CHICAGO HOUSING AUTHORITY

Solar Plus Storage Financial Analysis

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Executive Summary

Chicago Housing Authority's moderate tariff structure makes microgrid economical as well as qualitatively beneficial. Microgrid modeling tools were used to analyze the "Solar only" and "Solar+Storage" scenarios.

The "Solar+Storage" solution will help CHA offset their energy consumption by around 4million units (kWh) from the current scenario thus providing significant energy savings. Also CHA can further reduce their cost of energy considering ITC, SREC revenue and ancillary services benefits. Going forward this system can act as resilient power back up option and help CHA achieve their sustainability goals.

Analysis

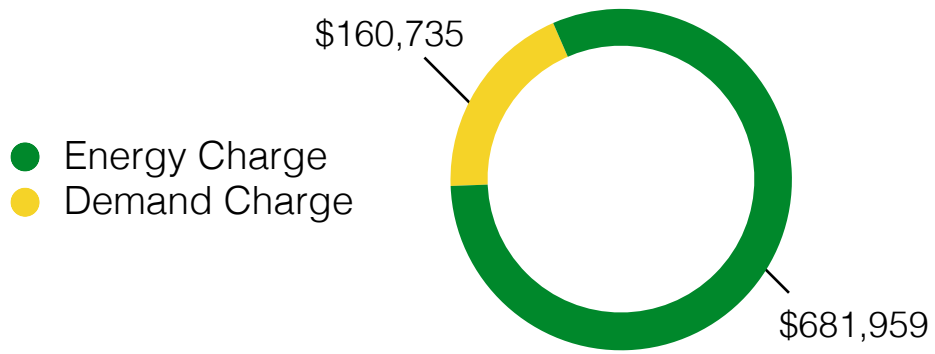
Load profile considered for analysis: ***Year 2015***

Note: For analysis, the peak load considered was 2,600kW which is a 30-min maximum demand interval (i.e. max of 30 min averages) instead of the instantaneous peak load 3,070 kW. This is how the utility companies calculate the average peak load.

Based on the current electricity consumption following is the annual cost for energy charges and demand charges for CHA's energy profile:

CHA ENERGY PROFILE (GRID ONLY)			
	Consumption	**Cost (Avg)**	**Annual Total Cost**
Energy Load	11,558,629 kWh	Flat Charge: 5.9 cents/kWh	$681,959
Demand Load	2,600 kW (Peak Load)	$6.86/kW/month	$160,735
Other Charges	NA	NA	$181,326
Total Charges	NA	NA	$1,024,020

Total Cost of Energy: 7.3 cents/kWh *(Total Cost of Energy includes both energy charge and demand charge)*
Other Charges: Includes Fixed Costs (Metering Charge, Customer Service Charge, Non-Standard Facilities Charge), ComEd Franchise Cost & Taxes (State Tax, Municipality tax).



Cases

Following are the default results obtained after modeling the above load profile and tariff structure in HOMER*.

Case 1: SOLAR ONLY

- Based on the peak load of 2.6MW, HOMER suggests a 4.48 MW of PV.
- Hours of operation: 4,375hrs/yr (HOMER output)
- Power output: 8,595,028 kWh/yr (HOMER output)
- Sellback rate for excess solar energy: 2.7cents/kWh
- Solar panel footprint: Depending on the technology, typical 4.8 MW solar system would occupy anywhere between 241,024 sq. ft. to 321,365 sq. ft. (22,400 m^2 to 29,866 m^2). **Roughly the size of four football fields.**

The revised cost of energy for "solar only" option is 3 cents/kWh (excluding the initial capital cost of the system). This yields energy savings of roughly $495,592/ year and demand savings of roughly $5,567/year. Including solar benefits, the total savings sum up to roughly $501,159/year.

