Long Duration Storage + Solar Microgrid Solution for Africa

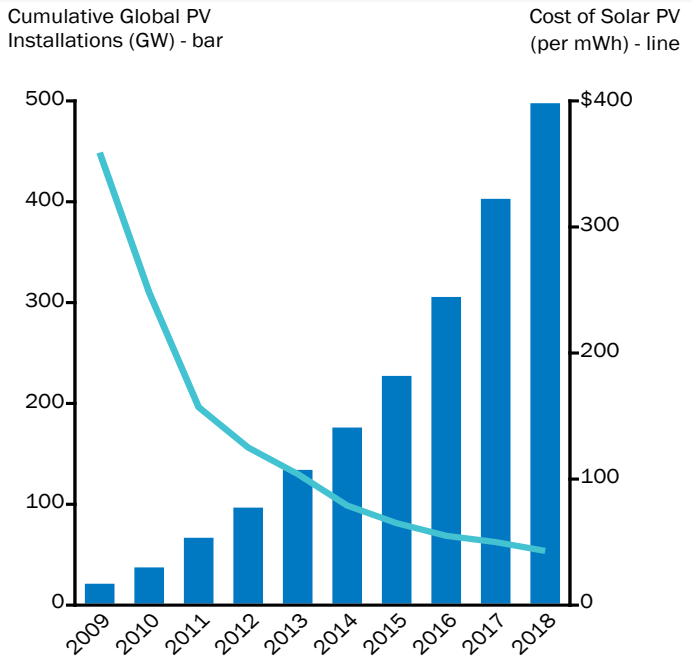
December 3rd, 2019

VIONX has a Solution for Africa's Pressing Energy Needs

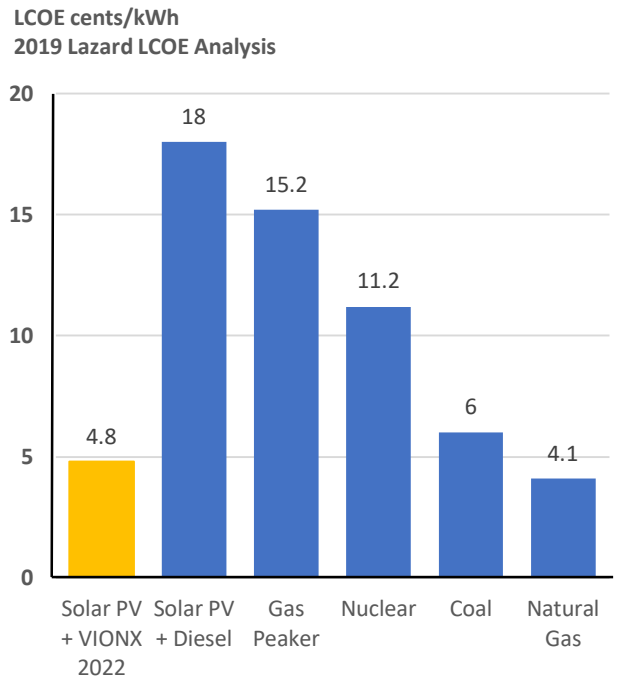
VIONX + PV has achieved cost parity with fossil fuels

- Plunging solar prices enable displacement of fossil fuel-based generation
- 24 X 7 baseload using solar + diesel genset remains highest cost
- VIONX Long Duration Storage + Solar PV delivers lowest cost baseload alternative

