Measuring the value of energy storage – a perspective

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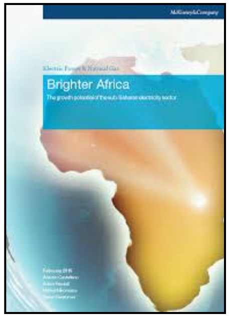
A brief introductions

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

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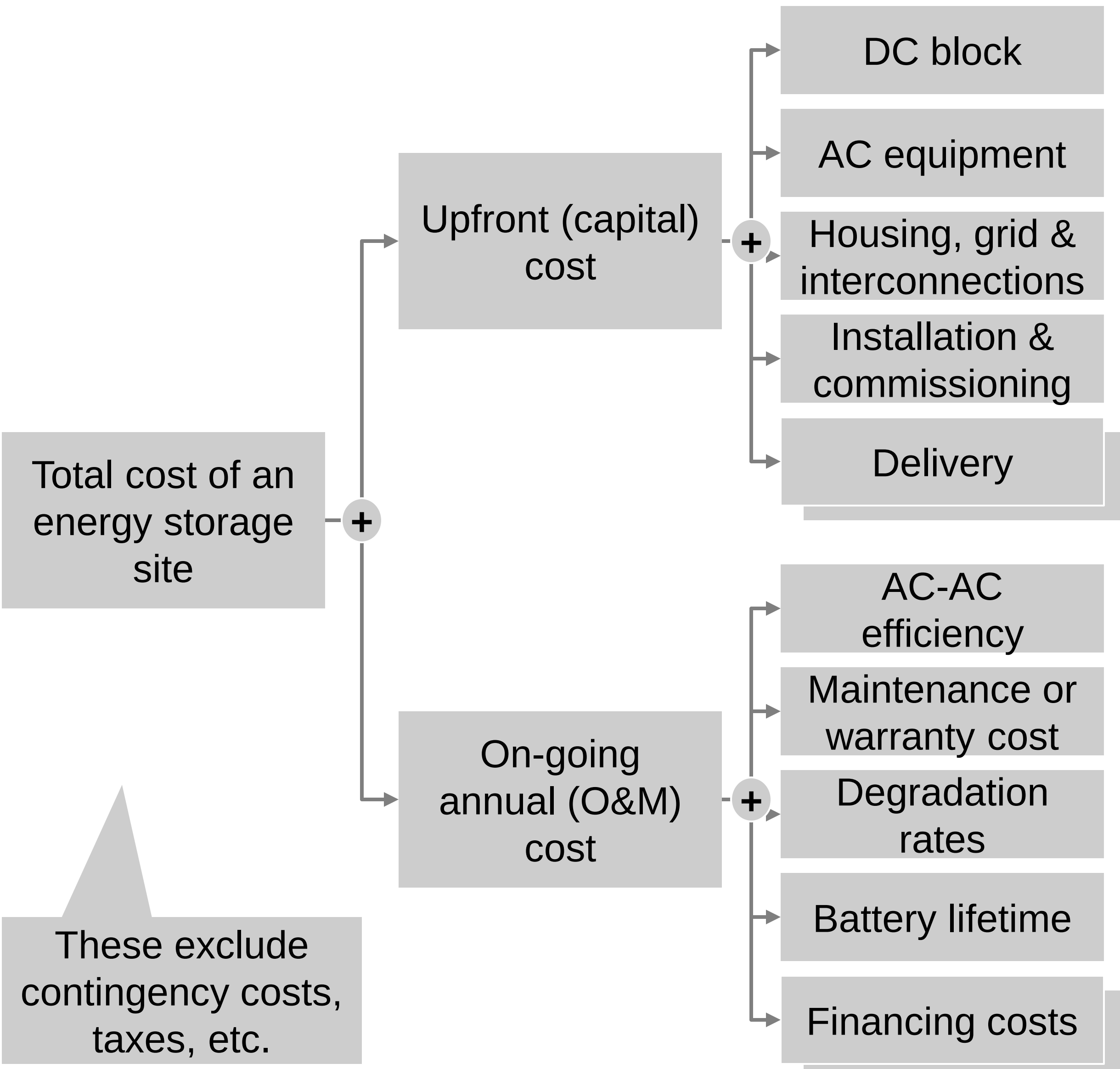
Cost to the energy storage site

SOURCE: Bushveld Energy

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



Observations

- Will vary for power (watts) and energy (watt hours)
- Some firms quote for AC, others for DC
- What is “containterised”?
- Transformers, site controllers?
- Is this done by the OEM, EPC, developer, integrators, etc.?
- Highly site specific (and do not forget about time)
- All batteries lose energy and all have parasitical AC systems
- These costs are predictive
- How strong is the warranty?
- This includes, temperature, DoD, “rest periods,” etc.
- Can be measured in years or full cycles or both
- 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

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	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 limi… stacks; no disch…

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

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?

