

VANADIUM FLOW BATTERY AND APPLICATION IN ASIA

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Save Money through Practical Energy, Resources, and Carbon Management

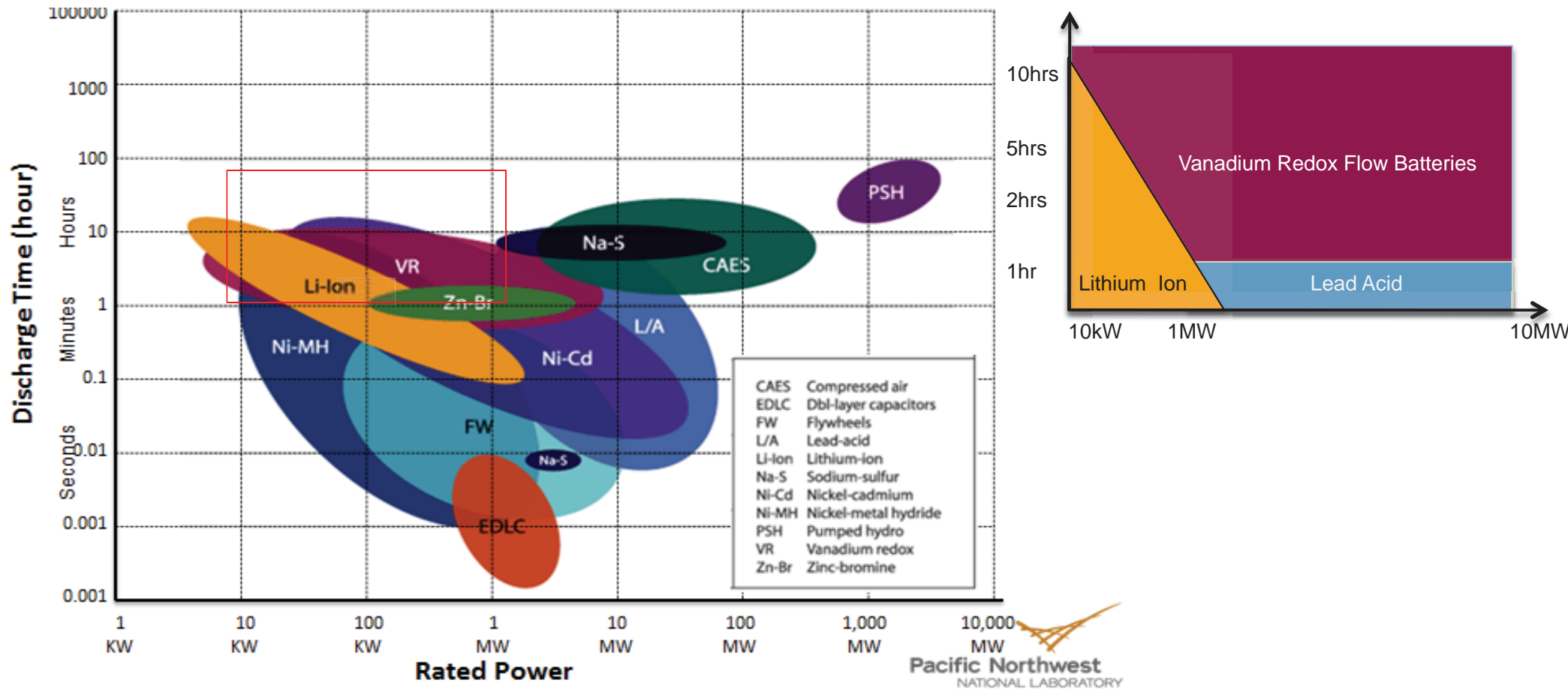


Global installed energy storage for the grid and ancillary services power capacity is expected to grow from 540 MW in 2014 to 21 GW in 2024.

Revenue from grid-scale energy storage is expected to total more than \$68 Billion from 2014-2024.

