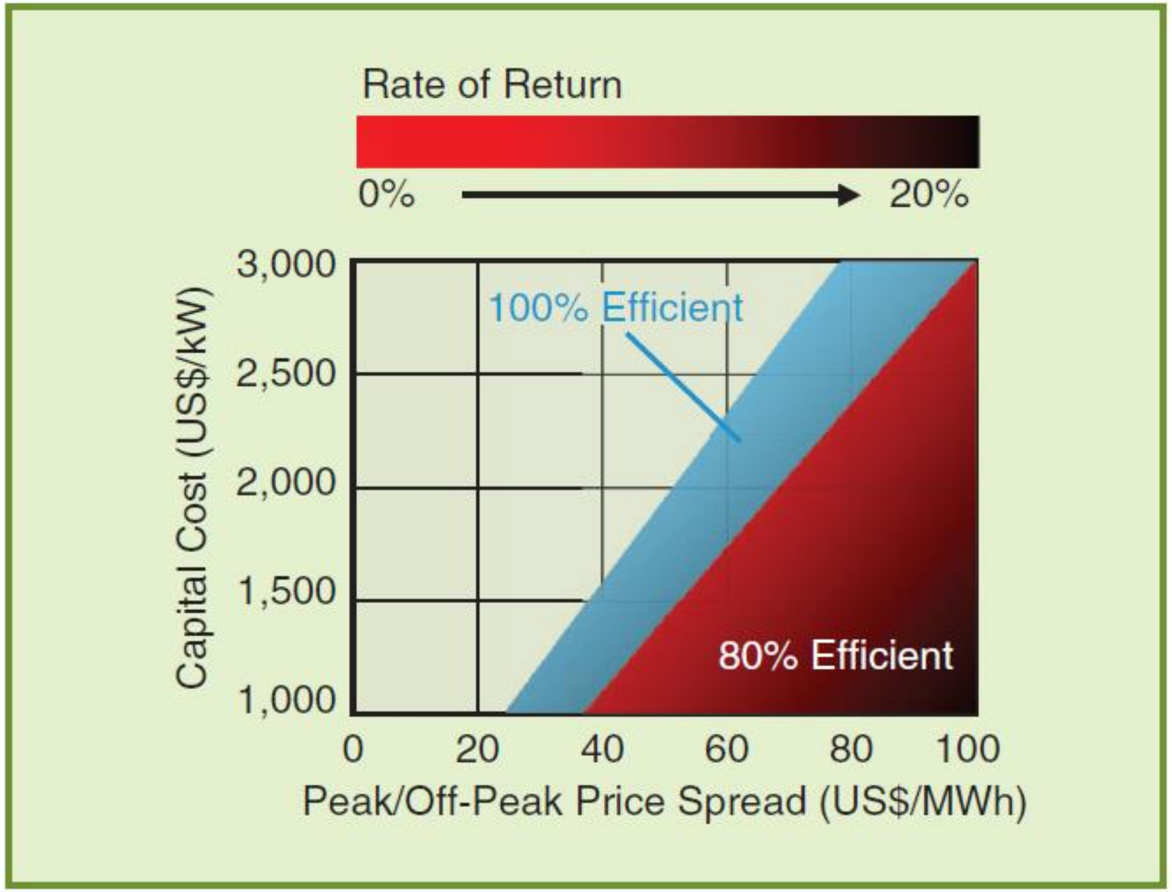


figure 2. Financial arbitrage value model for a storage facility with a 50-MW, 400-MWh energy storage system at 80% and 100% round-trip system efficiency.

Source: Manz, Piwko, Miller “Look Before You Leap: The role of Energy Storage in the Grid” IEEE P&E Magazine 2012

Forecasting: It helps to be smarter than everyone else

- The biggest swings in LMP tend to be due to “misses”:
  - Bad load forecasts
  - Bad wind & solar forecasts
  - Forced outages
- Known unknowns: If the ES owner knows better than everyone else, they can be *positioned* to take maximum advantage. Assumes an asymmetry of information.
- In short: “When to charge and discharge” is a non-trivial challenge. It is somewhat mitigated by having higher levels (longer duration) storage.
- For Hybrid Resources, forecasting evolves into “analytics”…but, the need to be smarter than everyone else is eased.

