


Prudent Energy

Storage for a sustainable future
The Global Leader in Advanced Energy Storage

SKA Telescope – Power Project

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Corporate Profile

Company Overview

- Prudent Energy provides the proprietary VRB energy storage system (VRB-ESS) for grid and renewable energy storage applications
- Founded in 2006 Manufacturing established in China 2009, offices in USA with R&D in Canada
- Manufacturing
  - 10MW /shift/y(2011)
  - Employee: ~150
- 33 patents globally including Self healing grids and several wind turbine storage concepts
- Approximately $25million in cash: no debt
- 2010 contracts forecast $13million
- Investors Include: DFJ, DT Capital, Northern Light, Sequoia Capital, Mitsui, CEL (French) and Jafco.

Low-cost Manufacturing Facility in China

Global

Products & Solutions Overview

Leveraging its proprietary cell stack design, Prudent Energy offers two product lines to address different energy storage applications

Key Standard Cell Stack

- Mature and proven standard 7.5kW cell stack
- Established mass production lines with high yield in China
- High reliability and consistency
- High scalability with parallel connection

Two Product Lines

	MW Class system	kW class System
		
Cell Stack	• Multi-cell stacks	• Single cell stack
Capacity	• 175kW Module • Up to MW-class system	• 5kW x 4 hour • 5kW x 8 hour
Application	• Wind Farm • Grid Expansion / Enhancement • PV	• Telecom Base Station • Remote Area Power Supply

Vanadium Metal

- Vanadium is found all over the world in mineral form, in tar sands, in fly ash and in oil fields.
- Vanadium is mainly used as an additive to iron, steel and titanium.
- Large quantities of Vanadium are readily available for use in flow cells.

