ENERGY SYSTEMS

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

U.S. DEPARTMENT OF ENERGY

Demonstration of a kW class Redox Flow Battery using an Advanced Bi-additive Vanadium Sulfate Electrolyte

US Department of Energy Technology Commercialization Fund Grant

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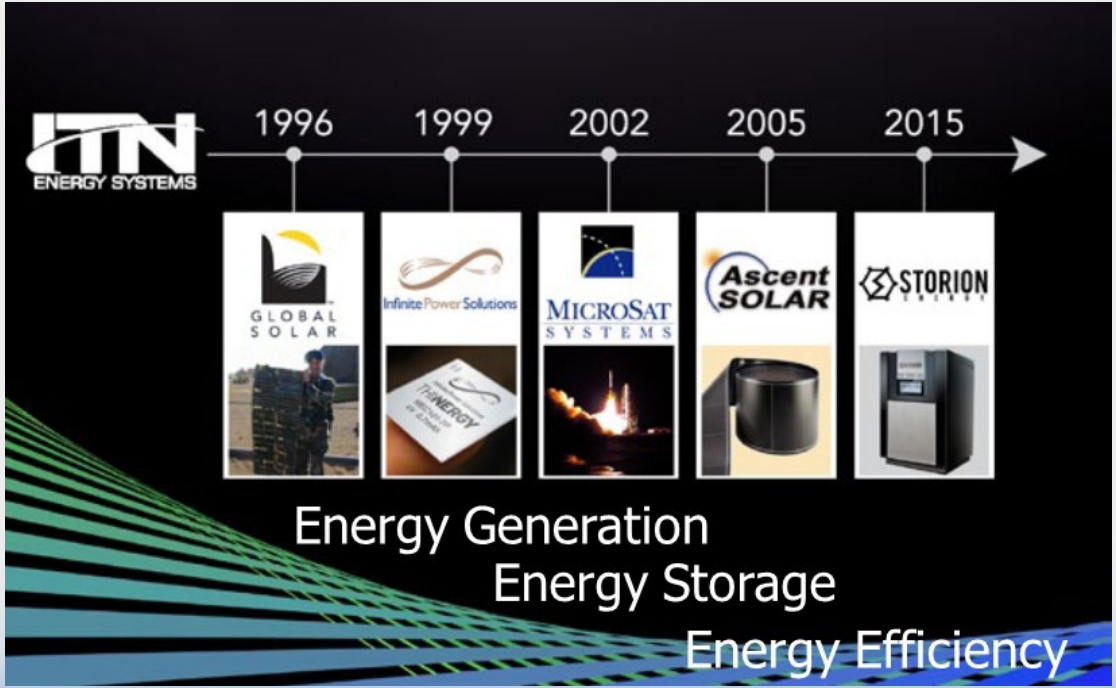
ITN Background

ITN Was Founded in 1995 with a Mission to Develop and Commercialize Emerging Technologies in the Areas of Energy and Environment

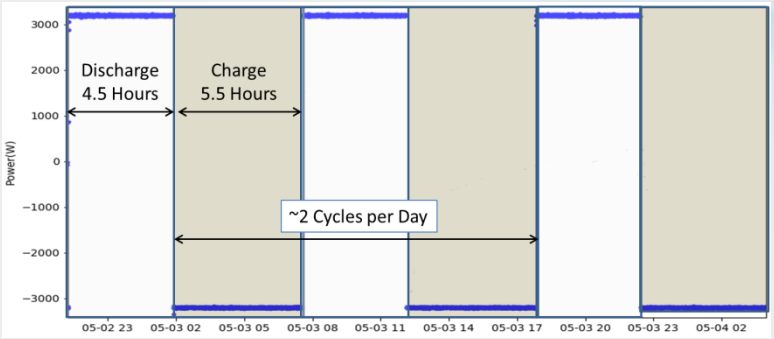


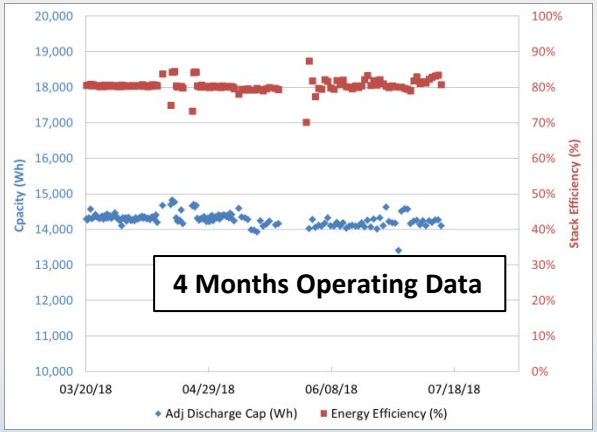
In 2015, ITN Launched Storion Energy to Commercialize its Vanadium Redox Flow Battery Technology

