Electrical Storage Technologies – Options for India

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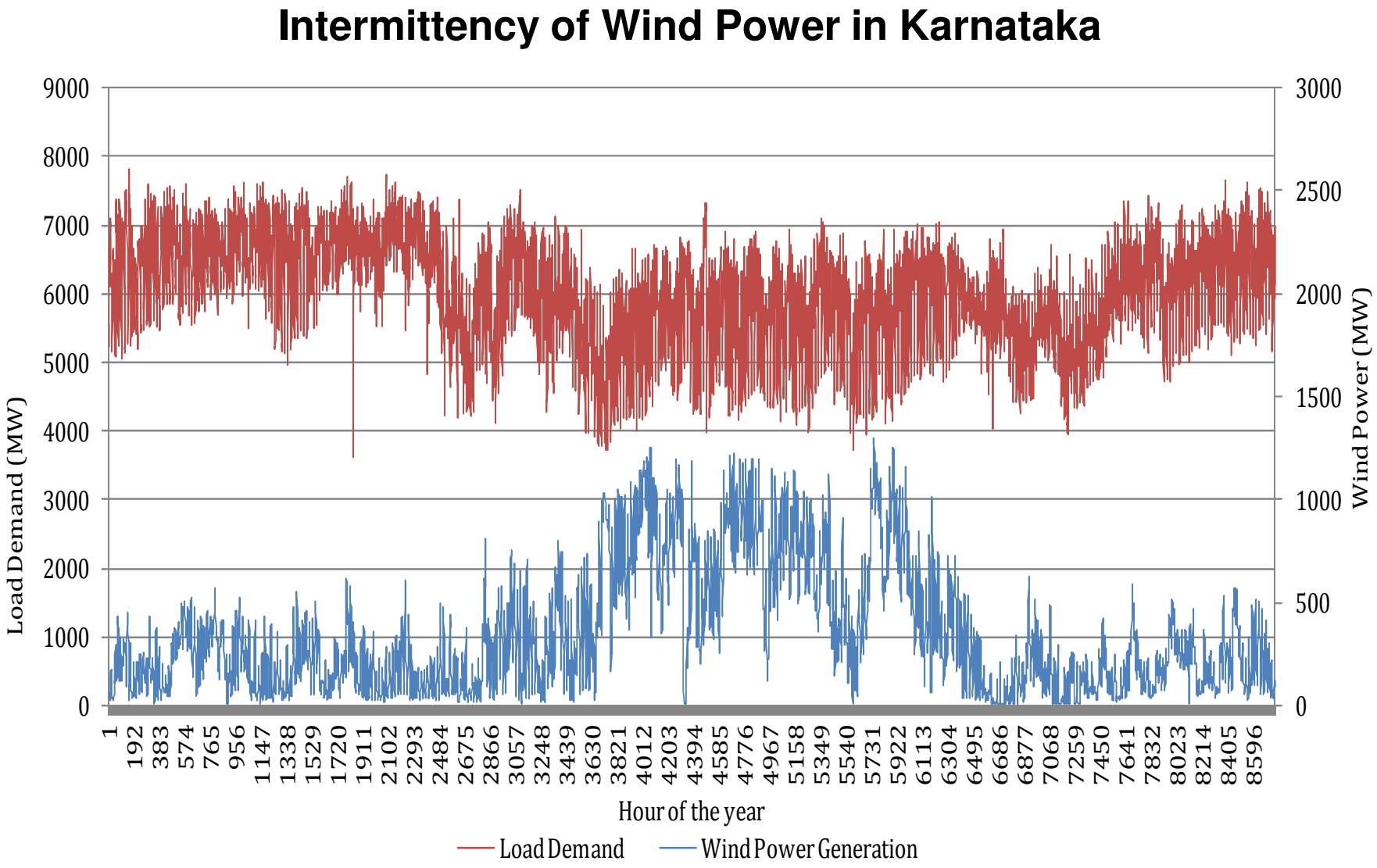
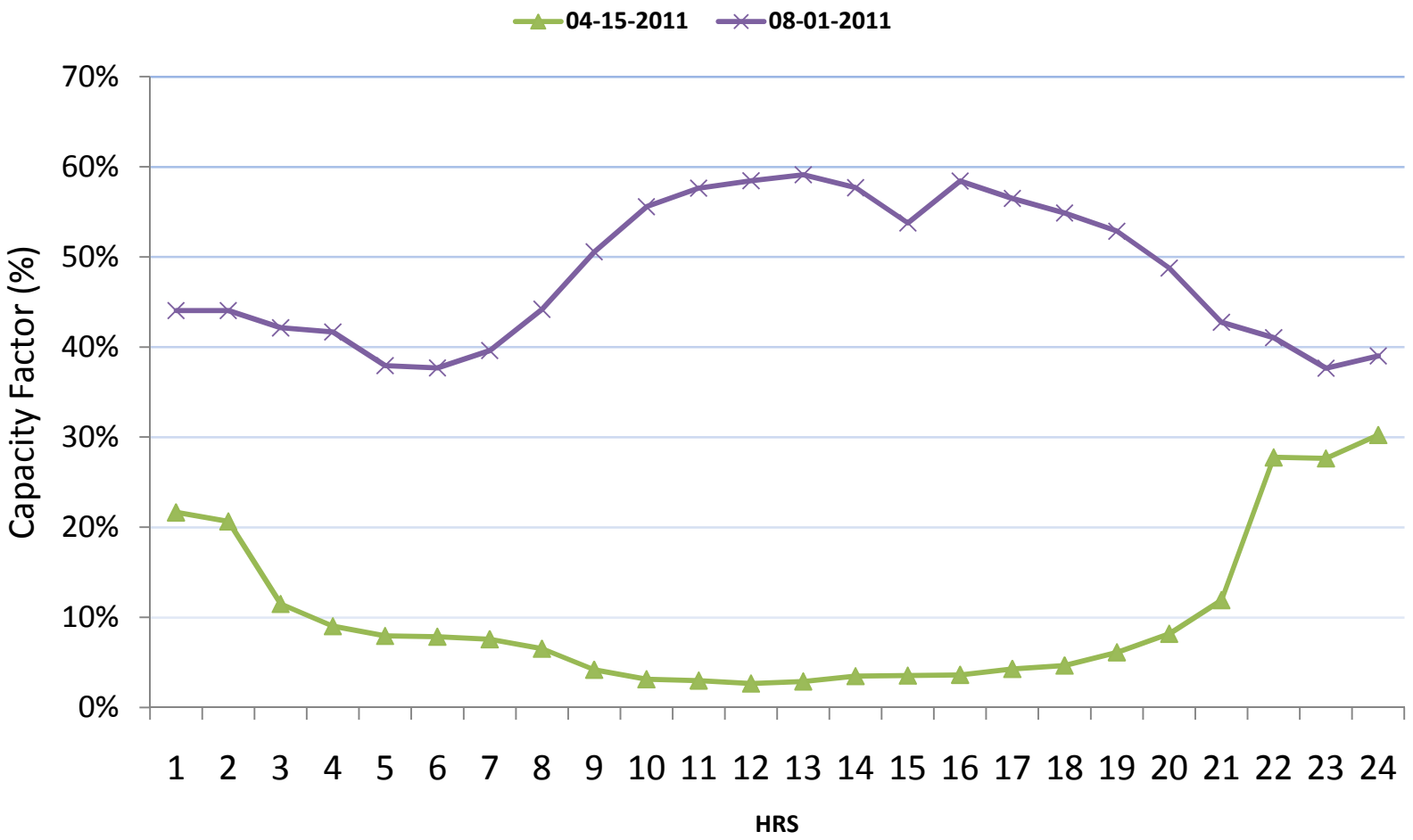
Why Storage?


