Advanced Flow Batteries, Dec 2018

30kWh ReFlex™ Module

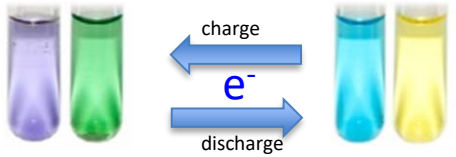
15-year, $½B Accomplishment

- world's toughest chemistry
- unlimited duty cycles
- 20+ Year Life
- plug & play flexibility
- seamless redundancy
- non-flammable
- non-reactive
- lowest lifetime cost
- fully recyclable

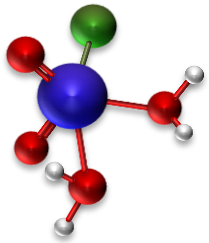
UET + RKP + BNM + US DOE + China DICP + 32 Utility and Commercial Customers


300,000ft² battery production plant


1.6GWh electrolyte production plant

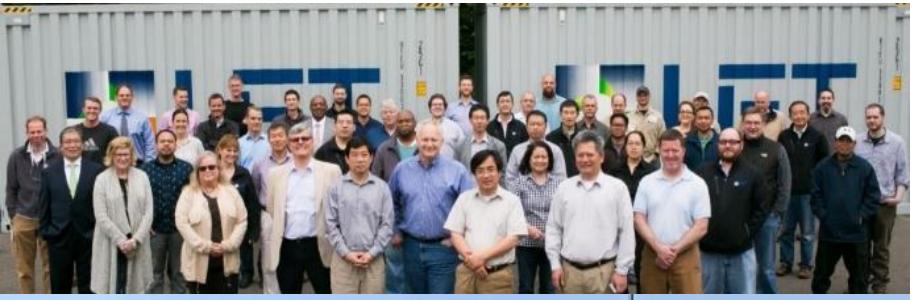


V^{2+} V^{3+} V^{4+} V^{5+}



$VO_2Cl(H_2O)_2$

U.S. DEPARTMENT OF ENERGY



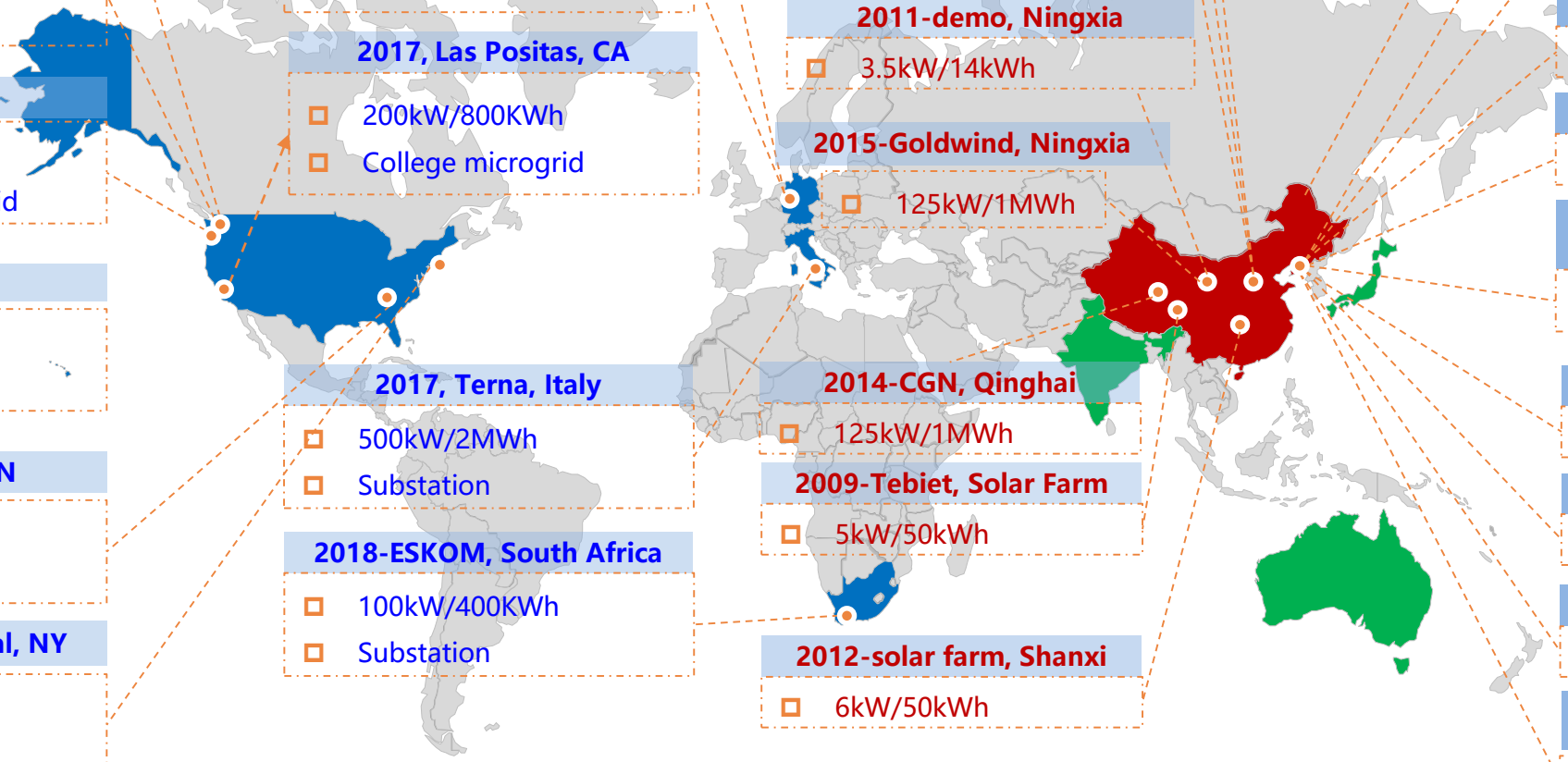
4MWh on ½ a basketball court

$500MM collaboration over 15 years to deliver the most resilient, safe and cost-effective battery for bulk electricity storage


ReFlex™ production


40MWh on 3 basketball courts

Field Experience from UET + RKP Global Deployments



2015, UET campus, Seattle
- 250kW/1MWh

2017, Snohomish PUD, WA
- 2MW/8MWh
- Substation

2015, Avista, WA
- 1MW/3.2MWh
- Smart microg-grid

2018, NEHLA, HI
- 100KW/400KWh
- Microgrid

2018-Chattnooga, TN
