FreedomCAR Program
R&D on Energy Storage Systems

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FCVT Program Goals

Support R&D of advanced vehicle technologies and fuels to dramatically reduce petroleum demand, decrease emissions and greenhouse gases, and enable a strong, competitive U.S. transportation industry

Goals of the FCVT Energy Storage Effort

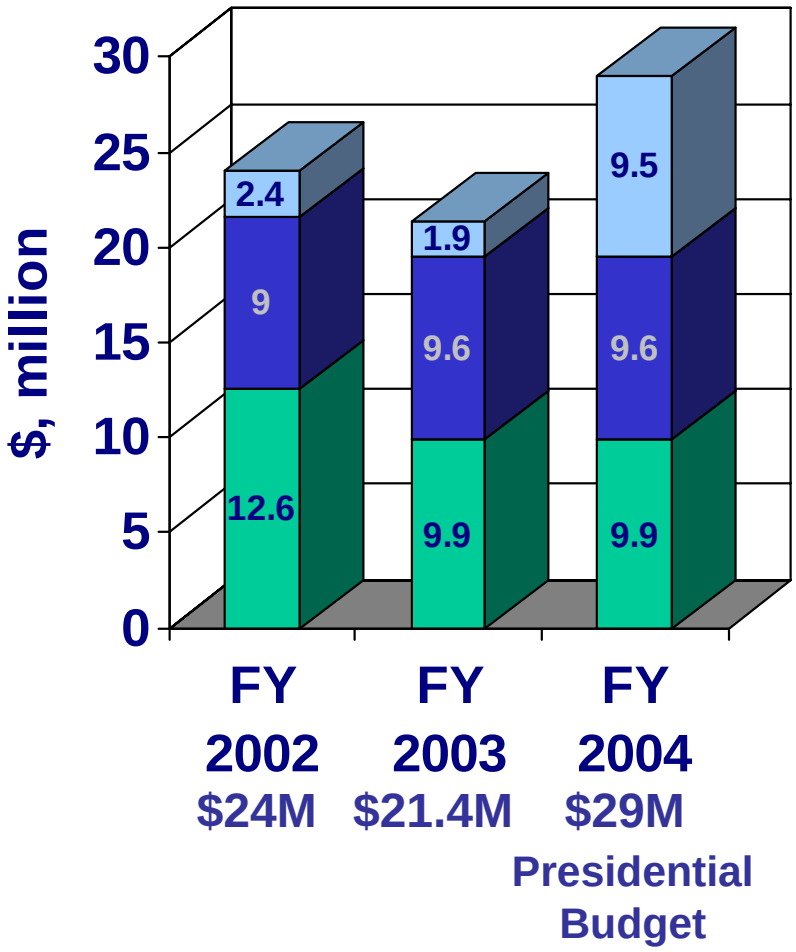
Conduct R&D on advanced batteries to facilitate the commercial viability of battery electric vehicles (EVs), hybrid electric vehicles (HEVs), 42 volt vehicular systems (42V), and fuel cell vehicles (FCVs)

Energy Storage Activities

- **Battery Technology Development**
  - Develop batteries for EVs, HEVs and FCVs
    - Cost shared contracts
- **Applied Research**
  - Tackle the barriers facing Li-based batteries
    - Work at 5 National laboratories and ARL
- **Long-term Research**
  - Conceive the next generation of battery technologies
    - Work at DOE labs and universities

U.S. Department of Energy
Energy Efficiency and Renewable Energy

Energy Storage R&D Budget



Long-term Research
LBNL, ANL, BNL,
Academic Institutions& Industrial Firms

Applied Research
ANL, ARL, BNL, INEEL, LBNL, SNL

Technology Development
USABC Battery Developers

Batteries for EVs

Performance of High-Energy Li-Ion Batteries (2003)

Characteristic	*Current Li-Ion*	*System Target*
Specific Power (W/kg, 80% DOD, 30 sec.)	280	400
Power Density (W/L @ C/3)	155	300
Specific Energy (W/kg @ C/3)	100	200
Power Density (W/L)	440	600
Cycle Life (Cycles at 80% DOD)	1,000	1,000
Selling Price ($/kWh @ 100 k units/yr)	2 to 4 times the target	100

Li/S Developmental System

Possibilities	*Issues*
• Meet all USABC Performance Goals • Meet USABC Cost Goals	• Poor Cycle Life • High Capacity Loss • Instability at Li Surface • Isolation of Sulfur

Batteries for HEVs

Performance of High-Power Li-Ion Batteries (2003)

Characteristic	*Current Li-Ion*	*System Target*
Specific Power (W/kg, 18 sec. pulse)	900	625
Power Density (W/L)	1,450	780
Cycle Life (25 Wh cycles)	300,000	300,000
Calendar Life (Years)	15 (Projected)	15
Selling Price ($/system @ 100 k /yr)	2 to 4 times the target	500