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

1

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

2

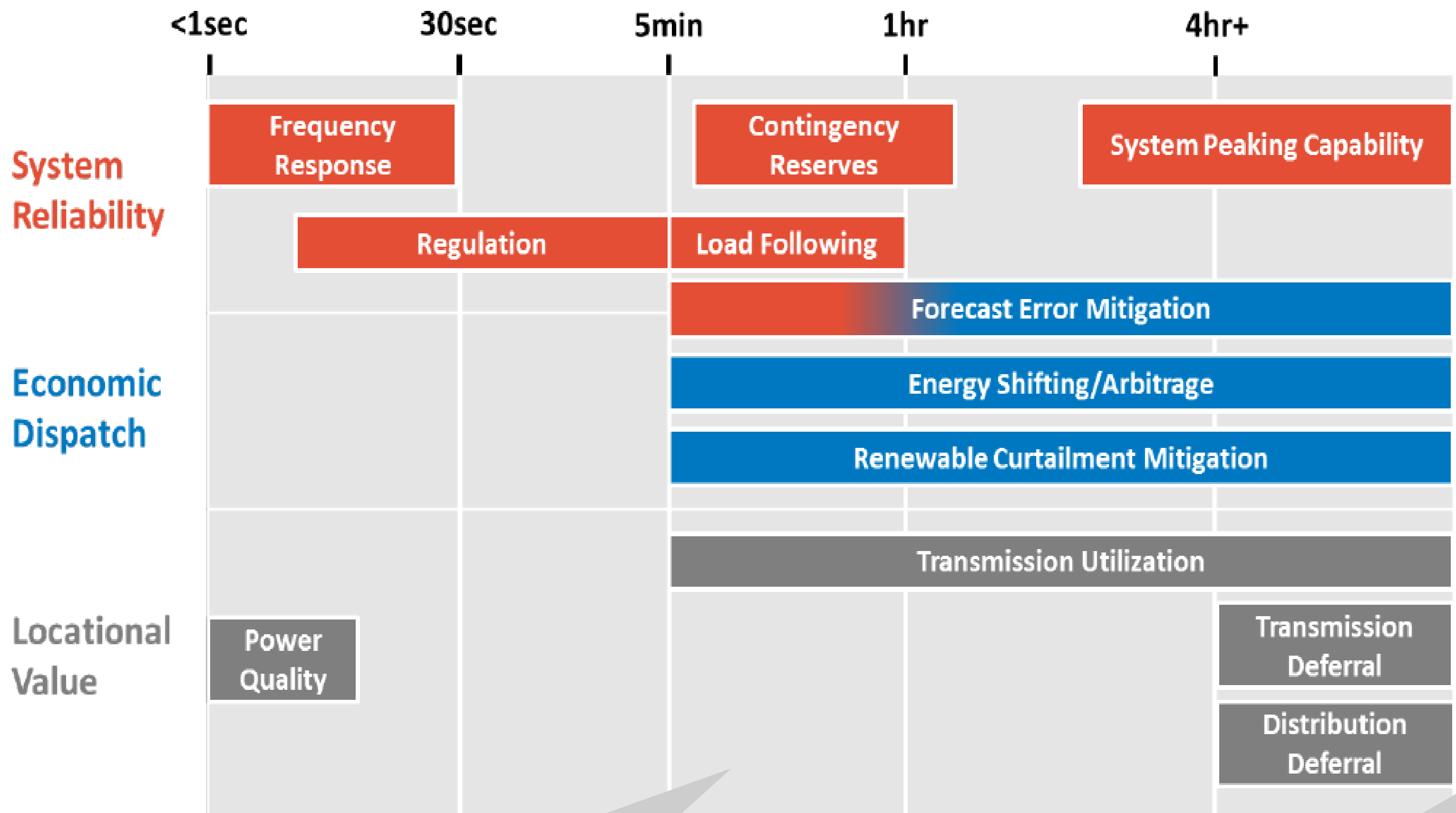
A behind the meter, electricity consumer, where the benefits are driven by the tariff structure and grid power quality