- 100kW/400KWh
- Microgrid

2017, Jacobi Hospital, NY
- 100KW/400KWh
- Microgrid

2015, Germany
- 60kW/120kWh

2014, Bosch, Germany
- 250kW/1MWh
- Wind integration

2017, Las Positas, CA
- 200kW/800KWh
- College microgrid

2017, Terna, Italy
- 500kW/2MWh
- Substation

2018-ESKOM, South Africa
- 100kW/400KWh
- Substation

2015-Goldwind, Beijing
- 600kW/2.4MWh

2008-Goldwind, Beijing
- 200kW/800kWh

2008-Microgris, Beijing
- 100kW/200kWh

2011-demo, Ningxia
- 3.5kW/14kWh

2015-Goldwind, Ningxia
- 125kW/1MWh

2014-CGN, Qinghai
- 125kW/1MWh

2009-Tebiet, Solar Farm
- 5kW/50kWh

2012-solar farm, Shanxi
- 6kW/50kWh

2010-residence, Dalian
- 5kW/50kWh

2010-Snake Island, Dalian
- 10kW/200kWh

2010-RKP campus, Dalian
- 60kW/300kWh

2011-cellphone tower, Dalian
- 4kW/54kWh

2011-Charge station, Dalian
- 60kW/600kWh

2012-Windfarm, the world largest at the time, Liaoning
- 5MW/10MWh

2013-Heishang, Liaoning
- 3MW/6MWh

2014-Jinzhou, Liaoning
- 2MW/4MWh

2014-Shenyang, Liaoning
- 100kW/400kWh

2016-Puwan industry Park, Dalian
- 750kW/3MWh

ReFlex™ leverages decades of field experience and is driven by customer needs and hard-won field experience

