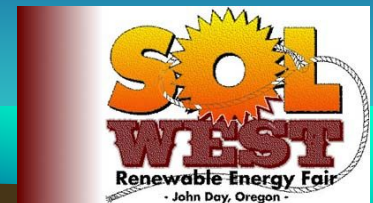




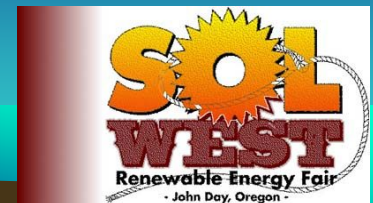
# How To Convert A Vehicle to Electric

Randy Richmond,  
RightHand Engineering, LLC



# Agenda

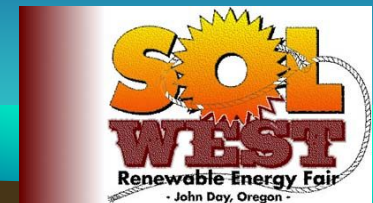
- Why I Decided To Do It
- EV Type Selection
- Donor Vehicle Selection
- Vendor Selection
- Component Selection
- Procurement
- Electrical Design
- Construction
- Testing/Driving/Fine Tuning
- The “Finished” Product
- Comparison: ICE vs EV
- What I Like, What I Miss
- What I Learned
- Driving an EV
- EV Maintenance
- Q&A



# Why I Decided To Do It

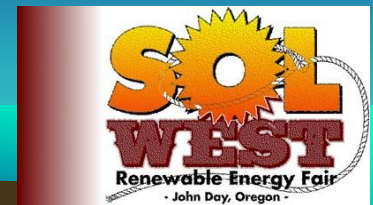
May 2006

- Long-time interest in EVs
- Gas prices rising
- Middle East situation – not wanting to fund the Jihad
- Remembrances of 70's gas rationing
- Consistent with my RE business & lifestyle



# My Needs

- Distance – 2 x 20 mile daily commute
- Speed – 60 MPH when needed
- Acceleration – Comparable to a 4 cyl ICE
- Passenger Capacity – 3 adults, 1 child
- Convenience
  - Heater necessary
  - Power Brakes necessary
  - Don't need AC
  - Don't need PS



# EV Type Selection

May-June 2006

- Research ([www.evnut.com](http://www.evnut.com), <http://eaaev.org>, others)
- Specialized EV (NEV, Sparrow/NMG, Tango, Xebra, Zap, Tesla, etc.)
- Factory Big-4 EV (Used, California Zero-emissions vehicles)
  - Ford Ranger Pickup EV (bad batteries)
  - GM S-10 Pickup EV (EV1s were crushed)
  - Chrysler EPIC Minivan EV (rare, expensive)
  - Toyota Rav4 EV (expensive)
- Commercial EV Conversion
  - Solectria/Azure (Geo Metro chassis)
  - US Electricar
- Used, Private EV Conversion
- **Do It Myself**
  - Within my skill set, educational, plus I get the vehicle I want

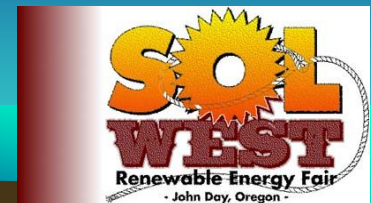


# Donor Vehicle Selection

June 2006

- Pickup is easiest to convert – built for extra weight, easy to place batteries, kits available.
- Had to have extended cab (to haul 3 adults)
- Had to be in good shape – something I would be happy to drive.
- Had to have <80K miles – mechanically sound with some longevity.

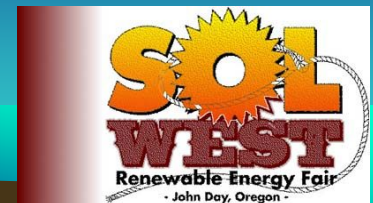
Late Model GM S-10/Sonoma, Extended Cab  
(drove as ICE Aug thru Nov 2006)



# Vendor Selection

June 2006

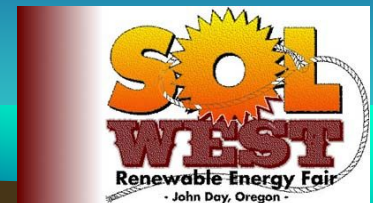
- Skill Assessment
  - I'm very good at electrical stuff
  - I'm fairly good at mechanical stuff
  - I can't weld
- Kit vs. Piece Meal (web research)
  - Canadian EV S-10 Kit (also Neon & Saturn)
  - EV America S-10 "Kit"