Stacking Benefits: the story is evolving

- Arbitrage didn't and doesn't do it
- We've always tried to stack
- It has always been about finding when ES is cheaper than alternatives
- A lot of the value is about avoided opportunity costs.
- A new degree of customization in ERS may be needed to unlock full benefits
- A couple angles you may not have seen follow

table 1. Applications of energy storage.

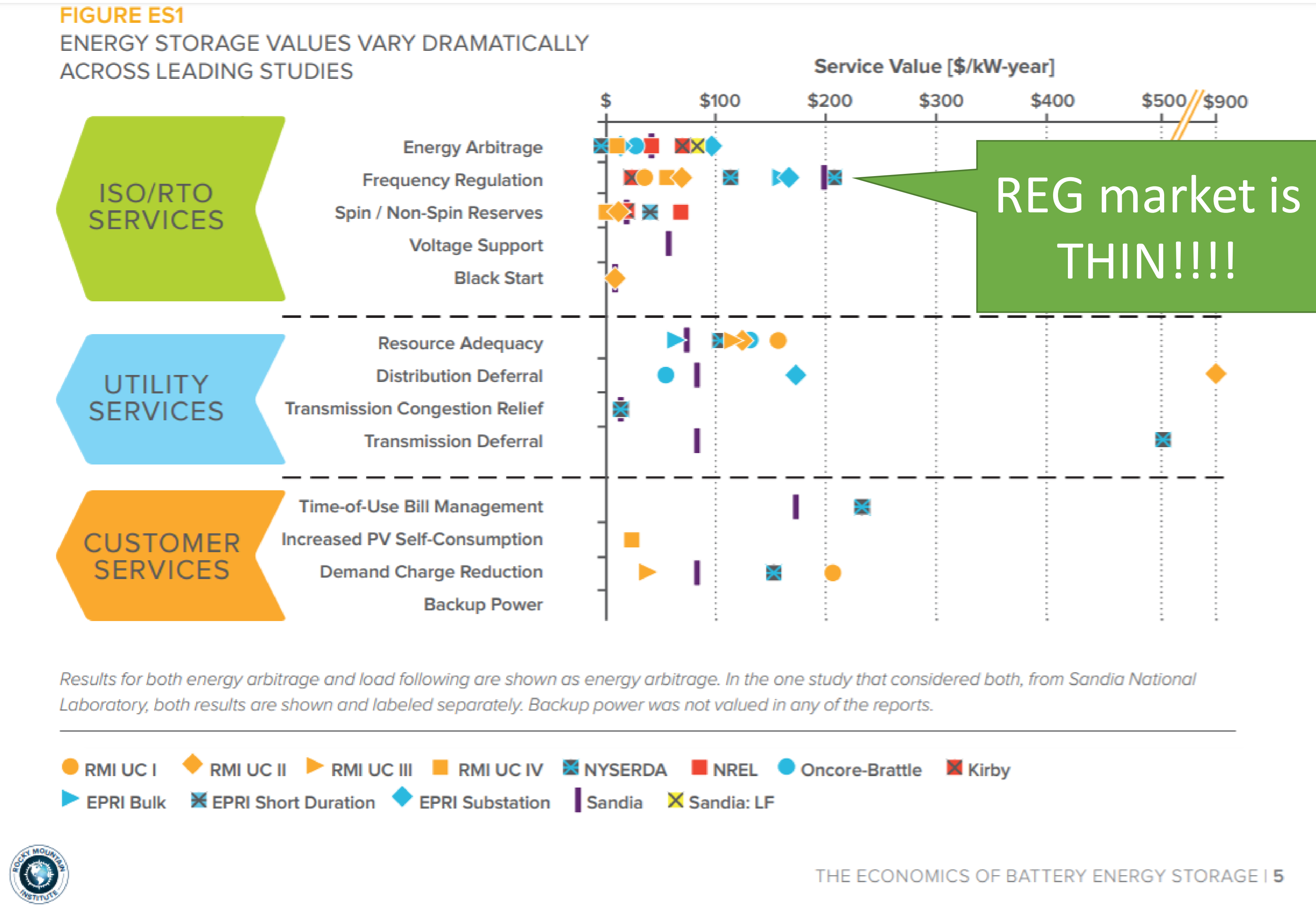
	Application	Description	Value
Applications for Energy Storage	Financial Energy Arbitrage	Buy low, sell high	Displaces most expensive generation
	Generation Capacity	Contribute to adequacy/reserve margin requirement	Defers investment in new generation
	Equipment Capacity	Reduce flow through overloaded lines and transformers	Defers investment in new equipment
	Line Congestion	Time shift delivery of renewable energy during congestion	Delays transmission line reinforcement
	Wind and Solar Power Smoothing	Reduce ramp rates of wind and solar plants	Contributes to reserve and regulation requirements
	Frequency Regulation	Rapidly inject and remove power for short intervals	Contributes to regulation requirements
	Spin and Non-Spin Reserve	Dispatch power in <10 min	Contributes to system reserves
	Governor/Inertial Response	Provide dynamic functional equivalents of synchronous generators	Reduces severity of frequency excursions events
Ancillary Applications for Energy Storage	Power Quality/ Harmonics	Suppress system harmonics	Contributes to power quality
	Black-start	Support system during system restoration	Contributes to system black-start capability
	Voltage Regulation	Manage delivery of reactive power to maintain voltage	Reduces need for new reactive power sources

