27th Technical Convention 2019

The 4th Industrial Revolution ("4IR") | *Building the Power Utility of the Future, Today*

Energy Storage on Municipal Grids:
Why this makes sense

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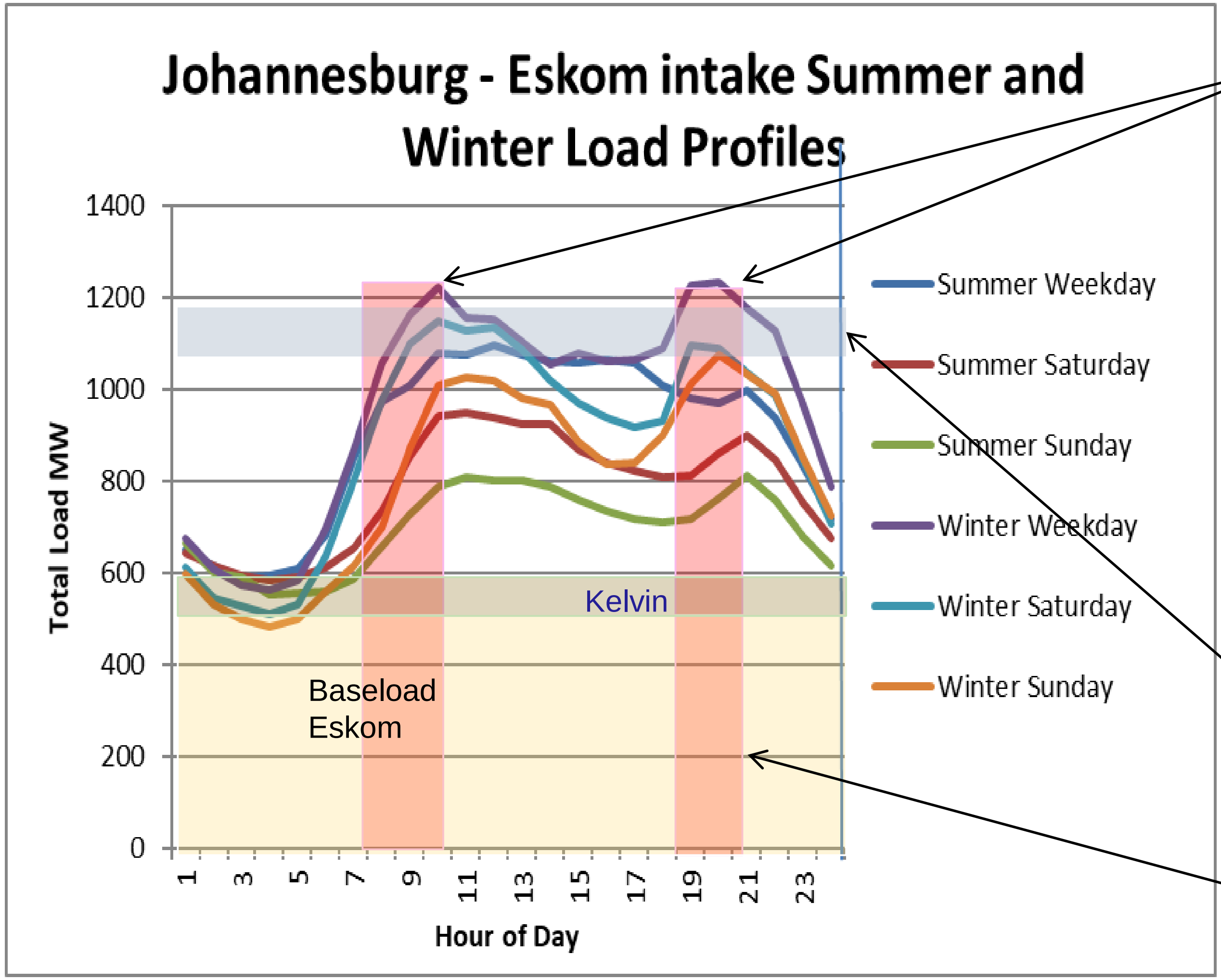
Hosted by CITY OF CAPE TOWN ISIXEKO SASEKAPA STAD KAAPSTAD

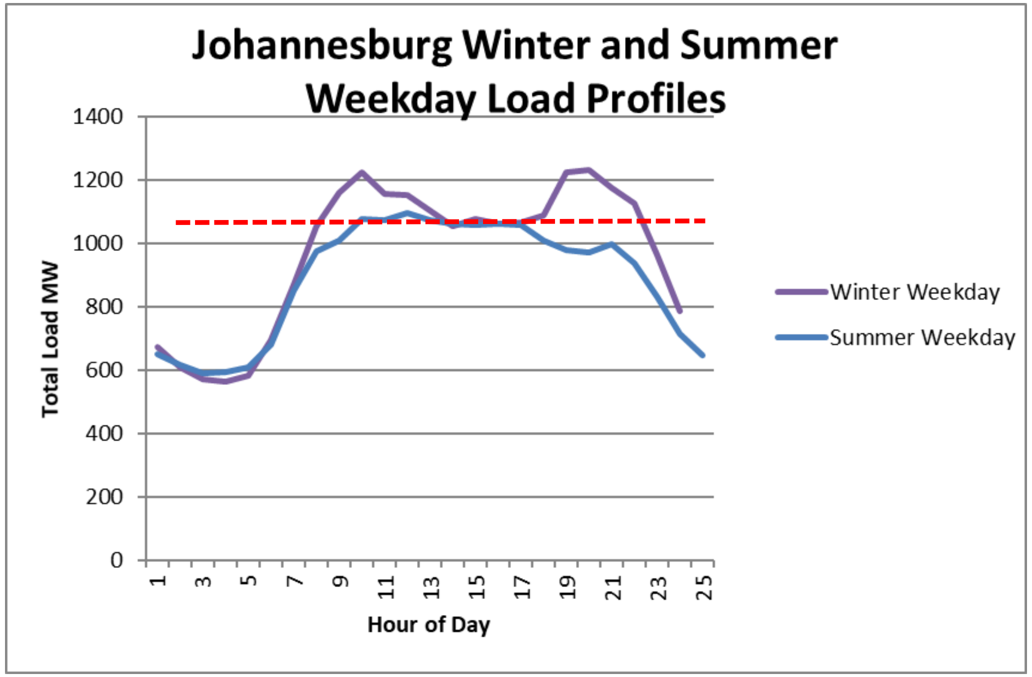
Analysing Current Energy Costs



- The graphic shows the load profile of the Johannesburg 275 kV power system
- The morning and evening peak periods are when Eskom power is most expensive.
  Summer peak cost is 93 c/kWh.
  Winter peak cost is 286 c/kWh.
- The average peak cost over a year is 141,54 c/kWh.
- Stage 1 Load Shedding approximates to 120 MW for these intake points
- The peak pricing extends all the way into the base-load portion of the load curve