Solar Price Drove Adoption

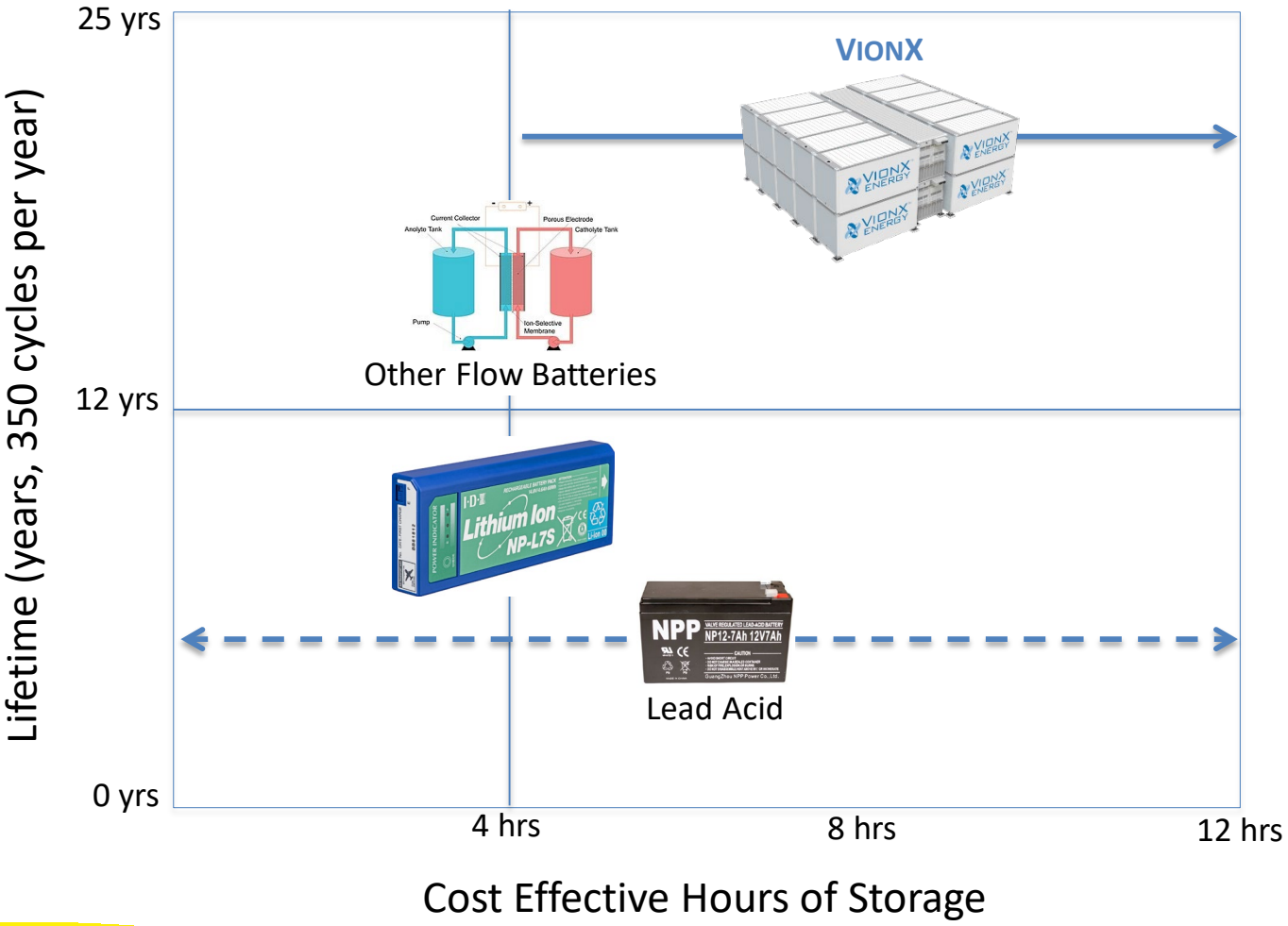


VIONX w PV has a Globally Competitive LCOE



VIONX: Designed for 4 to 12 Hour Duration

Vanadium is the only solution that marries lifetime and cost efficiency



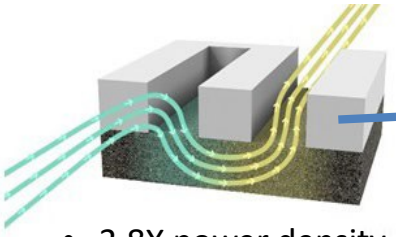
Patented Stack Design, Strong IP Protection