Source: Manz, Piwko, Miller "Look Before You Leap: The role of Energy Storage in the Grid" IEEE P&E Magazine 2012

What's the stack worth?

- Pick your assumptions!

- Does ES even get a seat at the table? … e.g.
- ES for non-wires alternatives looking better and less nichy.
- Can be great when there's lots of constraints



Source: Rocky Mtn Institute; 2015

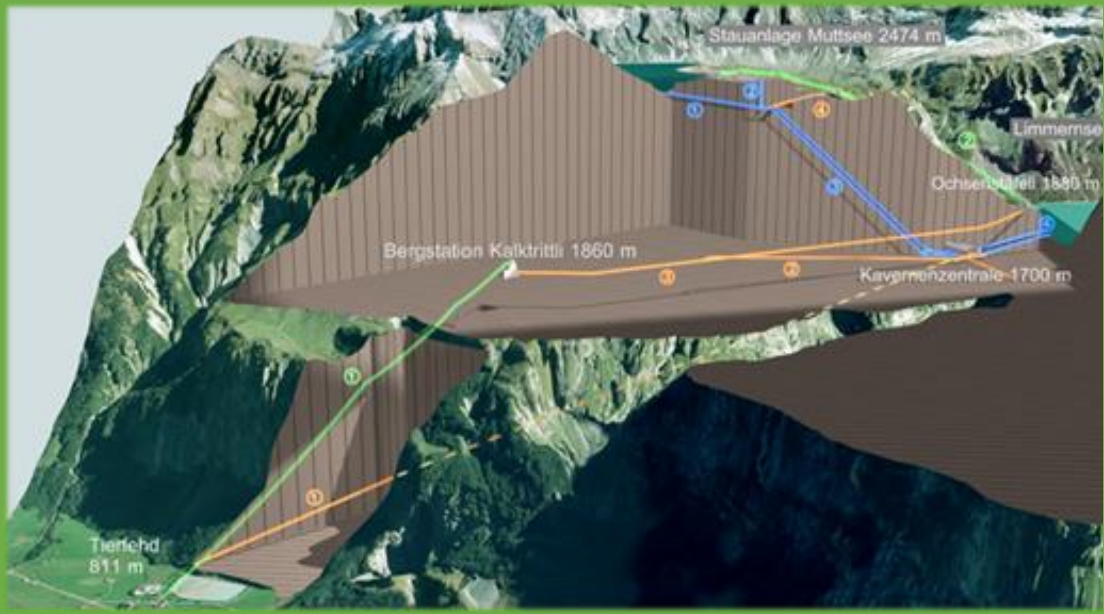
PSH … another look

- Operators everywhere love their Pumped Storage
- EirGrid: “I can’t count the number of times the PSH has saved our bacon”
- An ISO (you know): “If our PSH was available, I’d marry it!”
- Another ISO (you know): “We’d love to have a couple more!”