- Safe
  - » No risk of explosion or thermal runaway
  - » No flammable materials or toxic fumes
  - » Has a chemical off-switch!
- Flexible and Durable
  - » Runs any duty cycle without invalidating warranty
  - » Maintains full performance over 20 years
  - » Enables Storage-as-a-Service for any use case
- Green
  - » Common recyclable industrial materials
  - » Vanadium sourced from waste & mines
  - » No operational emissions or pollutants

ReFlex™ is 150X more available than containerization

100% of new customers in the US, EU and Australian are deploying ReFlex™

2MWh STATIONARY STORAGE SYSTEM

Availability of a 2MWh containerized systems

- 4 containers in series deliver 2MWh
- With no redundancy, a single container failure shuts down the entire system
- A module failure probability of 1% yields a **4%** possibility the system will shut down in a given period

$p := 0.01$ Probability of failure
$n := 4$ Number of modules on site
$m := 1$ Number of failed modules required to cause site failure

$$Pr(a,b) := \frac{a!}{b!\,(a-b)!}\,p^{b}\,(1-p)^{(a-b)}$$

$$Pst := 100\sum_{i=m}^{n} Pr(n,i) = 3.94$$ % Probability of site failure

ReFlex™ Improvements:

- ✓ 30% higher V utilization
- ✓ 5X fewer parts
- ✓ Seamless bypass
- ✓ Self-draining stacks
- ✓ Surface cooling
- ✓ No electrolyte fill
- ✓ 50% simpler hydraulics
- ✓ 50% lower pressure
- ✓ Fewer sensors
- ✓ Insulated enclosure

Availability of a 2MWh ReFlex™

- 60 modules arranged in 5 strings of 12 provide n+2 redundancy in delivering 2MWh
- If 3 modules fail, discharge duration will shorten 4 minutes without effecting power
- Assumes neither of the first 2 ReFlex™ are repaired before the 3rd fails
- A module failure probability of 0.2% yields only a **0.025%** possibility the system will only de-rate in the same given period

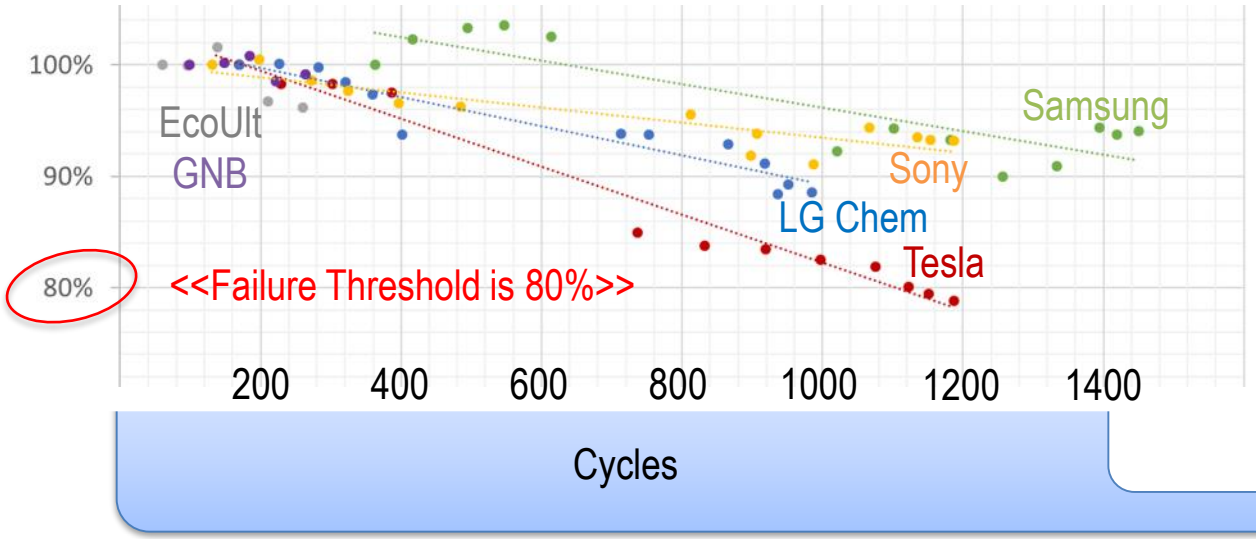
$p := 0.002$ Probability of failure
$n := 60$ Number of modules on site
$m := 3$ Number of failed modules required to cause site failure

