**Growth, Progress, Energy, and the Role of Electric Vehicles**

For perhaps two centuries, the West, and later other regions, have grown at rates of 1, 2, or 3% per year in terms of population, food, materials, or energy. We have come to believe that this is a normal and desirable way of life, and, in fact, if we are not growing at 3% per year, there is something wrong and we have to make a correction. But at 3% per year, growth doubles every 23 years.

Take a piece of paper and double it by folding it in half, then fold it 4 more times. The resulting wad of paper is perhaps 1/10 of an inch thick. Suppose we fold it 12 times as much, a total of 60 times. How thick will it be then? 12 inches, 30 inches? The correct answer is about 60 billion miles thick, 20 times the distance to Pluto! When anything doubles at a fixed period of time, the first few iterations may seem modest, but they quickly grow to incredibly vast amounts. For example, if energy grew at an average of 3%/year, in 1000 years, every inch of Earth’s surface would glow with 10,000 times the heat of the surface of the sun! Even senator Inhofe might concede that constitutes global warming!

In 2700 years we would consume all the resources on earth, all the resources in our solar system which has perhaps 100,000 times the resources of earth, all the resources of our milky way galaxy which has at least 100,000 million times the resources of our solar system, and all the resources of the 100,000 million galaxies that make up the entire universe! In a time that only takes us back to the Greeks, much shorter than civilization has been around, very much shorter than modern humans have existed, and a pinprick in geological time, we would have trashed all existence. And if we could access a universe ten trillion times larger than our own, we would destroy it in only 1000 years!

Physical growth at anything like 1, 2, or 3%/year leads to absolute absurdity in moderate historical times. There is no science, technology, or approach that can deal with it: growth has to stop. This upsets people who believe that growth is progress: growth makes things BIGGER, but progress makes things BETTER, and bigger is better only under very limited circumstances and for very limited periods of time. While we cannot say with mathematical certainty that growth must stop in, say, 10 years, since it leads to absurdity, we can question it and move in a different direction. In particular, electric vehicles enable us not only to continue but also to advance our transportation while radically reducing the amount of energy we consume.

The average American family owns two cars (actually 2.28) which travel a combined 20,000 miles per year [(1),](http://www.autospies.com/news/Study-Finds-Americans-Own-2-28-Vehicles-Per-Household-26437/) the fleet average for NEW cars is 24.4 miles/gallon [(2)](http://www.leftlanenews.com/us-fleet-set-economy-record-in-2014.html), and one gallon of the current gasoline-ethanol mixture used today contains 33.7 kWh of energy [(3).](http://en.wikipedia.org/wiki/Miles_per_gallon_gasoline_equivalent)  Putting this altogether, the average American family uses over 27,000 kWh energy/year in the direct operation of their cars (this does not include the energy needed to drill, refine, and other things, needed to deliver gasoline to their cars).

But according to this graph [(4),](http://visualization.geblogs.com/visualization/evs/) 57% of all trips are within 6 miles and 84% are within 15 miles. Given that the average number of people in a car is 1.7, it is obvious that most trips could be made with far smaller vehicles than today’s cars. However, the smaller you make gas engine vehicles, the uglier, noisier, dirtier, cramped, uncomfortable, and proportionally less efficient they become, because those are inherent properties of such engines and you need to surround than with all sorts of other equipment to make them acceptable, and those elements become compromised the smaller the vehicle. For example, a tiny Vespa motor scooter may get over 90 MPG, but it is 15-20 times smaller and less capable than a Toyota Prius, and yet is less than twice as efficient.

But electric vehicles are always quiet, smooth, clean, and efficient even at very small sizes, and you can shape the drive train components in EVs so that small EVs have much more usable space than small ICE vehicles. Thus small EVs should be much more acceptable to the public. I believe that this is an underappreciated fact about EVs.

