

PV-POWERED BIKE



From sea level to summit—Dallas Pass, Rocky Mountains, Colorado.

Early last year, I built a solar-electric bicycle. On this solar and human powered rig, I rode from San Francisco, California, to Carbondale, Colorado, arriving just in time to start a summer of classes at Solar Energy International. In the summer of 2001, I will go to China, and continue solar cycling around the world.

I was installing residential PV systems in the San Francisco Bay area when I had the idea to build a solar cycle. In January 2000, I decided to not only build it, but to live with it. The primary motivation was (and still is) the satisfaction of living and sharing a sustainable lifestyle free of materialism. I get to meet new people in new places, share ideas, spend days outside using my body, sleep under the stars, and allow life to unfold as taking the risk of the unknown pays off.

Ultimate Test

The trip was also the ultimate test for developing the solar cycle. After the first 30 miles, I realized that I needed a stronger PV mount. After 100 miles, I realized

that I needed brakes for the trailer. After 1,000 miles, I realized that I needed a trailer with spoked wheels. And after 1,500 miles, I finally decided that I needed a more powerful motor.

Cycling is the best way to see the world. It takes time, so you experience the places you ride through. Although I took roughly three and a half months to ride the 2,000 miles (3,200 km), I spent less than half of that time actually traveling. The rest of the time I spent hanging out in towns, modifying the rig, meeting people, backpacking, et cetera.

The coast was good training. I started with 30 mile (50 km) days, and was fine with 60 milers (100 km) by the time I hit the mountains in Prescott, Arizona. The looks I got from cars while riding over passes were priceless. It sounds like a lot of work, but the riding simply put me in the necessary shape, and then kept me there. Of course it took about two weeks to fall out of shape once I stopped riding.

I rode mostly on two-lane highways (50–60 mph; 80–100 kph speed limit) that were generally not overly congested. Still, cars were a constant threat to my life. The few roads that were two-lane, with no shoulder and heavy semi traffic going 65 mph (105 kph), forced me to come to grips with my mortality. On one of these

roads, a semi forced me into the sand shoulder. Luckily, I was able to lay the bike down as my trailer tipped, and the car behind him pulled over to make sure I was okay.

I often camped out in national forests, but there were many nights out in the desert, a quarter mile off the highway. I also stayed with kind people I met along the way. I am still so inspired by all the people who reached out to do whatever they could for me, and took serious interest in my journey. Some were people who have been living with PV systems for years, but there were also people who didn't know that solar-electric systems really work.

Extremes

I got a taste of extremes in Springerville, Arizona, allegedly the windiest town in the country. I rode into record (for the day) winds up to 75 mph (120 kph)! I also rode through record heat (for those days in April) in the Mojave Desert. I drank five gallons (19 l) of water in a day and a half, crossing the totally remote 120 mile (190 km) stretch on highway 62 from 29 Palms, California to Parker, Arizona. It was not until I arrived in Parker caked with salt that I was told that I'd done it in 110 degree (43°C) heat.

The following day, my original motor overheated after 5 miles (8 km). So I rode another 30 miles (48 km) in 100+ degree heat without any assist at all. I practically passed out before I decided to hitch a ride out of the low desert.

The next morning I was picked up by a pickup truck and dropped off outside of Prescott—50 miles (80 km) down the road, 1,000 feet (300 m) higher, and 15°F (8°C) cooler. After running out of spare tubes for my trailer in between towns a few times, I became pretty confident that I could get a ride from a pickup truck whenever I needed it.

Once I arrived in Carbondale, I landed in a teepee belonging to an SEI employee, and lived there on a picturesque hillside for the summer. During this time, I disconnected my trailer (it takes a matter of minutes). I used it as the power source at the off-grid SEI campground, while using my bike to commute to classes.

The SEI workshops I took were excellent opportunities to further my renewable energy education. They included *Renewable Energy in the Developing World*, *Microhydro*, *Wind Power*, and *Advanced Photovoltaics*. I found out that intense training in renewable energy is

PVs charge the solar-powered bike at camp—in Los Padres Mountains, California.



only part of the SEI experience. It also includes making friends, having a blast, and networking for future projects.

In fact, I would not be riding through Asia so soon had I not met my solar cycling partner, Colin Mitchell, at SEI over the summer. When I finished up at SEI, I took a train back home to Vermont, where I will be until next summer, when the Asian tour begins.

Performance

The rig has a 24 VDC system. In full sun, the array of four Solarex MSX Lite modules produces 4 to 5 amps. My trailer weighs 190 pounds (86 kg) empty, and I pulled an additional 85 to 100 pounds (39–45 kg) of gear. On flat ground, I can cruise at 18 mph (29 kph) without pedaling, with the motor drawing 13 amps.