# Component Selection

June 2006

- Motor – 9” ADC, 30 HP continuous (100 HP peak)
- Batteries – 24 x Trojan T-145 (6v, 260 Ah)
- Contactor – Albright SW-200
- Controller – Café Electric, Zilla 1K
- Charger – Zivan, NG5
- DC-to-DC Converter – Iota, DLS-45
- SOC Meter – Xantrex, Link-10
- Safety Items (Fuse, Breaker, Inertia Switch)
- Cabin Heater - Ceramic





# Procurement

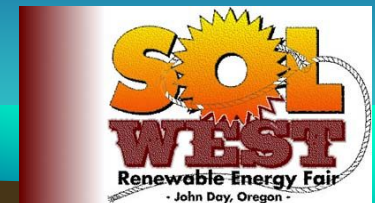
August 2006

|  |        |
|--|--------|
| 2001 GMC Sonoma Ext Cab Pickup, Tax, Reg   | \$8722 |
| 9", 30HP DC Motor  | \$1700 |
| Motor Adapter, Mount   | \$967  |
| Motor Controller, Cooling Kit, Throttle Box  | \$2272 |
| Control Box  | \$225  |
| 200A Contactor, Inertia Switch, 250A DC Breaker,<br>Emergency Shutoff Cable, 500A Fuse | \$544  |
| Battery Boxes & Mounts, Cables, Terminals, Insulators                                  | \$1695 |
| 24 Batteries & Watering System   | \$3854 |
| Battery State of Charge Meter  | \$145  |
| 30A Charger w/ thermal probe & Modifications   | \$1631 |
| 45A DC-DC Converter  | \$277  |
| 1500W Ceramic Heater   | \$60   |
| Water resistant Connectors   | \$260  |
| Radiator grill mounting plate  | \$135  |
| Brake Vacuum Kit   | \$423  |