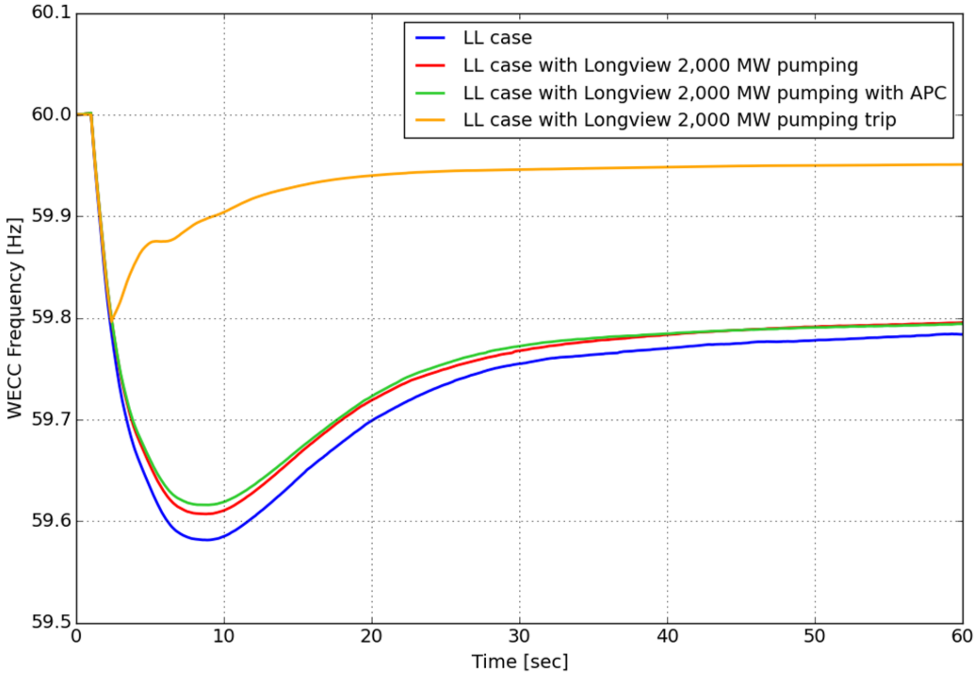
- “Beats the heck out of me as to how you’d get one built today”…