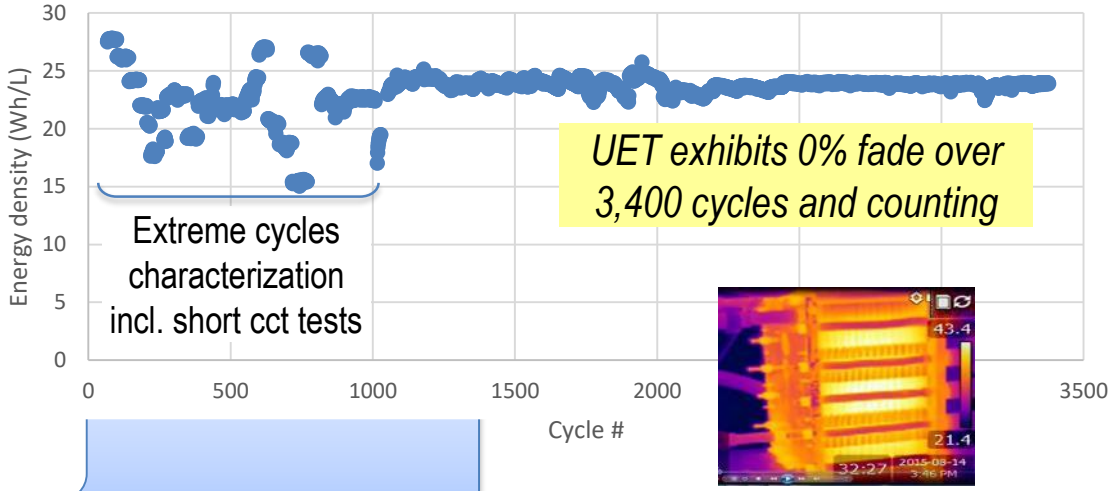
$$Pr(a,b) := \frac{a!}{b!\,(a-b)!}\,p^{b}\,(1-p)^{(a-b)}$$

$$Pst := 100\sum_{i=m}^{n} Pr(n,i) = 0.02514$$ % Probability of site failure

UET's no-fade performance is a strong advantage over lithium technologies that degrade 10-20% over 12 months

Source: http://batterytestcentre.com.au/wp-content/uploads/2017/07/Battery-Testing-Report-4-March-2018.pdf



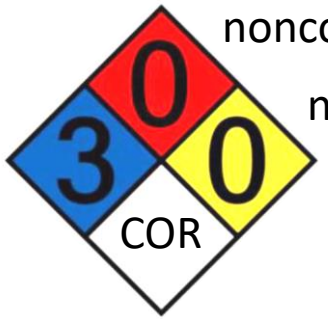


Full scale stack under short cct testing

- All lithium and lead acid batteries are exhibiting precipitous capacity fade after only 12 months of testing
- Tests are performed within manufacturers recommended SOC limits and including obligatory rest periods between charging and discharging
- Lithium batteries are typically deemed to have failed at 80% capacity due to accelerating decay mechanisms

- UET's vanadium flow batteries do not exhibit any capacity fade over >3400 cycles to 100% DOD with no rest periods between cycles
- This performance stability substantially eliminates operational risks when deploying large scale electricity storage plants

