In a few years, this battery powered car, and others like it, will be able to drive endlessly - even across continents - without recharging or burning fuel of any kind. These EVs will not only be the equal of your present, fuel-burning car, they will be vastly superior. Surprisingly, their secret is not in improved batteries, or even the design of the cars. Their secret is a dedicated, electrified guideway inspired by the simple slot car track. Welcome to a better future, welcome to TEV.

Electric cars will inevitably become dominant all over the world – but only when they have a low-cost, safe, and efficient electric highway system like TEV.
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This Nissan Leaf would be ideal for the TEV track
1 Introduction

This booklet describes a simple modification to our existing road transport system to carry people and light freight. It uses conventional, production electric vehicles such as cars, taxis, vans and minibuses but in a safer and more efficient way. Think of it as an electrically powered, smart highway. Here are some highlights:

- The system is called TEV, for “Tracked Electric Vehicles”. (TEV rhymes with REV as in Revolution)
- Most TEV vehicles are electrically powered so they do not produce greenhouse gases.
- All vehicles run on rubber tires; there are no rails
- Dual-mode vehicles can be driven on normal roads and on the TEV tracks. Single-mode vehicles never leave the tracks.
- The track system should be an international electric highway network with all countries using the same design standards.

TEV is not another well-meaning public-transit system designed for city-folk. Nor an academic exercise based on technology that doesn’t exist. TEV is very practical and down to earth. It is compatible with city and suburban living. It handles public and private transport equally well. It also tries to please the customer so it is likely to be popular.

Compared with our evolved mess of roads and rails, TEV will be faster, safer, more flexible, more comfortable, more energy efficient, better for the environment, cheaper to build and easier to maintain.

TEV should need no government subsidies because it will be a good investment. It will have a much higher passenger-carrying capacity per track that any practical system ever conceived, including high speed trains and commuter trains. (see Chapter 5). Door to door it will also be faster and safer than all present land based system.

TEV will be sustainable in energy for at least the next several centuries and probably for millennia. But that is just a beginning because it will also reduce problems like:
- traffic jams
- highway fatalities
- road noise and diesel fumes
- parking problems
- fog-snow-ice or debris on the roads
- drivers who are drunk, speeding or incompetent
- speeding tickets, speed traps
- road rage and stress.

Best of all, the basic technology for TEV already exists. It doesn’t need any “breakthroughs” to make it work; no magic batteries, no weird propulsion systems; nothing risky at all. All it needs is good, competent engineering. TEV is so simple that, on a technical level, it has virtually no risk of failure.

Automated Highway System

At first sight, TEV looks like a variation of a 1980’s driverless vehicle concept called “automated highways.” This concept has now been updated with the new name “autonomous vehicles”. These vehicles have a great future if restricted to relatively low-speed city and suburban driving where the risks of death and injury are low and the benefits in urban traffic management are high.

In our opinion, however, autonomous vehicles should never be used to carry people at high speeds on conventional highways especially in heavy traffic or bad weather.

By contrast and by design, these risks are avoided by the TEV system which is a restricted-access highway that physically separates its vehicles from conventional car and truck traffic. TEV cars behave as a group; they brake and accelerate together so reaction times are zero. They also have electronic information about conditions a long way ahead so that they can react instantly. A TEV track is designed to be intrinsically safe. On a covered track, anyone could drive safely at any speed in any kind of weather.
Unlike roads, TEV tracks can be manufactured in clean factories with modern equipment and superior quality control, then installed on foundations with pinpoint accuracy. There will never be a pothole on a TEV track.

TEV vehicles will have all the features of autonomous vehicles now being developed so, after leaving the TEV track, they can also operate as low speed driverless vehicles in cities and suburbs.

**Investment**

The capital cost of dedicated TEV tracks will be substantial. But due to TEV’s **enormous** traffic-carrying capacity, the cost per passenger-mile will be very low. For example, a two lane TEV track will cost much less to build than a 6-lane Interstate Highway and yet have three or four times more carrying capacity, a much higher cruising speed, vastly better safety, and much higher energy efficiency as well as being “green” due to being electrically powered.

For any country on earth, TEV will be a good investment that will pay for itself quickly though tolls, collected automatically. It will also eliminate many wasteful subsidies now given to marginal public transport schemes, especially railways. Just look at the **astonishing payback** calculation below for a single lane of TEV track with an assumed construction cost of $1million per mile and a toll fee of 10 cents per mile.

**Assumptions**

1. Consider a stretch of TEV track 10 miles in length.
2. Toll charges are 10 cents per mile, which is low for the USA.
3. Vehicle speed is 120 mph (200km/h), which will be routine for TEV in all weathers
4. Maximum track capacity is therefore 30,000 vehicles per hour (see Chapter 5)
5. Estimated cost to convert one highway lane to a TEV track is $1million per mile.

**Calculated results**

- The toll fee for ten miles is one US dollar
- Estimated construction cost of 10 miles of track is $10 million
- In one hour 30,000 vehicles will pay the $1.00 toll fee, producing an income of $30,000 per hour.
- 24 hours of maximum traffic will bring in a theoretical daily income of $720,000
- Payback at that rate is 14 days!
- A more practical 25% load factor would reduce daily income to $180,000 per day
- Payback is still less than 2 months.