Disruptive VIONX Exclusive IP enables flow battery commercialization

- 50+ Years of United Technologies R&D
- Over 50 patents filed
- Patented "interdigitated flow field" (X-Flow Field)
- Unique stack components
- Patented electrolyte process

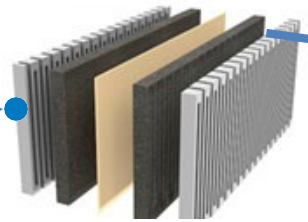
- Unmatched power density
- 30+ year durability
- Long duration at high stack power

X-Flow Field | UEA | Stack | System

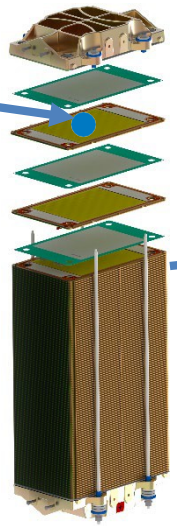


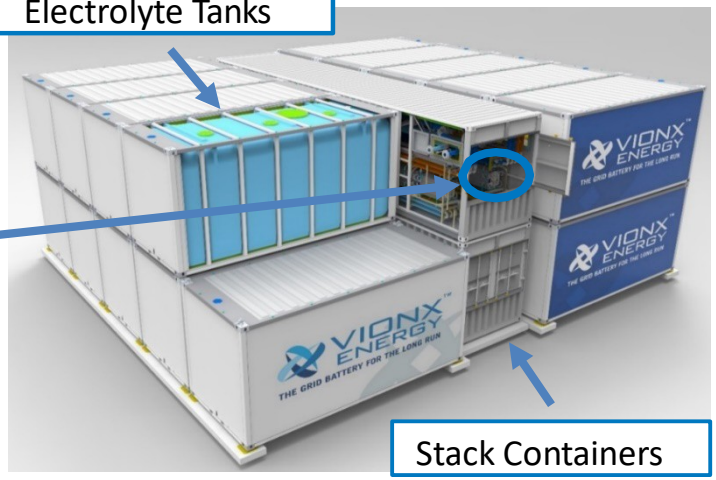
- 3.8X power density
- Low pressure flow