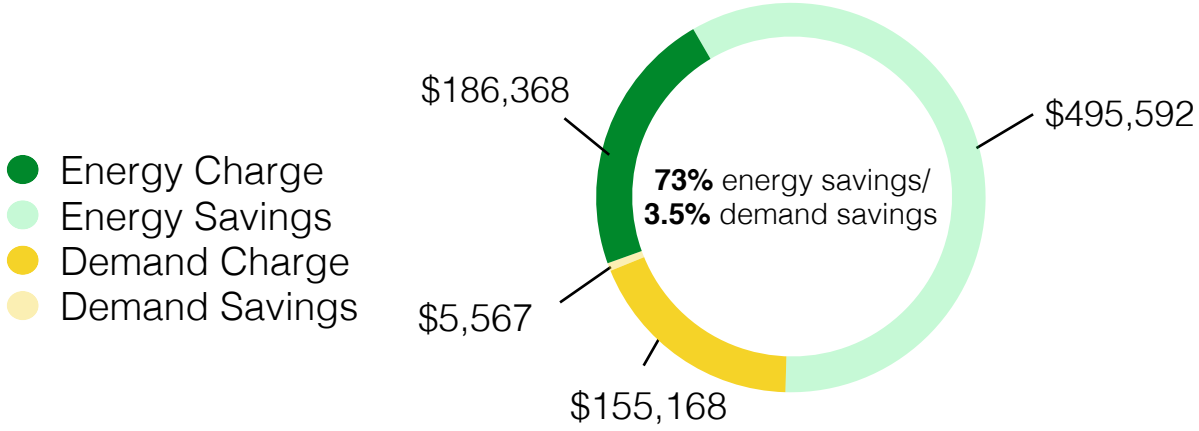
CHA ENERGY PROFILE (SOLAR ONLY)			
	Consumption	**Cost (Avg)**	**Annual Total Cost**
Energy Load	7,661,277 kWh	Flat Charge: 5.9 cents/kWh	$186,368
Demand Load	2,500 kW (Peak Load)	$6.86/kW/month	$155,168
Other Charges	NA	NA	$51,230
Total Charges	NA	NA	$392,766

Other Charges: Includes Fixed Cost (Metering Charge, Customer Service Charge, Non-Standard Facilities Charge), ComEd Franchise Cost & Taxes (State Tax, Municipality tax). By benchmarking with current bill, other charges are estimated as ~14% to ~15% of the total energy & demand charge. i.e., Fixed Charges @ 1.6%, Franchise Cost @ 4.3% and taxes @ 9.2%

TOTAL SOLAR BENEFITS FOR 4.48 MW PV	
Energy + Demand Savings	$501,159/year
Total ITC*@ 30%	$3,531,600
Annual SREC* for 15 years	$15,539,811

Total Cost of Energy: 3 cents/kWh *(Total Cost of Energy includes both energy charge and demand charge)*

Disclaimer: The solar benefits considered may vary from state to state and client to client. The existence of such benefits is at the sole discretion of the government and the federal policies.



*HOMER (Hybrid Optimization of Multiple Energy Resources)

*Solar ITC

The Investment Tax Credit (ITC) is currently a 30 percent federal tax credit claimed against the tax liability of residential (Section 25D) and commercial and utility (Section 48) investors in solar energy property. This credit is used when a business purchases solar systems outright and have them installed on their facilities. In the case of the Section 48 credit, the business that installs, develops and/or finances the project claims the credit. For more: http://www.seia.org/policy/finance-tax/solar-investment-tax-credit

*SREC

Solar renewable energy credits (SRECs) are tradable credits that represent all the clean energy benefits of electricity generated from a solar energy system. Each time a solar energy system generates 1,000 kWh (1MWh) of electricity, an SREC is issued which can then be sold or traded separately from the power. The credit value depends on the state and local SREC market. In this case, SREC value starts at $240 per solar credit in 1st year and decreases to $78 per solar credit in year 15 considering the volatility of SREC market.

FINANCIAL SUMMARY

SOLAR ONLY (4.48 MW)		
	With SREC	**Without SREC**
System Size	4.48 MW	4.48 MW
Project Payback	2.5 Years	8.8
IRR (20 Years)	26.6%	8%
NPV	$11.39 M	$1.12 M
CAPEX	$11.74M	$11.74M

Key Assumptions: *(all assumptions are based on industry standards)*

- Solar Panel cost (includes transportation & installation costs) = $2/watt
- Interest rate = 6%
- State Tax rate = 7.5%
- Federal Tax rate = 35%
- No ancillary services considered
- All costs used in the calculation are indicative.

CASE 2: SOLAR + STORAGE

Optimized Solar+Storage configuration from HOMER suggests 5000kW Solar and 4000kWh Flow battery storage.