Fire Safety Of Flow Batteries



- Aqueous electrolytes that comprise most flow batteries are non-flammable and non-reactive with water
- Stranded energy in the stacks is insufficient to cause re-ignition hazards
- Electrolyte and other materials that comprise the battery may release hazardous materials when exposed to a sustained external fire

Lithium Batteries

After a fire was contained, this photo captures the initial explosive re-ignition of a 2.5MWh lithium battery, severely injuring 3 experienced firefighters in ***Hilden, Germany***

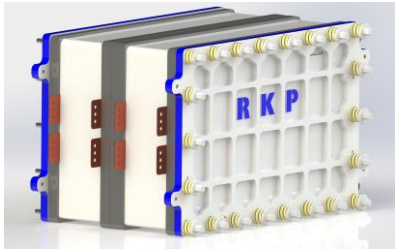
In Nov 2017, this lithium battery with state-of-the-art fire protection technology failed during commissioning, resulting in release of toxic fumes, closing freeways and evacuating citizens

High Residual Value ensures 100% Recycling

Plastics
- Tanks
- Piping
- Other

V^{5+} V^{4+} V^{3+} V^{2+}

Electrolyte (2 options)
1. 100% reusable (no decay) for next ReFlex™
2. 100% Vanadium recycling & reused for other purposes



Stacks (separate components)
- Painted Steel & Copper
- Plastics
- Carbon

Steel Shell & BOP
- Steel shell
- Coated Metal frames
- Pumps
- Air Handler
- Electronics

ReFlex™ triggers the "***Virtuous Cycle***" for constantly improving reliability and reducing cost

Prices fall with:

- *Streamlined supply chain*
- *Automated production*
- *Better performance*
- *Optimized design*
- *Higher volume*

Rack-mounted ReFlex™

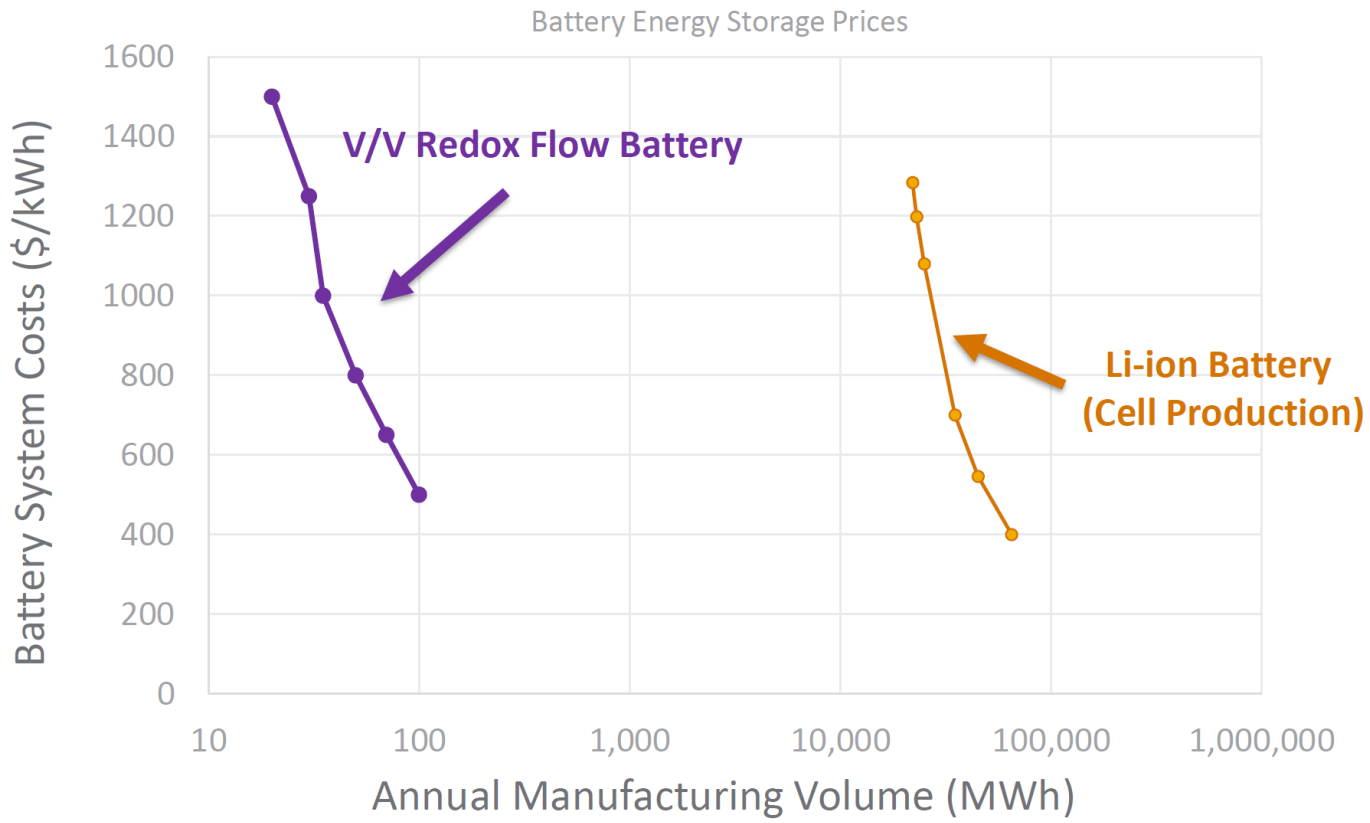
The ***Virtuous Cycle*** is why PV costs <2c/kWh today!