I tested the range of the bike on flat ground, with an unloaded trailer and a 150 pound (68 kg) rider, from full battery to empty battery (100% SOC to 20% SOC). With no pedaling and no sunshine, it has a range of 25 to 30 miles (40–50 km). With no pedaling, but with good sun, the solar cycle has a range of 35 to 40 miles (55–65 km). When pedaling, the rider's fitness level becomes the only limit.

On my journey, I averaged 45 miles (72 km) a day on my travel days, pedaling consistently at a moderate pace, averaging 12 mph (19 kph). Typically I would start the day (late morning) with the batteries at about 24.5 volts, and finish the day at dusk at about 24 volts. I would often reach 25+ volts by midday, because I didn't rely heavily on the motor until later in the day, when I was tired, and also more confident in the battery's state of charge.

Components

This solar cycle consists of a cargo trailer with a canopy of PV. The trailer is manufactured by Bikes At Work, and is 2 feet wide by 6 feet long (0.6 x 1.8 m), plus a couple feet in the trailer tongue. It has an impressive 300 pound (135 kg) capacity, and is mostly aluminum. The trailer carries the batteries, which power a 24 V pedal-assist electric motor on my bike, which in turn drives the bike's rear wheel.

The solar canopy consists of four Solarex MSX-30 Lites (30 W each). They are glassless and frameless polycrystalline panels. Initially, I had them mounted directly onto angle aluminum. But they are not rigid, so



David Clay, spreading the renewable word.

when I rode over a bump they would flap, which damaged some of the conductor joints.

My month's rent in Berkeley, California ran out the day before I finished building the rig, so rather than waste a month's rent, I decided to work out the bugs on the road. In Santa Barbara, I finally received my new modules. This time I mounted them on plywood, and suspended it from a rigid perimeter, first with latex tubing, which lasted about a month in the sun, and then with bungee cords.

This fall, I mounted the modules on plywood, and mounted that on angle-bar, similar to my first rack. The backing keeps the modules from flapping, which appears to be sufficient protection. Next time I will use a single 120 W framed module.

The 10 A Solar Converters charge controller (model PT 12/24-5) was originally a 5 A controller, but the manufacturer put in a 10 A diode and fuse, and said it would be fine. It is a maximum power point tracker, with

David Clay's route to Colorado (in red).





Four Solarex MSX-30 Lite PVs keep the batteries (in the plastic box) charged.



The bike's Curtis controller and Scott motor.

standard three-stage charging. It works with 12 to 24 V input and output, and is over 94 percent efficient.

The battery pack consists of two Dynasty 33 AH, 12 V, sealed lead-acid batteries in series. They lie on their sides with the control/fuse board on top of them, while snugly contained in a mini Rubbermaid Action Packer.

Trailer Tales

Hitching the trailer to the rear wheel axle area (as opposed to the seat post) with a universal ball joint gives great stability and tracking. Unfortunately, the 16 inch (40 cm) plastic rimmed wheels frequently blew tubes and ate through tires,

although they were problem-free for the first 800 miles (1,300 km). I tried to get spoked wheels for the trailer, but could not find any that were compatible.

My trailer weighed 280 pounds (127 kg) with all my gear, which posed a great threat to my safety when going down steep, winding hills. I learned this in Monterey, California when the trailer jackknifed and I flipped going 20 mph (32 kph). After a day of white knuckles and sheer terror on the steep winding cliffs of Big Sur, I hitched a ride in a pickup back to Monterey, where I put brakes on the trailer.

A friendly machinist (one of many along the way) supplied me with a piece of aluminum bar, which we laid across the trailer behind the wheels. We bolted the brake mount horizontally on the bar. A local bike shop set me up with a little brake cable component that splits a single brake line into two lines. So I had a single brake lever for the trailer that pulled on the brakes for both wheels simultaneously. I think the heat from friction of the brakes warped the plastic rim, which might have led to the frequent tire problems. But the brakes were essential.

Motor

Originally I had a pedal-assist motor setup called the US Pro Drive (model B-CTI-3VP-K), made by Currie Bicycles. It is a 400 W brush-type motor, with an integrated controller. The motor is mounted on a drive train that mounts onto the spoke base of the rear wheel, and provides a 14 to 1 reduction, with the help of a built-in planetary gear. It is a very tidy and compact setup, but I found that the motor would overheat on a daily basis, even when it was running below 16 A (400 W).