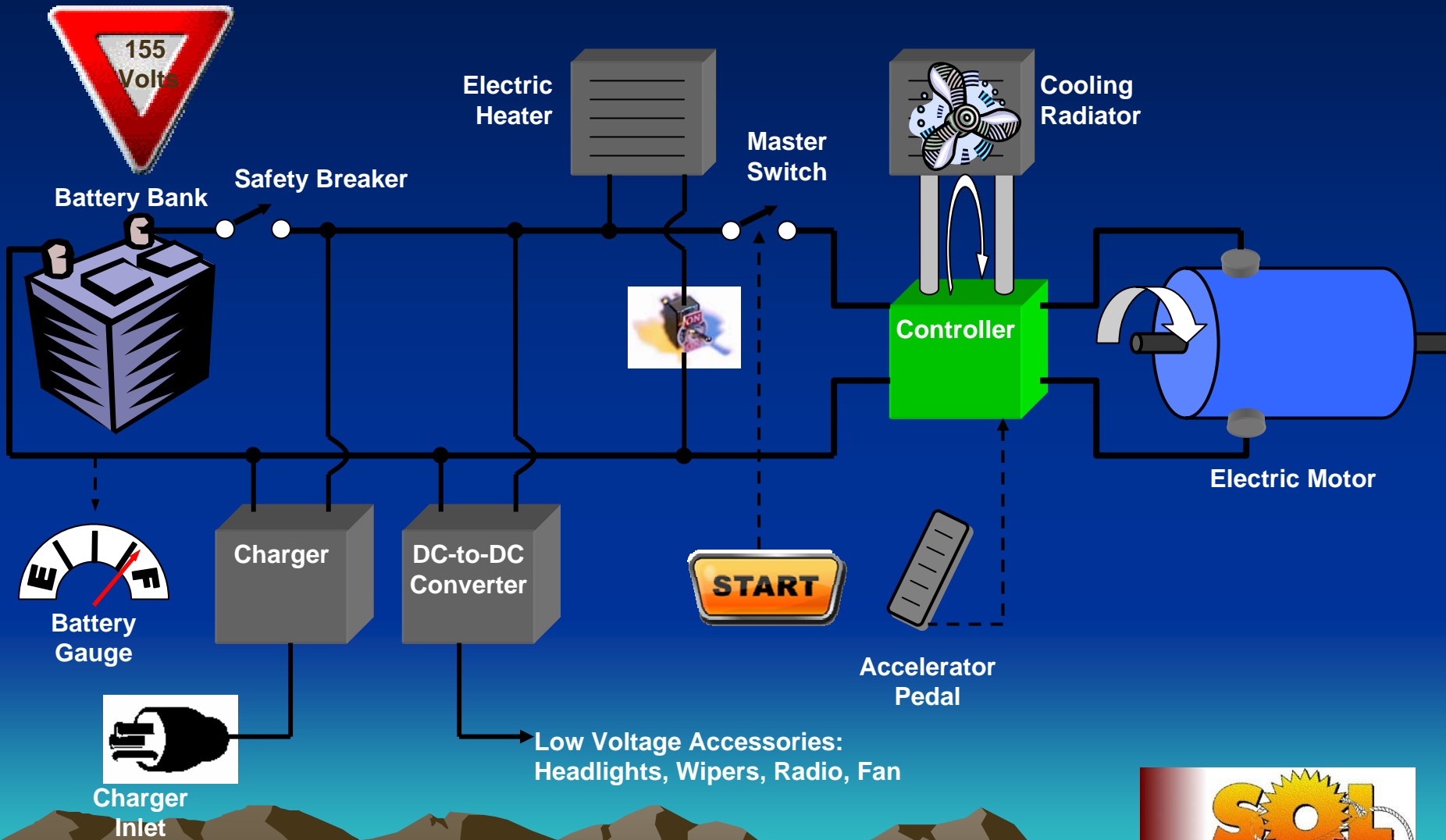
4 Month Lead

3 Month Lead

~\$22,000



# Electrical Design



# Construction

December 2006

## Removing ICE Equipment (40 hrs)

- Engine, Starter
- Fuel System
- Air Intake System
- Exhaust System
- Engine Cooling System
- Emission Control System
- Air Conditioning System
- Power Steering System

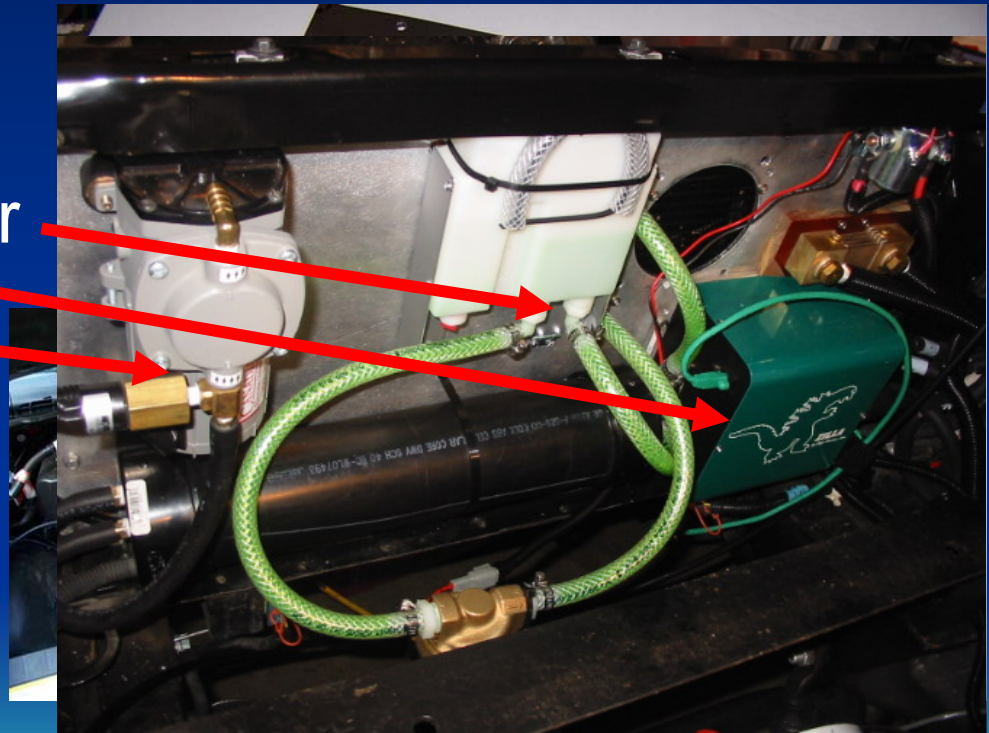


# Construction, Cont'd

Jan-Mar, 2007

## Installing EV Equipment (140 hrs)

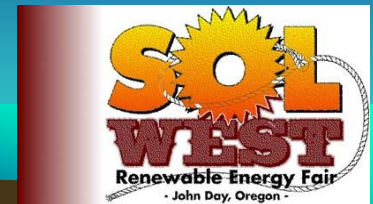
- Electric Motor
- Controller & Cooler
- Vacuum Pump
- Heater
- Battery Boxes
- Charger & DC-DC
- Wiring



# Testing/Driving/Fine Tuning

April 2007

- Controller Cooling System - problem fixed
- Speedometer – got working
- Springs – added active springs to rear
- Low Rolling Resistance Tires – made much easier to steer too.
- Tonneau Cover – lowered wind resistance, made batteries more secure.
- Tow bar, Tow lights, Drive line coupling – just in case I run out of juice.