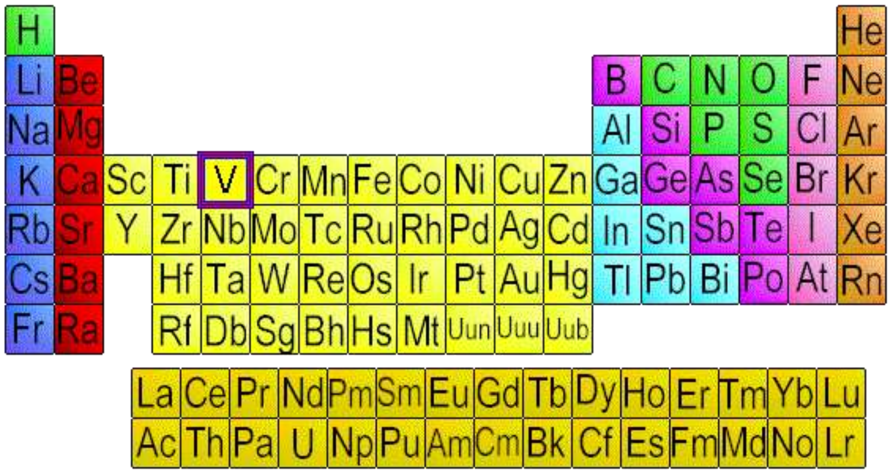


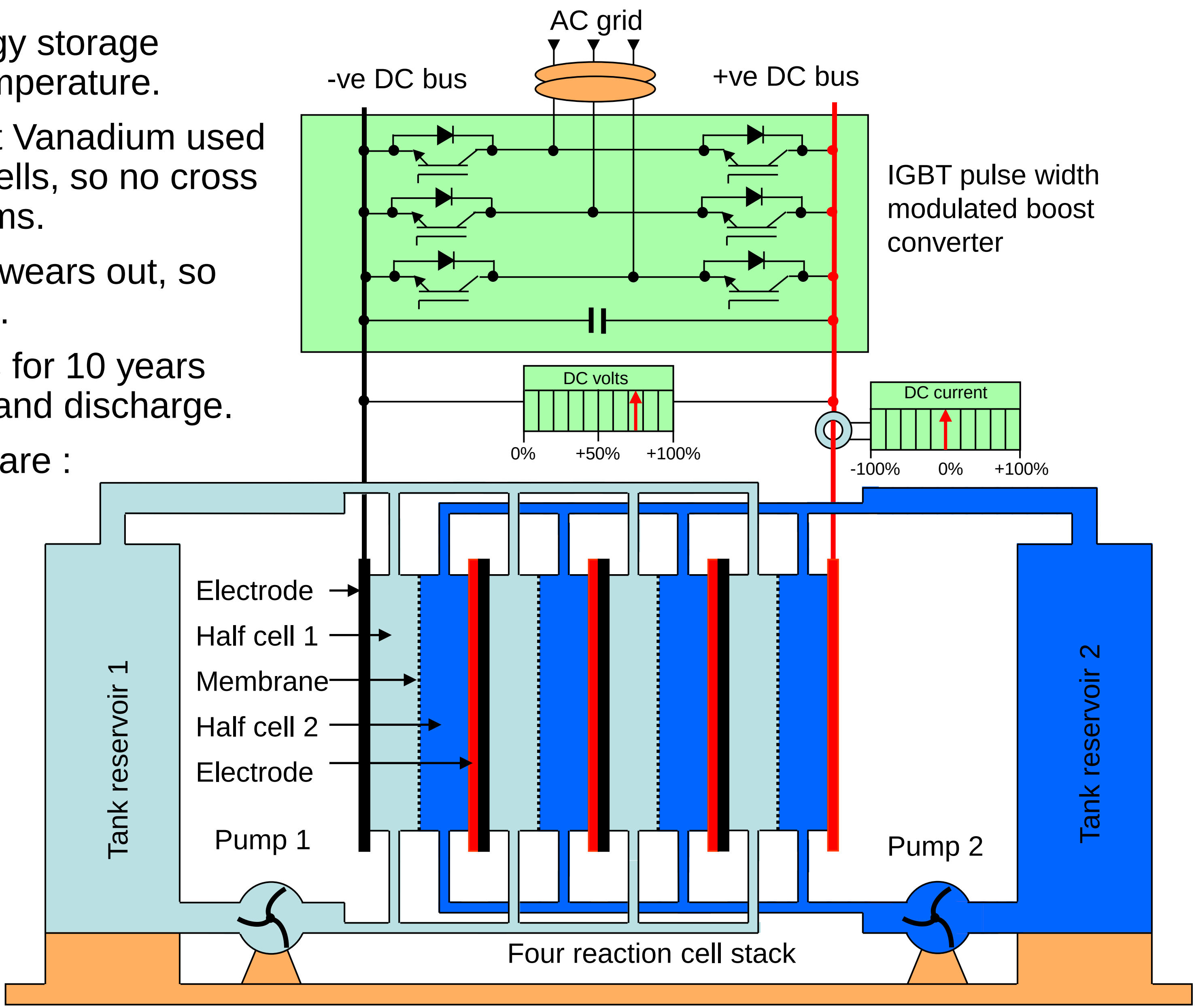
Photo from MII, courtesy of the Smithsonian Institution

- Vanadium is a silverish transition metal and the valence electrons exist in several shells.
- In the normal state Vanadium has 23 protons, 23 electrons and 28 neutrons.

• Vanadium electrolyte is classified as a dangerous good for transportation purposes due to its content of sulphuric acid. Its is not considered poisonous and in use is quickly permitted in Europe China and USA. It has the least environmental impact of all storage technologies.

The Vanadium Flow Cell Energy Storage Technology

- Electrochemical energy storage system at ambient temperature.
- Same unique element Vanadium used in both reaction half cells, so no cross contamination problems.
- The electrolyte never wears out, so very low maintenance.
- Unlimited deep cycles for 10 years with very fast charge and discharge.
- Most unique features are :
  - MW rating sets reaction cell size.
  - MWh rating sets tank size.
  - Vanadium is easily available.
  - Works by proton & electron transfer.