So, instead of using one large type of vehicle for all our travel, let us use three types of vehicles to cover the 20,000 miles. The first is a one person electric velomobile. This starts out as a recumbent trike of the tadpole type with two wheels in the front for maximum stability. Recumbents are much more comfortable than bicycles as you sit in a seat with a back as opposed to straddling a seat. It becomes a velomobile when you cover the trike with a lightweight, streamlined, and weatherproof aeroshell. When fitted with headlights, tail lights, turn signals, and a small battery, it weighs about 70 pounds [(5).](http://en.velomobiel.nl/quest/technische_gegevens.php)  Few people will want to peddle, so we rip out everything associated with human propulsion and then replace the rear wheel with one than contains a two KW geared hub motor for maximum torque and light weight (about 11 pounds [(6)),](https://www.electricbike.com/hubmotor/) add a one kWh LiON battery which weighs about 16 pounds, and electric resistant wires in the seat. The resultant one person weatherproof velomobile weighs less than 100 pounds.

Here [(7)](http://www.kreuzotter.de/english/espeed.htm) is a page from a website that shows a menu for computing the energy needed to travel at certain speeds for bicycles and velomobiles. If you fill in various values for vehicle and passenger weight, the type of vehicle, the slope, temperature, and so on, it will tell you the energy needed. I tested this with my e-bike, and if I adjust the result by about 40% my results match those of the menu. If I apply this to the velomobile, I get a range of 87 miles at 25 mph. So, if we round it down a bit we get an efficiency of 85 miles per kWh. If we use this vehicle for 6000 of the 20,000 miles we travel per year, we consume just 70 kWh per year.

The second vehicle is just a two person version which travels at the same speed and range, should weigh less than 200 pounds, carries two people plus 70-80 pounds of cargo and gets about 40 mile per kWh. If this is used for 10,000 miles, we consume 250 kWh per year. And the third is a 2nd generation electric car, which should be available in about two years, which should have an efficiency close to 3.7 miles per kWh, for the remaining 4000 miles, and so consumes about 1080kWh per year.

When we add up the kWh for the three vehicles we get a bit over 1400 kWh per year. So we travel the same distance as most Americans do now, with the same freedom and spontaneity, in an effortless weather proof environment, with somewhat slower speeds in some cases, but the same speed in other cases, using about 20 times less energy.

So a twenty fold reduction in energy for roughly the same capability is impressive. But there is more. We need about 1400 kWh per year to operate these three vehicles for a combined distance of 20,000 miles. In those parts of the US that get an average amount of sunlight, a one KW peak PV array starts out producing about 1250 kWh per year, and declines at an average rate of about 0.5% per year [(8),](http://www.nrel.gov/docs/fy12osti/51664.pdf) so that after even 50 years it is still producing 78% of its original power. So a 1.4 KW array will start producing about 1750kWh per year and even after 50 years is still producing almost 1400 kWh per year, so that PV array will power all your three vehicles for about 50 years.

Now it does take energy to produce the 1.4 KW array, about as much as the array generates in 3 and 3/4 years [(9),](http://www.nrel.gov/docs/fy04osti/35489.pdf) or about 6,500 kWh. Which is ¼ the amount of energy used at present for just one year. Since 4\*50= 200, the three EVs I described are not 20 but 200 times more efficient than current automobiles.

There are at least two other benefits of this velomobile-EV mix: integration with mass transit and home and solar/wind storage. If the U.S. ever joins the rest of the world and develops high speed rail, imagine a long distance trip by combining a velomobile with a train. You drive to the train station in your velomobile, drive onto the train, get out of your vehicle, plug it in, walk to other parts of the train for the journey, then return to your vehicle, unplug the (fully charged) vehicle, and the drive to your final destination. You always will have your transportation with you and will not need to transfer (or possibly lose) your luggage.

Note that the big electric car is only driven 4000 miles per year, or less than ¼ of the time for present day use. That means that the car and it large battery are almost always at home. And so the car can serve as the main power storage for both the house and for solar and wind energy. Since the battery will not decline much because of travel, we might as well use it for other purposes.

Note that the above presentation is not a prediction of what will happen, but serves as an existence proof that gives a configuration of EVs that can maintain something close to our current automobile use, while dramatically reducing energy.

**References**

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