Low Cost, High Performance, 50-year Electrodes

PRIMUS POWER™
Smart Grid Storage

Under this ARPA-E project, Primus Power will develop an extremely durable, highly active, conductive, and inexpensive electrode for flow batteries.

Flow batteries offer one of the most exciting opportunities for affordable grid storage, however electrodes are costly and are the single largest cost component in a well integrated design.

Grid storage can yield numerous benefits in utility and customer-owned applications:

- ✓ renewable firming
- ✓ peak load reduction
- ✓ load shifting
- ✓ capital deferral
- ✓ frequency regulation

By incorporating volume production practices from the chlorine, filter media, and electroplating industries, Primus Power will effectively reduce electrode costs to exceed GRIDS cost targets while providing the durability essential for widespread grid-scale adoption.

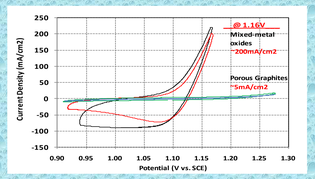
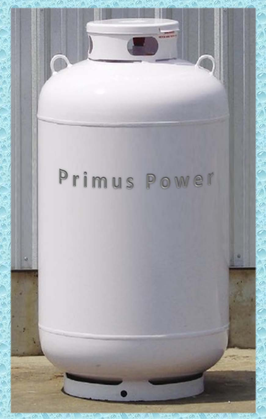


Figure 1: Comparison of the best-performing carbon electrodes with Primus Power's advanced electrodes

To achieve the project goals, Primus Power will direct cross-industry collaboration with US manufacturers in the development of advanced electrode materials. These manufacturers will see a new market created for the new materials, furthering both job creation and technological advancements in manufacturing.

This project will enable:

- ✓ advanced batteries that will reduce emissions, as batteries are charged by lower-emission off-peak electricity and discharged to replace higher emission, on-peak generation
- ✓ the creation of higher efficiency batteries, reducing the energy required for charging the batteries, with a resulting reduction in generation and emissions
- ✓ increasing the cost-effective deployment of renewable generation technologies by addressing intermittency and regulation challenges that wind and solar currently face

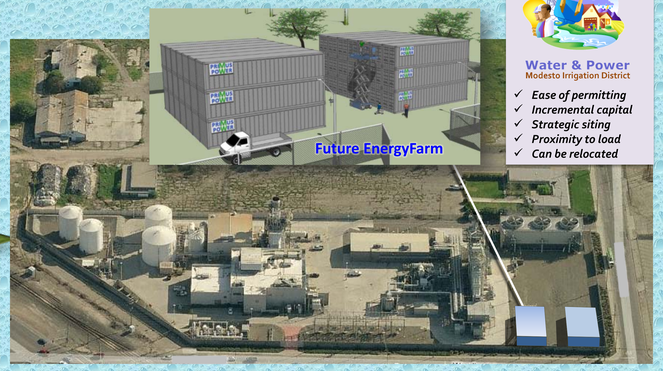


Standard 28"ϕ steel ASME, NFPA58 conforming tank

The EnergyCell is our volume production module

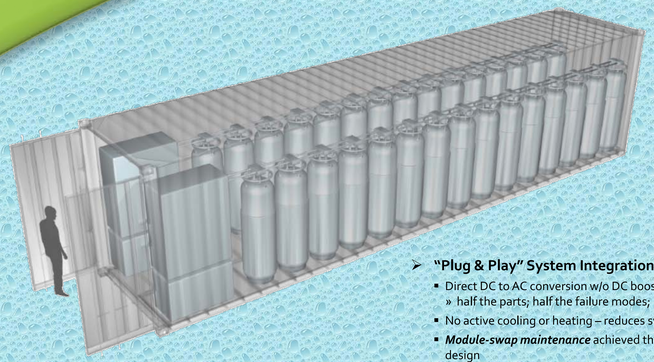
- ➢ Starting with ***compelling active materials***
  - ▪ $1.80/kWh vs. $30/kWh for lead paste
  - ▪ 700Wh/kg & 1700Wh/l (gasoline yields 1600Wh$_e$/l)
- ➢ ***Maintenance-proof*** welded triple containment
  - ▪ 15-year design life with 200,000 hour pumps
  - ▪ >>5,000 cycles to 100% DOD
- ➢ Leveraging ***economies of scale***
  - ▪ One of the largest batteries modules in the world
  - ▪ 20kW/60kWh @ 48Vdc (equiv. 30,000Ah Pb-A battery)
- ➢ Leveraging ***economies of mass production***
  - ▪ small enough for a production line
  - ▪ 75% part count reduction
  - ▪ low cost commodity materials
  - ▪ standard manufacturing processes