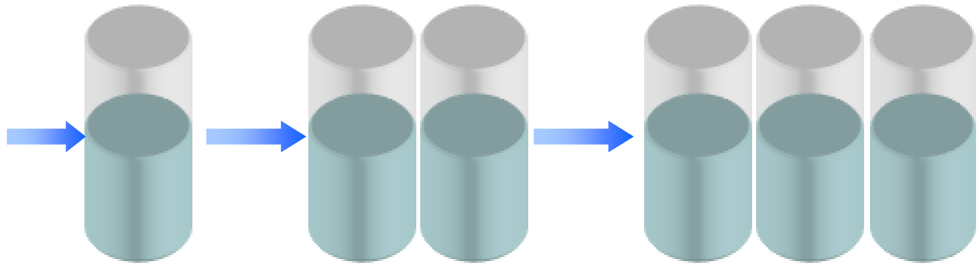


The Evolution To Scalable And Flexible Designs

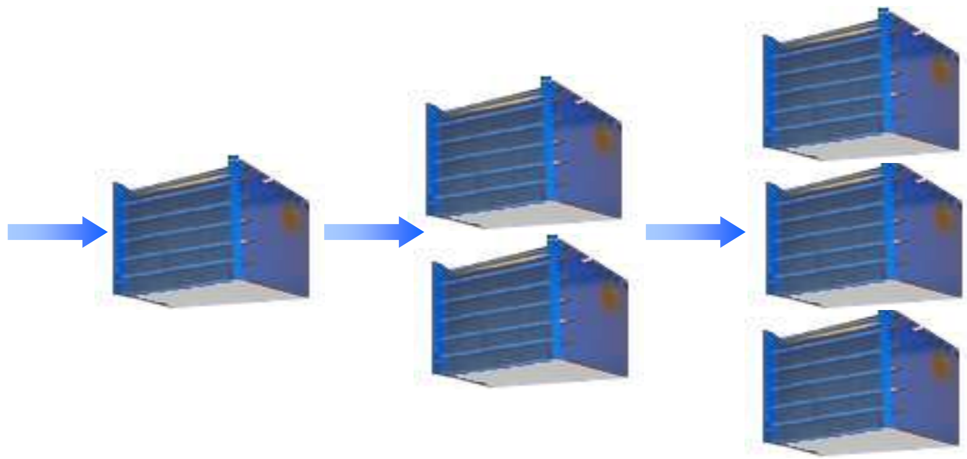
Original concept built and proven on site

Current 175kW system now modular and mass produced as a packaged product.

- Electrolyte can be extracted from fly ash, spent catalysts or mined.
- Unlike lithium there is no shortage and it is long life and completely reusable.
- Scaling for extra MWh energy storage is by adding electrolyte storage tanks



- Scaling for extra MW power is by adding reaction cells and associated converters.



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Standout features - 1

- Timing is likely to coincide with ”apocalyptic” fossil fuel supply crisis
  - While capital cost for fossil plant is low, the running and logistical costs are very high
  - Better to consider non-fossil supply
- Fortunately PV costs are falling & already approaching European ”grid parity” but ...
  - ....the sun does not shine at night
  - ...so reliable storage will be essential