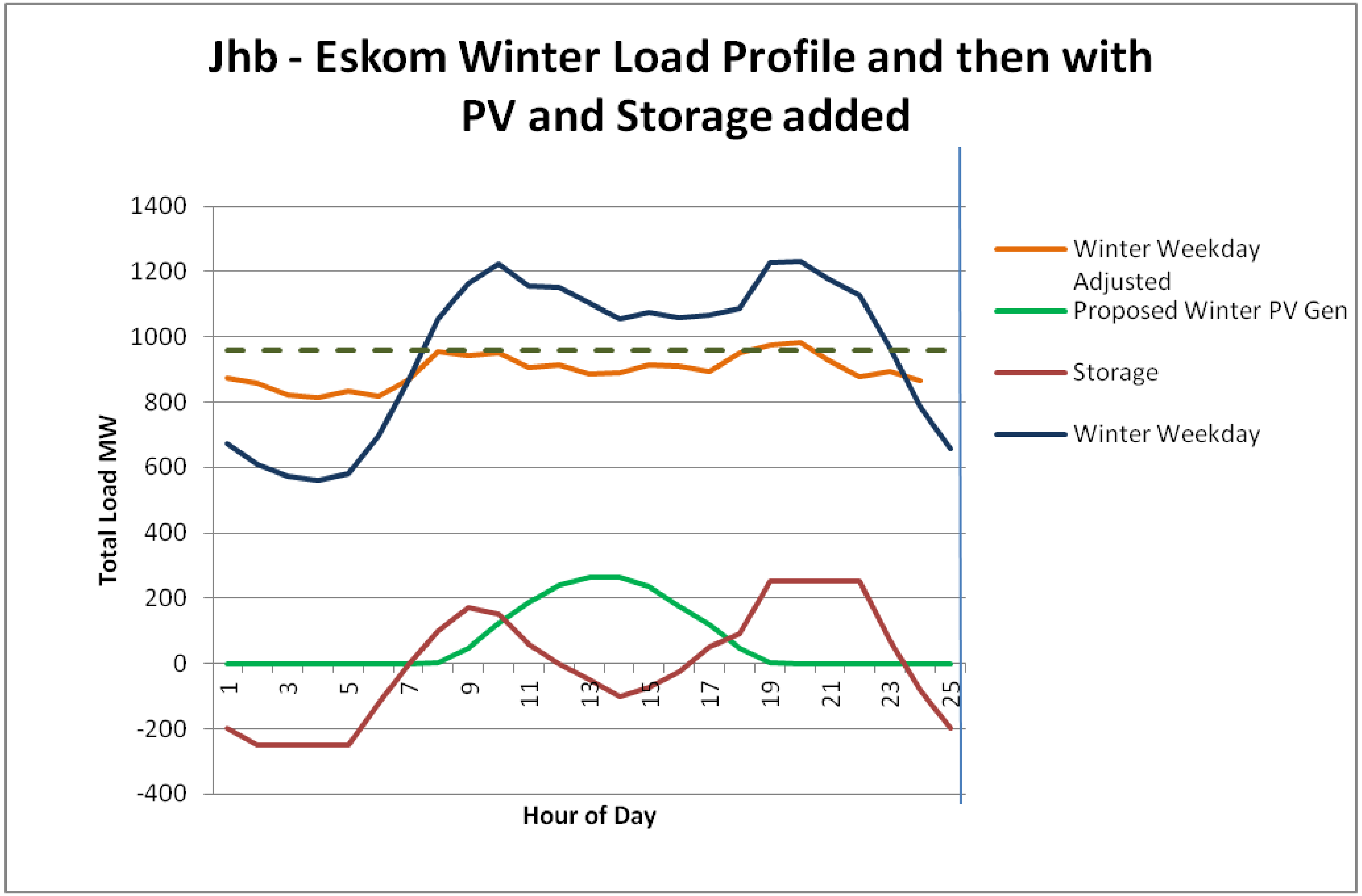
Load that is the Least Cost to Supply

- Peaky loads cost a lot to service
- As a grid operator, we do benefit from the diversity that the community connected to the grid demands
- However, the more peaky the load of our own customers is, the more costly it becomes for a distributor to both source the power and to deliver it.
- In reality very few loads are flat –
- Whatever can be done to remove the kinks in the load curve, will reduce costs of both cost drivers
- The supplier of last resort – this will be Eskom or the future ISMO's new role – will be the price setter, and the price for capacity will become more and more costly over time, particularly for peaky load.



- **The ideal load – a flat line – is a constant demand and a predictable quantity of energy to be delivered**

A recipe for reducing costs



- The winter load profile can be largely flattened with a coordinated combination of:
  - 350 MW of PV generation
  - 250 MW (1650 MWh) energy storage
- Up to stage 2 load shedding can be averted – effectively no load shedding
- The same combination applied to the Summer Load curve can both flatten the profile and begin to reduce peak energy purchases

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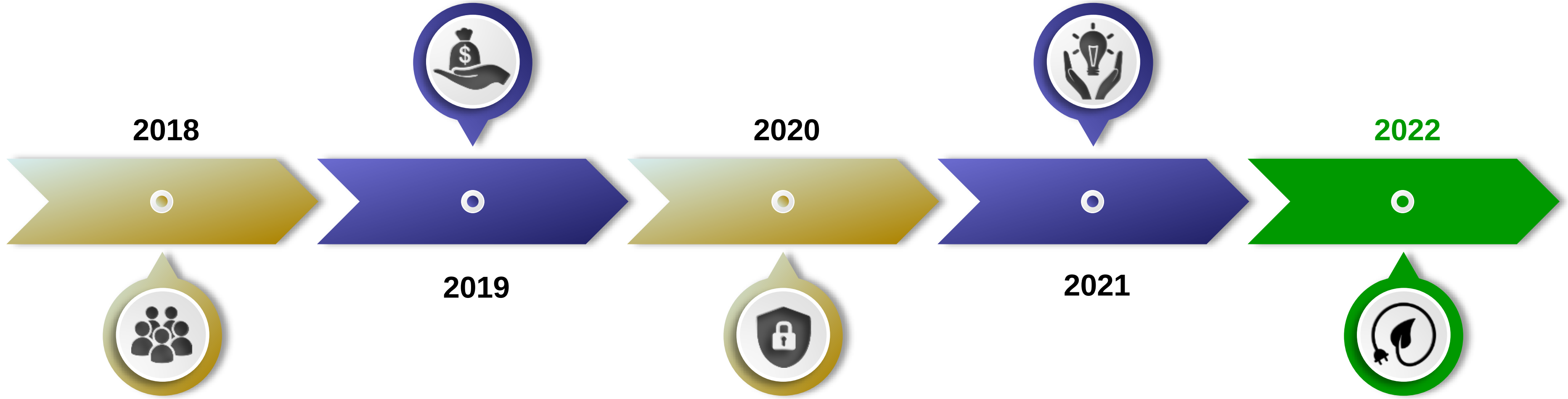
City Power Turnaround Strategy Map - VUCA