Linthal 2015

Power	4 x 250 MW
Head	560-724 m
Speed	500 ± 6 % rpm



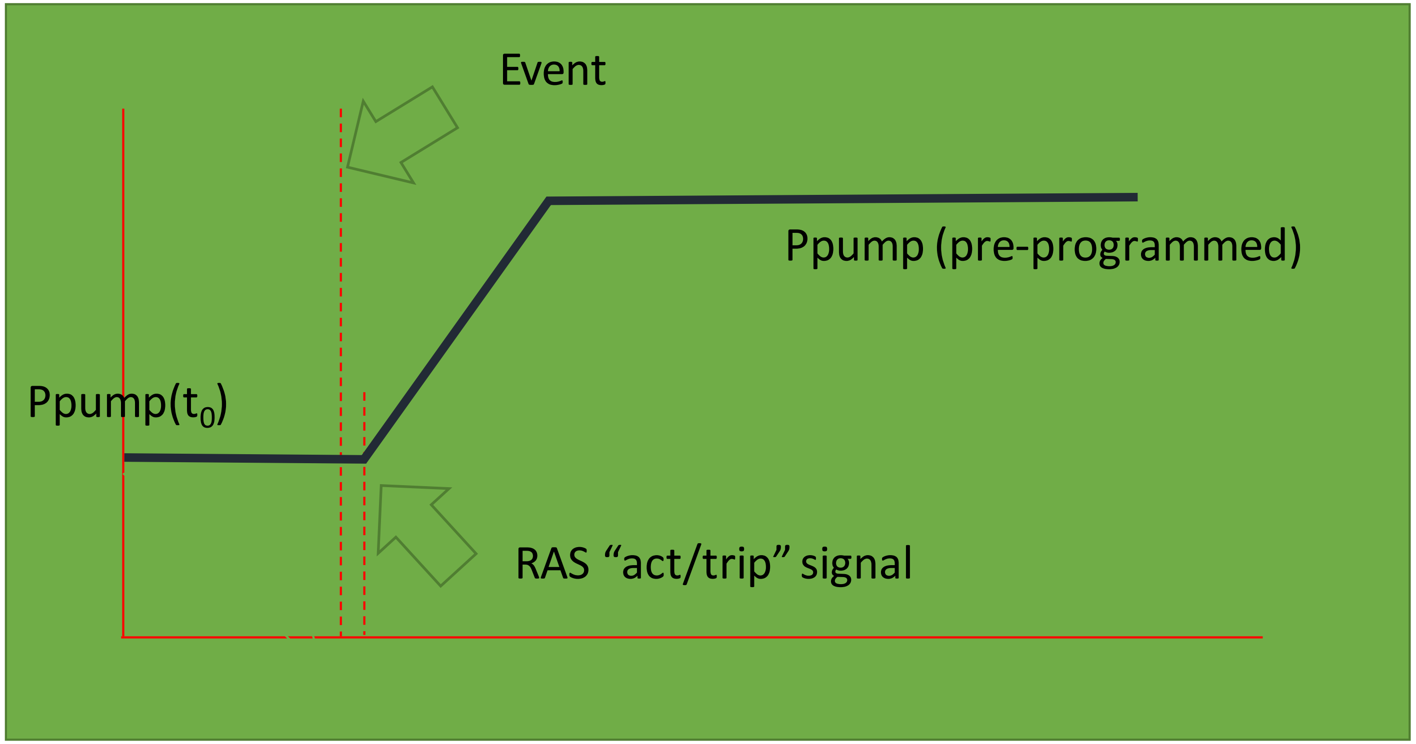
Fast Stop/Trip (as FFR)



- Tripping of PSH in pump mode
  - ERCOT has a separate category of FFR
  - EirGrid uses their Turlough Hill PSH this way now
  - Distrust, costs associated with breaker actions.
- "Electronic" trip, is accomplished by electronics rather than breaker action.
  - Less stressful/lower variable costs for equipment.
  - Lower penalties for false triggers.
  - An advantage for asset owner and ISO
- In future, "armed" tripping may be a big advantage; not unlike PDCI RAS.
- Puts an operational tool in hands of ISO/RTO that has lower reliability (i.e. NERC, WECC) "friction" for implementation that breaker actuation.

Open-Loop (RAS) – cool things with IBR ES

- Could be armed depending on operating condition
- Remote trigger (e.g. PDCI block, PV trip)
- Existing precedence in WECC.
- For VS, set exactly and set ramp rate. Not a breaker actuation; a control action.
- Can be customized based on situational awareness. Possibly very powerful benefit.
- *Only makes sense with really big stuff!*