- *High Power Density Stacks*
- *Efficient System Designs*
- *Field Demonstration Units at ARPA-E Charges and Commercial Partner Sites*

ITN VRFB Demonstration-Group NIRE

Part of ARPA-E CHARGES Program





Long Duration Energy Shifting/Arbitrage (1-2 Cycles per Day)

ITN/PNNL TCF Project Overview

- ITN Energy Systems and PNNL Received a Technology Commercialization Funds Grant from DOE Office of Electricity
- The Project Goals are
  - Optimize Performance of PNNL Bi-Additive VRFB Electrolyte to Minimize HVAC in Aggressive Climates
  - Evaluate the Commercial Potential in kW Class System Operation
- Concurrent Development and Testing Activities at ITN and PNNL

Additive Motivation

- Without Additives, V^{5+} Precipitates at Temperatures Around 40°C
- VRFB Systems Operate up to 15 Degrees Above Ambient
- Desires to Extend V^{5+} Stability to 50°C or Higher with Additives to Help Minimize Cost and Parasitic Losses from HVAC
  - Particularly Important for Aggressive Climates Such as Phoenix, AZ

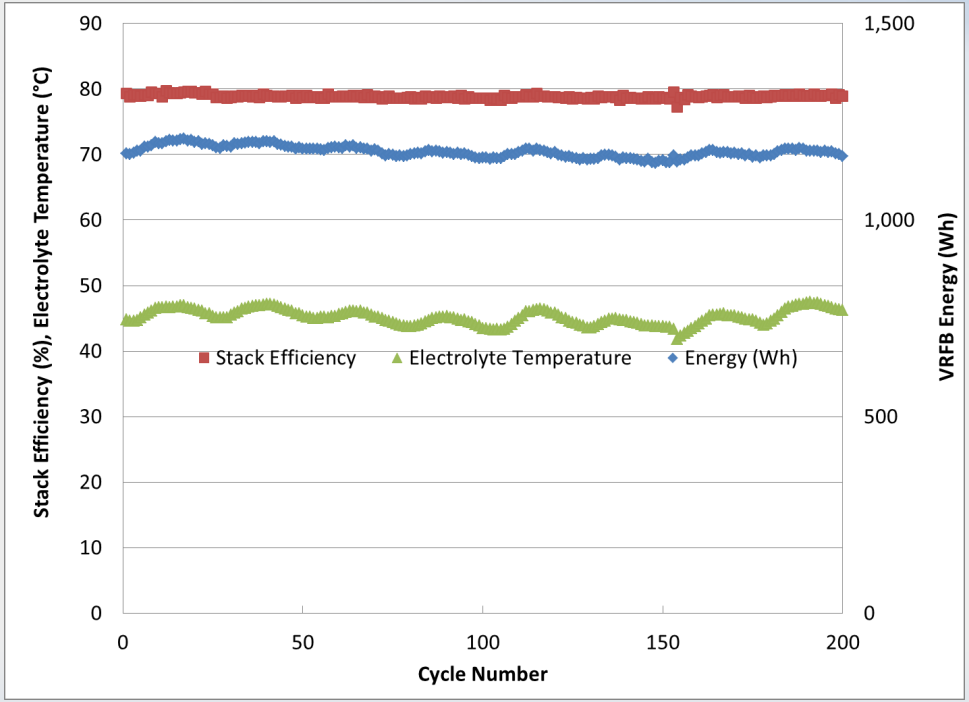
Climate data for Phoenix Int'l, Arizona (1981–2010 normals,[b] extremes 1895–present)[c] [hide]

