The Bicycology Energy Trailer

An experiment in mobile renewable energy

Illustration 1: The Energy Trailer in action as part of the 2007 Camp for Climate Action near Heathrow, London

Introduction

The Energy Trailer is a mobile renewable energy system that can be towed by bicycle and used at events both an educational tool and a practical resource, for example showing films or playing music. It was built in 2006, and has continually evolved since then. It combines pedal- and solar-power generation, battery storage, charge control, and electrical displays, a small soundsystem, a portable DVD player, and games and activities including a gameboy and a bubble machine. All of this in one trailer pulled by one cyclist, and powered 100% renewably!

Trailer, Body and Hitch

Illustration 2: Trailer chassis and body separated

The chassis and wheels are from a standard bike trailer (an “Adventure ST2” steel trailer, which cost about £120 new). Steel was chosen for strength and durability at the expense of being a bit heavier than the alternative alloy model. The box body was built using thin plywood reinforced with battens glued and screwed along the edges and corners. This made a light but very strong body with a hinged top. There is a large forward compartment for general storage and a smaller rear compartment in which the audio and electronics hardware is located. The hinged top is lockable via two cheap window locks that need a simple square key.

Illustration 3: Inside the body, showing forward storage space and rear electronics/audio compartment

The body was painted white and over time it’s been decorated with stencils and stickers. The trailer’s standard hitch has been retained, and this attaches to the bike’s rear axle using a hitch pin. Between hitch and the bar from the trailer there is a large spring with a rubber shock absorber. After about a year’s use, this rubber piece broke. It was replaced with a doubled over length of synthetic cord, and this has held so far, and still provides a certain amount of shock absorption between bike and trailer.

Power Generation

<u>Pedal generator</u>

Illustration 4: The "turbo trainer" rear axle stand turns any bike into a pedal generator

Right from the start we had the idea of using a so-called “turbo trainer” (a stand that raises a bikes back wheel off the ground) to turn a normal bike into a generator. The great thing with this approach is that you can use the same bike as both prime mover and static power source.

The electrical generator is a 12 volt permanent magnet DC motor (in this case, a car wiper motor)

with a 3 cm diameter hard plastic wheel (cannibalised from a vacuum cleaner) glued onto the axle. We have used these wiper motors before in several other pedal power projects, and they are well matched to typical human power applications, capable of generating up to 8 amps at around 12 volts (approximately 100 watts). The generator was mounted on the turbo trainer so that the plastic wheel was driven directly by the back tyre of the bike. A cable from the pedal generator stand then plugged in to the Energy Trailer's electrical system via a car cigarette lighter socket.

Illustration 5: Generator (car wiper motor) driven directly by back wheel

Solar and Wind

A Unisolar 21 watt photovoltaic (PV) panel is mounted on top of the trailer. Being semi-flexible, this panel is more resistant to flexing and impact damage than are normal glass-fronted PV panels. It wasn't the ideal shape, though, being long and thin compared to the trailer body. However, it was the only largish PV panel we had to hand. At times we have also used three smaller 5 watt panels that can be plugged in when we were static in order to supplement solar generation.

Illustration 6: Trailer with supplemental 5 watt solar panels in use

We made a very small wind turbine that uses a car radiator fan glued to the axle of a stepper motor (recycled from a printer) as the electrical generator, and which lights up LEDs when the wind blows it. It is mounted on a pole that swings up from the side of the trailer. The turbine can rotate freely to face into the wind. This small wind turbine is not connected to the main power system, as it only produces a fraction of a watt at best. It's there to catch attention, to provoke discussion ("how big a turbine would you need to generate useful power"?), and small children in particular like to play with it and watch it going round.

Illustration 7: Micro-wind turbine attracts attention!

Charge Control, Batteries, and Displays

We chose to use relatively small 12 volt sealed lead acid batteries, as wet acid batteries are messy and potential dangerous in terms of acid burns. We use either two or three 7 Amp Hour batteries in the trailer. Charge control is especially important with sealed batteries as there is not the option of topping them up with distilled water if they are overcharged. Also an overcharged sealed lead acid battery can explode! To control battery charging we need a way of preventing battery voltage rising too high. For 12 volt batteries the upper limit

is typically around 14.5 volts. Good charge control systems will gradually limit the current flowing into the batteries so that they are charged as fully as possible without damaging them.