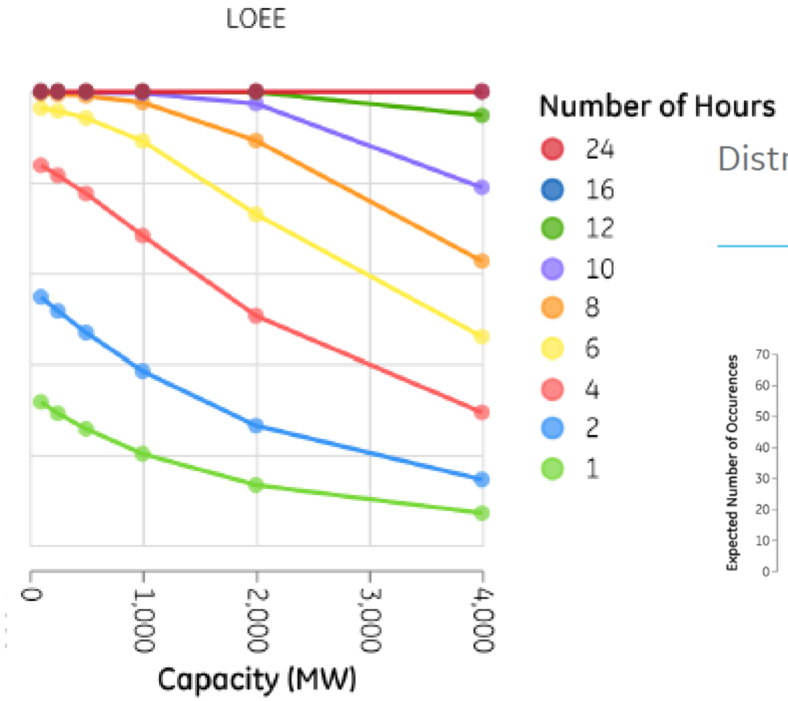
- Complexity of these options will favor a small number of large devices. WECC precedence for these approaches, from decades of operation of DC projects

Capacity/Resource Adequacy – Are there 2 types?

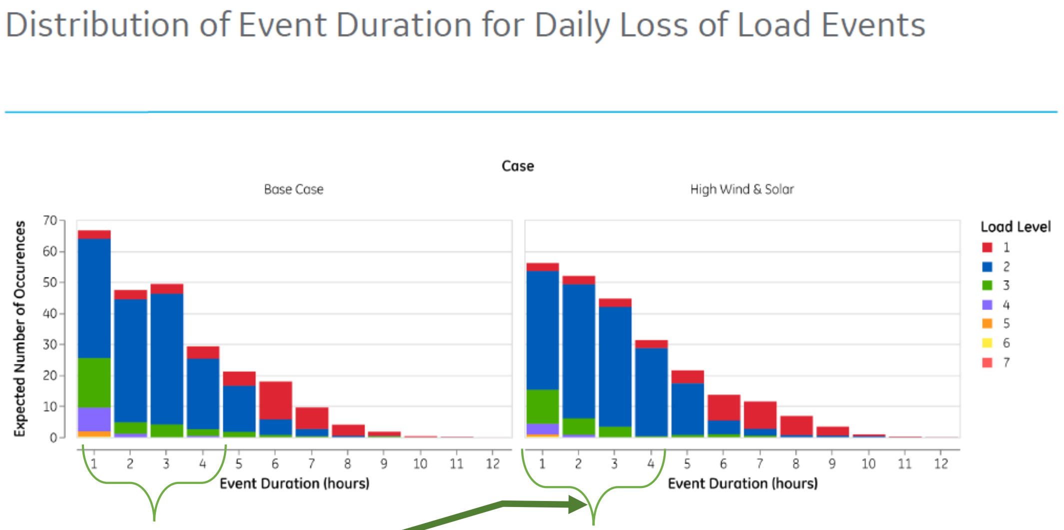
- This is huge, changing rapidly, and unclear.
  - There is some level of angst about longer duration adequacy.
  - Wind & solar droughts;
  - Polar Vortexes, Bomb Cyclones, Aliso Canyon, Orange Albatrosses, etc.
- The Conundrum:
  - relatively short duration storage is highly valuable for improvement in standard reliability metrics. e.g LOLE.
  - Higher PV penetrations tend to amplify this.
  - ES of 2 – 4 hour duration helps A LOT.
  - Outliers benefit from longer ES.
  - How to value?
  - Is it economically/societally “fair” to target some types of outliers over others? Are some types of customer interruption somehow worse than others?