REVENUE COMPLETENESS AND ASSURANCE
- Smart Meter installations done
- Visible Public Lighting
- Adherence to NRS Service Standards
- Metering Collection Targets Achieved
- ICT strategy
- Prepaid conversion done

BUSINESS AND FINANCIAL SUSTANABILTY
- Refurbished plant
- Guaranteed plant capacity
- Smart City Power
- Meaningful economic transformation achieved



FOUNDATION - DRIVEN THROUGH PEOPLE, PROCESS AND SYSTEM STABILISATION
- Empowered leadership lead the change agenda
- Competent staff driving results
- Staff engaged and aligned to the City Power Way
- Processes are standardised and optimal
- Effective governance
- Risk and Business Intelligent Organisation

SECURITY OF SUPPLY AND NETWORKSTABILITY
- Preventative maintenance 'as the norm'
- Access to services in informal settlements
- Revised funding model
- Cost reflective tariff
- Minimal technical losses & non technical losses
- Visible public lighting
- Stable network
- Alternative energy player

CREATE VALUE FROM NEW OPTIONS
- Smart renewable energy trading
- Smart grid
- Smart plant
- Smart meter vending and billing
- Happy customer

Batteries pre-date the grid, but in the meantime…

- Batteries were invented long before the concept of a grid came into being –
- The mechanically generated energy delivered by the grid has been several orders of magnitude larger than what could be practically stored in and delivered from batteries
- Until now that is – advances in new chemistries and technology, both energy density and cycle life aspects have advanced dramatically
- And, coupled with rapid cost reductions -
- Has made energy storage at an appropriate scale a reality
- We can now think in the scales that are needed to apply storage as DSM measures to solve several of the grid's problems

129MWh, 100 MW Tesla Battery in South Australia

100 Ah traditional battery – 100 A x 12 Volts x 1hour = 1,2 kWh

Storage as a DSM measure makes sense….

Energy Storage can be applied to:

- Optimizing energy procurement costs
- Protecting the Economy
- Preserving overloaded distribution infrastructure
- Unlocking property development
- Supporting densification
- Optimizing Investment in renewable energy systems
- Providing basic energy services

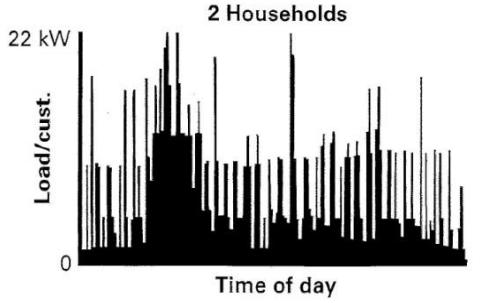
However ~

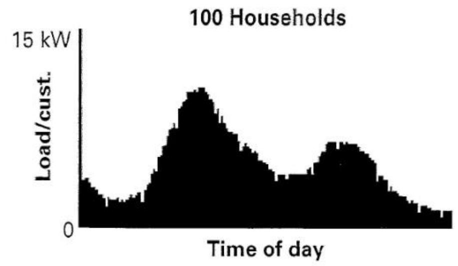
It all depends on where it is placed on the distribution network and how it is operated:

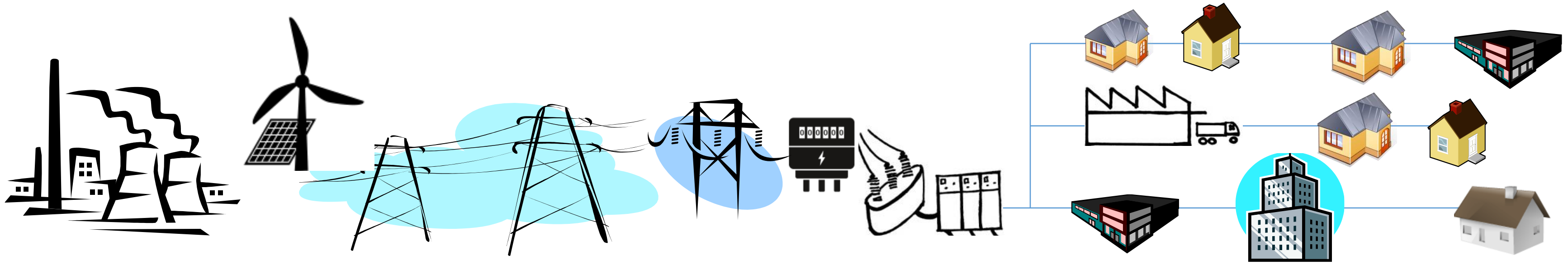
- Benefits of stacking for better, improved DSM
- Putting storage at the door of the customer has advantages

Key Properties of the Grid

- We often take the grid for granted – we do not properly acknowledge its properties and expect it is simply an infinite source of electricity
- It is *the* classic network – it connects everything together, very similar to the WWW
- What happens at one node of the grid has an impact on other nodes at locations both above and below that point
- Grids allow us to take full advantage of diversity
- Those connected to it form part of a community
- It is no longer a one-to-many kind of network, it naturally has the ability to connect many SSEG generators to loads