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

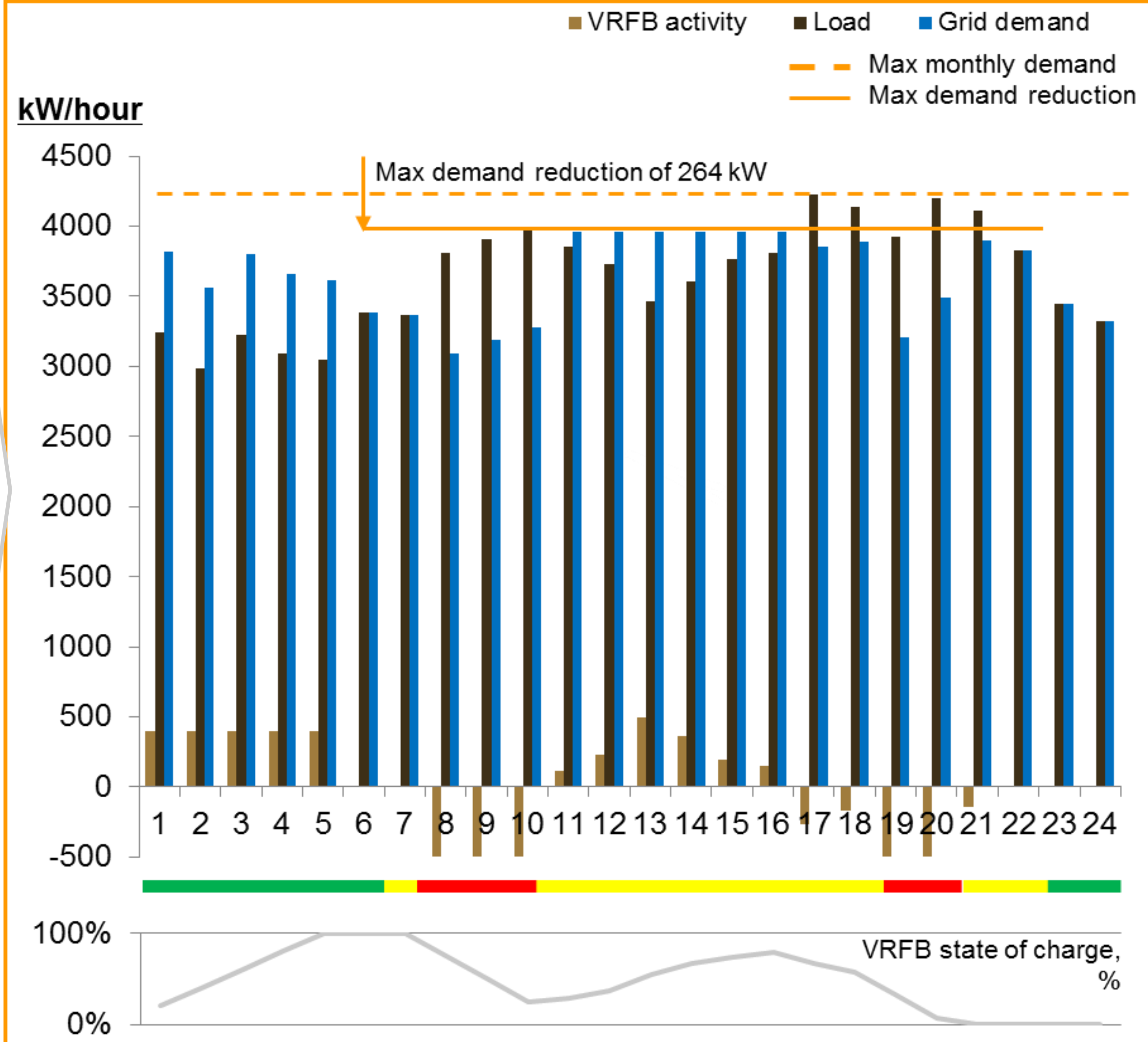
Source: PGE IRP Draft (Nov 2016)

