Measuring the value of energy storage – a perspective

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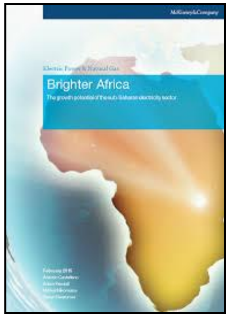
A brief introductions

A little about me…

- Co-Founder of Bushveld Energy, an energy storage solutions company, part of AIM-listed Bushveld group of companies that are developing an integrated vanadium platform in SA
- Focused on vanadium redox flow battery (VRFB) technology
  - Markets and develops projects across Africa
  - Establishing manufacturing of electrolyte and VRFBs in South Africa
- Previously at McKinsey & Company, working in Russia and across Africa, focusing on power sector (strategy and plant operations) and economic development



SOURCE: Bushveld Energy

Energy storage can sound complicated but evaluating value is still a function of cost and benefit

Why does energy storage seem complicated

- It sounds like generation, but it is not; plus we just started to understand renewables…
- The amounts of applications for energy storage are immense, from homes to mini-grids to utility power station-sized installations
- The amount of different technologies and companies offering those technologies is overwhelming and changing rapidly

Energy storage currently lacks standardisation on terminology, performance evaluation or a history of best practices in its implementation

Value, though is still a simple calculation

Value of an energy storage installation

=

Benefit created from an energy storage installation site

-

Cost to the energy storage site

SOURCE: Bushveld Energy

We can first start with the cost of an energy storage site, which consists of many factors

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Total cost of an energy storage site =

- **Upfront (capital) cost** +
  - DC block
  - AC equipment
  - Housing, grid & interconnections
  - Installation & commissioning
  - Delivery
- **On-going annual (O&M) cost** +
  - AC-AC efficiency
  - Maintenance or warranty cost
  - Degradation rates
  - Battery lifetime
  - Financing costs

These exclude contingency costs, taxes, etc.

Observations

Factor	Observations
DC block	Will vary for power (watts) and energy (watt hours)
AC equipment	Some firms quote for AC, others for DC
Housing, grid & interconnections	What is "containterised"? Transformers, site controllers?
Installation & commissioning	Is this done by the OEM, EPC, developer, integrators, etc.?
Delivery	Highly site specific (and do not forget about time)
AC-AC efficiency	All batteries lose energy and all have parasitical AC systems
Maintenance or warranty cost	These costs are predictive How strong is the warranty?
Degradation rates	This includes, temperature, DoD, "rest periods," etc.
Battery lifetime	Can be measured in years or full cycles or both
Financing costs	Loan repayment or internal rate of return (incl. taxes and incentives)

SOURCE: Bushveld Energy

Let us look at an example, from a flow battery from 2 years ago

	2015 Uni.System™ (AC)
Peak Power	600 kW_{AC} over 2 hours
Nominal Rating	500 kW_{AC} over 4 hours
Maximum Energy	2.2 MWh_{AC} over 8 hours
Cycle and Design Life	Unlimited cycles over 20 year life
Available State-of-Charge	100%
Frequency Reg. Efficiency	$75\%_{AC}$
Peak Shaving Efficiency	$70\%_{AC}$
Response Time	<100 ms
Voltage Range	465-1000 V_{DC}
Max. Current	1500 A_{DC}
Footprint	820 ft^2 (41'W x 20'D x 9.5'H)
Ambient Temp.	-40°C to 50°C (-40°F to 122°F)
Total Weight	170,000 kg
Self Discharge	Max energy loss <2%*

*Self-discharge limit ... stacks; no disch...

AC systems, means supplier is including the inverter, BMS, switchgear

This typically a limitation for solid state batteries

Some OEMs will oversize a system to show 100% DoD capability

If AC, it should include all parasitical systems (verify)

Will I need to budget in a step-up transformer?

Will I need extra cooling or heating at my site?