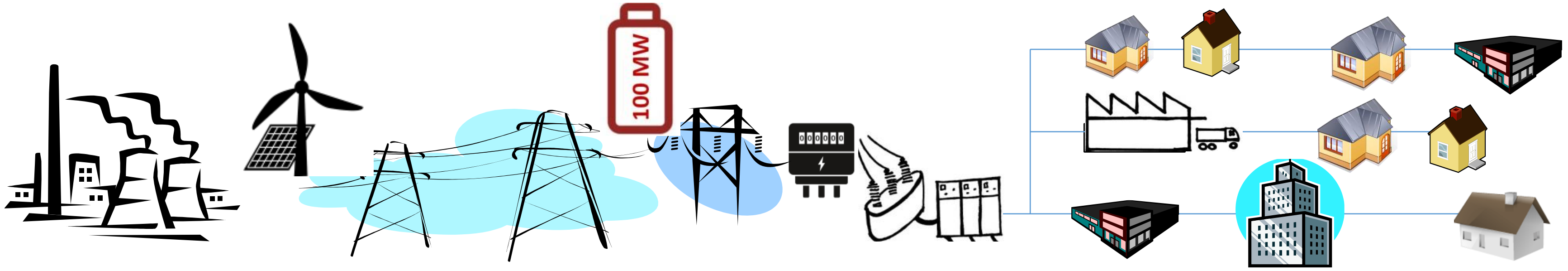


The impact is also felt on this part

And vice-versa

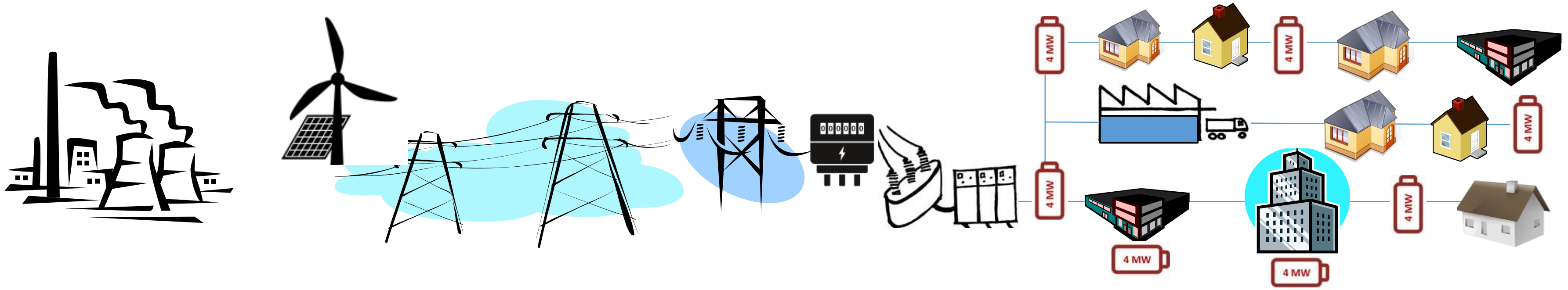
When something changes on this part of the grid -

Value of Storage connected at Transmission level



- **Consider what a 100 MWh storage system placed at a point on Eskom's high voltage transmission network can provide:**
  - A means to store surplus renewable energy at a national level,
  - Avoid transmission network bottlenecks and
  - Provide frequency support (reserve margin) for the national generation industry

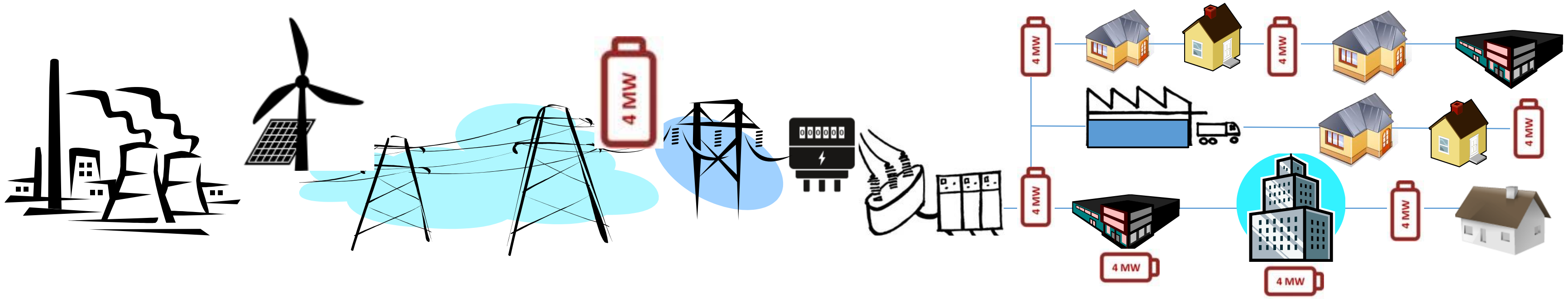
Better ‘stacked’ value when connected at Distribution level



- **If the same storage capacity of 100 MWh was deployed by strategically placing twenty-five smaller 4 MWh systems further downstream on the medium voltage distribution networks, the systems would still realize Transmission network benefits and add further value through:**

  - Energy purchasing arbitrage (Routinely, over the life of the storage system)
  - The alleviation of distribution network bottlenecks and overloads
  - The avoidance of Eskom Notified Maximum Demand Charge penalties,
  - The deferment of network refurbishment or network upgrade capital expenditure
  - Improvement of the power factor over the entire transmission and distribution networks
  - Realizing a significant improvement in the security of supply for customers.
  - Providing a measure of standby power to end customers (alternative to diesel power)

Enabling 'the stack' – coordinating operations



National Control	Regional Control	Distribution Control	End Customer
Generation Scheduling Frequency Control Reserve Margin Maintenance RE Surplus optimization	Tx Constraint Management Voltage support	DX Constraint Management Arbitrage, NMD management Enhanced QoS Power Factor Control	Secure Supply Arbitrage Demand Response SSEG Optimization EV charging coordination

Bi-directional control scheme

- New bi-directional control infrastructure is required to direct when energy storage assets should be deployed in their power generation mode and when they should be in their 'flexible load' mode.
- The control system should inform National Control of what stored energy is available to count as a contribution to the reserve margin (4th IR and Smart Grid aspects)
- The rules of engagement to co-ordinate the use of all energy storage assets are required – industry regulation – BESS Grid Code

Storage will earn it's daily keep

Joburg City Power Johannesburg

- Time of use tariffs are designed to change the behavior of the loads serviced
- These tariffs are also the foundation of the business case for energy storage systems
- TOU tariffs have expensive periods, typically when loads are high that stress the generators and distribution networks
- The cheaper periods are when the load subsides and things calm down – typically overnight
- Arbitrage is the practice of storing cheap period energy for use in a future, expensive energy period
- The base business case for storage is to do this every day to save costs and this is how it 'earns its daily keep' and pays for itself

Megaflex tariff - Local authority

Voltage	Active energy charge [c/kWh]											
	High demand season [Jun - Aug]						**Low demand season** [Sep - May]					
	Peak		**Standard**		**Off Peak**		**Peak**		**Standard**		**Off Peak**	
		VAT incl		*VAT incl*		*VAT incl*		*VAT incl*		*VAT incl*		*VAT incl*
< 500V	**300,18**	*345,21*	**91,34**	*105,04*	**49,84**	*57,32*	**98,28**	*113,02*	**67,83**	*78,00*	**43,23**	*49,71*
≥ 500V & < 66kV	**295,45**	*339,77*	**89,52**	*102,95*	**48,61**	*55,90*	**96,38**	*110,84*	**66,33**	*76,28*	**42,09**	*48,40*
≥ 66kV & ≤ 132kV	**286,13**	*329,05*	**86,67**	*99,67*	**47,07**	*54,13*	**93,34**	*107,34*	**64,25**	*73,89*	**40,75**	*46,86*
> 132kV*	**269,66**	*310,11*	**81,69**	*93,94*	**44,36**	*51,01*	**87,96**	*101,15*	**60,54**	*69,62*	**38,41**	*44,17*