# The “Finished” Product

May 2007

## The Seattle Times



### Fans of plug-in cars build their power base

The auto industry says plug-in hybrid cars are at least a few years away, but a growing legion of converts to the technology say the future is now.

BY HAL BERNTON AND MIKE LINDBLOM  
*Seattle Times staff reporters*

Sometime in the future, your car may make your round-trip commute with electricity generated from rooftop solar cells.

When you want to venture east of the Cascades for a weekend winery tour, an internal-combustion engine — powered by biofuels — would kick into action.

This vision has helped propel plug-in hybrid cars from a footnote in automotive technology into a serious alternative that car manufacturers are working to bring to market within the next five to 10 years.

Meanwhile, a grass-roots network of plug-in converts — professors, students, garage mechanics and others — is already fashioning the first generation of these vehicles in hopes of prodding the industry into faster action. They say these cars can get more than 100 miles per gallon for some travel.

“We have proved that we can make



*This 2001 GMC Sonoma EV Conversion truck has been converted from a gas-powered vehicle weighing 3,250 pounds to an all-electric truck weighing 4,900 pounds with a 100-horsepower electric motor and batteries.*

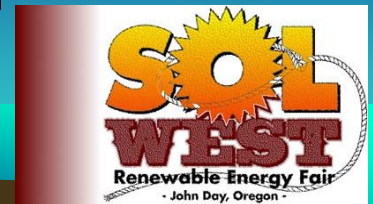


E' Pickup debut at  
Cascadia  
TransTechEnergy  
Conference at Microsoft  
Campus, Redmond,  
WA, May 1 2007.



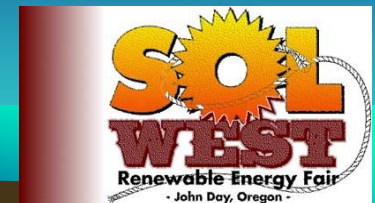


# The Finished Product, Cont'd



# Comparison: ICE vs EV

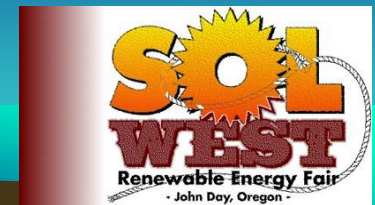
|              | Pre Conversion   | Post Conversion  |
|--------------|--|--|
| Miles        | 76640 miles  | 1220 miles so far  |
| Engine       | 2.2L, 4 Cyl, 120 HP, gasoline Internal Combustion Engine (ICE) | 9" Series DC, 100 HP, (30 HP average), Electric Motor          |
| Transmission | 5 speed manual   |  |
| Fuel         | 19 gallons of regular or Ethanol gasoline                      | 144 volts (24 x 6), 260 Ahr (37 KWhr), wet lead acid batteries |
| Fuel Mileage | ~20 miles per gallon   | ~2 miles per kilowatt hour                                     |
| Fuel Range   | ~400 miles   | ~40 miles typical, (with 20% reserve)                          |





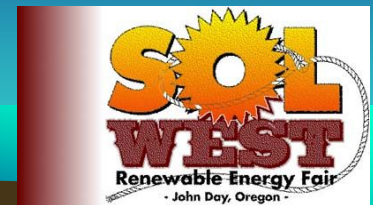
# Comparison, Cont'd

|                | Pre Conversion                   | Post Conversion  |
|----------------|----------------------------------|--|
| Fuel Cost      | 15¢ per mile @<br>\$3 per gallon | 4.5¢ per mile @<br>9¢ per kilowatt hour  |
| Refueling Time | ~3 minutes                       | ~4 hours @ 240V, 30A.<br>~16 hours @ 120V, 15A.  |
| Weight         | 3250 pounds                      | 4900 pounds  |
| Cost           | ~\$22,000 new                    | \$ 8,000 used vehicle<br>\$10,700 EV kit<br><u>\$ 3,300 batteries</u><br>\$22,000 Total<br>+ 180 hours owner labor |