Intermittency of Wind Power in Karnataka
Load Demand (MW)
Wind Power (MW)
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
3000
2500
2000
1500
1000
500
0
1
192
383
574
765
956
1147
1338
1529
1720
1911
2102
2293
2484
2675
2866
3057
3248
3439
3630
3821
4012
4203
4394
4585
4776
4967
5158
5349
5540
5731
5922
6113
6304
6495
6686
6877
7068
7259
7450
7641
7832
8023
8214
8405
8596
Hour of the year
Load Demand
Wind Power Generation

Why Storage?

Wind in Karnataka: Seasonal and Diurnal Variations



Why Storage?

- Non-optimized location of generation
- Uncertain availability of generation
- Low reliability of generation
- Inadequate dispatching or scheduling control
- Deferral or avoidance of alternative upgrade in Transmission, Distribution and Generation sectors
- Energy arbitrage (peak - off-peak displacement)

EPRI, 2010; Barnes & Levine, 2011

2011 Global Installed Storage Capacity for Electrical Energy

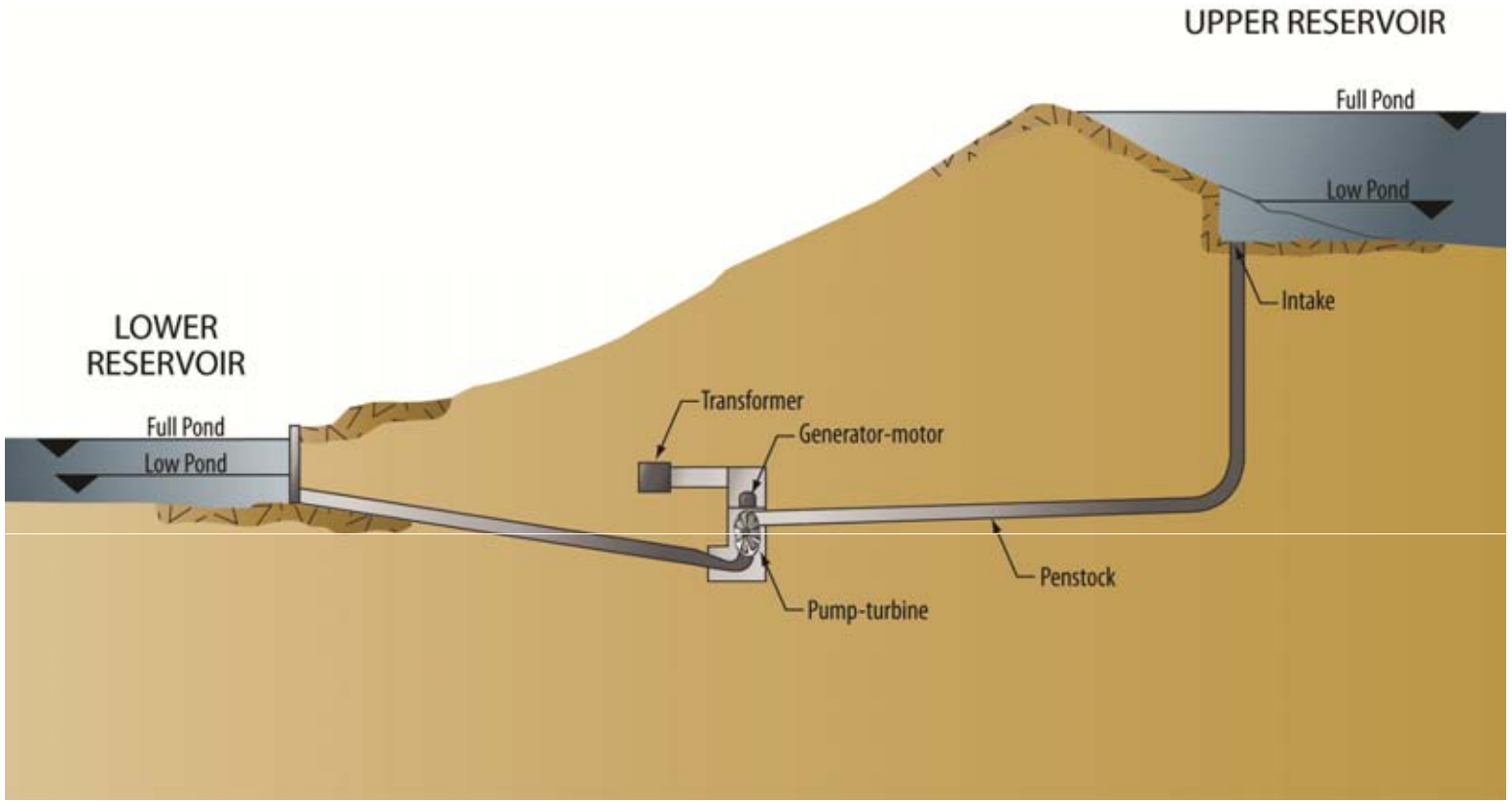
Technology	Power (MW)	Energy (GWh)
PHS	129,000	102
CAES	400-650	3.73
NaS	365.3	2.191
Li – Ion	~20	0.06
Lead Acid	~35	--
Flow (VRB, ZnBr)	3	0.024