UET'S RESPONSE TO LITHIUM CHALLENGE

STEEPER COST REDUCTION BY UET, AT 1/1000 THE PRODUCTION

Comparative Production Volumes

Pacific Northwest NATIONAL LABORATORY



~ 100,000 MWh of annual Li-ion production capacity entering 2017

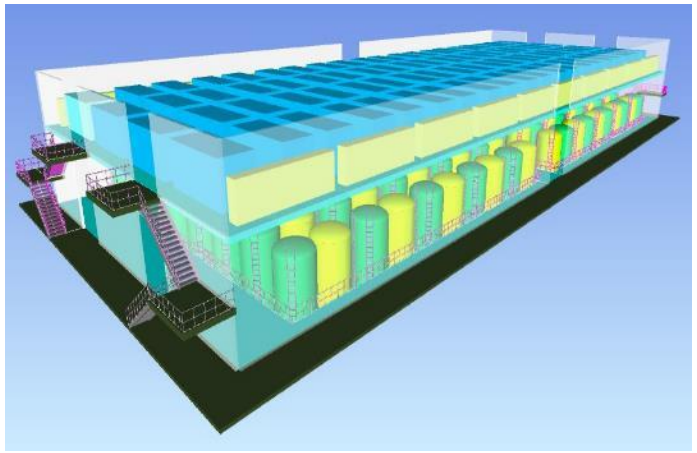
ReFlex™ Commercial Applications

ReFlex™ offers a 4-7 year payback for NYC commercial customers thru Demand Charge savings plus additional revenue streams via safe and resilient EV charging, critical infrastructure support, and demand response

UET's FDNY approved technology offers 20 year life, 100% recycling, and an evergreen capacity growth program