Of course, it will take years for TEV to reach these passenger numbers, but note that this is not a limitation of the TEV system, it is a limitation of the rate of its acceptance. The system itself is fully capable of very fast payback under realistic conditions. In fact, TEV could become the biggest cash-cow in transportation history.

Another practical benefit in the short term is that TEV can even accommodate cars with engines as long as they meet certain standards. This feature will make TEV introduction much quicker and less expensive. It will be discussed more later.

Getting funding for construction should not be a problem; the present trend in road construction is towards a “public private partnership” (3P) where the risk is transferred from the public purse to investors. In some countries bond issues underwritten by governments could also do the job, just as they did for the Interstate Highway system in the USA. Preferably, the TEV project should be funded privately as a profit-making enterprise. Governments will then tax the proceeds as usual so they will be happy.

TEV is not just for developed countries; there is no point in stopping pollution in the USA and Europe if China, India and other large countries are stuck with an oil-burning transportation system. TEV is exactly what these countries need to build sustainable economic growth without ruining their environments. Being largely an infrastructure project TEV will also create a lot of well paid jobs for people in their own countries. TEV is open source so there are no royalty payments.

So, welcome to our idea of the future! Welcome to TEV. We hope that you will become as optimistic as we are that this efficient, pleasant,
and environmentally **sensible** system could be your gift to your grandchildren. Please help make it come to life.

**The aim**
The aim of this booklet is to flesh out some of the details of TEV in non-technical terms. The early chapters show some astonishing benefits of the system such as passenger capacity (huge), parking (automatic), freight handling cost (low), and so on. One of the chapters is about energy supply and is a must read for environmentalists.

The technical information is straightforward and provides proof of the stunning superiority of TEV over any present system based on roads or railways. One example: road transport is a source of **a third of all the greenhouse gases on the planet**. It is also the most difficult source to correct. This book shows that TEV could easily **cut those emissions in half** within a few decades. Nothing else comes close.

So, we hope that this booklet will leave you with a sense of astonishment that such intimidating problems as traffic jams, pollution, climate change and oil dependency can be solved - **so easily!**

Will Jones, Freeport, Bahamas, December 2016
2 Single mode and dual-mode vehicles

A basic feature of TEV is that it uses familiar vehicles such as cars, mini-vans and minibuses as the primary transport modules for people and goods. This has three major advantages:

- First, there will be little or no resistance from the public to convert to the new system because it will be a convenient extension of the present road system.

- Second, the enormous expenditure required for developing special vehicles will be avoided because the automotive companies will be willing and able to do the vehicle development required.

- Third, many of the vehicles will be bought by their users, just like our present road vehicles, and not by public funds.

Note: Any transport system that uses private vehicles may seem politically incorrect to those who see the future in terms of state-owned public transport systems. But, since TEV solves the public transport problems so well, at a lower cost than existing systems, it will soon appeal to them too.

Another basic feature of TEV is that it uses a restricted track system on which EVs and also specially modified engine powered vehicles can go. These “TEV Tracks” are purpose-built, optimized guide-ways, where vehicles are driven at high speeds under full automatic control. Think of the track system a new type of electric interstate highway, a slot-car track for grown-ups.

A third basic feature is that TEV vehicles are divided into two types called **Single-mode** and **Dual-mode**. Single mode vehicles are always restricted to the track during operation, and unlike most present public transport vehicles, are usually driverless. Dual-mode vehicles, on the other hand, can drive on the tracks under automatic control, but can also be driven on normal roads just like conventional cars and vans.
Let’s begin with Dual-mode vehicles

The use of “dual-mode” vehicles, which can drive on normal roads as well as on the high-speed tracks, makes TEV very different from conventional transport systems that use trains, buses, cars or trucks.

The icons below represent various kinds of TEV vehicles. All these vehicles are relatively minor advances over existing cars and vans, but some are truly revolutionary in their abilities and functions.

The shapes of the icons are not relevant. A white circle represents a human driver and a black circle represents a passenger. Let’s review the vehicles in sequence.

The TEV car: a revolutionary advance; a privately owned, dual-mode personal transport for the masses

This dual-mode vehicle car can drive both on restricted TEV tracks and on public roads. It enters and leaves the track network at Entrances and Exits. For the present at least, dual-mode vehicles will need human drivers when driven on conventional roads. However, they can operate automatically on the track without a driver. For example, a driverless TEV car could be sent to an airport to pick up a passenger. It could also be sent across the country.

This dual-mode car may be a “pure” electric vehicle (EV) with battery power only, or a hybrid with a small engine-generator on board. On the track, however, it is usually a pure electric car that produces no local pollution.