- Navigant Research, 2015

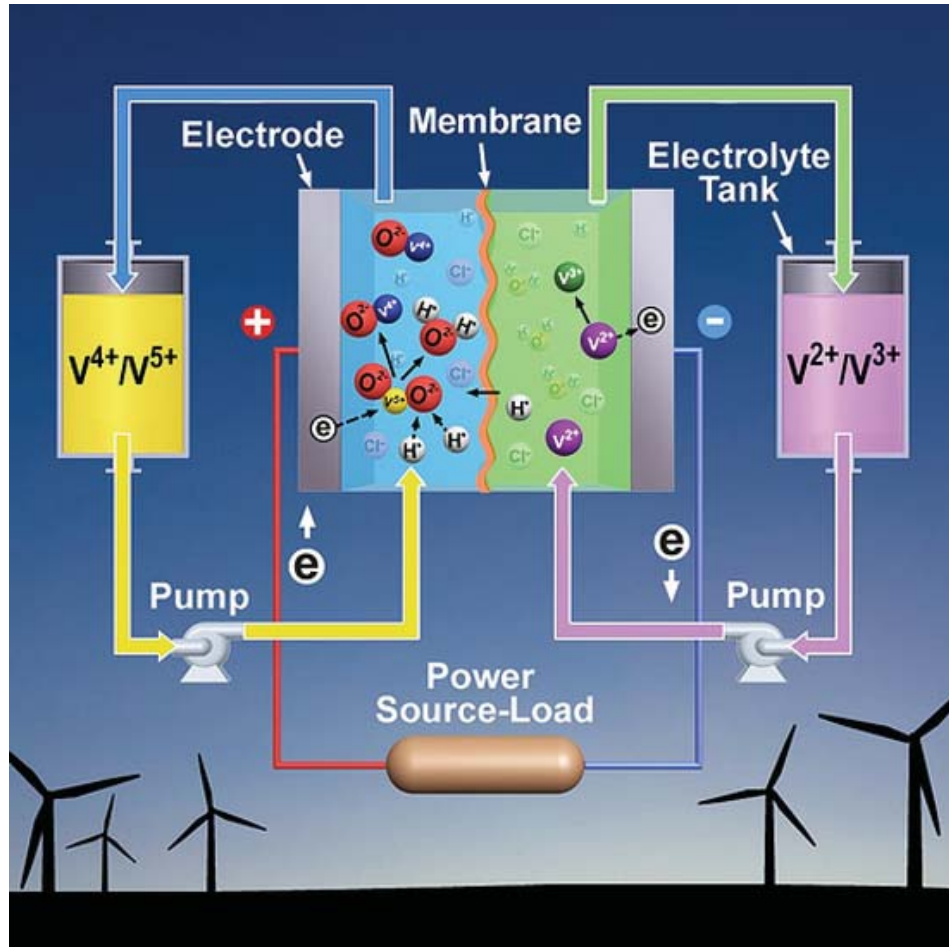
Energy Storage Technology Options



“Flow batteries increasing to 30% by 2017 as leading energy storage technology”

-Lux Research

Vanadium Flow Battery



- A researchable battery
- Use the same chemical – generate electricity through different oxidation states
- Fuel stored in liquid electrolyte

Vanadium Flow Battery Benefits

Great long-
duration system

Scalable: multi hour,
multi MW

Flexible: power
capability and
energy capability
independent

100% charge/
discharge cycle

>20,000 cycles

Long life (20 years)

Does not combust or
explode

No emissions

Long Duration Energy Storage Market



Commercial and Industrial



Microgrid



Renewable Energy Generation



Electric Grid

Facts of Vanadium Flow Battery

- Low volumetric energy density
- Electrolyte is 40% of the total system cost
 - ▣ Sometimes difficult to find high quality material
- Installed cost \$700 – \$1,000/kWh
 - ▣ Cost is decreasing with new innovation
- Vanadium supply
- Commercially available with small installations
 - ▣ Hundreds of systems installed globally
 - ▣ Companies in Canada, USA, Thailand, China, and other countries