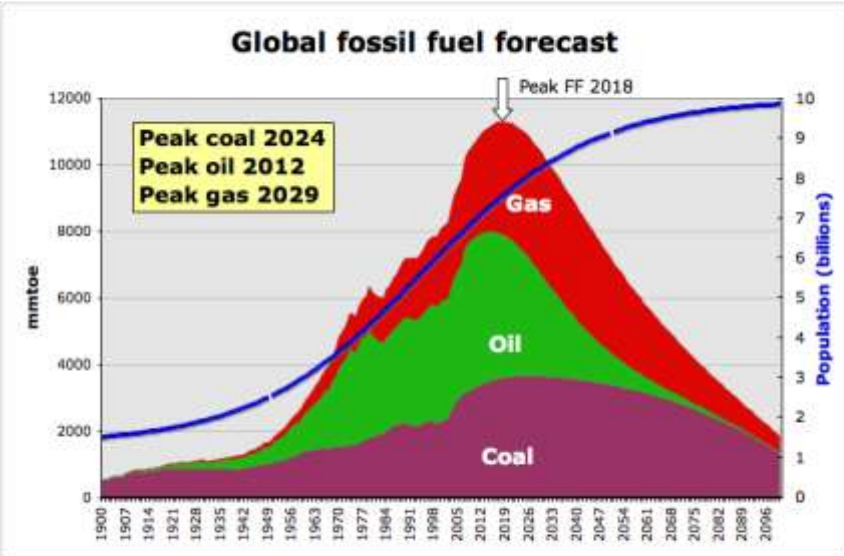
Standout features - 2

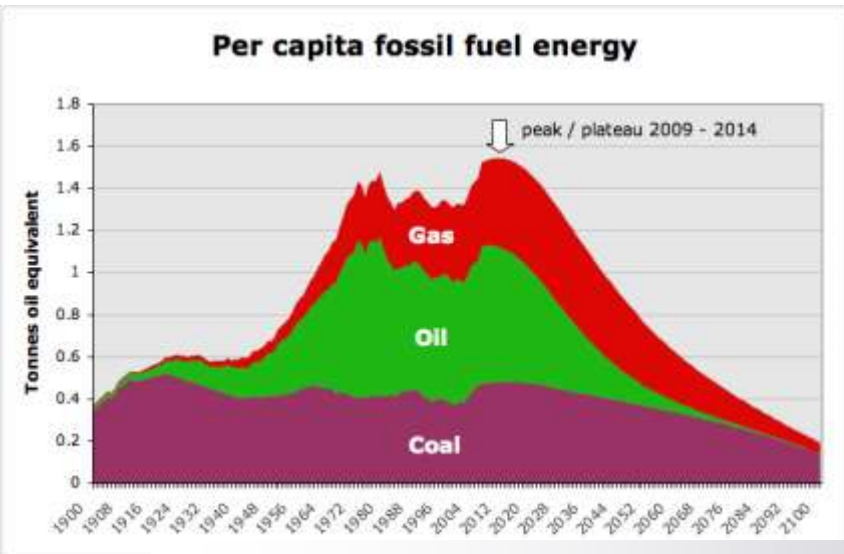
- Extremely remote locations over a vast area
  - Centralised power supply with transmission will be very expensive in capital and operation
  - So go for decentralized, modular power plants at each power consuming location
- Extreme weather
  - High temperatures, sandstorms (?), occasional torrential rain?
    - Any of these may close down PV (though wind can usually operate through storms)
  - So storage will require high kWh per kW

Standout features - 3

- Sites must not generate radio frequency interference (RFI)
  - So power generation must either:
    - Not generate RFI
    - Or be shielded from RFI
- Each mini-network will preferably be DC
  - ...fortunately this favours PV generation and DC /DC storage

A scenario for global fossil fuel production de Sousa and Mearns 2008 http://europe.theoildrum.com/node/3565





The chart summarises the work of others:

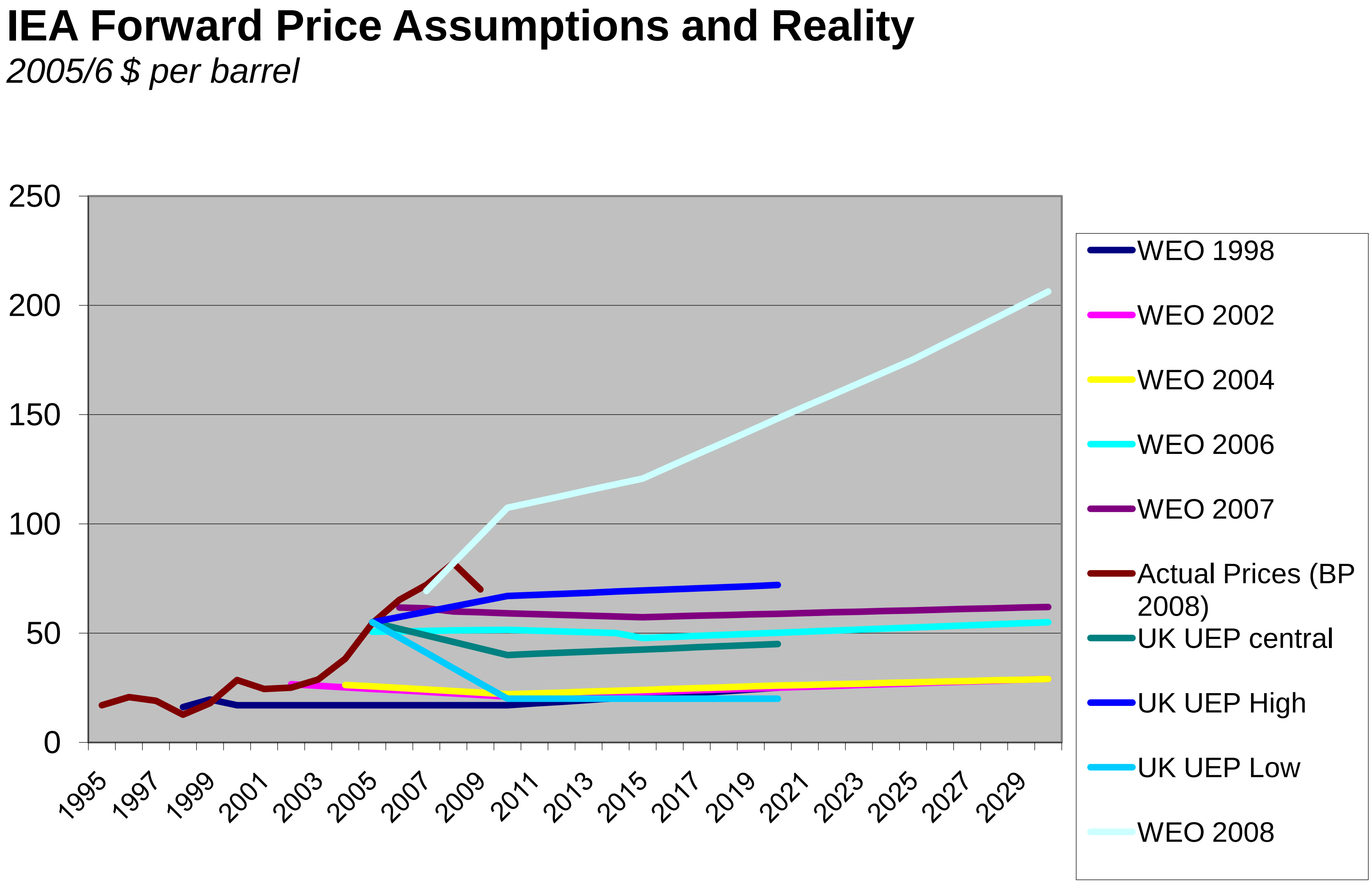
- Coal from Energy watch Group, Germany
- Oil from Samuel Foucher, The Oil Drum
- Gas from Jean Laherrere
- Population from United Nations

Peak in FF production around 2018, followed by relentless decline

Rising population means that per capita FF energy availability will decline rapidly (Olduvai theory of Richard Duncan 1989)