We used a commercial charge controller, a Trace C35 (Trace has since been bought out by Xantrex; the “35” means that it can handle up to 35 amps) which is very robust and flexible, but also quite expensive (about £140 new, though look for special deals on old stock). To save weight we took the C35 out of its metal case so in the photo it just looks like a naked circuit board. The C35 can be used in different ways, but we use it in “diversion” mode, which means that it diverted power into a dump load when necessary to prevent overcharging. The dump load consisted of 3 large resistors fixed to a metal heat sink. When the C35 diverts power to the dump load, the resistors get hot and the heatsink transfers the heat to the surrounding air. Sometimes we wire a small 12 volt computer fan in parallel with the dump load to assist air flow around the heatsink.

Illustration 8: Two sealed lead acid 12 volt 7AH batteries secured inside the subwoofer chamber

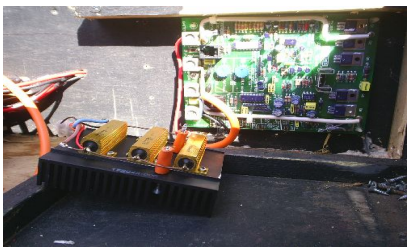

Illustration 9: Charge control circuit board, with resistive dump load in foreground

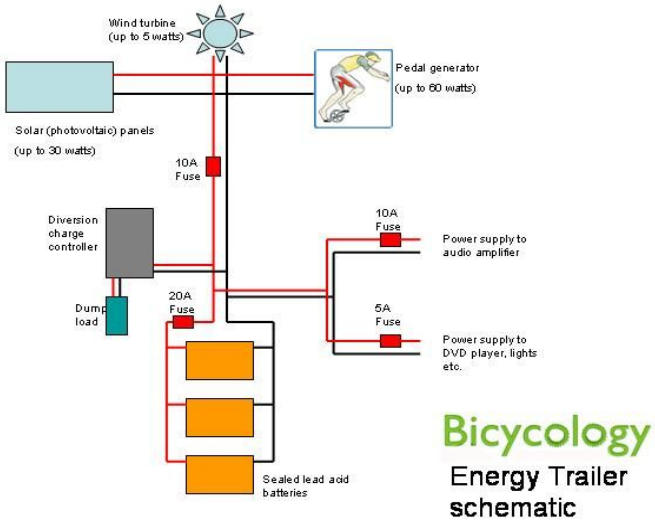

Illustration 10: Schematic. Note that the wind turbine was never integrated into the system as it produces too little power

It's important to understand why this sort of "active" regulation, in which a dump load physically dissipates excess power, is needed for pedal and wind generators. With solar panels you can use a simpler regulation approach which just rapidly disconnects and reconnects the panel to the battery to control the battery voltage. But with pedal and wind power you have to consider the mechanical inertia of the generating device. If you simpler disconnect a pedal generator it suddenly becomes "free", offering minimal resistance to the person pedalling. Similarly, if you short circuit it, it becomes very hard to pedal, as if brakes had been applied. If you rapidly disconnected or shorted a pedal generator, you would produce large mechanical forces in the system, which would be dangerous and destructive. If you disconnected a wind turbine from a load there would be nothing to stop it spinning faster and faster. It would self-destruct in strong winds! So you need to do something with the excess power, smoothly diverting it from the battery to somewhere else – and hence we adopted the diversion charge control approach for the Energy Trailer.

Illustration 11: Voltage and current display

We made a display box to show the battery voltage and current flow to or from the batteries. This uses LCD displays because they use very little power and are visible in daylight. When the current shows a positive the battery is charging; when it is negative the battery is discharging. Multiplying the volts by amps gives the power in watts.

Soundsystem

The aim with the Energy Trailer soundsystem was to create a system with good sound quality and low power consumption, rather than a very loud system. For loudness, the Bicycology "Son of Pedals" soundsystem is in a different league, but is much bigger and heavier!