United Technologies



Unitized Electrode Assembly



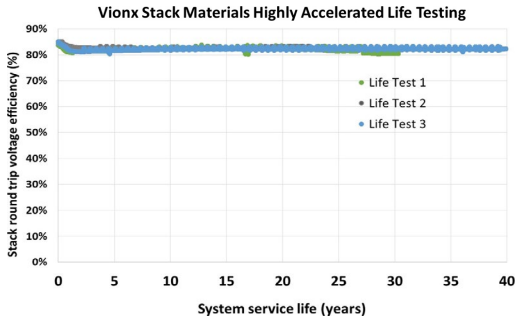


No Degradation Confirmed by Lab/Real World Results

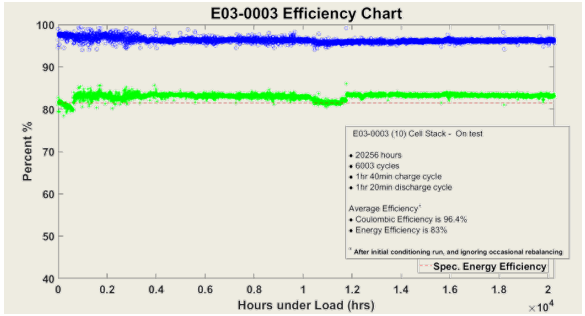
Proven durability

Lab Results

Stack Efficiency Maintained for 40 Years



20 Year Daily Usage w No Degradation



Real World Results

>20k Hours w 97% Availability

System Health

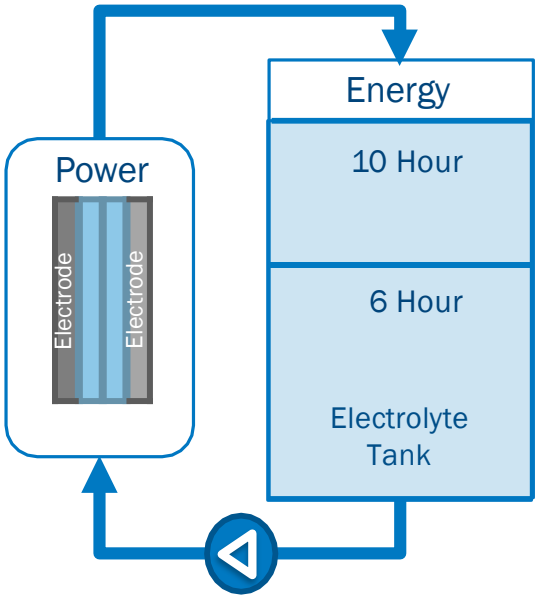
Resource	Pump Run Time (h)	Power Run Time (h)	Power/Pump Run Time (h/h)	Total Discharged Energy (MWh)
CERL-Mod1	10029.77	9522.450	0.9494189	277.6302
CERL-Mod2	10037.40	9529.517	0.9494009	275.0676

VIONX Advantage: Longer Duration = Lower Cost

CAPEX advantage due to independent power and energy scaling

VIONX Open Architecture

- Power and energy are independent
- Duration increased by adding electrolyte
- No additional power components needed



Li-ion Closed Architecture

- Power and energy are dependent.
- Duration increased by adding power and energy
- Power is added to achieve longer duration

2 Hour
$ Power
$ Energy

4 Hour
$$ Power
$$ Energy

8 Hour
$$$$ Power
$$$$ Energy

8 Hour Li-ion = $$$$ Power + $$$$ Energy

VIONX VRFB is Fully Recyclable at End of Life

Vanadium residual value offsets disposal cost with significant net positive value

VIONX End of Life Recycling

- Vanadium electrolyte is completely recyclable with the following options:

  Option 1: Vanadium is recovered and reused as liquid electrolyte in another Vanadium redox flow battery system

  Option 2: Vanadium Oxide (V2O5) is reclaimed from the electrolyte by a simple process of precipitation. This final V2O5 product is the form of Vanadium openly traded in the market

- VIONX Flow battery systems components are fully recyclable (ex. steel, plastic, carbon)
- Vanadium residual value offsets end of life disposal cost with **significant** net positive value at end of life

DC System Balance of Plant

Electrolyte

Na_2SO_4 + **H_2O** Neutral 7 pH

Drain Electrolyte → Extract Vanadium → Dispose Neutralized liquid → Ship/recycle Vanadium

Flush/Filter BESS System (Stack Container, Electrolyte Container, Stacks)

Reclaim Vanadium in flushing fluid

Disassemble BESS → Recycle/Dispose Components

Reclaimed Vanadium Oxide

Significant End of Life Value $74/kWh assuming residual value equal to lifting cost

VIONX DC System comprised recyclable components
(Steel, plastic, carbon)

VIONX History: How We Got Here

Commercial ready as a result of disruptive IP, investment and years of development

Premium Power

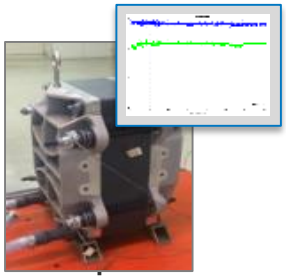
- Founded

Zinc-Flow®

United Technologies

VIONX ENERGY

VIONX Stack Durability



VIONX: 2nd Deployment

VRB + Wind (Worcester, MA)