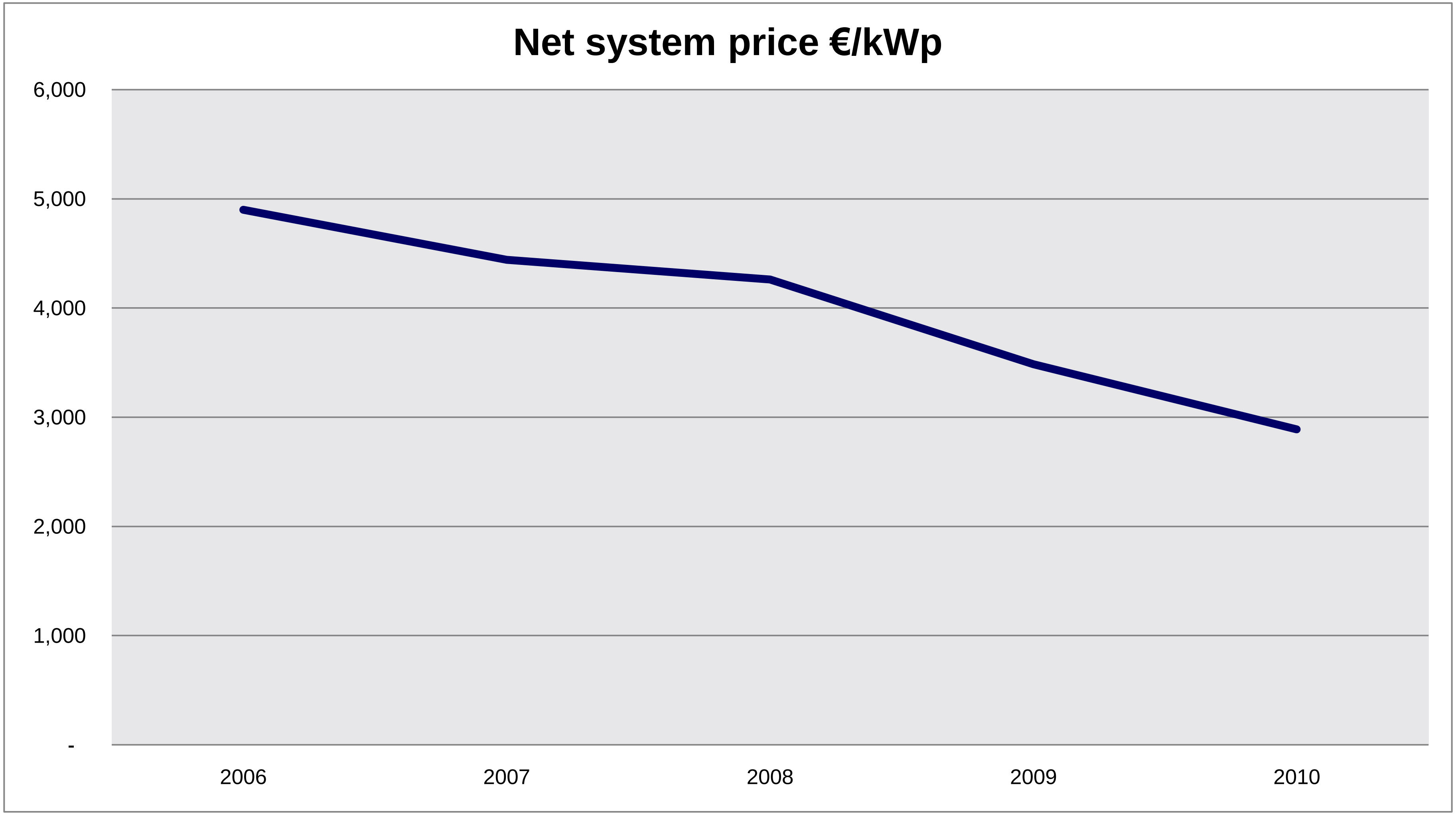
But this is only one view of very complex geological, socio-economic issues.

WEO Price Projections Update



All official OECD energy price projections have been optimistic & wrong

PV prices are falling – Germany - 2010



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Whole telescope power costs – say 50 MW (optimistic?)

Conventional Power imported		
EU Average industrial price 2009	€/MWh	11
MWh consumed	50*8760	438,000
Annual cost	€ millions	49

Transmission not included

RFI contra-measures not included

Future costs due to resource scarcity unknown

Decentralised and some central diesel power stations (contracted out)

Decentralised diesel Power		
Average global price 2010	€/MWh	220
MWh consumed	50*8760	438,000
Annual cost	€ millions	96