Optimizing energy procurement costs

Arbitrage Break-even Cost Point

Analysis of break-even point of energy storage cost vs. maximum arbitrage potential of the Local Government Megaflex Tariff

1kWh Storage used for 6 days of the week, one shot per day, to shift 1kWh from peak to off-peak, all year round

Plant Parameters

Technology Aspects	Units	Value
Cost of Storage System	$/kWh	295
Storage System Expected Cycle Life	Number	7000
Efficiency of Charge and Discharge cycle	%	85%
Capital Aspects	Units	Value
Rand to Dollar Exchange Rate	Ratio	14,61
Local cost of Storage	R/kWh	4309,95
Capital loan interest rate	%pa	5,5%
Capital Loan Term	Years	10
Cost of Finance	R/kWh	-1303
Total financed plant cost	R/kWh	5613
Theoretical Plant Life, 6 days p/week, 1 cycle/day	Years	22,4
Expected Operational Lifespan	Years	15
Charge / Discharge Cycles Required	Number	4696
Staff Operating costs	R/kWh	1440
R&M Plant costs @ 10% of capital cost	R/kWh	430,995
Total Cost of Financed and Maintained Plant	R/Kwh	7484
LCOE over expected plant life 1 shot per day	c/kWh	159,37

Megaflex Tariff Application

11kV Intake point, e.g. Randburg

Operational Aspects Energy	Units	Value
HV Distribution System Losses	%	4,00%
MV / LV Distribution	%	3,00%
Value of Winter Evening Energy Arbitrage	c/kWh	246,84
Value of summer Evening Energy Arbitrage	c/kWh	54,29
Loss-less average value of daily arbitrage	c/kWh	102,43
Average daily rate to re-charge system	c/KWh	43,72
Cycle cost to overcome system recharging losses	c/kWh	6,56
Cycle savings due shift of losses out of peak	c/kWh	3,07
Net average value of daily energy arbitrage	c/kWh	98,94
Operational Aspects Network and Demand costs	Units	Value
Peak Period Duration	hours	2
Demand reduction potential per kWh of storage	kVA	0,5
Monthly network charge per kW	r/kVA	7,63
Monthly demand charge per kW	r/kVA	28,99
Daily network and demand charge savings potential	c/kWh	60,23
operation during the annual half hour peak.		
Total potential daily arbitrage value of 1kWh storage	c/kWh	159,17

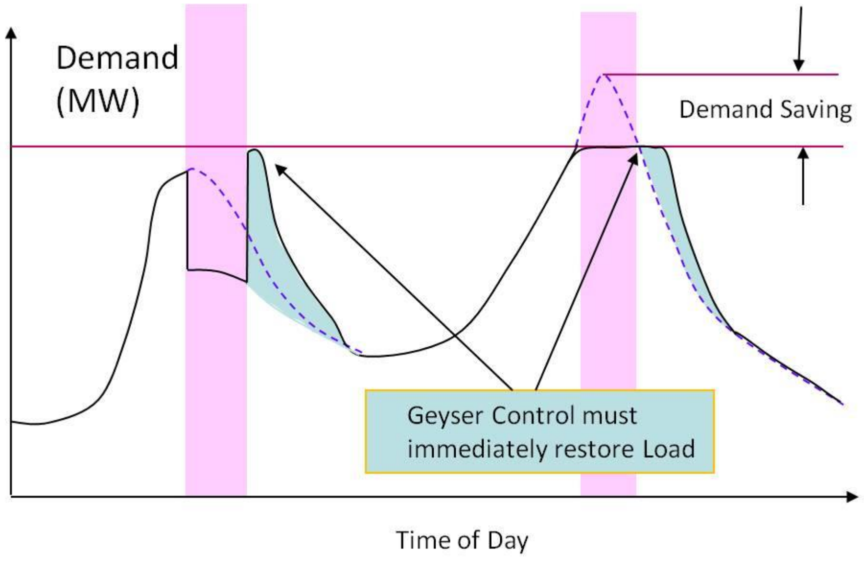
GL Cost Element
890000
Bulk Purchases: Eskom

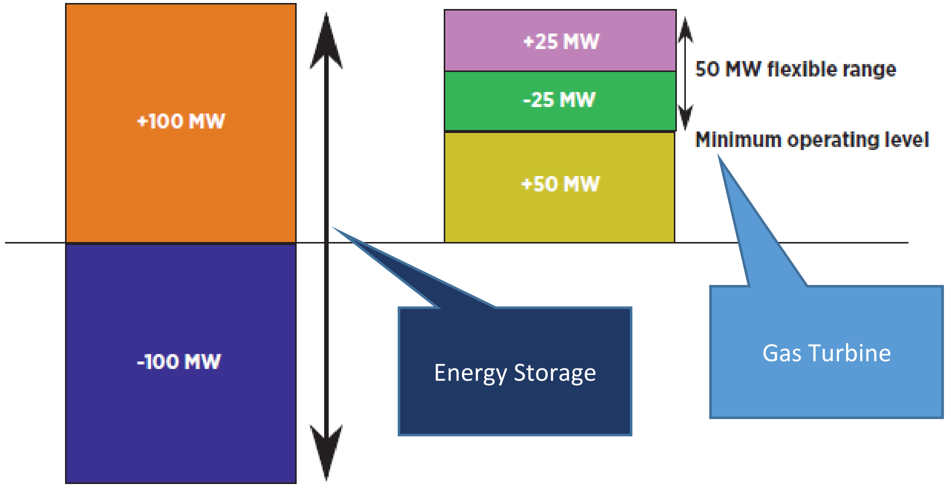
Network Access Ch.
+
Off-Peak Energy
+
Standard rate Energy
+
Peak rate Energy
+
Network Demand Ch.