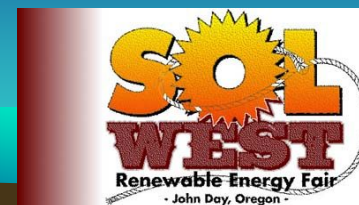
# What I Like - What I Miss

- 1/3 the cost per mile
- Never stopping at gas stations
- Fueling at home
- Silence
- Seldom using the clutch
- Nearly instant cabin heat
- No oil changes, radiator flushes, starter repairs, muffler/exhaust pipe replacements
- No exhaust fumes
- Keeping up with traffic going up hills
- Engine compression going down hills
- AM radio reception



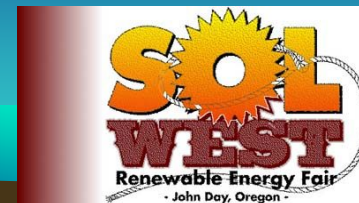
# What I Learned

- Even the best kits need adapting.
- Take complete base line of vehicle before conversion - many dash warning lights lit.
- I expected to be able to push a full 1000 amps to the motor – but learned wet PbA batteries are limited to about 400 amps. So acceleration is slow.
- I should have kept track of the weight – I wanted to stay under the GVWR. Wish I had used lighter (T-105) batteries instead.



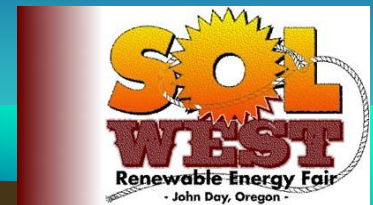
# Driving an EV

- Power steering sucks amps, so most do without – takes more arm power
- Hills, highway speeds, low tire pressure, quick accelerations suck amps and reduce charge distance.
- Unless you have regenerative braking, there is no “engine compression” on the down-hills.
- Don’t use the accelerator pedal to hold you stationary on a hill – it burns up motor brushes.
- Have an Emergency Electrical Disconnect within easy reach of the driver. Electrical or mechanical failures can occur giving full power to the motor. In addition, have a fuse and inertia switch.
- Ceramic heaters heat up much more quickly, but may not put out as much heat as the ICE.
- EVs are very quiet, especially at low speeds – expect to use your horn more.



# Driving an EV, Cont'd

- A Battery SOC gauge is a MUST. Never drive below 20% SOC to avoid battery damage. Try to stay above 60% SOC by the mid-point of your drive (unless you can recharge along the trip).
- Try to recharge batteries as soon after driving as possible. Especially if below 50% SOC.
- You will need an at-home charging station. Wire it for 30 to 50 amps, 240 volts. This gives you greatest charger options.
- When away-from-home, there are about 8 different types of 30 to 50 amp, 240 V outlets. Have adapter cables in the vehicle.



# EV Maintenance

- Electric motors come to a complete stop with the vehicle. You don't need to use the clutch at stops – no more clutch replacements.
- Electric motors need no oil – no more oil changes.
- Electric motors put out much less heat than an ICE – no more radiator, hose, fan belt service.
- Electric motors don't need a starter – no more starter repairs.
- Electric motors don't need to ignite fuel – no more spark plug changes.
- Electric motors don't go out of tune – no more tune ups.
- Electric motors don't give off exhaust – no more muffler/exhaust pipe replacements.
- Perform battery maintenance every 1-3 months – check for signs of over heating, bad cables, bad connections. Clean corrosion, tighten connections, and water batteries. Use extra caution to prevent electrical shock, and explosive short circuits.



# Q & A

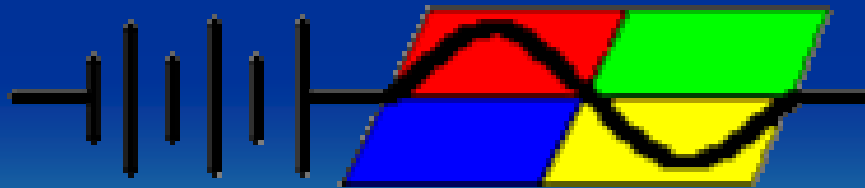
**Randy Richmond**

RightHand Engineering, LLC

SolWest booth H, Trowbridge Pavilion

[Randy@RightHandEng.com](mailto:Randy@RightHandEng.com)

[www.RightHandEng.com](http://www.RightHandEng.com)



Makers of *WinVerter*<sup>TM</sup>

Specializing in EV & RE data logging