Solar Output:

- Hours of operation: 4,375 hrs/yr (HOMER output)
- Power output: 8,595,028 kWh/yr (HOMER output)
- Sellback rate for excess solar energy: 2.7cents/kWh
- Solar panel footprint: Depending on the technology, typical 4.8 MW solar system would occupy anywhere between 241,024 sq. ft. to 321,365 sq. ft. (22,400 m^2 to 29,866 m^2). **Roughly the size of four football fields.**

Storage Output:

- Annual Battery Throughput: 41,012 kWh/yr (HOMER output)
- Storage footprint: Depending on the technology, typical 1MW/4MWh flow battery would occupy 2,889 sq. ft. (268 m^2), without service access. **Roughly the size of a tennis court.**

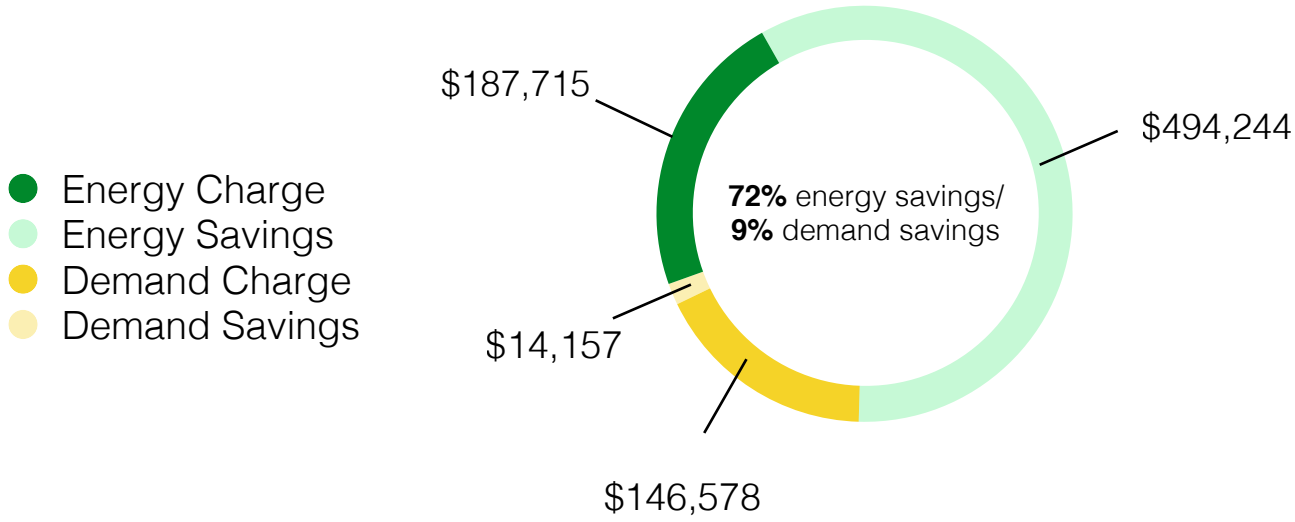
CHA ENERGY PROFILE (SOLAR + STORAGE)			
	Consumption	**Cost (Avg)**	**Annual Total Cost**
Energy Load	7,673,261 kWh	Flat Charge: 5.9 cents/kW	$18,771
Demand Load	2,100 kW (Peak Load)	$6.86/kW (avg. per month	$14,657
Other Charges	NA	NA	$5,014
Total Charges	NA	NA	$38,442

Other Charges: Includes Fixed Cost (Metering Charge, Customer Service Charge, Non-Standard Facilities Charge), ComEd Franchise Cost & Taxes (State Tax, Municipality tax). By benchmarking with current bill, other charges are estimated as ~14% to ~15% of the total energy & demand charge. i.e., Fixed Charges @ 1.6%, Franchise Cost @ 4.3% and taxes @ 9.2%

ANNUAL ANCILLARY BENEFITS	
Energy + Demand Savings	$50,840/year
Frequency Regulation*	$85,200/year
Demand response*	$38,814/year
Arbitrage* *(Net metering)*	$60,000/year
Total Savings *(Energy + Ancillary)*	$692,415/year

Total Cost of Energy: 2.9 cents/kWh *(Total Cost of Energy includes both energy charge and demand charge)*

Disclaimer: The ancillary services benefits considered are based upon the existing PJM's program. The existence of such programs in future is at the sole discretion of PJM.



*Frequency regulation

Regulation is a service that corrects for short-term changes in electricity use that might affect the stability of the power system. It helps match supply and demand and adjusts output to maintain the desired electrical frequency for the grid to function normally.

*Demand Response Market

Demand response is a voluntary PJM program that allows end use customers to reduce their electricity usage during periods of higher power prices. In exchange, end-use (retail) customers are compensated through PJM members known as Curtailment Service Provider for decreasing their electricity use when requested by PJM.