Capacity Value for Longer Duration Storage stays high longer – but it depends a lot on where you are

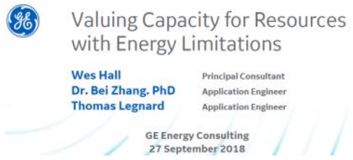
- These are result s from GE work in NY
- As expected, capacity value of all storage resources declines with saturation.
- Longer (higher energy) storage, like 8+ hours retains capacity value at higher ES penetrations
- Results suggest a mix of short and long duration ES is desirable



WHOA! Not so fast: Lot’s of Solar keeps the evening peaky… 4 hours retains its value longer



Most LOLE events (in NY) are 4 hours, or less, but once those are covered, longer duration capacity is beneficial



More on the ELCC debate (in California, elsewhere)

- Energy storage must be handled differently than supply-side solar and wind

Quote from CPUC

- New (11/15/2018) proposal regarding capacity value of energy storage from CPUC
- A novel means of crediting ES with the fact that it helps the value of PV (and wind).

ELCC%	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wind	15%	10%	[illegible]	39%	24%	33%	30%	29%	17%	9%	13%	10%
Storage	101%	101%	102%	296%	142%	116%	123%	117%	105%	97%	97%	115%
Solar	3%	4%	11%	4%	10%	22%	29%	20%	10%	1%	1%	1%

	Total Nameplate
Wind	10,522
Storage	1,187
Supply Side Solar	13,785

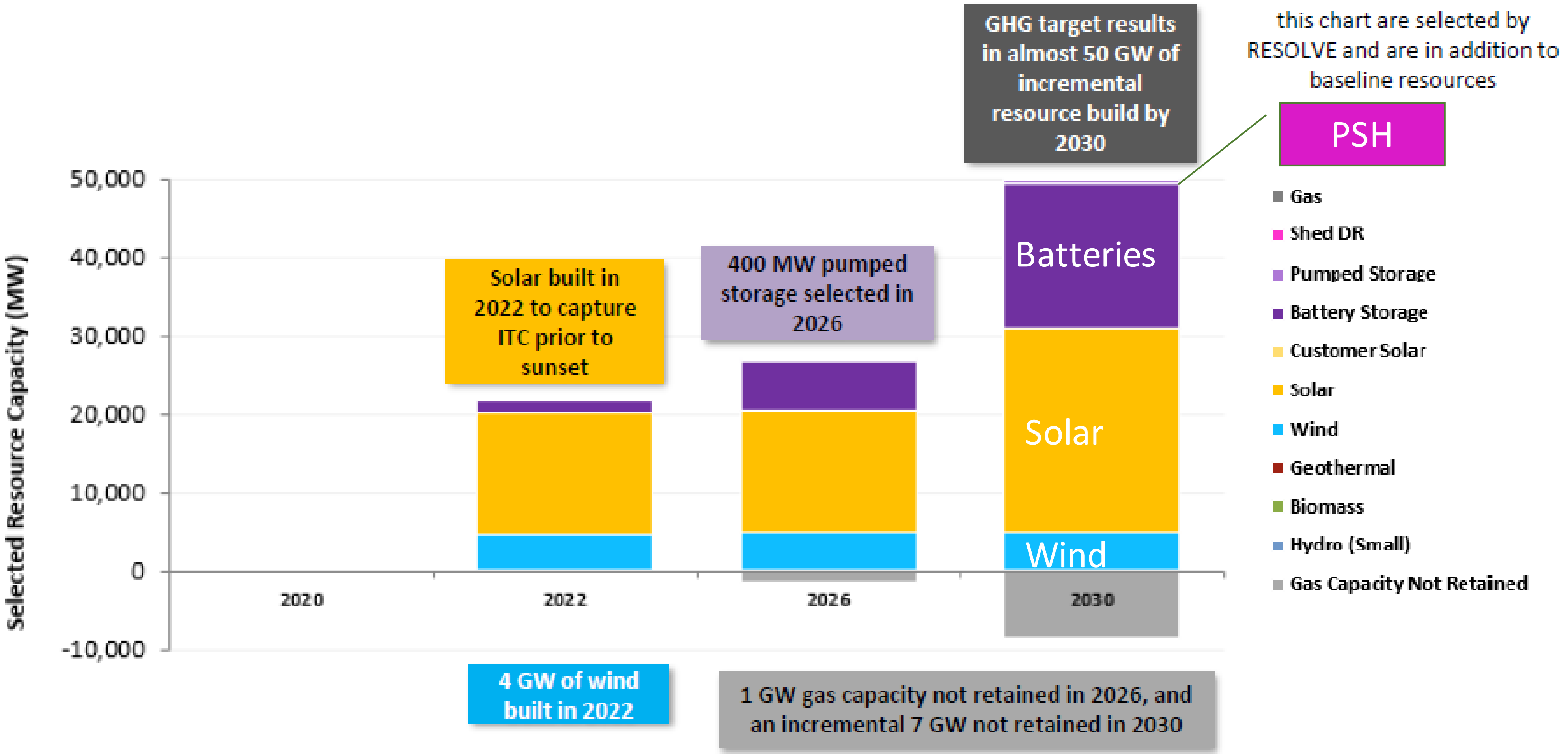
296% ELCC !!??