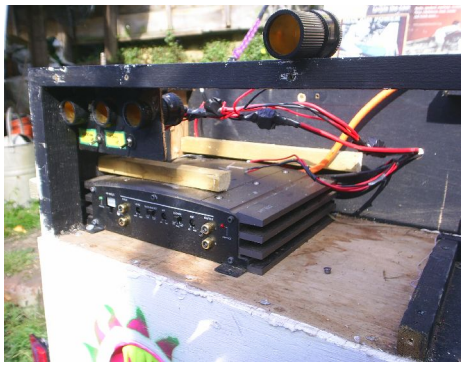
Illustration 12: 100 watt 2 channel amplifier

The heart of the Energy Trailer soundsystem is a 2-channel in-car amplifier. Initially this powered two JBL Control 1 loudspeakers. Later a separate bass cabinet was built into the lower rear part of the trailer, so one channel was used for the sub-bass enclosure and one for a single JBL speaker for mid and high frequencies. The sub-bass enclosure was designed as a 4th order bandpass system, in which the speaker is mounted between two chambers, one sealed and one open to the

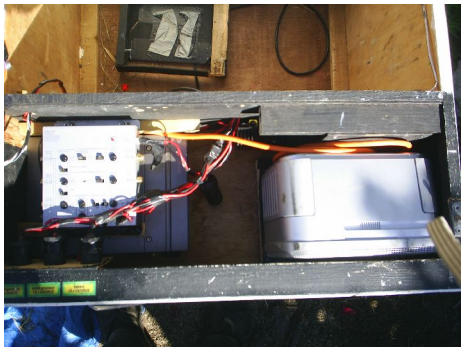
Illustration 13: JBL speaker on right; active crossover on left

outside. Bandpass systems are very efficient at converting electrical power into sound over a relatively narrow range of frequencies, but they need careful design and construction. Free software (winISD) was used to design the enclosure. The speaker used an 8 inch speaker taken from an old hifi speaker cabinet. To design the cabinet, we measured the electrical and acoustic properties (Thiele-Small parameters) of the speaker ourselves. This is a nice approach because, once you know their characteristics, you can recycle any suitable old speaker to make your own subwoofer.

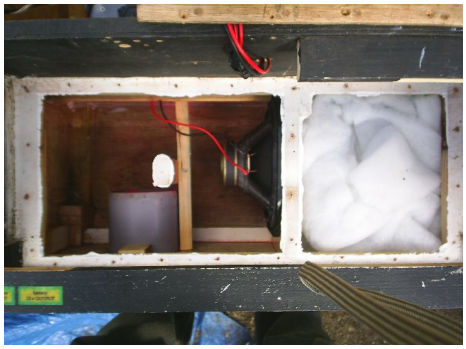

Illustration 14: Looking down into the subwoofer chambers, with right sealed chamber full of wadding, speaker between the chambers, and large port in the left chamber

An active crossover was used to filter the audio signal and send low frequencies (below 120Hz) to channel 1 (subwoofer) and all other frequencies to channel 2 (JBL speaker). We borrowed a commercial crossover, but eventually we'd like to build our own, like the one in the Bicycology "Son of Pedals" sound system.

Cinema

The Energy Trailer was originally designed with a portable DVD player mounted on the rear shelf to offer a "micro-cinema" experience for small audiences. We tried this on our first tour from London to Lancaster. However it proved difficult to get the environment dark enough for daylight screenings, even with blackout material that could be pulled around the sides of the DVD screen. Also, although people appreciated the novelty value, they didn't particularly want to sit down and watch for more than a few minutes in the middle of the day in a public place.

Illustration 15: DVD player on rear shelf

We have since worked more on combining pedal power with film screenings using video projectors. Using pedal power for the sound for a film screening is quite easy with the Energy Trailer. If a large battery is available, then the projector can be powered from the battery via an inverter, and the power consumed can be partly provided by pedal generation. However, even with a relatively low power projector (e.g. an Epson EMP S3 which consumes 155 watts on low brightness), a single pedal generator can only provide about 50% of the required power. So technically, this is pedal-power-assisted cinema! Two or more pedal generators would be needed to fully meet the power demand of a video projector and sound. As described elsewhere, another recent Bicycology project has used an LED projector with extremely low power consumption, and this makes pedal powered cinema totally feasible with just one bike.