What is missing? Recharge rate, disposal, site requirements…,

SOURCE: UniEnergy Technologies – Gen 2 Uni.System 2015

Evaluating the benefits of energy storage is more difficult and application specific; we'll look at three site types

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1

A utility application, where distributed energy storage can add over a dozen values

2

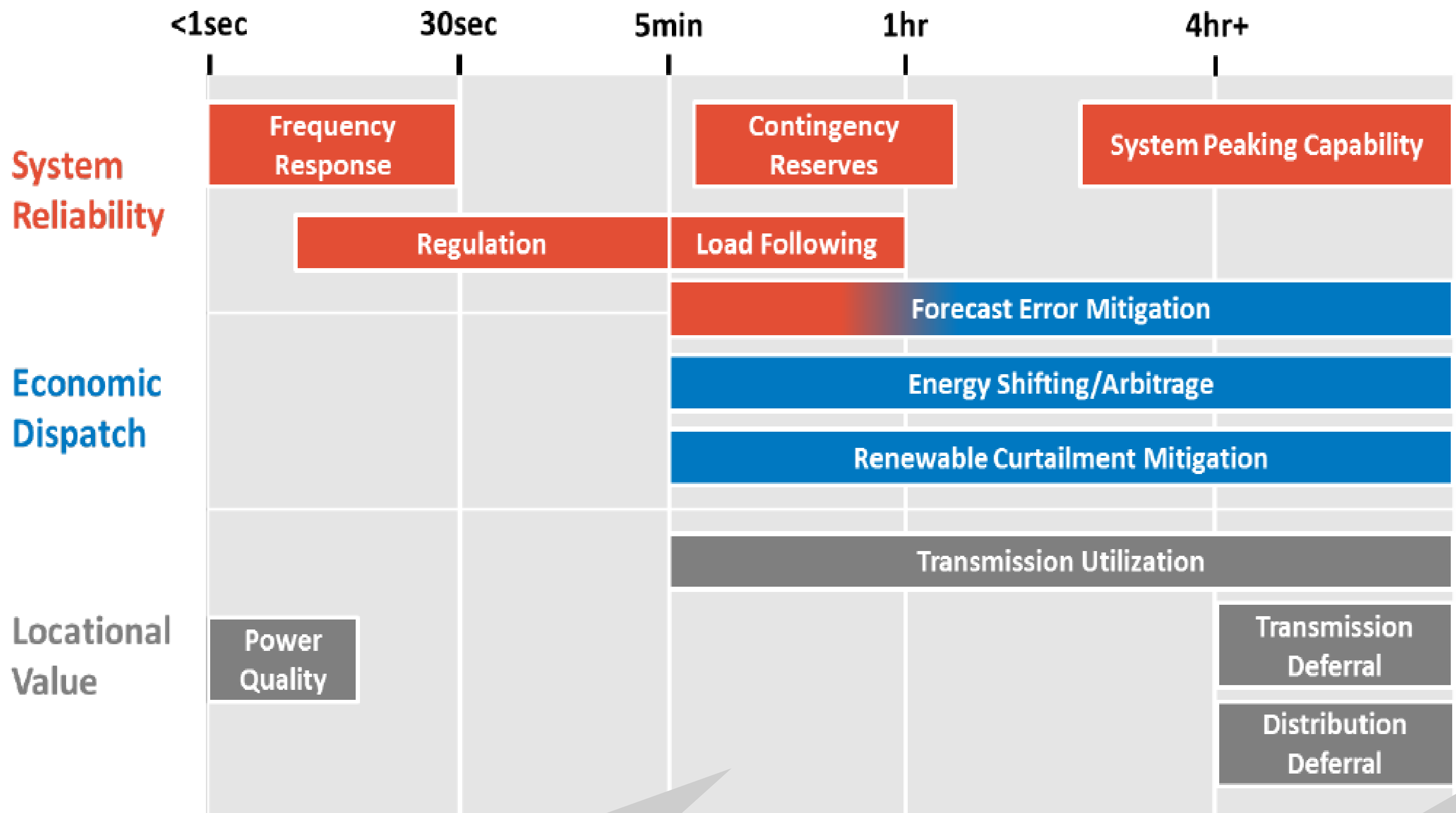
A behind the meter, electricity consumer, where the benefits are driven by the tariff structure and grid power quality