*Arbitrage (Net Metering)

Arbitrage is the practice of charging the batteries during off peak period and use the stored energy during peak times in order to make the energy costs worthwhile. Using storage for "energy arbitrage" works better when there's a significant difference between the on-peak and off-peak electricity charge.

The revised cost of energy for solar+storage option is 2.9 cents/kWh (excluding the initial capital cost of the system). This yields an annual energy savings of roughly $508,401/year. Including ancillary service benefits, the total savings sum up to roughly $692,415/year.

FINANCIAL SUMMARY

SOLAR + STORAGE (4.8 MW + 4000kWh)				
	With Ancillary services		**Without Ancillary Services**	
SREC	With SREC	Without SREC	With SREC	Without SREC
Project Payback	2.8 years	8.2 years	3 years	12 years
IRR (20 year)	23.9%	8.4%	21.7%	5.6%
NPV	$11.89M	$1.67M	$9.98M	-$0.24M
CAPEX	$14.27M	$14.27M	$14.27M	$14.27M

Key Assumptions: *(all assumptions are based on industry standards)*

- Solar Panel cost (includes transportation & installation costs) = $2/watt
- Flow Battery cost (includes Schneider Controller costs & Installation costs) = $730/kWh
- Interest rate = 6%
- State Tax rate = 7.5%
- Federal Tax rate = 35%
- Demand charge escalator = 3 % & ITC @ 30%
- All costs used in the calculation are indicative

QUALITATIVE BENEFITS

Following table highlights the qualitative benefits that CHA can have with a solar + storage configuration. A 4.48 MW + 4000 kWh solar plus storage system with significant energy savings will help CHA reduce their carbon footprint by a huge margin of 74%.

Gases	Only Grid	Solar + Storage	% Change
Carbon Dioxide	7,305,054	1,887,579	-74.16%
Sulphur Dioxide	31,671	8,183	-74.16%
Nitrogen Dioxide	15,489	4,002	-74.16%

Annual emissions are in metric tons

Conclusion

Based on the above analysis, we can see that the cost of energy for both “Solar only” and “Solar+Storage” configuration is significantly lower than the current cost of energy from grid. Considering SREC, ITC and ancillary services benefits “Solar+Storage” system has an attractive payback period of 2.8 years.

However, the SREC revenue stream over the 15 years can change based upon the policies prevailing at that time. Irrespective of the SREC revenue stream, the solar plus storage option with ancillary benefits based on a 1MW flow battery still has an attractive payback period of 8.2 years.

Note: While lithium ion batteries cost around $700/kWh - $800/kWh for a complete system including the O&M and replacement cost, Li-ion batteries are not considered in our analysis due to the following drawbacks,

1. Thermal runaway in Li-ion batteries can pose SAFETY issues thus making it unsuitable for commercial applications.
2. 50% capacity degradation over five to ten year period.
3. Higher lifetime cost per kWh.
4. Half the life time of flow batteries.

Tools Used

HOMER PRO

Economic and engineering optimization tool developed by National Renewable Energy Lab, US Department of Energy.

DER-CAM+ TOPOLOGY | ANALYTICS |

The Distributed Energy Resources Customer Adoption Model developed at Berkley Lab is used to verify HOMER’s output.

Technical Appendix

SOLAR ONLY						
System Size	**5MW**		**8MW**		**10MW**	
SREC	With SREC	Without SREC	With SREC	Without SREC	With SREC	Without SREC
Project Payback	2.6 yrs	9.4 yrs	2.6 yrs	11 yrs	2.6 yrs	12 yrs
IRR (20 year)	26.10%	7.20%	25.40%	6.00%	25.00%	5.30%
NPV	$12.20M	$.74M	$18.38M	$.05M	$22.15M	-$.77M
CAPEX	$13.09M	$13.09M	$20.89M	$20.89M	$26.09M	$26.09M

SOLAR + STORAGE (With Ancillary Benefits)						
System Size	**5MW + 4MWh**		**8MW + 4MWh**		**10MW + 4MWh**	
SREC	With SREC	Without SREC	With SREC	Without SREC	With SREC	Without SREC
Project Payback	2.8 yrs	8.8 yrs	2.8 yrs	9.9 yrs	2.8 yrs	11 yrs
IRR (20 year)	23.70%	7.80%	23.90%	6.50%	23.80%	5.80%
NPV	$12.71M	$1.29M	$18.88M	$.59M	$22.65M	-$.22M
CAPEX	$15.62M	$15.62M	$23.42M	$23.42M	$28.62M	$28.62M