Barnhart & Benson, 2013; EPRI, 2011

~2.5% of the World installed capacity of power

Total installed capacity of power in India: ~ 225,000 MW

Mechanical - Pumped Hydro Storage System



hdrinc.com

Potential: 94,000 MW, 56 sites (CEA, 2012)

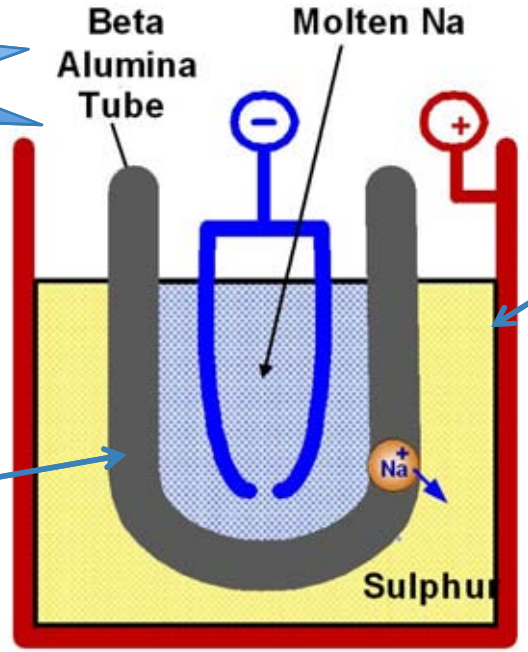
Current Installed Capacity in India: ~6,000 MW

Long Lead Time, η = 80%, >25,000 cycles

Capital Cost – Rs 3 Crores/MW

Electrochemical - Sodium Sulphur Battery

High temperature operation (300 ^{0}C)



Corrosion from molten sulphur

Delicate material, rupture can cause accidents/fire

Chemistry:

Anode: $2Na - 2e^- \leftrightarrow 2 Na^+$

Cathode: $xS + 2Na^+ + 2e^- \leftrightarrow Na_2S_x$ (x = 3~5)

Cell Reaction: $2Na + xS \leftrightarrow Na_2S_x$ (x = 3~5)