Solar Bike Loads

Load	WH / Day	Weight (lbs.)
Motor (DC)	300–800	20
Boombox	10–50	5
Computer	0–70	7
Cell phone	0–5	1
<i>Total</i>	310–925	33

It wasn't until I was in Durango, Colorado, on the doorstep of the trip's most brutal passes, that I finally got the Scott 1 hp motor (model 4BB-O2488). I removed the Currie motor from its drive train, replaced it with a sprocket on a shaft, and mounted the motor and controller on the bike's rear rack (which needs reinforcement for long-term use).

The Scott is also a 24 V brush-type motor. Even with my fully loaded trailer, it never overheated going over 11,000 foot (3,350 m) passes. For both motors, I used a 5 K ohm potentiometer, with a volume dial mounted on my handlebars for a variable speed throttle.

Electronics

The 175 A Curtis motor controller (model 1204/5) was more than the rig required. A 60 A controller would have been sufficient. But when I was rebuilding the motor setup in Durango, it was easier to get both the motor and the controller from the same supplier. I found that both the Curtis and my original controller attempted to maintain a constant motor rpm. This meant that when I hit an incline, the motor drew more current, though I would have preferred my pedaling to absorb the change in terrain. As a result, I found myself having to fiddle with the throttle in order to reset the rpm.

I chose the E-Meter because I had planned to use the RS232 port to download data onto my laptop (though I never got around to it). It was small enough for my handlebars, once I found the right plastic jam container to put it in. All the bike really needed was a digital volt/amp meter, at a quarter the price of the E-Meter I used.

I carried a battery charger with me in case of prolonged periods without sun. Although I spent countless nights where I had access to the grid, I never used it after I got my PV array working. On the other hand, charging from the grid is what got me from San Francisco to Santa Barbara, after I broke my first PV array. Luckily, most of those nights were spent at coastal campgrounds where the grid is often found in the bathrooms.

Loads & Loads

The majority of the extra weight was in the PV backing and rack (which ended up being steel, after meeting a

Solar Bike Costs

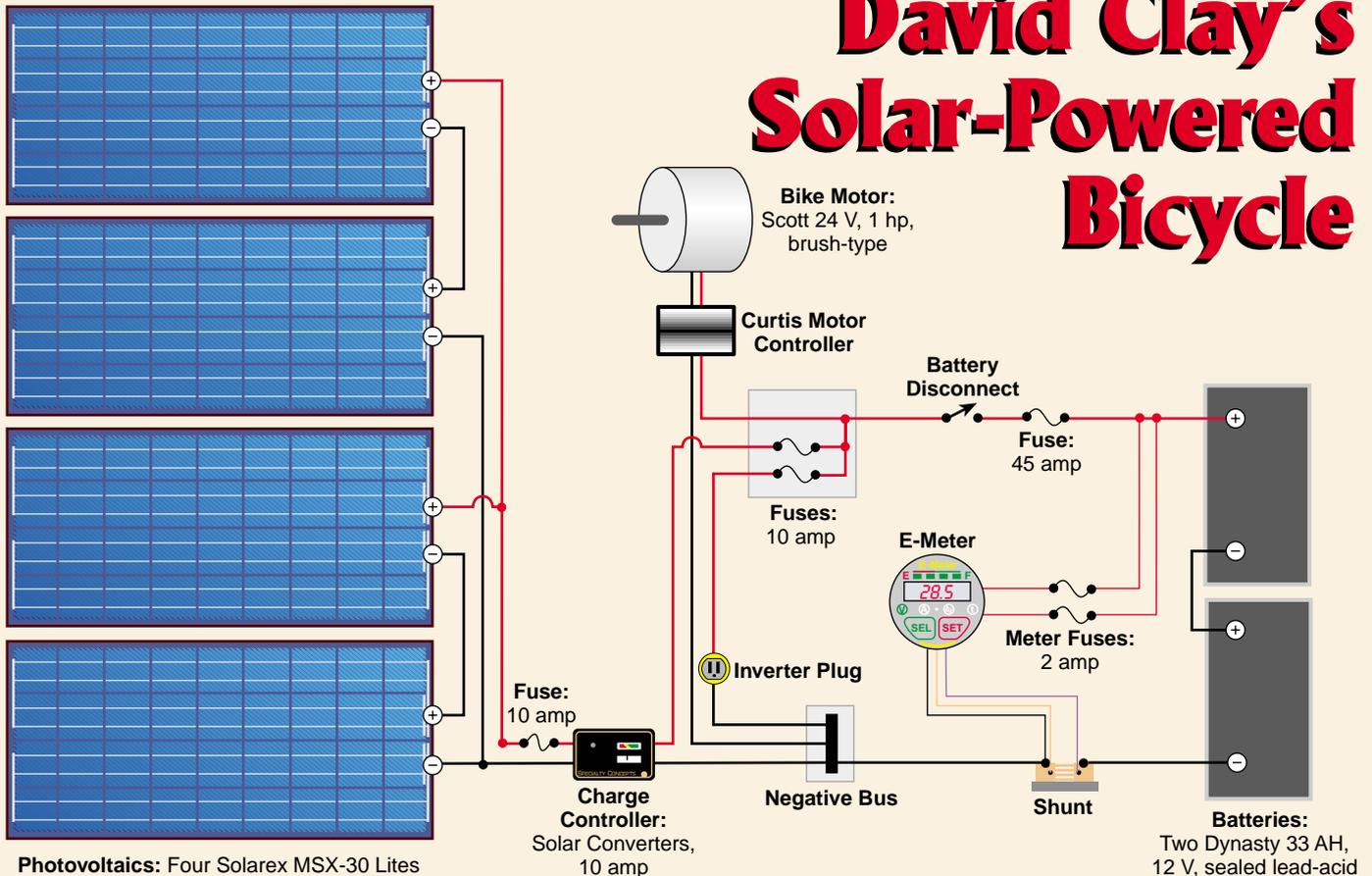
Item	Weight (lbs.)	Cost (US\$)
4 Solarex modules, 120 W	32	\$620
Bikes at Work trailer, 6 foot	35	400
Scott motor, 1 hp	20	250
2 Dynasty batteries, 33 AH	60	200
Curtis controller, 175 A	5	200
E-Meter	1	200
Miscellaneous	35	100
Amcamex inverter, 140 W	2	90
Charge controller, 10 A	1	55
Battery charger, 2 A	5	50
<i>Total</i>	196	\$2,165