SOLAR + STORAGE (Without Ancillary Benefits)						
System Size	**5MW + 4MWh**		**8MW + 4MWh**		**10MW + 4MWh**	
SREC	With SREC	Without SREC	With SREC	Without SREC	With SREC	Without SREC
Project Payback	3 yrs	12 yrs	2.9 yrs	13 yrs	2.9 yrs	14 yrs
IRR (20 year)	21.70%	5.10%	22.50%	4.70%	22.70%	4.30%
NPV	$10.80M	-$.61M	$16.97M	-$1.32M	$20.74M	-$2.13M
CAPEX	$15.62M	$15.62M	$23.42M	$23.42M	$28.62M	$28.62M

Technical Appendix

INDICATIVE COST DETAILS				
Cost Type	**Solar Only (4.8 MW)**	**Total Cost**	**Solar+Storage (4.8MW + 4MWh)**	**Total Cost**
PV Module *(25 yrs)*	$2/W	$9,600,000	$2/W	$9,600,000
PV O&M	$0.01/W/yr	$44,800/yr	$0.01/W/yr	$44,800/yr
PV Inverter *(10 yrs)*	$104/kW	$465,920	$104/kW	$465,920
PV Inverter O&M	$1.2/kW/yr	$5,600/yr	$1.2/kW/yr	$5,600/yr
PV Inverter Replacement	$42/kW	$197,120	$42/kW	$197,120
ES, Aux, Container *(20 yrs)*	-	-	$382/kWh	$1,527,680
PCS/Inverter *(20 yrs)*	-	-	$72/kWh	$287,600
BOS + Grid Tie	-	-	$28/kWh	$111,000
ES/PCS Installation	-	-	$121/kWh	$484,500
EMS	-	-	$25/kWh	$98,000
Soft Costs	-	-	$36/kWh	$142,091
Battery Replacement	-	-	$68/kWh	$270,093
EMS Annual Maintenance	-	-	$4/kWh	$8,000/yr
ES Inverter O&M	-	-	$0.72/kWh	$2,875/yr
ES Inverter Replacement	-	-	$34/kWh	$137,000

Note: PV - Photo Voltaic Solar Panels, ES - Energy Storage Units, O&M - Operations & Maintenance, Aux - Auxiliary Materials, PCS - Power Conversion System, BOS - Balance of System, EMS - Energy Management System.

All indicative costs were provided by: Schneider Electric for Inverters and Controllers, ViZn Energy for storage and components, Wanxiang for solar and components.

