

## INTRODUCTION

The year 1999 was chosen as "Year of Transportation" for ASPI. In following ASPI's commitment to *walk the talk*, the concept of solar powered transportation ensued. A goal was defined: to power a vehicle from the sun

for local errands on a daily basis. This is a description of the process ASPI took to reach that goal, as well as a general description of the final result.

It is beyond the realm of these eight pages to provide all the information necessary to follow ASPI's example. However, this paper along with the Equipment Sources and References listed on page 6, should give all the information necessary. With a pint of initiative and a gallon of sweat, you could be doing your local errands in a vehicle powered from the sun.



ASPI's electric car plugged into it's solar charging station.

## DESIGNING FROM SCRATCH VERSUS CONVERTING AN EXISTING VEHICLE

The first decision made was whether to design the solar vehicle from the ground up, or convert an existing car to run off electricity generated from solar electric panels. This was a major decision with numerous implications. Foremost of which, was that a vehicle built from scratch could be made light enough for solar panels powering it to be designed onto the vehicle itself. Whereas, converting an existing vehicle would require additional storage batteries in the vehicle, and a fixed solar charging station to recharge the vehicle while parked. The weight of standard compact vehicles is so substantial that they require more solar panels to move them than could possibly fit on them.



A solar car built from scratch in Hawaii.

ASPI opted to convert an existing vehicle even though it meant the additional infrastructure of a fixed solar charging station. First, cars that run directly off of the sun with onboard solar panels are very different from what most are accustomed to. They must be super-light (approx. 300lbs), extremely aerodynamic, and typically utilize bicycle tires. They are more like sleek spaceships than standard vehicles. Hence, licensing and insuring such a vehicle could pose quite an undertaking. There were also questions of safety and cargo space as well. Could the vehicle be designed to safely withstand potential impacts with larger vehicles? Could the vehicle be designed with enough cargo space to make it useful for daily errands? Second, the time involved in designing and fabricating a vehicle from scratch could prove daunting and expensive. In electrifying an existing car, over 95% of the engineering has already been done and efforts could be put entirely into only those parts of the car related to the electric conversion. A third consideration was the expense of the solar panels. With such a large investment (approximately \$6000), it made more sense for them



Plugging the car in.

to be installed safely in a fixed location than to risk their injury while rolling down the highway. Besides, John and Anne Horstman just donated a 1988 Dodge Colt Sedan to ASPI that would be perfect for the project.

In retrospect, a solar charging station made even more sense in fully employing the solar equipment. Had ASPI designed a solar car with built in solar panels, and the vehicle was not being utilized for some reason, then the energy produced by the solar panels sitting in the sun on the parked vehicle would simply go to waste. However, with a solar charging station, when the vehicle is charged up or is not there, the excess energy produced by the charging station solar panels is used to offset ASPI's office electricity usage as described later in this report.

### THE CAR GOES ELECTRIC

With the choice to convert made, it was time to get busy. The initial focus was on converting the car into a quality electric vehicle. The solar charging station would be built later. Minimizing weight was extremely important to allow the vehicle to have a decent range of travel between recharges. A donor car should be less than 2500-lbs, ideally less than 2000-lbs, curb weight, before starting the conversion. The donated Dodge Colt weighed in at 2150-lbs.

A note to readers, light pickup trucks can make excellent conversions to electric, since their already hefty suspension does not later have to be beefed up due to the added weight, approximately 800-lbs, of the batteries to the vehicle. Also noteworthy, air conditioning (ac) consumes virtually as much horsepower as it takes to move small vehicles down the road. Power steering is another energy eater. Thus, avoid converting vehicles that have power steering. Vehicle with ac are O.K., it just means that the ac equipment will not be used and will have to be discarded. Along with ac equipment the donated Dodge Colt also had power brakes, as most compact cars do, which is easily accommodated with an electric vacuum pump, and is also recommended, due to the added weight of the batteries (see "Restoring the Vacuum System to Your Power Brakes in an Electric Car Conversion", available from *KTA Services*). The Colt does have a stereo, but no power windows; each of which does not consume enough energy to affect range.

Before installing the electrical components, the internal combustion (IC) system had to be removed. A helpful habit during this phase is to study, measure, mark, and describe everything (especially wires) before it is removed or taken apart. Working in a garage proved critical to the success of this project, as many removed parts were saved and later reinstalled in the vehicle. Also helpful was acquiring the factory service manual for the vehicle. For a complete description of the electric conversion process, please refer to Mike Brown and Shari Prange's book, "Convert It". Following is an abridged review of the process.