friend in Santa Barbara who had steel and a steel welder, and not aluminum). Wire, hardware, fuses, lugs, bungees, and the plywood underneath the battery box all add up to a lot of weight.

My Taiwanese-made Amcamex modified sine wave inverter, 24 VDC to 110 VAC (model MP-140X), gave

An E-Meter monitors battery state of charge.

David Clay's Solar-Powered Bicycle



me the ability to power AC electronics off the solar panels. The boom box was the only load that got consistent use besides the motor. I found pedaling to the rhythm of my personal music selections to be blissful—it made riding even more enjoyable than it already was.

I used my laptop computer in conjunction with my cell phone to wirelessly connect to the Internet. I also have a special analog modem that allows me to go online where a digital signal is not available, which was necessary considering I was out of digital range as soon as I left the coast. I mostly used my wireless capability for email. I would save my Web surfing for when I had access to a land line, since wireless data is still very slow (under 1 KBPS).

I also started the journey with an AC compact florescent light, and an AC, AA battery charger for the nickel-metal hydride AAs in the bike lights. Both of these appliances were soon sent home in one of my frequent attempts to ditch weight. I never used either of them when I had them, and never missed them when they were gone. Candles provided all the illumination I needed at a fraction of the weight and twice the ambiance. And I never rode with my trailer after dark, so a single charge on my bike light batteries lasted the entire trip.

Solarcycling.com

I am starting a small business selling solar trikes and trailers over the Internet. Initially, I am focusing on the solar-powered recumbent tricycle. Rather than having the PV canopy over the trailer, as my first solar cycle had, the PV is over the trike, providing shade and rain cover. Recumbent trikes have two wheels in the front, and because they are very low to the ground, they are incredibly stable. Like the solar trailer, the solar trike is also a contained and mobile power station.

Other than selling solar cycles, the main objective of solarcycling.com is to teach people how to build their own solar cycle. My real goal is to spread inspiration, creativity, and knowledge, so people can be empowered to make lifestyle changes.

Asian Tour

Any profits made by solarcycling.com will help fund a planned journey through Asia. My friend Colin Mitchell and I are going to ride a couple of solar trikes through China, Southeast Asia, India, and possibly into Europe, beginning in 2001. It is an open-ended journey that may take years—anything might happen. Lifestyle speaks so much louder than words, while the adventures and revelations are endless.

We plan to hook up with as many alternative organizations as we can. We will be checking in with the rest of the world by posting regular updates, photos, and possibly video on the solarcycling.com Web site. We seek publicity, contacts, support, ideas, and wish to involve as many people as possible. We are also considering the possibility of like-minded sponsors to help fund this adventure. Anyone with any kind of interest is personally encouraged to get in touch with us.

In an ongoing attempt for personal development, solar cycling has become more than low-impact transportation. Solar cycling is my way of life, based on empowerment and unified love—free from the self-enslavement and unobserved devastation of consumerism.

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