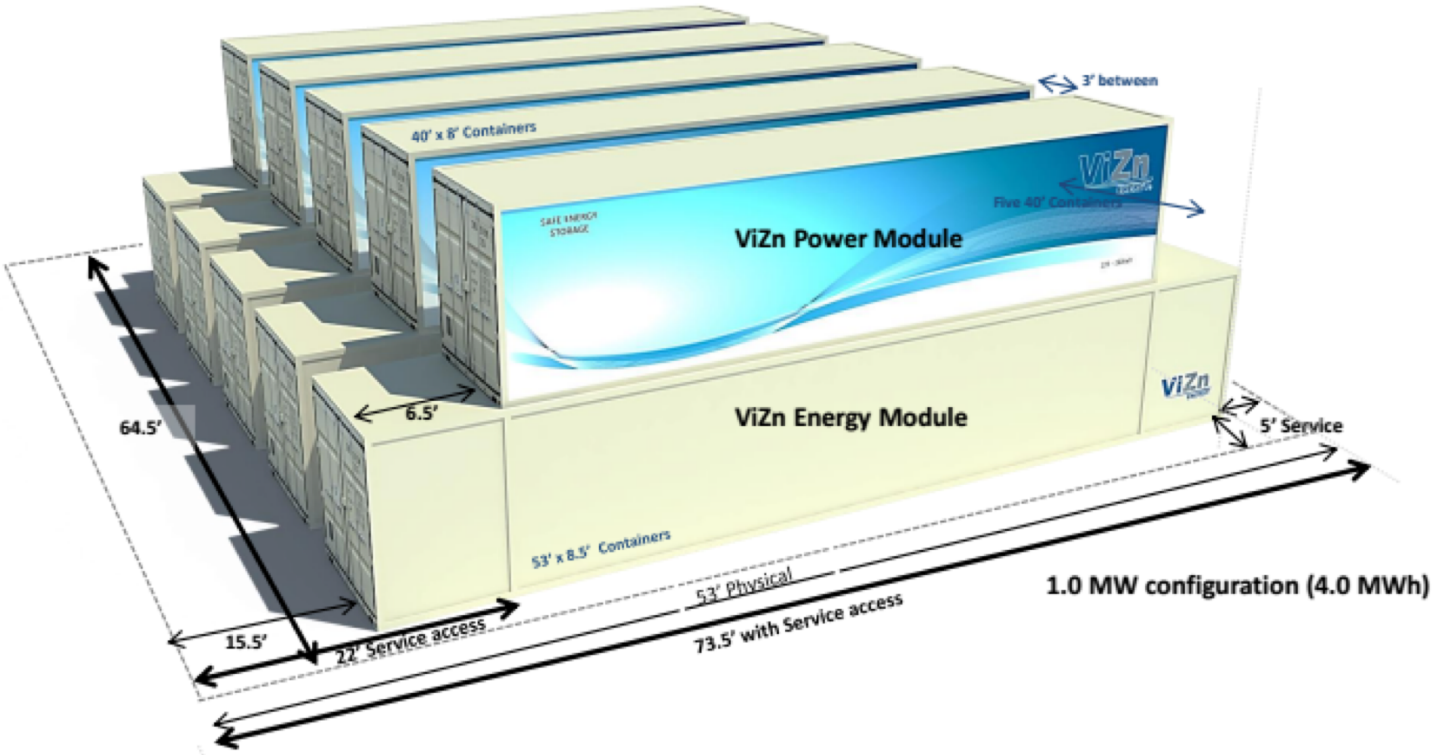
Appendix

1. Energy charges
   Energy Charge is the measure of the charge obtained by multiplying the amount of electricity consumed over a specific period of time and the utility electricity charge over that period of time. It is measured in $/kWh.

2. Demand Charges
   Demand Charge is obtained by multiplying the instantaneous power (kW) consumed and the demand rate as per the contract with the utility partner. It is typically measured in the average of a 15minute period. It is measured in ($/kW/month)

3. Flow Battery
   A flow battery is a fully rechargeable electrical energy storage device where fluids containing the active materials are pumped through a cell, promoting reduction/oxidation on both sides of an ion-exchange membrane, resulting in an electrical potential. In a battery without bulk flow of the electrolyte, the electro-active material is stored internally in the electrodes. However, for flow batteries, the energy component is dissolved in the electrolyte itself.

Below picture is for a 1MW/4MWh system configuration: (For representation purpose only)



Knowledge Base

1. How is a Microgrid different from smart grid?

   The term 'Smart Grid' refers to the modernization of the electricity transmission and distribution system so that it automatically monitors, protects and optimizes the operation of its interconnected elements.

   A Microgrid is a sustainable and reliable energy system comprising of a number of different energy sources capable of seamlessly operating on or off the provincial grid. Microgrid use smart grid technologies to enable the development of and operation of Microgrids.

2. What is the Microgrid Control System's role in the project?

   Although the smart control system is not highly visible (compared to solar PV and wind turbine), it nonetheless is a critical component of PowerStream's Microgrid. The Microgrid Control System (MCS) is based on a supervisory control architecture providing the ability to monitor, track, and forecast load, generation and storage resources throughout the Microgrid. The MCS maximizes the use of renewables to provide power to the load in the most economical method possible in both grid-connected and islanded mode scenarios.

3. Is it possible to quantify the outage or downtime cost?

   Yes. If you can estimate the dollar value of following applicable losses, it is possible to quantify the outage cost.

   Cost of Downtime (per hour) = Lost Revenue + Lost Productivity + Cost to recover + Cost of intangibles (i.e. reputation cost)

4. Do I get ancillary benefits when the microgrid operates in islanded mode?

   No. The ancillary services cannot be availed when the microgrid operates in the islanded mode.

5. How much energy ViZn's 1MW/4MWh storage system can supply for 24 hours, 36 hours and 48 hours?

   The 1MW/4MWh storage system can supply at a nominal power of 340kW for 8.8 hours. Hence the battery can supply approximately at 124.7 kW for 24 hours, at 83.1 kW for 36 hours, at 62.3 kW for 48 hours.