New methods can result in some difficult to grasp valuations

Energy Division Monthly ELCC Proposal for 2020 RA Proceeding

Donald Brooks
Supervisor, Energy Resource Modeling
Energy Division
California Public Utilities Commission
November 15, 2018

A little diversity, please?



2019-20 IRP: Preliminary Results

What did your Grandmother teach you about baskets and eggs?

HickoryLedge

CPUC Energy Division
October 4, 2019

Behind the Meter

- More TOU, dynamic pricing will drive more BTM ES
- "externalities" ….
  - How much energy storage (and other DER) is going to be catalyzed by California fires, and the resultant policies?
- Failure to meet 1-in-10 year capacity doesn't (ever?) cause blackouts.
- Grid failures do.
- Are we (the industry) even asking the right questions w.r.t. resource adequacy?

Energy Storage: Neither fish or fowl

Is it a transmission asset or a generation asset?

Is it a competitive product, or a public good?

Who should own it? Control it?

RTO/ISO Ownership

“This is a network asset/public good”

“We need the flexibility to operate for the best reliability and economy outcome for the grid”

“We don’t know exactly what we’re going to do with it over its life”

Developers/Asset Owners

- “Do this competitively”
- “Tell us what you want, give a market/payment signal, and we’ll provide it”

And as if that wasn't complicated enough: hybrids

- e.g. Solar PV + Batteries
- We (Nick) used to say "don't do it, that's stupid"
- Got that wrong.
- Why does it make sense now?
  - Solar (and Wind) success at a level we barely dreamed a decade ago
  - Battery costs really did plummet, as did panels
  - "Synergy"… not just a buzz word anymore: DC Coupled PV+Batteries becoming the norm.

Hybrid Energy Storage: who has the car keys?

RTO/ISO Ownership

“This is a network asset/public good”

“We need the flexibility to operate the individual bits, for the best reliability and economy outcome for the grid”

“We don’t know exactly what we’re going to do with it over its life”

Developers/Asset Owners

- “Do this competitively”
- “We are like other generating resources, only better: much more flexible and fewer constraints”
- “Your present market structure already works for hybrids”
- “In future, tell us what you want, give a market/payment signal, and we’ll provide it”

Are the elements separate?

What’s the name plate?

What’s the capacity value and contribution to resource adequacy? Control it?

Where are we going?

BTHOM, but nevertheless some (Nick) predictions:

- Seasonal Storage is the next big frontier. We will creep up on that with concerns about progressively longer challenges:
  - 4 hours ▶ 8 hours ▶ 12hrs ▶ a few days ▶ many days ▶ …..
- All eggs in one basket approach will start to have some serious cracks.
- "When is it storage and when is it DSM?" debate will rage on.
- V2G is going to be huge
- Motion towards universal service business models. maybe.
- We will find we missed something important…

Thanks

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