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



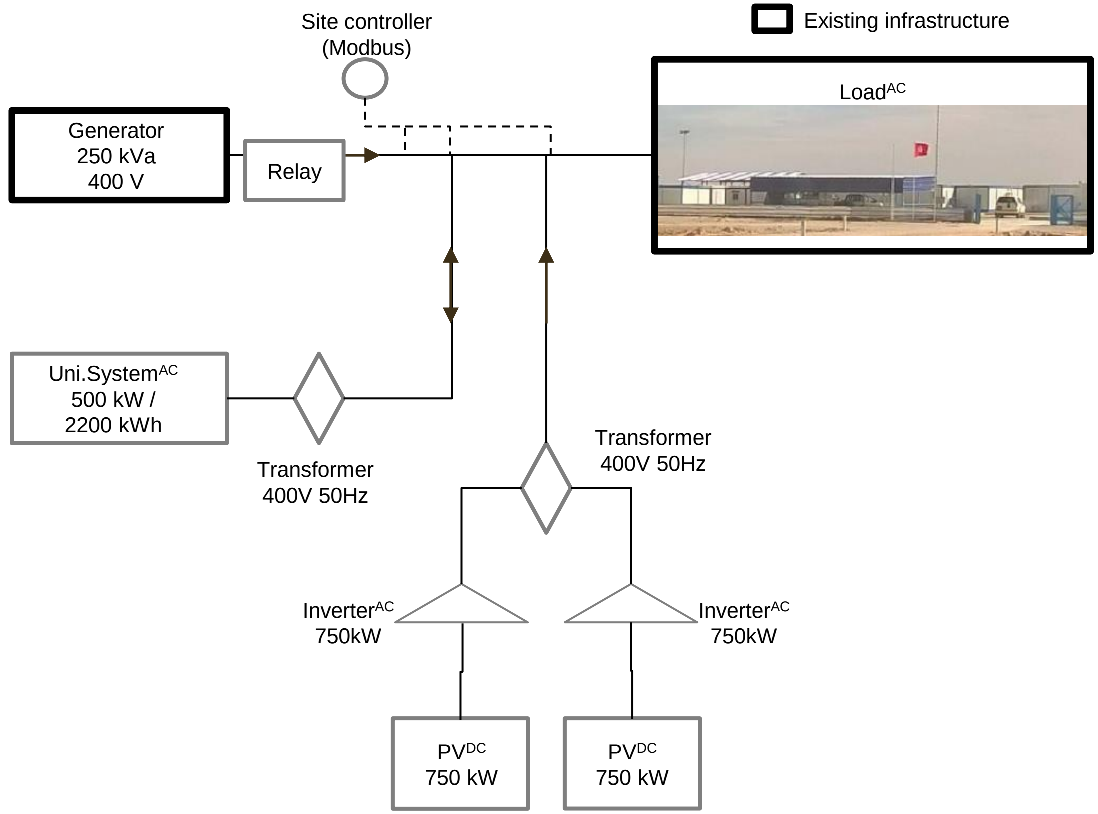
SOURCE: Bushveld Energy

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

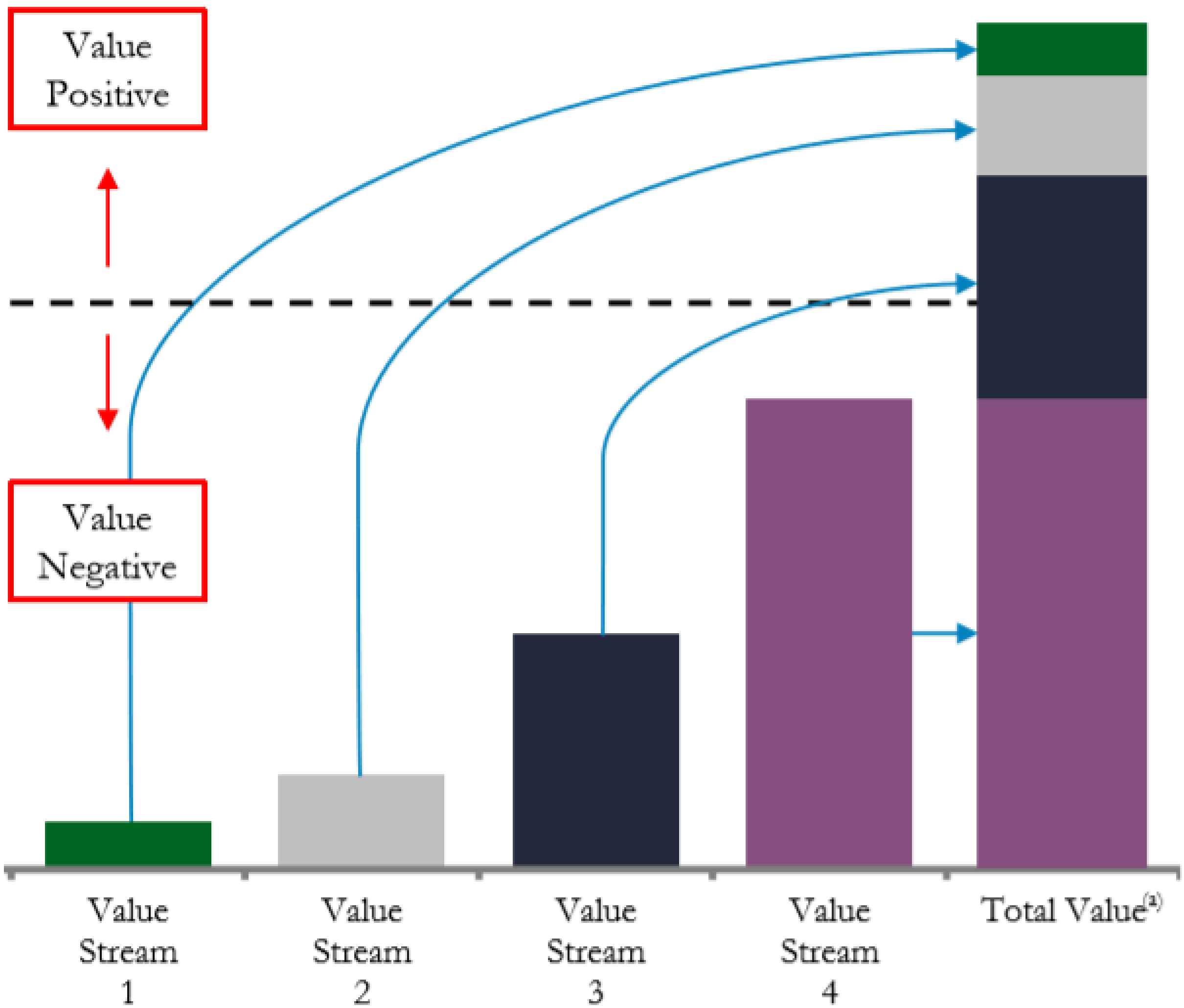
SLD of a technical configuration



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

Stacking is the means to aggregate multiple storage value streams

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