#### CRITICAL MEASUREMENTS BEFORE REMOVING INTERNAL COMBUSTION (IC) COMPONENTS

Start by taking a number of measurements. Measure the ride height of the vehicle at all four wheel wells. Do this by holding a ruler vertically through the center of each wheel, and measure the distance from the ground to the center of wheel arch on the vehicle body. Our heights ranged from  $22 \frac{1}{2}$ " to 24". Measuring these heights again after the conversion lets you know if any major differences were introduced to the center of gravity of the vehicle during the conversion process. It is also a reference to match the vehicle's height to after conversion. Both of which are accomplished with stiffer suspension components.

Next weigh each axle of the car. The Colt's front axle weighed 1270-lbs, and the rear axle weighed 880-lbs. The goal is to come relatively close to the same weight ratio between axles when the conversion is complete. A final important measurement, before removing the engine, is the location of the transmission bell housing. Its location must be the same after the electric motor is installed replacing the internal combustion engine, so that the output transmission shaft stays in its original alignment. With rear wheel drive vehicles, the top of the bell housing can be measured vertically to some mark on the firewall. However, the Dodge Colt having a transverse mounted engine required a two-by-four to be put across the fenders and then measurement taken down to the bell housing from there.

Also study the throttle linkage before disassembly, noting how the pieces go together and the travel distance between full on and full off at both the pedal and at the carburetor or fuel injection system. These measurements are critical for connecting the throttle linkage components to the electric throttle equipment.

#### **REMOVING IC COMPONENTS**

Start by removing the hood, which facilitates removing the IC engine. ASPI sold its engine to a local junkyard prior to removing it from the vehicle, while the vehicle was still running. This helped to fetch a higher price for the engine. Referring to the factory manual will direct the removal process. Drain and properly dispose of all fluids except the brake fluid and transmission fluid if your vehicle has it. The transmission oil should also be drained. When the transmission is reinstalled this should be replaced with low-friction synthetic oil, since the rpm range of the electric motor is significantly greater than its IC engine counterpart.



Joshua checks under the hood of ASPI's electric car.

With the engine and transmission removed there is one more critical measurement, the distance between the rearmost surface of the engine (where it joins with the transmission) and the rearmost flat surface on the flywheel. This number is critical for designing a hub adapter to mate the transmission and flywheel assembly to the new electric motor.

Remove all of the IC related components. In addition to the engine and transmission combination, this includes the engine mounts, gas tank, radiator, coolant hoses, alternator, and exhaust system. Be sure to label all wiring with masking tape and indelible markers as they are disconnected from the removed components.

### **INSTALLING ELECTRIC CONVERSION COMPONENTS**

By this point, you have reviewed the Equipment Sources and References, and have decided on the equipment you will utilize. With some vehicles, Volkswagen Rabbits for instance, you can utilize packaged systems with all the appropriate equipment, including pre-welded battery racks and motor mounts, as well as the adapter hub for your vehicle. Packaged systems are available from *Electro Automotive*.

With the stripped vehicle, the first thing to reinstall will be the transmission now mated to the new electric motor. However, before this is done there is the important matter of mating the new motor with the existing vehicle transmission. This is done with a precision-machined hub adapter and transmission bell housing cover plate. Unless you are quite skilled in machining precision components, the adapter and cover plate should be farmed out to a fabrication shop experienced in making them. With many vehicle types, they may already have a pattern on hand for your motor selection and transmission. In which case, you will simply have to give your vehicle model and motor type to receive the appropriate hub and plate assembly. At the time ASPI converted the Dodge Colt, there was no pattern on hand, so the transmission was shipped to *Electro Automotive* in California for them to design from. Since they were able to add a new pattern to their inventory, they paid for



returning the transmission.

Since the electric motor's size and shape is vastly different from the engine it's replacing, the existing engine mounts will have to be altered to support the new motor. You may opt to have an experienced welder do the alterations. ASPI opted to acquire a welding machine and learn to weld instead. If you ever thought of learning some welding skills this would be a good opportunity, as the battery supports will also need to be fabricated. Classes on welding are commonplace.

Battery pack in trunk.



Battery pack & motor controller under hood.