VIONX: Commercial System

UL DNV·GL XL CATLIN

2004 — 2014 — 2015 — 2016 — 2017 — 2018 — 2019

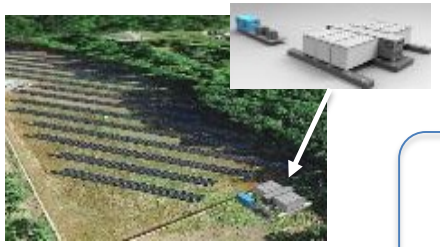
ZincFlow 45
Abandoned

VIONX: 1st Deployment

(Ft. Devens US Army Base, MA)

VIONX: 3rd Deployment

Vionx VRB + Solar
(Shirley, MA)



1st Commercial Project

MILTON HYDRO

$150M Invested to Date

VIONX Has Grid-Scale Validation Systems Running

VIONX has live solar and wind grid integration and time shifting projects

✓	**4 Hours Military & Microgrids** Ft. Devens, MA		**160kW / 640 kWh System** ✓ Micro-Grid Control Compatibility ✓ Time-of-Use Rate Reduction ✓ Demand Charge Reduction
✓	**6 Hours Wind Integration** Worcester, MA		**500kW / 3,000 kWh System** ✓ Wind Integration (600kW Wind) ✓ Time-of-Use Rate Reduction ✓ Demand Charge Reduction
Q3 2019	**6 Hours Solar Integration** Shirley, MA		**500kW / 3,000 kWh System** ✓ PV Integration (1 MW Solar) ✓ Voltage Support ✓ Load Following

VIONX Commercial Product Design

VIONX architected with a scalable design that marries high performance + low cost

Modular Architecture

Makes supply chain flexible, and easy to outsource, while minimizing installed cost and complexity

- Each component can be made by the optimal partner in the optimal location:
  - Core IP/stack technology in the US
  - Containers/BOP in Asia
  - Final assembly local
- Flexibility to add power or energy as project evolves
- Site cost and complexity minimized by centralization of power and control components to two containers

Designed to Maximize Uptime, Minimize O&M

Design improvements have lowered O&M 70%

- Problems can be diagnosed/fixed without the high cost and extended downtime of draining the system
- Easy to swap in/out components
- Electrolyte 100% double walled/contained

VIONX VNX 1200 Battery (1.2 MW 10 hr)