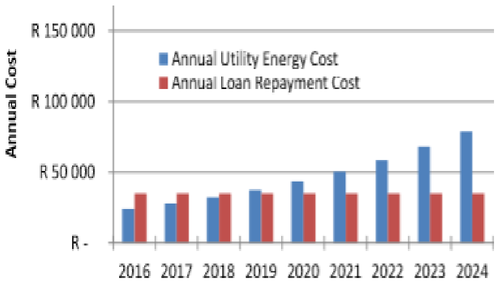
Although simple in theory, actual stacking requires significant analysis of questions such as:

- 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

1 Years to cash repayment



Method description

- 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"

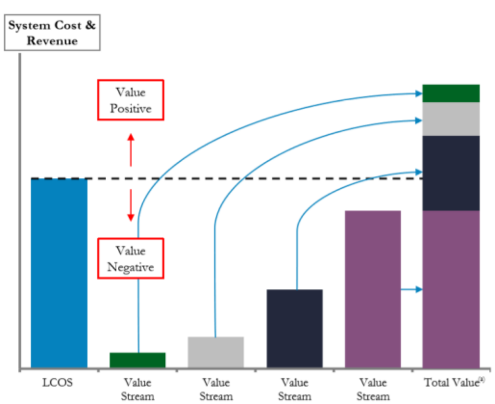
Select pros & cons

\+ 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