Development Goals: 42Volt

Characteristic	*USABC Commercialization Goals*	
	M-HEV	*P-HEV*
Discharge Pulse Power (kW)	13 for 2 sec.	18 for 10 sec.
Regenerative Pulse Power (kW)	8 for 2 sec.	18 for 2 sec.
Engine-off Accessory Load (kW)	3 for 5 min.	3 for 5 min.
Available Energy (Wh at 3 kW)	300	700
Recharge Rate (kW)	2.6	4.5
Energy Efficiency on Load Profile (%)	90	90
Cycle Life, Profiles/Engine Starts	150k/450k	150k/450k
Calendar Life (Years)	15	15
Cold Cranking Power @ -30°C	8 (21 V minimum)	8 (21 V minimum)
Maximum System Weight (kg)	25	35
Maximum System Volume (L)	20	28
Maximum Self Discharge (Wh/Day)	<20	<20
Operating Voltage, Maximum/Minimum (V dc)	48/27	48/27
Operating Temperature Range (°C)	-30 to 52	-30 to 52
Selling Price ($/system @ 100,000 units)	260	360

*M-HEV is mild hybrid electric vehicle, P-HEV is power assist hybrid electric vehicle.

Proposed Goals: FCVs

FreedomCAR FCV Goals

Characteristic	*Minimum*	*Maximum*
Pulse Discharge Power (kW)	25 for 18 sec.	75 for 18 sec.
Maximum Regenerative Pulse (kW)	22 for 10 sec.	65 for 10 sec.
Total Available Energy (kWh)	1.5	5
Round Trip Efficiency (%)	>90	>90
Cold-start at -30°C (kW)	5	5
Cycle Life	TBD (15 year equivalent)	
Calendar Life (Years)	15	15
Maximum Weight (kg)	40	100
Maximum Volume (L)	30	75
Production Price @ 100,000 units/year ($)	500	1,500
Operating Voltage, Maximum/Minimum (V dc)	440/220	440/220
Maximum Self Discharge (Wh/Day)	50	50
Operating Temperature (°C)	-30 to 52	-30 to 52
Survival Temperature (°C)	-46 to 66	-46 to 66

Barriers to Advanced Batteries

- **Cost**
  - Cost is above FreedomCAR targets
    - Raw materials & materials processing
    - Cell and module packaging
    - Electrical and mechanical safety devices
- **Abuse tolerance**
  - Overcharge
  - Crush
  - Short circuits
- **Life**
  - Calendar life

Approach to Cost Issues

- Identify key cost issues (e.g., separators)
- Develop and evaluate lower-cost cell components (electrolytes, anodes, cathodes, and separators) and packaging alternatives
- Develop low-cost processing methods for producing advanced cell materials
- Work with potential US suppliers to implement low-cost material production

Approach to Abuse Issues

- **Investigate failure modes through comprehensive cell testing and diagnostic efforts**
  - Understand and address thermal runaway mechanisms
  - Share with developers to develop inherently safer systems
- **Assess the behavior of vehicle-size modules under abusive conditions, using standardized tests**
- **Develop and evaluate technologies to minimize adverse behavior under abuse**
  - Chemical additives to minimize smoke and/or fire
  - In situ overcharge protection
  - Detection and battery management controls

Approach to Life Issues

- Identify life-limiting mechanisms
- Investigate and develop materials for advanced cell components that address these life-limiting mechanisms and extend cell life
- Develop and validate accelerated life test methods

Current Contracts

Activity	*Contractors*
NiMH Full System Development	Texaco Ovonic Battery Systems, LLP (TOBS, formerly GM-Ovonic)
Li-ion Batteries for EVs, HEVs, and 42V Systems	SAFT
Lithium/Sulfur Development	SION
	PolyPlus
Technology Assessment	Typically 2 – 4 companies at a time
Benchmark Testing	
Low-Cost Separators	Celgard, Advanced Membrane Systems, Ultimate Membrane Technologies, ENTEK
Ultracapacitors	INEEL (multiple products under evaluation)

Potential Economic Benefits

- **Market potential for HEV and/or FCV batteries is HUGE**
- **Sale of cars and light trucks in U.S. was about 14,000,000 in 2002**
- **HEV market penetration of just 1% would result in $70,000,000 worth of battery sales**

Potential Environmental Benefits

Fuel Savings and Avoided CO_2 Emissions

	Conventional ICE	*Hybrid*
Fuel Economy, mpg	27	45
For each HEV		
Fuel saved, gallons/yr	175	
CO_2 avoided, lbs/yr	3,300	
For 1,000 HEVs		
Fuel saved, gallons/yr	175,000	
CO_2 avoided, lbs/yr	3,300,000	