Primus Power will begin Installing the EnergyFarm in Modesto, California in 2012

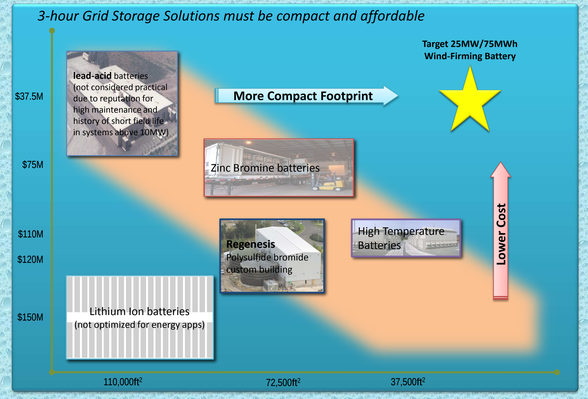


Water & Power
Modesto Irrigation District

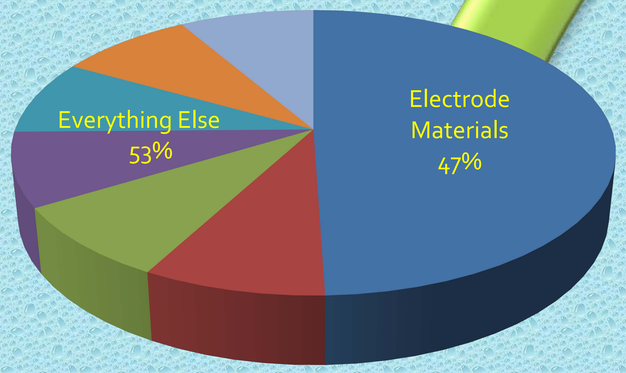
- ✓ *Ease of permitting*
- ✓ *Incremental capital*
- ✓ *Strategic siting*
- ✓ *Proximity to load*
- ✓ *Can be relocated*



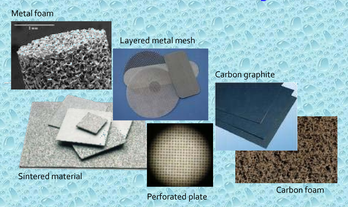
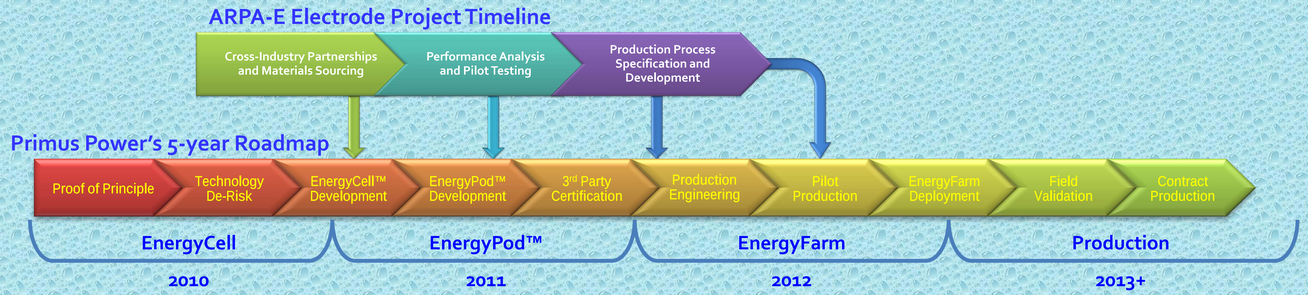
- ➢ **"Plug & Play" System Integration**
  - ▪ Direct DC to AC conversion w/o DC boost phase
    - » half the parts; half the failure modes; half the losses; half the cost!
  - ▪ No active cooling or heating – reduces system loads by 70%
  - ▪ ***Module-swap maintenance*** achieved through common module design
    - » no engineers; no forklifts; no special tools; no advanced training
- ➢ **"Rack & Stack" Cargo Containers**
  - ▪ Transformerless and seamless integration and load sharing
    - » Parker's advanced power electronics
  - ▪ No single-point failure modes
  - ▪ 200 MW/acre



Component Cost Breakdown



Various Electrodes Under Investigation



ARPA-E Electrode Project Timeline