Transmission not included

RFI contra-measures not included

Future costs due to resource scarcity unknown

Decentralized PV Solution with VRB storage

PV capacity factor	by 2018	20%
Energy losses, in storage & transmission	(say)	25%
PV capacity required	MWp	333
Turnkey cost of PV power plant	€million/MWp	1.5
Turnkey cost of PV power plant	€ million	**500**
Battery, required output	MW	50
Worst case, no input power	hours	24
Battery energy storage needed	MWh	1200
Capital cost	€ millions	**346**
Total Power costs (first costs)	€millions	**846**

Decentralized PV station - 2

- PV life 20 years
  - PV output deteriorates
  - Add additional area and/or replace
- PV cleaning, not included
  - In a desert environment unknown
- VRB cell stack life 15 years
  - Uniquely, the VRB can take unlimited cycles but the membrane ages
- Replacement of stacks at 15 years (say) €10 – 12 million

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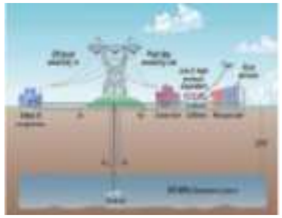
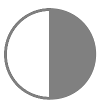
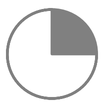
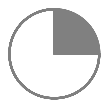
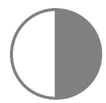
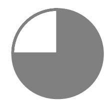
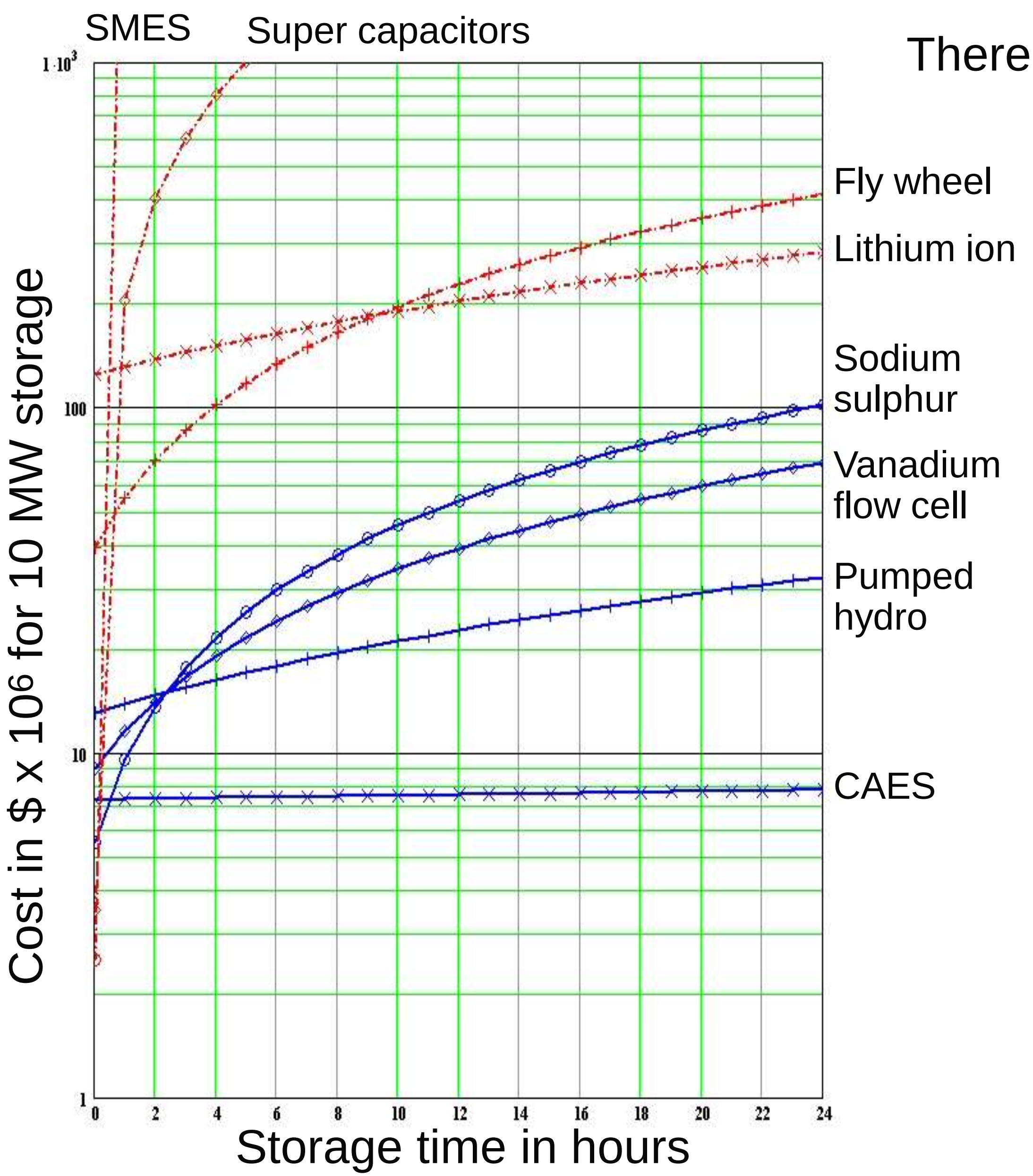
Summary of Alternative Grid Energy Storage Solutions