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °F (°C)	88 (31)	92 (33)	100 (38)	105 (41)	114 (46)	122 (50)	121 (49)	117 (47)	116 (47)	107 (42)	96 (36)	87 (31)	122 (50)
Mean maximum °F (°C)	78.7 (25.9)	82.8 (28.2)	90.0 (32.2)	98.6 (37)	105.9 (41.1)	112.5 (44.7)	114.4 (45.8)	112.5 (44.7)	108.6 (42.6)	100.1 (37.8)	88.1 (31.2)	77.1 (25.1)	115.2 (46.2)
Average high °F (°C)	67.2 (19.6)	70.7 (21.5)	76.9 (24.9)	85.2 (29.6)	94.8 (34.9)	103.9 (39.9)	106.1 (41.2)	104.4 (40.2)	99.8 (37.7)	88.5 (31.4)	75.5 (24.2)	66.0 (18.9)	86.6 (30.3)
Daily mean °F (°C)	56.4 (13.6)	59.7 (15.4)	65.2 (18.4)	72.7 (22.6)	82.1 (27.8)	90.8 (32.7)	94.8 (34.9)	93.6 (34.2)	88.4 (31.3)	76.7 (24.8)	64.1 (17.8)	55.4 (13)	75.1 (23.9)
Average low °F (°C)	45.6 (7.6)	48.7 (9.3)	53.5 (11.9)	60.2 (15.7)	69.4 (20.8)	77.7 (25.4)	83.5 (28.6)	82.7 (28.2)	76.9 (24.9)	64.8 (18.2)	52.7 (11.5)	44.8 (7.1)	63.4 (17.4)
Mean minimum °F (°C)	36.2 (2.3)	39.4 (4.1)	43.2 (6.2)	49.5 (9.7)	58.0 (14.4)	68.4 (20.2)	73.7 (23.2)	73.7 (23.2)	67.1 (19.5)	53.6 (12)	40.8 (4.9)	34.6 (1.4)	33.5 (0.8)
Record low °F (°C)	16 (−9)	24 (−4)	25 (−4)	35 (2)	39 (4)	49 (9)	63 (17)	58 (14)	47 (8)	34 (1)	27 (−3)	22 (−6)	16 (−9)
Average precipitation inches (mm)	0.91 (23.1)	0.92 (23.4)	0.99 (25.1)	0.28 (7.1)	0.11 (2.8)	0.02 (0.5)	1.05 (26.7)	1.00 (25.4)	0.64 (16.3)	0.58 (14.7)	0.65 (16.5)	0.88 (22.4)	8.03 (204)
Average snowfall inches (cm)	trace	trace	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	trace	trace
Average precipitation days (≥ 0.01 in)	4.1	4.4	3.9	1.7	1.0	0.5	4.2	5.0	2.8	2.5	2.6	3.9	36.6
Average relative humidity (%)	50.9	44.4	39.3	27.8	21.9	19.4	31.6	36.2	35.6	36.9	43.8	51.8	36.6
Mean monthly sunshine hours	256.0	257.2	318.4	353.6	401.0	407.8	378.5	360.8	328.6	308.9	256.0	244.8	3,871.6
Percent possible sunshine	81	84	86	90	93	95	86	87	89	88	82	79	87

Source: NOAA (relative humidity and sun 1961–1990)[107][108][109], Weather.com[110]

Summary of Achievements

- 3.2 kW Stack
  - Continuous Cycling for ~220 Cycles
  - Maximum Temp ~50°C
- Additional Testing with Various Operational Protocols
  - Total Cycles >1,200
  - Avg. Peak Temp Each Cycle~ 45°C
  - No Precipitation



Summary

- ITN has Been Actively Developing and Commercializing Redox Flow Batteries Since 2010
- ITN has Demonstrated Demo Units at ARPA-E Charges and Commercial Partner Sites
- The TCF Program has Been Extremely Helpful to Support ITN/Storion Energy Commercialization of VRFB Products
  - ITN has worked closely with PNNL to Evaluate their Bi-Additive Electrolyte for VRFB to Extend the Operating Temperature Range with Minimal HVAC
    - ITN Testing Confirms Stable Cycling is Possible at Temperatures ~50°C with This Formulation for Over 1,000 Cycles
    - Similar Results Were Achieved with Concurrent Testing at PNNL (>3,500 cycles at 50°C)
    - Additional Work has Been Completed at PNNL on Systems Balance-of-Plant, e.g. State of Charge Monitor