With the new electric motor and existing transmission installed, the next area of focus is installing the batteries. With existing battery technology, the most cost effective choice is standard lead-acid golf cart traction batteries. Batteries are available that will provide a longer lifetime of duty, however, their cost is still prohibitive at this time. Besides lead-acid batteries are readily available, and virtually totally recycled.

ASPI discovered that designing and building the battery frames consumed the most time in the conversion process. The motor you have selected will likely have an operating range of between 72

and 144-volts. Higher voltages will give better vehicle performance. With the Dodge Colt, ASPI was able to fit twenty 6-volt golf cart batteries, giving an operating voltage of 120 volts. The batteries were split, 12 in the trunk, and 8 under the hood, to keep from drastically changing the vehicle's center of gravity. ASPI purchased its batteries from Craft Battery Incorporated, phone 606-824-9183.

With the electric motor and batteries installed, the rest of the components can be mounted in the space available. These include:

1) Battery charger;

2) Motor controller and heat sink plate;

3) Throttle potentiometer;

4) Appropriate fuses, circuit breakers, disconnect switches, and relays;

5) Pump and vacuum system to restore power brakes;

6) Amp meter for electric motor system;

7) Volt meters for both original 12-volt system and new electric motor system;

8) Resistive heating components to replace cab-heating system.



20-watt solar panel charging auxiliary battery.

Refer to the Mike Brown and Shari Prange's book, "Convert It" for a full description of installing the equipment listed above. Depending on your climate and proposed use for your conversion, you may not need to install the electric heating system to keep the cab warm in winter. If you do need to, realize that your range will drop about 20 % when utilizing the heating system. For instructions on replacing the heating system refer to "Electric Heating for your Electric Car", available from *KTA Services*.

With the loss of the alternator, there will need to be a means of keeping the original 12-volt system charged. Many conversions utilize a step down dc-to-dc converter, which keeps the existing 12-volt battery recharged from the newly installed motor traction batteries. ASPI opted to do something different and mounted a 20-watt solar panel on the vehicle. The existing 12-volt starter battery was replaced with a deep cycle 12-volt traction battery, which the solar panel was then connected to. As long as the vehicle is parked in the sun for a couple hours a day the 12-volt battery remains charged up.

With the completion of installing the electric conversion components there is the final task of boosting the suspension. This may involve replacing the springs, adjusting torsion bars, and perhaps installing air shocks. If you converted a small pickup truck, this final task may not be necessary, as the suspension would already be oversized. Check your ride height measurements to see how much they have changed, and weigh the front and rear axles again to see how much weight has been added to the vehicle. For information on boosting the suspension refer to Shari Prange's article in Home Power Magazine, Issue #44, titled, "Electric Vehicle Suspension".

# **EVALUATION OF THE ELECTRIC CAR CONVERSION**

As of spring of 2000 the donor Dodge Colt had been converted to run off of electricity, but the solar charging station had not been built. The vehicle was being recharged from the utility grid. The vehicle travels 80 miles between charges, while taking about 9 hours to recharge. This is perfect for running daily errands around town then recharging overnight. The economic bonus even with recharging the vehicle from the electric grid, is that it only cost \$1.37 in electricity (assuming electricity cost of  $5.2\phi$  per kWh) per charge. The Dodge Colt before conversion got about 25-mpg in the city. Thus, it would take 3.2 gallons before the conversion to go the same 80 miles. At \$1.30 a gallon, ASPI could save \$2.79 per 80 miles traveled, or \$1018 per year if the vehicle was driven 80 miles per day. In reality, the savings comes to about \$900 per year when factoring in the cost of replacing the batteries every 8 to 10 years as needed. With the cost in equipment for the conversion coming to approximately \$6500, the vehicle will pay for itself, in gas savings, in 7½ years if driven 80 miles each day.

Even without the solar charging station there were other advantages to ASPI's electric car, which include:

A Reduction of toxic fluids necessary to operate the vehicle, i.e. no radiator coolant nor motor oil is used.

☼ The vehicle in urban traffic, unlike its gasoline counterpart, uses no energy while stopped in traffic, at stoplights, or when coasting. Anytime the foot is off the gas pedal zero energy is being consumed by the vehicle.

✤ No spark plugs to change, nor tune-ups to perform.

The only real maintenance involves topping the batteries in the vehicle once every three months with distilled water (about \$3 worth) and wiping the battery tops clean. This process takes about 15 minutes. The electric motor is estimated to perform in excess of 700,000 miles with brush changes every 100,000 miles (a five minute operation).