Electrochemical energy storage is the most preferred practical solution for distributed grid energy storage applications

	Pumped Storage	Compressed Air Energy Storage (CAES)	Fly Wheel & Super Conductor	Open Cycle Gas Turbines, Diesels or Coal Fire Station	**Electrochemical Energy Storage**
Solutions					
Comments	• Mature • Long lead time • Geographical limitation • Large scale	• Limited by unpromising geology • Long lead time • Inefficient • Similar pricing • Large scale	• Short storage time (~seconds level)	• Medium CAPEX • High impact on environment • Low average efficiency	• Fast delivery • Low operating cost • Environmentally friendly • Higher initial CAPEX
Fit for Commercial Grid Storage Applications	 Yes, but limited by geology	 Not a practical solution	 Not a practical solution	 Yes, but has drawbacks	 Yes, preferred solutions

Comparison Of Main Energy Storage Technologies (EPRI – 2008)



There are two leading new technologies

	Vanadium flow cell	Sodium sulphur
Number 50% cycles	>100000	3500
Environment risk	Low	High
Response time	Fast	Fast
Round trip efficiency	75 %	68 %
Operational costs	Very low	Very High

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Comparison of Competitive Technologies

VRB and NaS are the two practical technologies with commercialized products for grid energy storage applications, in particularly with wind power applications

Comparison of Competitive Technologies

Solution	Key Player	Life Cycle[1]	Price[2] ($/kWh)	Environmental Risk	Fit for Wind Applications
Lead Acid	• Enersys • Exide	3,500	1,300-1,800	Medium - recycling required	• No • Limited cycles and depth of discharge
Lithium-ion	• A123 • BYD	2,000	~3,000	Medium - recycling required	• Only fit for frequency regulation • Limited storage hours
Zinc Bromine	• ZBB • Premium Power	2,500	~1,000	High	• Limited cycles and cross mixing plus electrode issues • Must rebalance regularly
NaS	• NGK	3,500	~675	High	• Requires redundancy of capacity by 3x for special charge control and cycles
VRB	• Prudent Energy	>100,000	500-750	Medium to Low - no recycling required	• Best fit • Perfect power and duration match and real-time charge control

Notes:
(1) times of over 50% depth discharge; (2) Initial System CAPEX; A123's cost estimation based on 1MWx10min battery price of US$500,000, other cost data come from real project or bidding

Wide range of sizes available

Commercially available in 2010

- From 5 kW and 20 kWh
  - In telecommuncations in Africa and small solar in China
- To 10 MW and 120 MWh
  - Commercially offered

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Summary and Conclusions (Generic)

- The life of the SKA telescope project will probably outlive us all
- During this time there will be ever tightening shortages of fossil fuel
  - Which IMHO invalidate fears of run away CO2 emissions!
- PV technologies will become more efficient and cheaper
- Energy storage is an essential component to deliver 24/7 power
- This solution looks dauntingly expensive but better bite the bullet now and look for the necessary funding

Questions?

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