3

Off-grid applications, where storage is part of a larger energy solution

1. Utility energy storage has over a dozen benefits that could be realised by one system

Utility scale energy storage use cases and their relevant time scales



Other benefits include
- Technical loss reduction
- Time shifting of losses
- System resiliency

System reliability benefits are well known and quantified; utilities still analysing dispatch and locational value streams

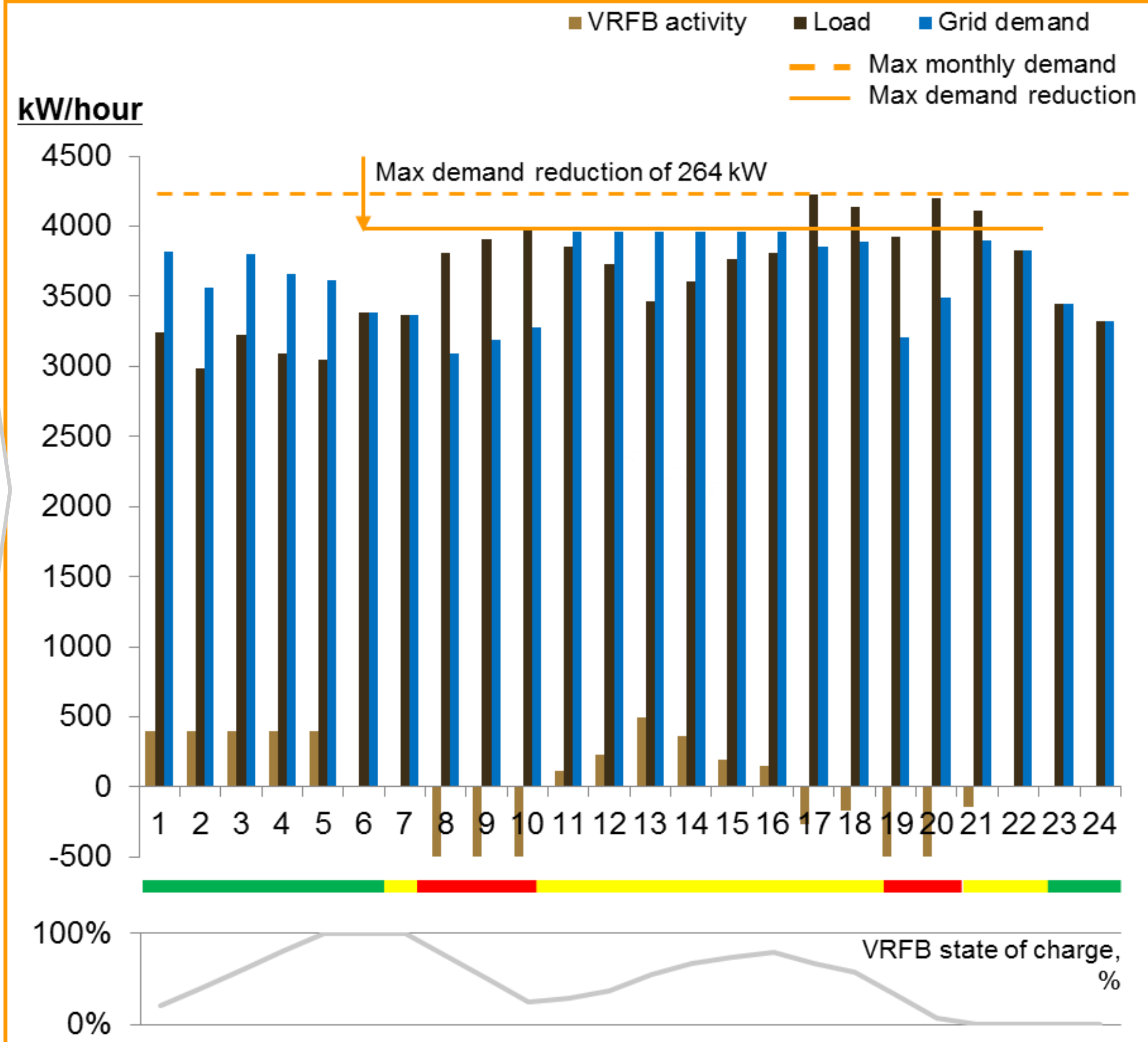
Source: PGE IRP Draft (Nov 2016)