Case Studies

Provided by American Vanadium, a Canadian integrated energy storage company

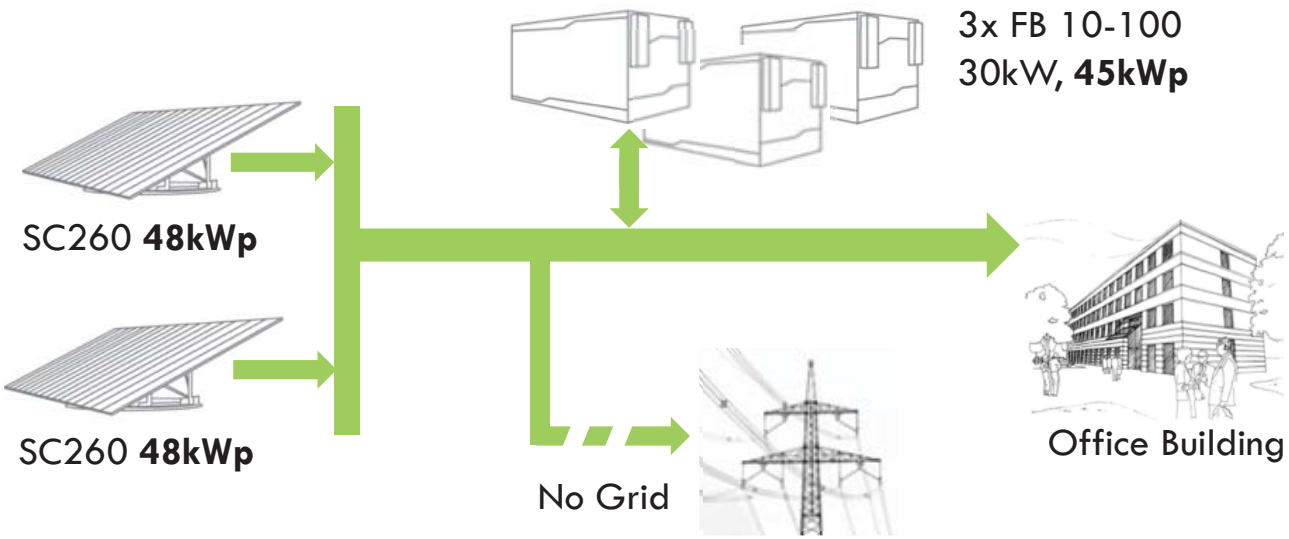


Island System (India) PV Integration



suncarrier

cellcube



Primary Mission

- Storage is commanding variable in Island-mode
- Backup for Office-Building

Update: June 2012



Storage 1: FB 10-100

3x FB 10-100 March-May 2012		
Power	3x	10 kW
Energy	3x	100 kWh
Load jumps	Storage 1	3.778
	Storage 2	3.316
	Storage 3	2.416
cycles:	> 95 % DoD	258
roundtrip efficiency (1)*		76 %
roundtrip efficiency (2)*		75 %
roundtrip efficiency (3)*		74 %
Cumulative Charged Energy		34,6 MWh
Cum. Discharged Energy		25,9 MWh

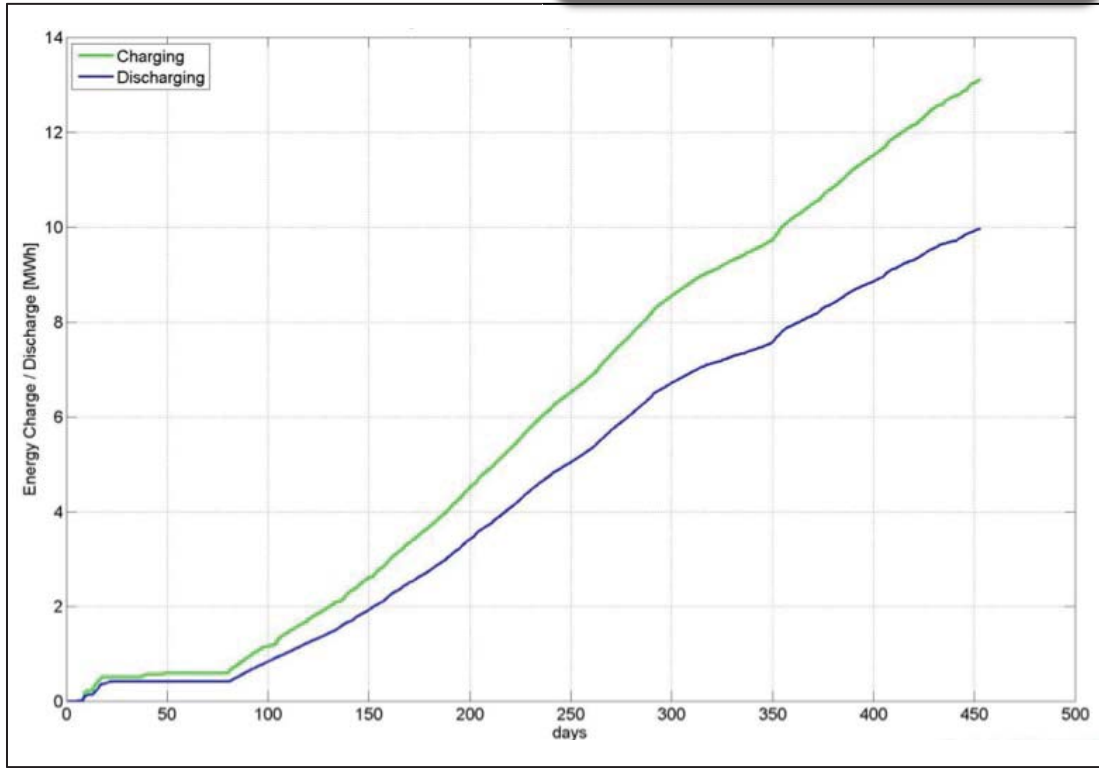
Customer Data:

*without pump- and inverter-losses

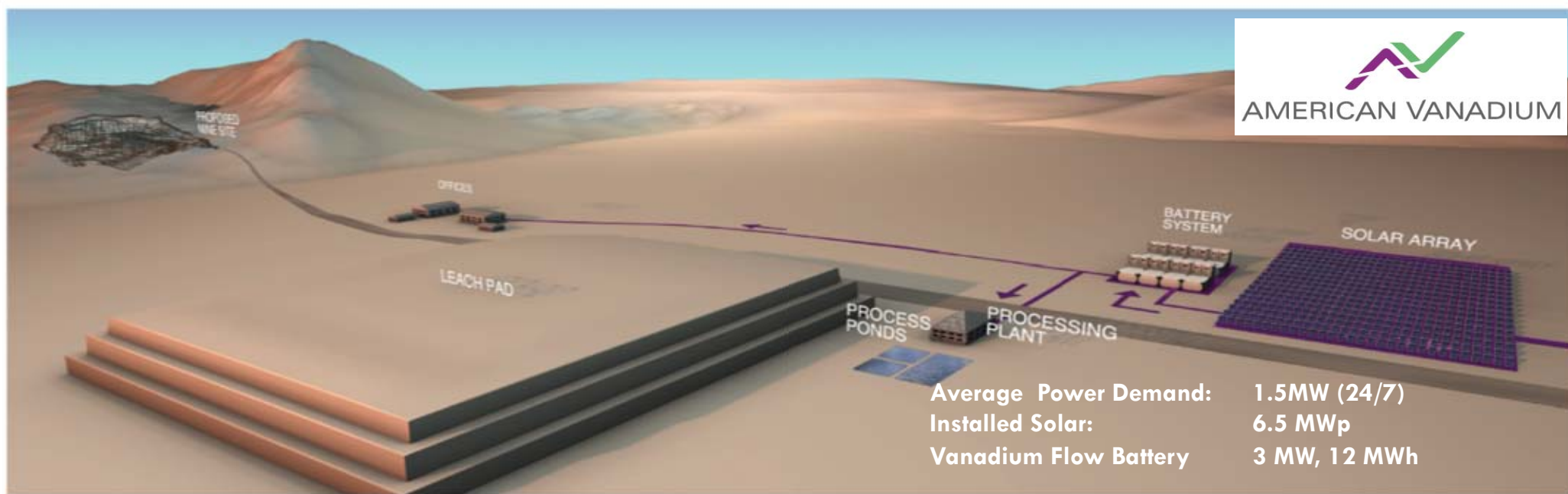


3x FB 10-100 CellCubes at Indian Customer site

Inverter - Technology	
SMA inverter, 400VAC	15kVA
DC direct coupling	50V



Gibellini Project “From Mine to Megawatts”



FEASIBILITY STUDY – AMEC Sept 2011

Internal Rate of Return (IRR)	43%
Net Present Value	\$170 million (7% discount)
Payback	2.4 years
Average Annual Production	11.4 million lbs V ₂ O ₅
Operating Cost	\$4.10 / lb V ₂ O ₅
Capital Cost	\$95.5 million
Average V ₂ O ₅ Selling Price	\$10.95 / lb*
V ₂ O ₅ Selling Price Range	\$7.68 - \$13.63 / lb*

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