Savings on these charges can pay for storage services

DSM on steroids – load shifting and peak lopping

- Energy storage can behave as a load as well as a generator
- Unlike a load reducing geyser control system there are no time constraints on when the system needs to be re-charged – a geyser control system must restore load within an hour or so after the peak period, to avoid cold water complaints
- Gas peaking plant can only reduce the peak to the equivalent of its generating capacity.
- A storage system can reduce the peak by its inverter capacity as well as fill in the valleys in its recharging mode – it has twice the control swing





Optimizing energy procurement costs

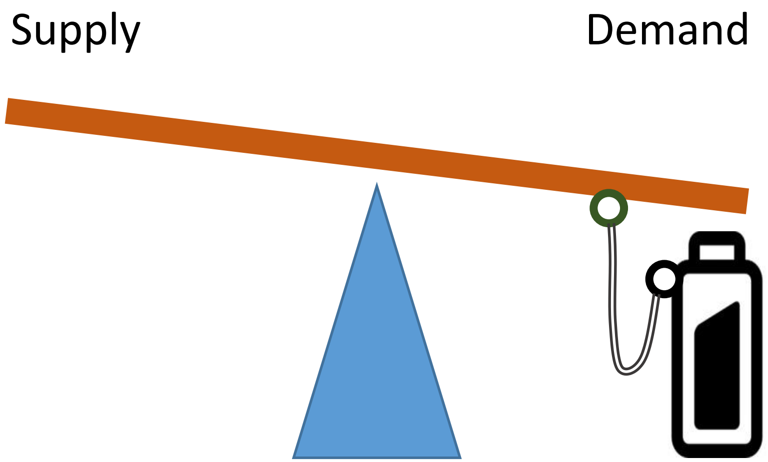
The highest value of all?

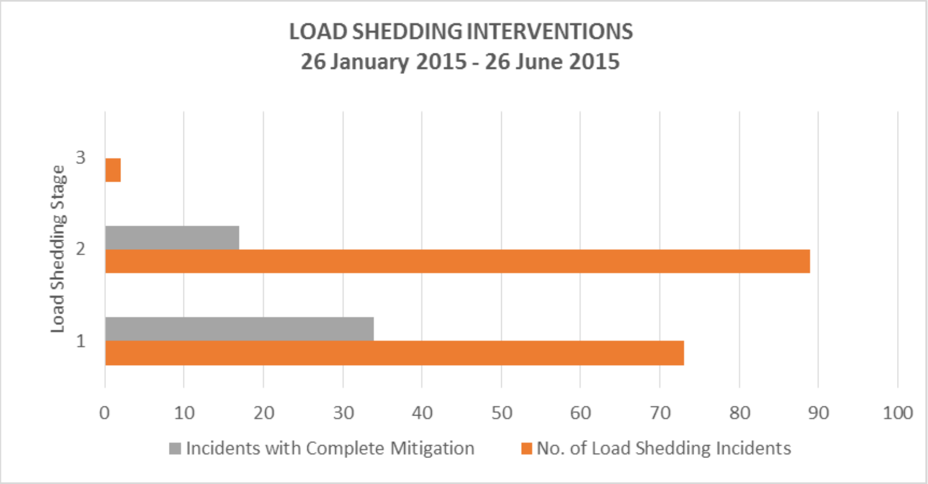
- Storage is an antidote to load shedding -
- Direct cost of unserved energy is estimated at R17 per kWh (planned outages)
- + Indirect costs can be as high as R87 per kWh (figure from IRP 2019 Update)
- Those companies that have UPS units (storage systems) to ride through power interruptions are already reaping the benefits of storage
- The benefit is proportional to the frequency of load shedding – how much can we expect over the next few years?
- Under continuous Stage 1 conditions, the system may pay for itself in <1 year?

Stage 1 applied during business hours – 08h00 to 16h00 translates to 16 hours without power over a month. The additional value over the month for each kWh of storage available may be anywhere from R272 to R1392.
For stage 2, the value is twice this, for stage 3, 3 times, etc.etc.

Improving the Quality of Supply

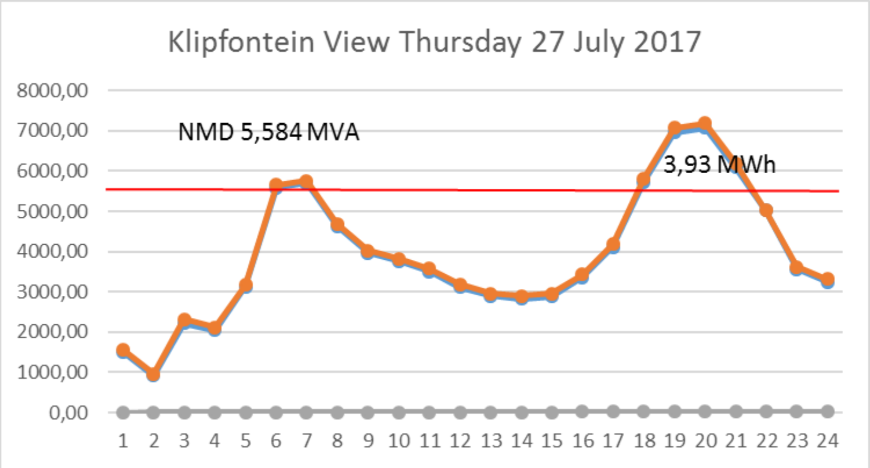
Protecting the Economy





NMD penalty avoidance

- NMD penalties are incredibly punitive
- Many municipalities are being penalized, a result of under investment in network upgrades



Monthly NMD Penalty=

(MUC-NMD)*Event No*(Network Demand Charge+Low Voltage Subsidy)

Tariff: Nightsave Urban kVa.
NMD: 5,584 MVA.
Exceedance in July 2017: 2,161 MVA
Excess NMD charge per kVA in July (8 events): 8 X R 21,36 = R 170.88 per kVA
Total paid in Excess NMD Charges for 2017/2018: R2 609 637,18

Energy Storage is a powerful DSM tool to clip the peaks and fill the valleys to avoid NMD penalties

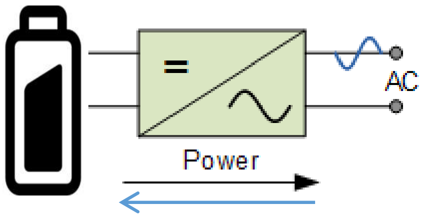
Investment comparison – Diesel vs. Storage

Diesel Generator

1. Expensive Fuel – R5,70 /kWh
2. Generator only Used in an emergency
3. Sunk cost, only 'pays back' when an emergency applies
4. Complicated parallel operation, supply interruption at grid failure and grid restoration
5. Spinning plant fault current issues
6. Complicated, high maintenance machinery
7. Must be regularly 'preparedness tested'