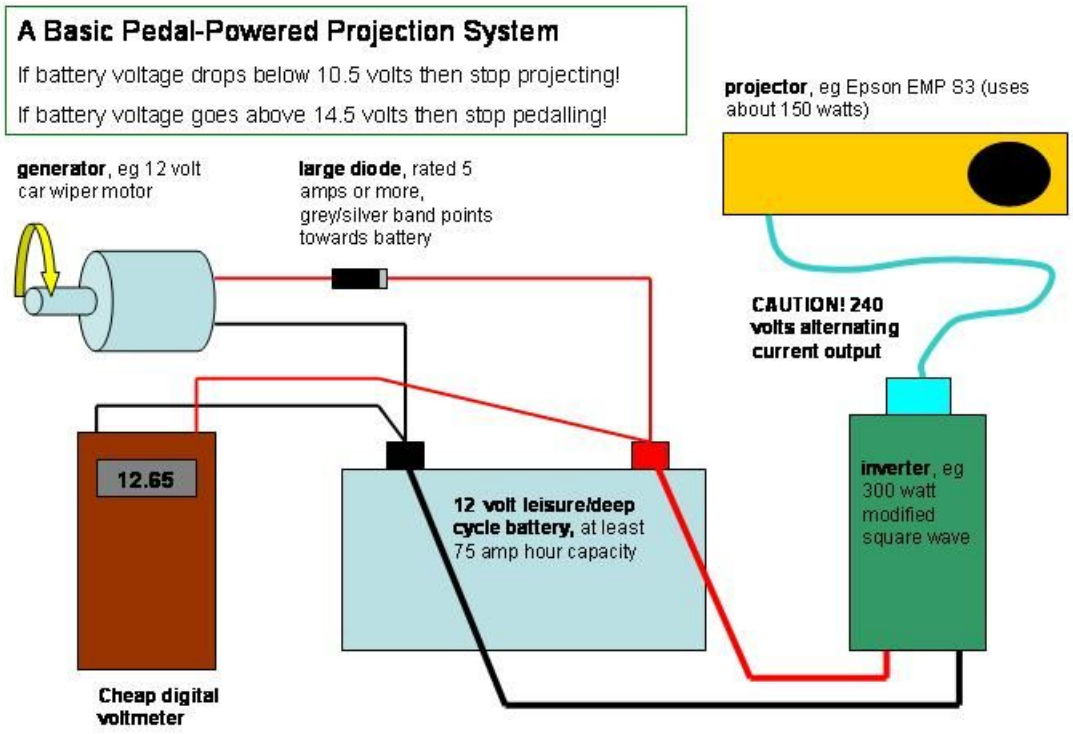

Illustration 16: Overview of a basic pedal-powered cinema system

Fun and Games

To provide additional activities aimed at children, the Energy Trailer generally carries a gameboy, which runs from the 12 volt supply via a variable voltage DC:DC adaptor set to produce 3 volts. There is also a bubble machine, which was bought from the Early Learning Centre and originally ran from four 1.5 volt batteries. This again runs from a variable voltage adaptor, which can be set at 1.5, 3 or 6 volts to give different intensities of bubble production!

Illustration 17: The key to pedal-powered gameboy is to find someone to pedal while you play!

The trailer has outputs via car cigarette lighter sockets that come directly from the 12 volt batteries (i.e. they are always on) but it also has an output that is wired to the pedal generator input, and which is isolated from the battery via a diode. This means that it only works when the pedal generator is working. This means that bubble generator and/or gameboy will only work when someone pedals, and this is ideal for getting people to understand where the power is coming from.

Links and Resources

Name	Details	web
Bicycology	Our website	www.bicycology.org.uk
Campaign for Real Events	DIY pedal power pioneers; lots of DIY info	www.c-realevents.demon.co.uk
DIY Subwoofers	DIY info on building bass speaker systems	www.diysubwoofers.org
Magnificent Revolution	Pedal-powered cinema	www.magnificentrevolution.org
Maplin	General electronics supplies	www.maplin.co.uk
Son of Pedals	Details of Bicycology's big soundsystem	www.zenatode.org.uk/sop/
Steward Community Woodland	Instructions for making pedal generators	www.stewardwood.org
Wind and Sun Ltd	Solar & wind hardware	www.windandsun.co.uk
winISD	Free loudspeaker cabinet design software	www.linearteam.dk

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