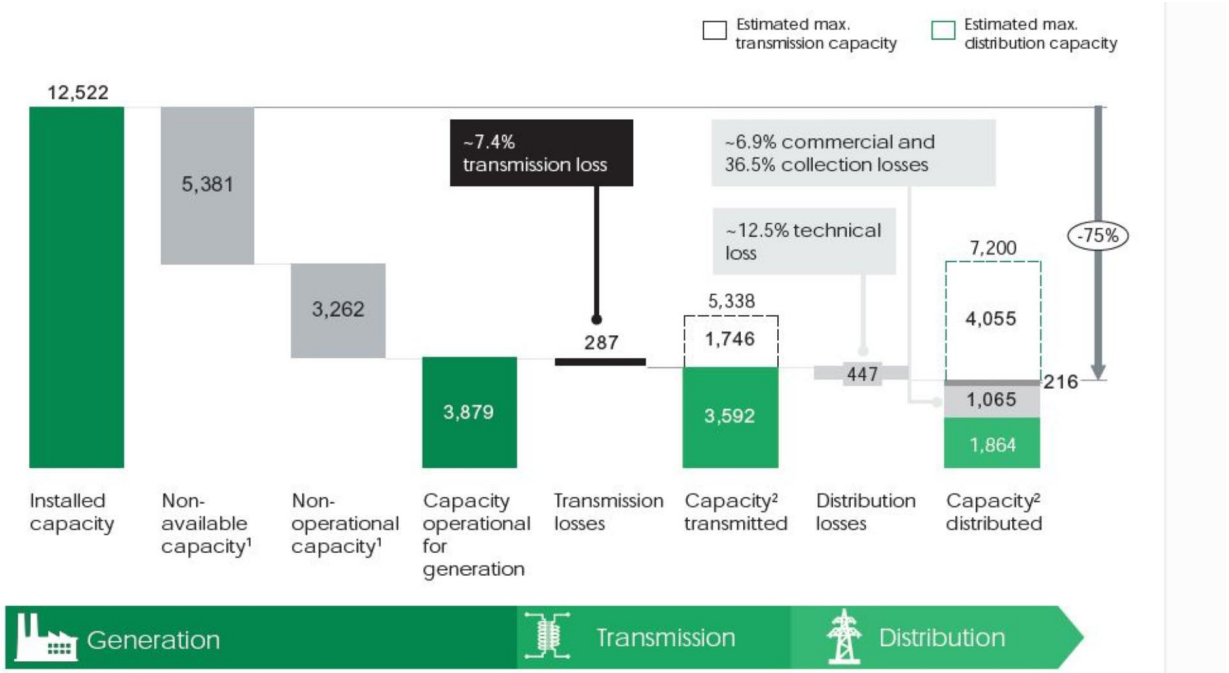
Shown: 1.2 MW / 10 MWh DC System

Nigeria Case Study: Grid currently Insufficient to Meet Demand

Exemplifies a need for an African energy solution to meet growing demand

- Nigeria has 12,500 MW of installed generation capacity grossly insufficient to meet demand
- An estimated 14-20 GW of businesses in the country possess and rely on standby generators for power
- Nigeria Federal Government plans to work towards adding 13GW of off-grid solar power by 2030 to meet the growing needs as per Intended Nationally Determined Contribution (INDC) to the United Nations Conference of Parties 21 (COP21)

Nigeria Power Sector Energy Flow (MW)



Source: Nesistats

Proposed Solution: Solar + VIONX Storage

Safe, Clean, Economical Baseload enabled with VIONX's long duration storage

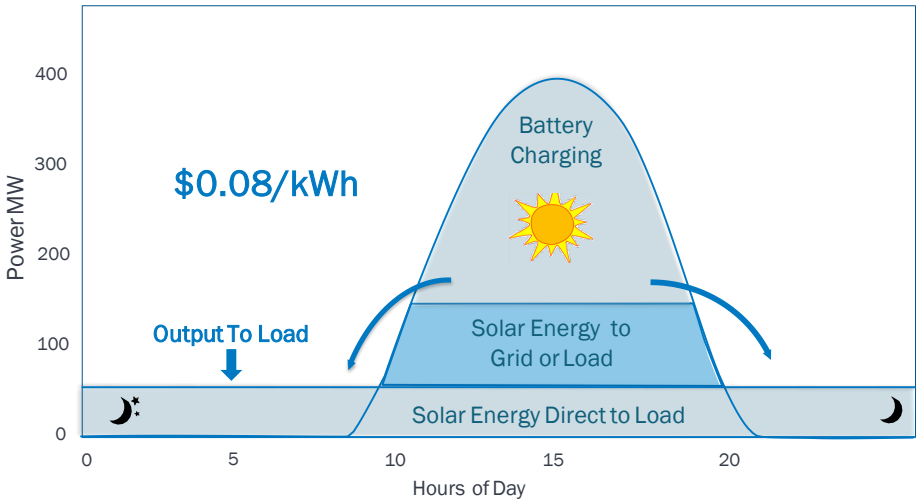
VIONX Storage + Solar key attributes:

- Enables complete transition away from fossil fuel-based generation
- Enables islanded microgrids that can't rely on their neighboring grids for power
- Provides supply to meet daily cyclic requirements and reserve capacity for a 'rainy day'
- Maximizes annual energy output with increasing duration when coupled with solar

VIONX long duration storage enabling attributes:

- Lowest lifetime cost (LCOE) at long duration
- 30yr life with no degradation
- No cycling or calendar-based capacity fade
- Safe (Non-Flammable – No thermal runaway)
- Fully recyclable with positive end of life residual value

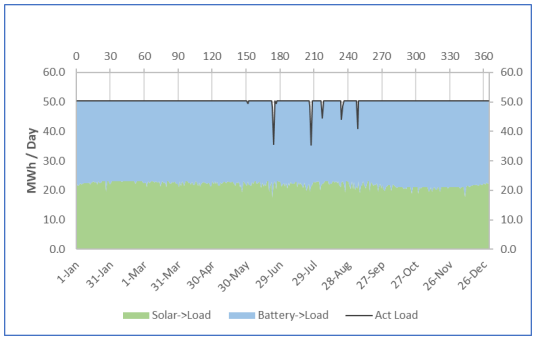
Nigeria Microgrid: Solar + VIONX



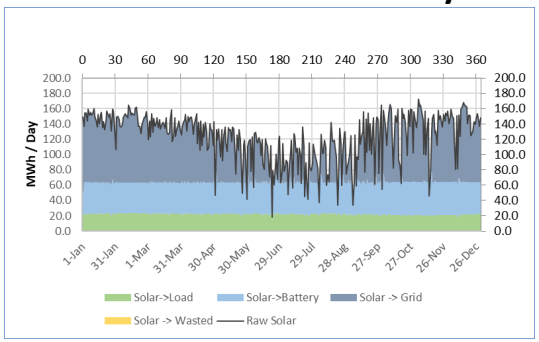
Renewable Baseload Energy = Solar + VIONX

Solar + 7.5 MW VIONX In Nigeria in 2020

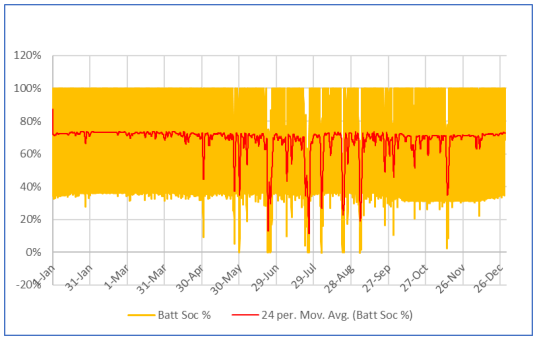
Load Energy vs. Day



Solar Allocation vs. Day



Battery State of Charge



- Charts represent 30MW solar case

Site	Onitsha, Nigeria		▪ VIONX 2020 pricing ▪ Purchased Elyte @ $7/lb ▪ 25yr project life		▪ 7.5 MW Battery, ▪ $404/kW Installed solar ▪ $313/kW Battery install cost		
System	(5)x1.5MW x 8.6MWH						
Load	2.1 MW						
Solar Size (MW)	**% Energy**	**Days Short/yr**	**Avg Excess Solar available if invertor upsized MWh/day**	**Solar + Diesel LCOE (54% diesel)**	**Solar + Storage LCOE without utilizing excess solar ($/MWh)**	**LCOE Solar + Storage + Diesel Genset= 100% demand ($/MWh)**	**LCOE with all available energy ($/MWh)**
15	91.40%	139	40	$190	146	$159	139
20	97.50%	52	52	$186	146	$150	110
25	99.20%	20	61	$184	155	$156	91.7
30	99.70%	10	73	$182	165	$166	80.1

VIONX – Energy Storage Unlimited

VIONX Flow Battery addresses the needs of storage for renewable integration

GRID SCALE

Engineered for the grid
1-100+MW systems

4 - 10+ HOUR ENERGY

Unmatched Levelized Cost of Storage

UNLIMITED CYCLING

No degradation
30-year life

BANKABLE

Decades of validation
A+ rated warranty insurance

SAFE

No fire risk
Double wall containment
Integrated leak sensing