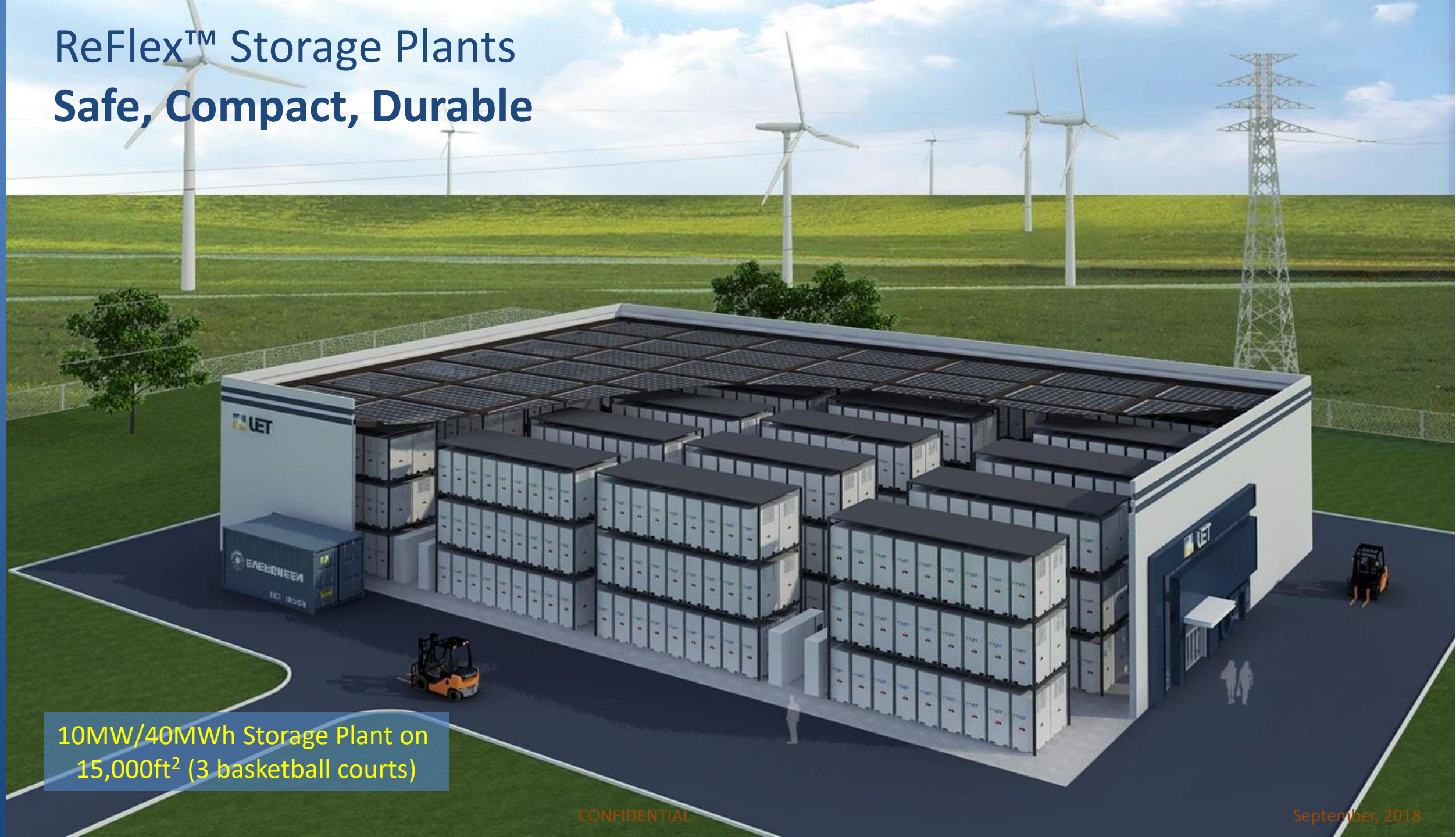
Building an 800MWh VRFB Peaking Power Station

- Rongke Power (UET's sister company) is building the world's largest battery
- The 200MW/4h plant is for peak power, grid resiliency & renewable integration
- The facility is currently under construction
- Due to the intrinsic safety of vanadium flow, the storage plant will **include office space for the local utility**!



- **8M people** in Dalian
  - » Safety is a big deal
- **>1000 competitors** with all technologies
- **5 years** safe and reliable field experience at scale
- **2 years** to build it
- **1 Solution** → Vanadium Flow
  - » Load Shifting
  - » Minimizing curtailment
  - » System stabilization
  - » Infrastructure support

ReFlex™ Storage Plants
Safe, Compact, Durable



10MW/40MWh Storage Plant on 15,000ft^2 (3 basketball courts)