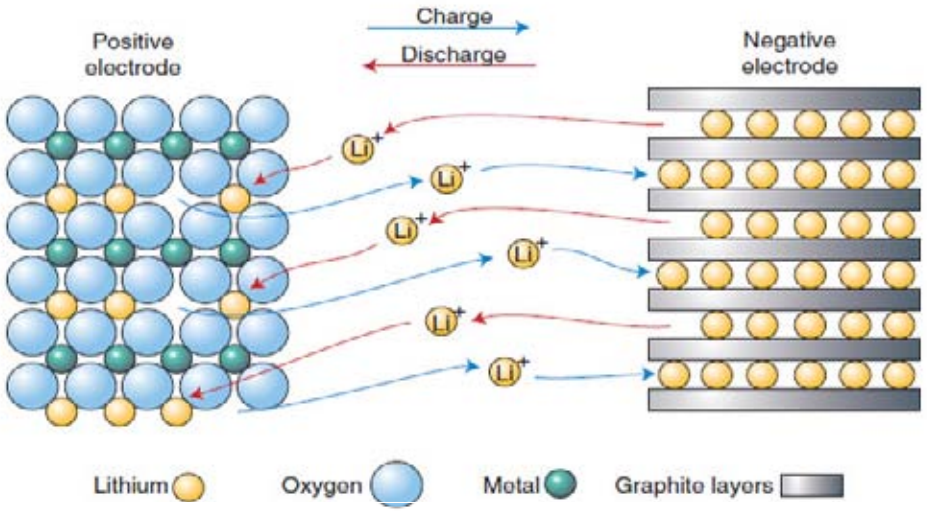
High energy density, low maintenance, η = 75%

Lifetime of 2,500 cycles at 100% DOD or 4,750 cycles at 80% DOD

High rate of self discharge, $350/kWh

In India, sodium manufacturing is a major concern

Li - Ion Battery



Anode – Graphite (C)

Important class of cathode materials:
$LiMn_2O_4$: electric vehicle (Chevy Volt)
$LiCoO_2$: consumer electronics
$LiFePO_4$: used in electric vehicles

Electrolyte – $C_2H_4CO_3$ & $CH_3OCO_2CH_3$

South America has nearly 80% of global Li reserves

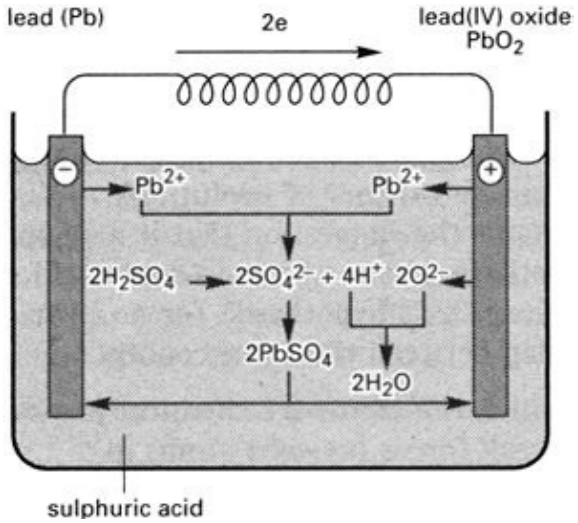
Lifetime of 4,000 cycles at 100% DOD or 6,000 cycles at 80% DOD

$\eta > 90$ %, $ 650/kWh

Amount of Li metal per 100,000 cars : 480,000 Kg (Rs. 293 Crores, Li - $100/kg)

High Cost, Overcharging protection, Overheating and Capacity Fading

Lead Acid Battery



Electrochemistry

Reaction at negative electrode:

$Pb\ (s) + HSO_4^-\ (aq) \rightarrow PbSO_4\ (s) + H^+\ (aq) + 2e^-$

Reaction at cathode electrode :

$PbO_2(s) + HSO_4^-(aq) + 3H^+(aq) + 2e^- \rightarrow PbSO_4\ (s) + 2H_2O\ (l)$

Low internal resistance and high energy to weight ratio

Sulfation, Higher operating temperatures reduce battery life, Less eco-friendly

Lifetime of 500 cycles at 100% DOD or 750 cycles at 80% DOD

η= 90 %, $250-300/kWh

Summary

- Cycle life data, efficiency, depth-of-discharge and life-cycle energy requirement are the critical parameters
- Ranked from least to most limited by **energy requirements**: PHS, Li-ion, NaS, PbA
- Ranked from least to most limited by **material availability**: NaS, PbA, PHS, Li-ion
- Ranked from least to most **expensive**: PHS, PbA, NaS, Li-ion
- Ranked from lowest to highest **life-cycle**: PHS, Li-ion, NaS, PbA