# THE ELECTRIC CAR CHARGING STATION GETS BUILT

After months of driving the electric car, it proved itself worthy for ASPI to make the final investment into a solar charging station. ASPI calculated that 1500 Watts of solar panels in our environment would power the vehicle for 25 miles per day on average (more during summer months and less during winter months). We decided on this size for two reasons, first the car will rarely be driven more than 25 miles per day around town, and second the cost of solar panels prohibited ASPI from investing more into the charging station.

Initially the design was to mount the solar panels and wire them in such a way that they would directly recharge the batteries in the vehicle whenever the car was parked at the station. This posed two problems. First, quite often the car would not be at the charging station during the hours of the day when the sun would be shining at its peak. Second, the potential energy the solar panels could have produced would go to waste, because they would not be charging anything while the car was not there.

Next, the design looked into having a battery bank at the charging station to soak up the solar panels output while the car was not there. Then the batteries at the charging station would dump its charge into the batteries in the car when the car arrived. This solved the two problems mentioned above, but at a higher investment and maintenance cost to take care of the second battery bank at the charging station.

Also, batteries are terminal equipment. They will eventually wear out. In this scenario we now had 40 batteries, 20 in the vehicle and 20 at the charging station to replace every 8 to 10 years. At \$48 a battery that's expensive. ASPI then decided on an arrangement that hasn't been utilized in Kentucky. This arrangement is called net metering. The power produced by the solar panels back feeds the office's electric utility meter during daylight hours. In essence, the meter would only spin backwards when the office was using less than the solar panels were putting out. Typically the meter would simply spin more slowly, with the office usage being offset by the production put out by the solar panels. For more information on net metering please see Technical Paper #49, or call ASPI and take a tour of the solar charging station.

Depending on how we balance the energy budget, the solar charging station can be seen as either powering the vehicle for 25 miles a day (on average), or offsetting the office electricity use by about 40%. The price of the solar system came to \$9200, which given current electricity prices of  $5.2\phi$  per kWh, means the system needs to operate for 65 years, at current low cost electricity prices, and not taking into account inflation, to pay for itself in electricity savings. This time is drastically reduced if we balance the energy budget based on the cost of offsetting the gasoline that the electric car would have been using. Twenty-five miles a day would have consumed 1 gallon of gasoline before the conversion. At \$1.30 per gallon the solar system will pay for itself in 20 years. Again realize that if we took inflation and rising fuel cost into account that payback time would be reduced. Also, once the equipment pays for itself, the fuel cost for the vehicle will be free and the operating cost will be minimal (about  $32\phi$  a day).

## LIFE WITH A SOLAR POWERED ELECTRIC CAR

Many may view a limited range of 80 miles per day in a vehicle as not a useful objective, even if 25 of those miles are derived from sunshine. However, this has met ASPI's objective. To have a vehicle for daily errands around town that is powered in a sustainable fashion.

There is a simple satisfaction in driving a truly quiet vehicle that is not required to stop at "convenient" stores. True convenience is pulling up to the charging station after the daily errands are complete, plugging the car in, and contemplating the recycled sunshine that will supply our needs for tomorrow. One day, all will come to appreciate the true value of sunshine.

# REFERENCES

"Convert It: A Step-By-Step Manual for Converting an Internal Combustion Vehicle to Electric Power", Michael P. Brown with Shari Prange • ISBN 1-879857-94-4

Home Power 6/yr, PO Box 520, Ashland, OR 97520 • 800-707-6585 • www.homepower.com • hp@homepower.org

"The New Electric Vehicles: A Clean & Quiet Revolution", Michael Hackleman • ISBN 0-9629588-7-5

"Solar Photovoltaic Advances: Home Grown Electricity and the Electric Utility Grid", ASPI Technical Paper #49 • 606-256-0077

"Why Wait for Detroit? Drive an Electric Car Today", Steve McCrea and R. Minner • ISBN 1-897857-92-02

# **EQUIPMENT SOURCES**

### **Electric Vehicle Components**

*Electro Automotive* Catalog of Components and Complete Kits. 408-429-1989 • www.elec-troauto.com

KTA Services Catalog of Components. 909-949-7914 • www.kta-ev.com

### Solar Electric Equipment

*Backwoods Solar Electric Systems* Catalog of Solar Panels and Related Equipment. 208-263-4290 • www.backwoodssolar.com/

*Solatron Technologies, Inc.* Supplier of Grid-connected Solar Equipment. 888-647-6527• www.partsonsale.com

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