2. In South Africa, we usually see up to five use cases for behind the meter energy storage

Context to SA example

- Value streams include
  - Reduction of peak demand charge
  - Arbitrage / time shifting
  - Back-up power and uninterrupted power
  - Improved power quality
  - Higher utilisation of PV (e.g. weekends)
- Analysis is updated to reflect addition of both a 500kW / 2MWh VRFB to a large industrial load
- Sizing the battery system to the application and technology is essential (in this case, we can get 1.5 daily cycles; adding PV increases it to almost two)

Site load profile, with grid and battery power supply



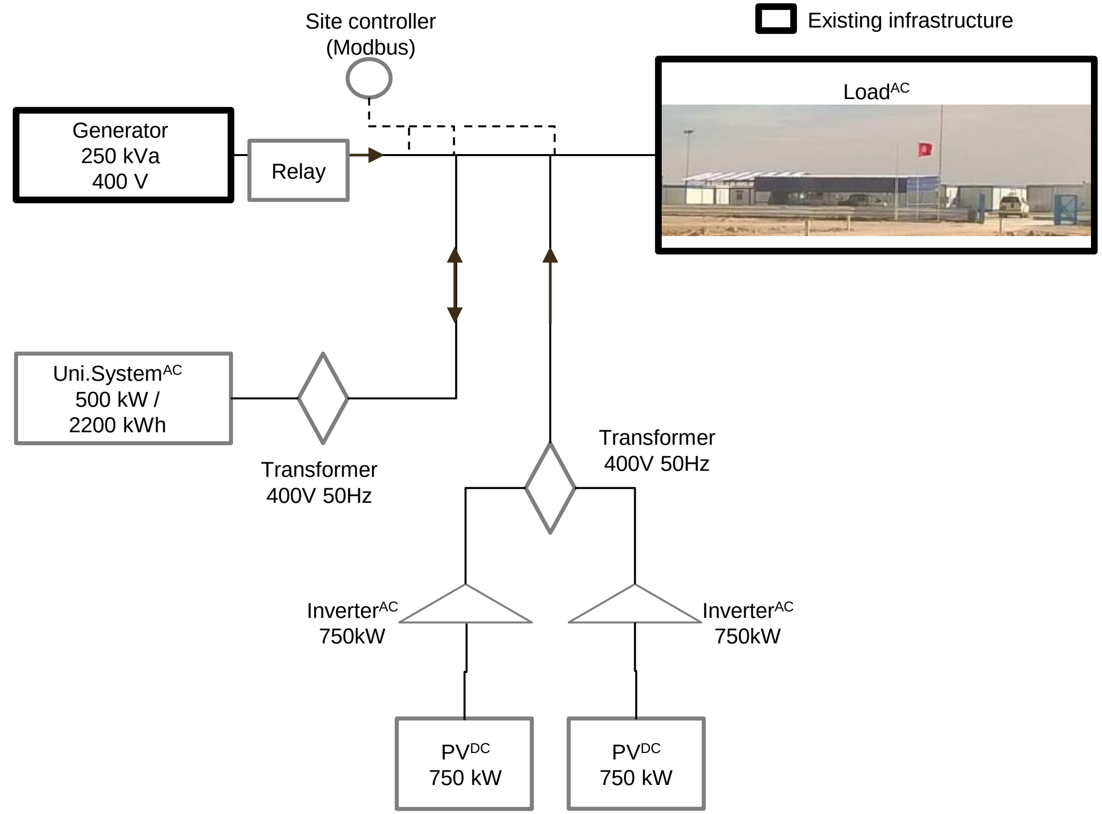
SOURCE: Bushveld Energy

3. The off-grid case is the most straight forward, as it typically involves diesel or other liquid fuel displacement

Context to off-grid example

- In off-grid, storage acts to increase the amount of energy that can come from solar or wind, while decreasing diesel/HFO reliance (though not eliminating it)
- Calculation of the benefit involves combining the cost of the PV, storage and expected diesel usage to create an energy tariff (very similar to an IPP)
- Sizing the battery system and the PV installation are critical, especially optimising for the amount of diesel reliance