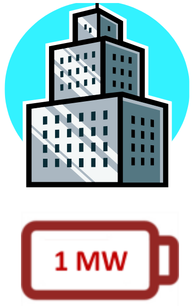
Energy Storage System

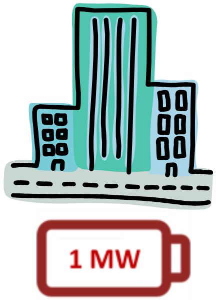
1. Recharges with cheapest energy available, including renewable options. R 0,43 to R 0,49 / kWh
2. Used everyday and in emergencies
3. Payback certainty through daily arbitrage duty
4. Easy inverter based parallel grid integration, seamless load transfers
5. No fault current issues
6. Reliable machinery
7. Daily use, routine daily functional testing



Avoiding Unserved Energy Costs

- **The best location for SA's energy storage assets is on the customer's premises and to run their sites as power islands during grid outages or load shedding.**
- Can be implemented by the distributor (Value Added Service) or by the customer (TOU tariff response)
- This will keep the economy going and at the same time maintain revenues for the distributors as they restore their grids or comply to load shedding calls.
- Eskom previously initiated power 'buy-back' initiatives, in effect paying large industrial customers not to consume power to reduce the load.
- It was not a well supported Demand Response scheme as it shut down a portion of the economy as those businesses simply 'closed shop' in responding.
- If those businesses were to have substantial storage systems, they could participate in a DR program that will have the same effect yet allow economic activity to continue as normal.





Protecting the Economy

Minimizing Use of Network Charges

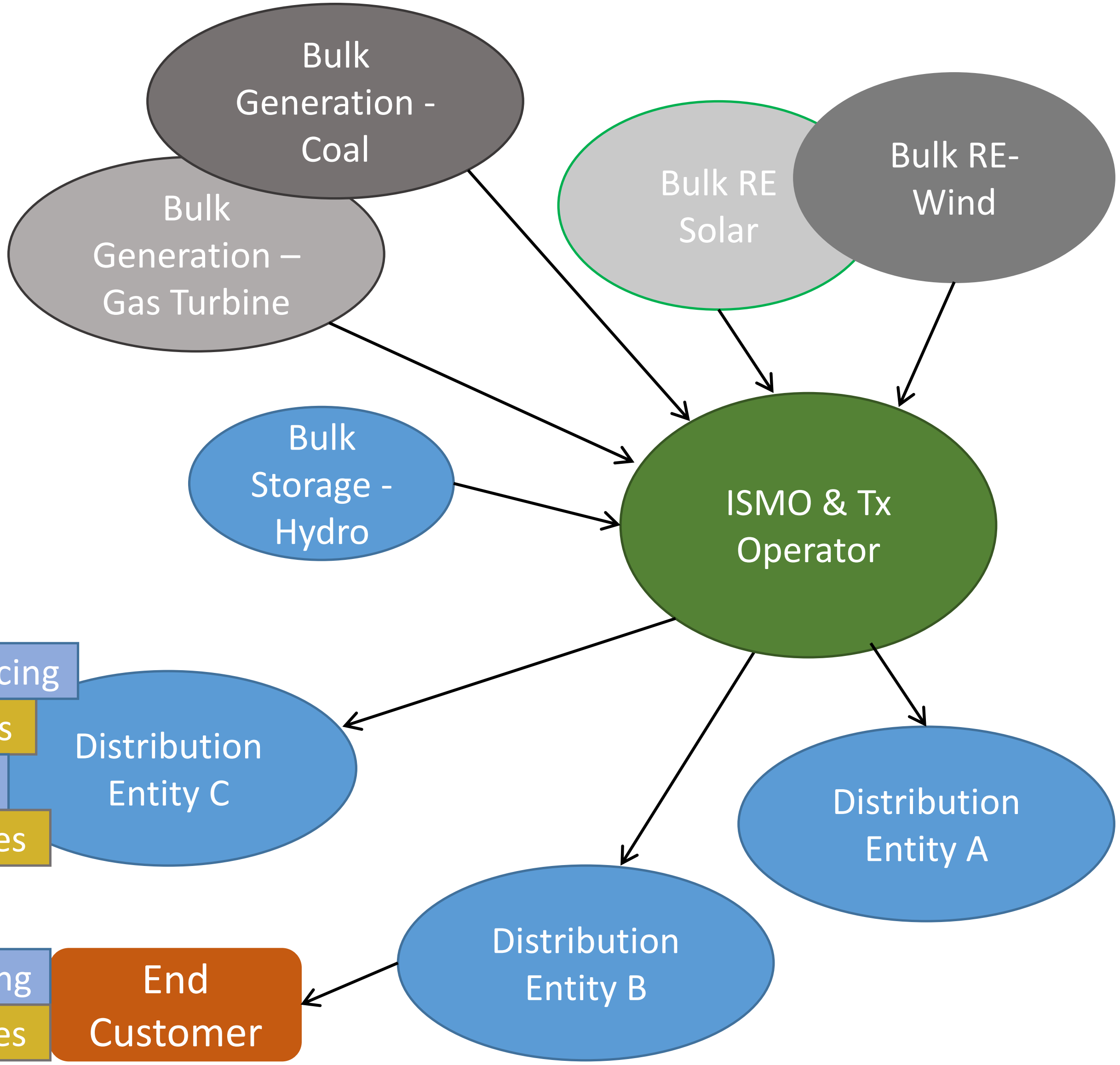
- In terms of third party transport of energy –
- It is a NERSA accepted tariff principle that both Generators and Loads should pay to use the grid
- Energy generated for trade across the grid must pay for using the grid to get there
- The cost per kWh 'transported' is inversely proportional to the capacity factor of the generating plant
- Using storage to double the capacity factor of will reduce the cost of transport
- Releasing stored energy during peak periods provides added value to the generator as well as the local distribution network operator

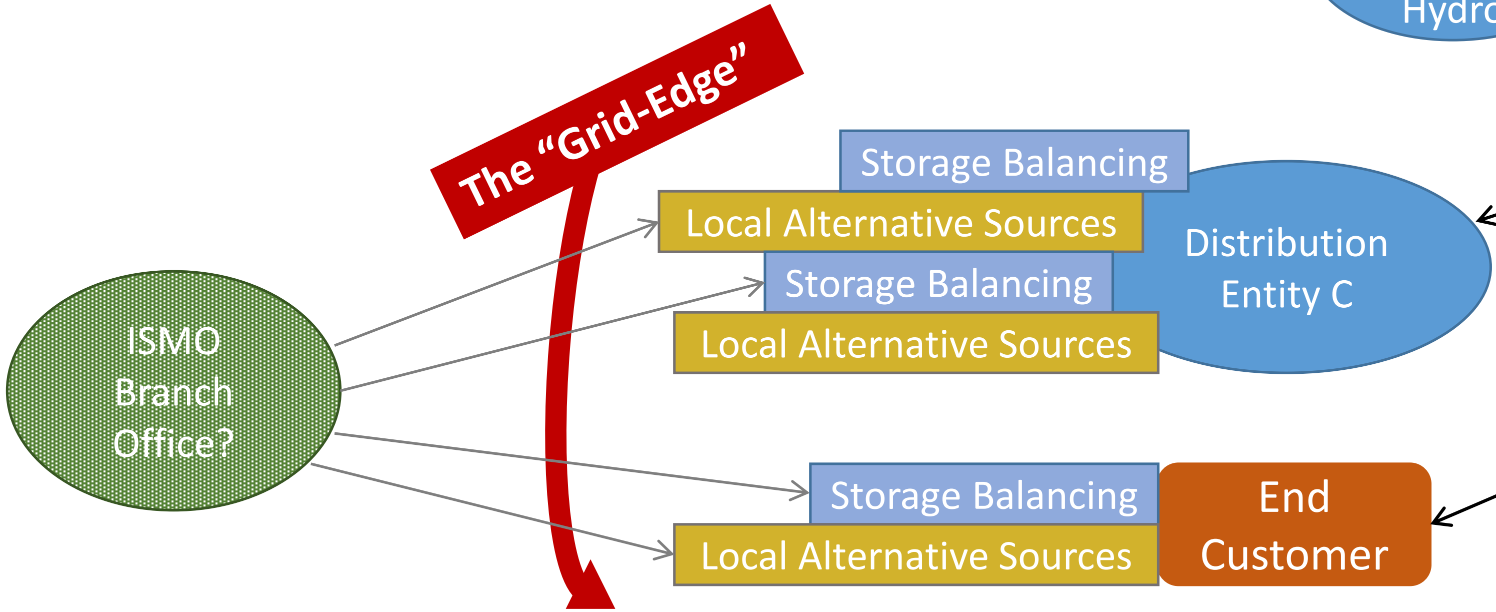
176	R/kVA	Basic grid use charge							
PV System Installed capacity kVA	Capacity Factor %	Daily production factor kWh/day	Daily Production kWh	Monthly Production kWh	Grid capacity required kVA	Monthly Grid Access cost R	Energy Storage System Capacity kWh	Grid use cost per kWh	PV + Storage Capacity Factor
1 000	30%	5,5	5 500	167 200	1000	176 000	None	1,05	23%
1 000	30%	5,5	5 500	167 200	818	144 000	1000	0,86	28%
1 000	30%	5,5	5 500	167 200	545	96 000	2500	0,57	42%
1 000	30%	5,5	5 500	167 200	300	52 800	3850	0,32	76%

Optimizing RE Investment

Allow Storage to find its Niche

- Possible model of the future ESI
- The optimal value of energy storage is at the 'grid edge'
- Either behind the Eskom – Municipal Distributor meter
- Or, behind the meter of end customers





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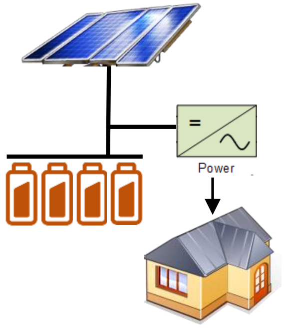
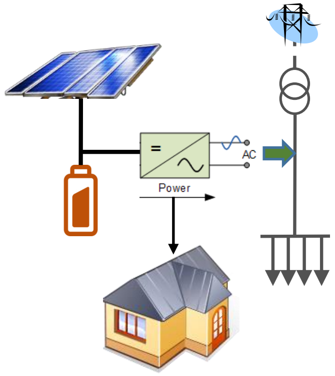
RE - Service with or without the Grid?

Running RE plus Storage as an island off-grid:



- Vulnerable to bad solar days
- Must 'size-up' for worst case
- No backup or expensive backup
- Nowhere for valuable surplus energy to go
- Freedom from electricity billing disputes
- Not impacted by any measure of load shedding
- Not impacted by catastrophic grid failures
- Has proven useful where natural disasters have occurred
- Definitely not the 'least cost' option

RE plus Storage and staying part of a grid connected community:



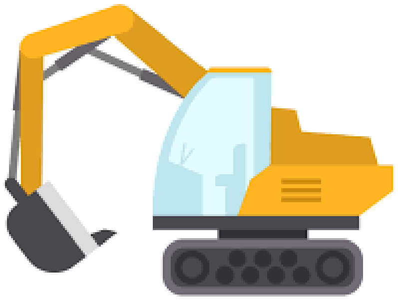
- Best backup available
- The grid becomes a marketplace for RE surpluses
- Creates higher value for surplus energy stored and released during peak periods
- Contribute towards benefiting the grid community - subsidies
- Receive community benefits through diversity
- Provides valuable support to the grid operator
- Smaller, more affordable storage assets can deliver the same benefits – lower cost option

Distribution Infrastructure - Expansion and Refurbishment

Preserving infrastructure

Unlocking Development

- SA has a 70 billion Rand backlog in distribution infrastructure maintenance.
- It is estimated a third (R23 billion) of this is for distribution network strengthening, often needed for only short duration peak loads.
- Upgrade work involves the physical replacement of existing distribution infrastructure plant and cabling, a capital intensive and disruptive activity.
- This problem is constraining property development in municipal areas which is also affecting economic development.
- The life of aging distribution infrastructure is extended where the networks can be de-stressed through peak load reduction.
- **Well-placed energy storage can permanently avoid or solve a fair share of these problems – particularly since it already pays for itself from daily arbitrage savings.**



Conclusion

- Distributors could consider storage funded through the operating budget in place of costly capital funded network upgrades
- Storage to complement self-dispatched renewable energy SSEG uptake on municipal grids is key to our sustainability. Consider policy that requires an element of storage be included in PV applications.
- Energy storage systems are powerful DSM tools as they can behave as both dispatched loads and as dispatched energy sources, it is a direct 'proxy' for gas and diesel peaking plant

- **The best value for future energy storage assets is on distribution networks, both Municipal and Eskom's.**
- **The EDI needs to encourage the wholesale uptake of energy storage systems in all forms and ownership models as it will be key to the sustainability of the industry in the coming years**

Type of installation	Nominal Storage capacity per participant (kWh)	Potential Number of participants	Contribution to Total (MWh)
Individual Residential PV prosumers (kWh)	3	100 000	300
Sectional Title Residential (kWh)	50	5 500	275
Large Power Users <100 kVA	100	8 000	800
Key Customers >100 kVA	1 000	300	300
		Total	1675

SAESA | South African Energy Storage Association

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