SLD of a technical configuration

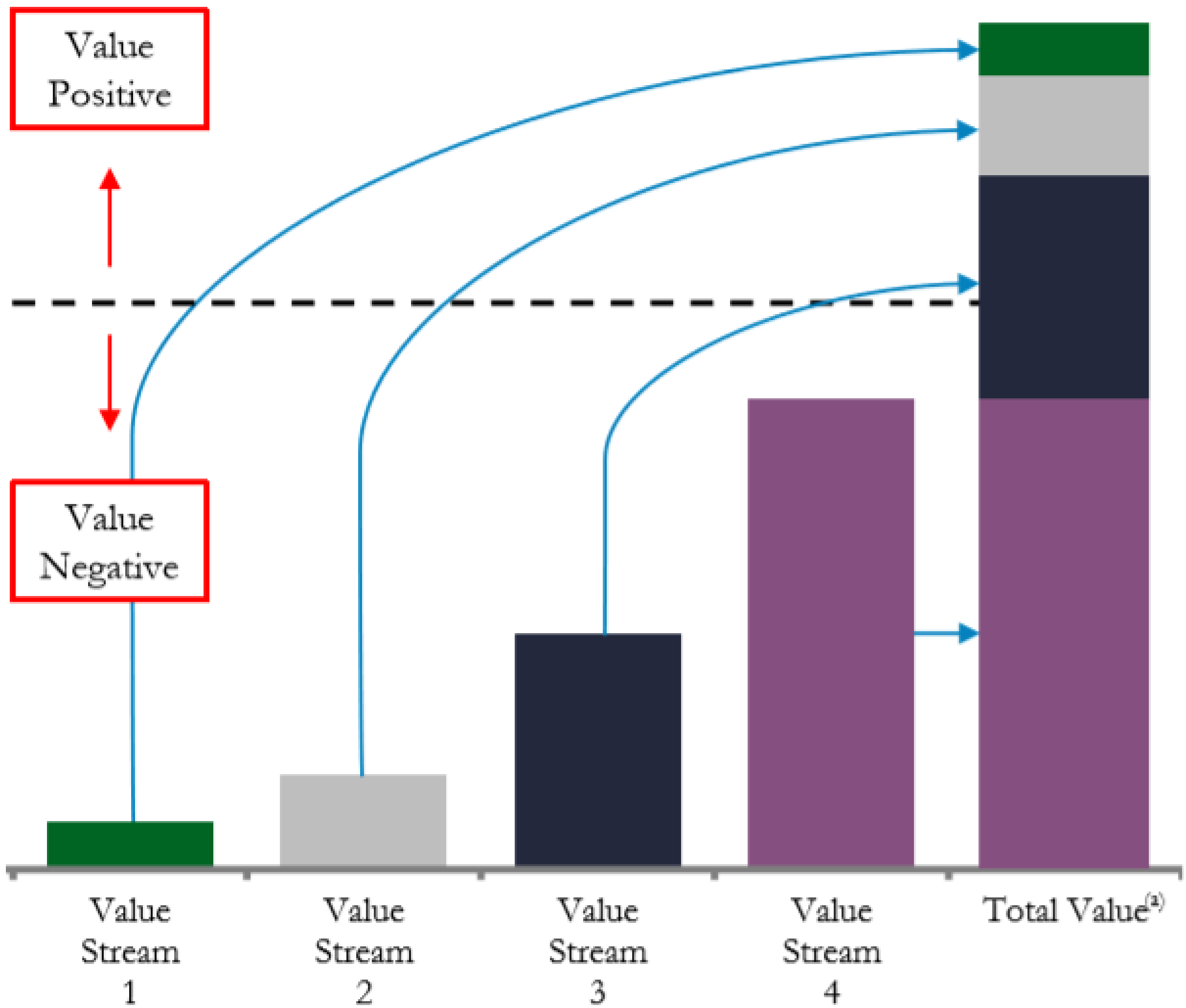


Storage allows for larger PV sizing, of 6-7 times the load and 2-3 times the battery in terms of power

SOURCE: Bushveld Energy

Stacking is the means to aggregate multiple storage value streams

For multi-value stream sites, value "stacking" is the approach to quantify total value



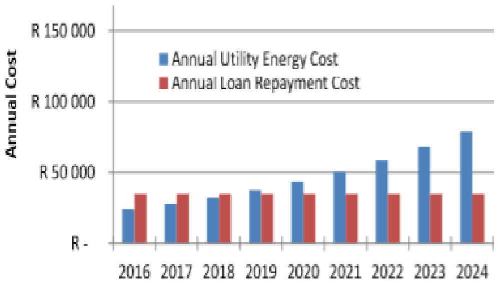
Although simple in theory, actual stacking requires significant analysis of questions such as:

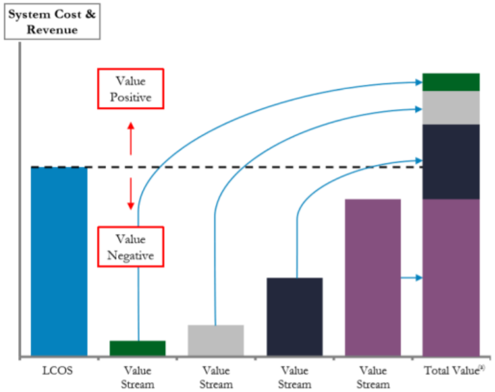
- How many of the values can one system perform?
- To what degree can each value be captured (e.g. 50%, 80%)?
- How will multiple implications impact the battery's cost (e.g. inverter, software) and lifetime (e.g. cycles, stage of charge)?
- How to value future cost increases?

SOURCE: LAZARD'S LEVELIZED COST OF STORAGE—VERSION 2.0

We have seen two methods to calculate the cost / benefit for specific sites and compare costs across technologies

	Method description	Select pros & cons
1 Years to cash repayment	▪ Calculates the annual financial benefit from the system ▪ Estimates the number of years it will take for the project to recoup the investment / becomes “cash positive”	+ Simple and can be done without discounting - Must be site specific - Not as accurate when doing fleet / portfolio or strategic analyses
2 Levelised cost of energy stored	▪ Calculated on a “per kWh” basis (similar to LCOE for generation) ▪ Adds the total discounted costs of installing and operating over the lifetime of the project (years and/or cycles); ▪ Divides costs by the aggregate discounted energy stored during the project lifetime	+ More accurate and holistic, if assumptions are correct + Can be coupled with generation and transmission levelised costs - End results often not driven by technical assumptions but financial (e.g. cost of capital)





SOURCE: LAZARD’S LEVELIZED COST OF STORAGE—VERSION 2.0; FreedomWon/Anthony English

The 3 summary points in valuing energy storage

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1. Although complicated, the value of energy storage **is quantifiable**

2. Costing of energy storage needs to incorporate **many different parameters** (not just upfront DC block cost or efficiency)

3. Measuring the benefit usually requires **stacking** multiple benefits / revenue streams

Thank you for your attention