Note: This, of course, is an idealized scenario because most vehicles will still be engine driven for decades to come. Is it possible for those vehicles to run on TEV tracks? The answer is yes with some restrictions like long tunnels and dirty exhausts. But there’s no fundamental reason to stop them using the TEV system, especially during the startup decade or two. It will help pay the tolls that builds the system.
A dual-mode taxi

This vehicle is a TEV-compatible taxicab that has a human driver. It can take a passenger from door to door, just like any normal cab. However, since it can also use the high speed TEV track, its operating range is greatly extended which improves its value to customers and increases the revenue to the taxi driver. Off the track, it may be powered by a hybrid engine to ensure adequate range on the highway. It could also be an autonomous vehicle on slow speed roads and have no driver.

A dual-mode parcel van

This is a dual-mode commercial delivery vehicle used by package handling companies to make deliveries. Amazon comes to mind. A human operator picks up parcels from existing distribution centers, drives the van to a local TEV Entrance and gets on the TEV track. Later, the van leaves the track at an Exit and the driver takes it by road to its destination. Similar vehicles may eventually have their own freight track system, operating at a lower speed. Initially, however, they would be allowed to operate on passenger carrying TEV tracks, but only under strict regulations.

Now let’s look at some “single–mode” vehicles on the TEV system.

Single-mode vehicles in the TEV system are just as revolutionary, in their way, as the dual-mode types. They use the same tracks but, in normal operation, they are driverless and do not leave the track network to exit on to public roads. Instead, they stop to pick up and deliver their passengers or parcels at prearranged places called Stops which may be public or private. These Stops are analogous to conventional bus stops and are smaller and simpler structures than Stations. Entrances and Exits, as already described, are the specialized interfaces between road and track. Single-mode vehicles are like horizontal elevators; you get in, the door closes, you are taken to your destination of choice, and you get out.
Robo-van: a revolutionary, single-mode, driverless parcel delivery vehicle

This is the TEV vehicle that will quietly revolutionize parcel delivery. In a sense, it may be the most profitable vehicle in the entire TEV fleet. Owned by firms such as UPS, FedEx, Amazon and other logistic companies, these robotic vehicles will deliver parcels and light freight, often overnight when energy costs are lower. They will travel over hundreds, or even thousands, of miles with virtually no labor cost or double-handling. For example, parcels can go directly from a supplier in Poland to a factory in England – or to India for that matter. Deliveries will be timelier, costs will be lower, and breakages much reduced. Just-in-time deliveries for manufacturers will make factories more efficient. Most importantly it is probable that the revenues from TEV freight delivery alone will pay for much of the construction cost of the TEV Electric Highway network.

These driverless vehicles can be adapted to exit on to private roads, and even on to factory floors. By following electronic guide-ways, for example, they can deliver their payload to a specific assembly line.

Robo-cab: a single-mode, driverless taxi

Robo-cab is another practical vehicle that TEV makes possible for city use. It is a driverless taxi cab that is summoned from any TEV Stop. The procedure is this: you walk to a TEV Stop, enter an order on your smart-phone along with your destination number, which can be literally any other TEV Stop in the entire system. When your cab arrives, it displays your identification number. Another swipe with the same phone opens the cab door so you are assured of keeping your place in the passenger queue. The cab will not move for anyone else.

Video cameras record all vehicle entries and exits for security reasons. Robo-cabs can therefore be used by children, old people or handicapped people and can go across town, or even across the country if required, at any time of day or night. The price of using these cabs will be very low compared with driver-type taxis and this alone will make them immensely popular. The limitation, of course, is that
Robo-cabs will only take you to the your nearest TEV Stop, not all the way home. On the other hand, it will be a cheap ride.

Robo-Minibuses serve the suburbs

Robo-Mini-buses are also simple horizontal elevators for people. They will be used for short trips on moderate-speed urban or suburban tracks. They are not intended for high speed or long distances but will bring the suburbs much closer to the city centers. They use the same kind of TEV Stops as the Robo-cabs. They are not truly revolutionary vehicles, because similar designs, but bigger, already exist, usually in airports. Robo-minibuses will be a very useful form of public transport however because they will run on the same, well-developed TEV system.

Like many TEV vehicles, their schedules can be adaptive to public demand. They can be used in convoys for commuter service, just like a train, but they are better employed as express vehicles that go directly to specific stops in the city. Remember, TEV vehicles do not stop on the tracks, so express mini-buses can bypass stopped mini-buses making for quicker journeys. These vehicles will replace crowded commuter trains which are amazingly wasteful of the priceless rights of way they occupy.

Could engine powered cars be allowed on the TEV system?

It quite practical to run engine powered cars on the TEV track – so long as they have the same controls as the EVs and the track ventilation is adequate. It doesn’t make much sense in the long term because they are oil consumers but in the short term, especially during the startup decades of TEV, it would be a good way to pay for the construction costs. It would also give people a chance to get used to the TEV system before committing to buy an EV.

Most car companies have been working on autonomous, engine powered cars. So, in the early years of TEV, there is little reason not to allow these vehicles to use the track – after all, they pay tolls. Everyone would gain confidence in the TEV system a lot quicker this way.
A luxury minibus: TEV vehicles may not be quite as fancy as this stretched limousine but they both provide nice public transport to get into town without worrying about parking.
3 Vehicle designs

The typical private TEV car is a compact electric car with room for four people plus luggage, like most cars seen on the streets everywhere in the world. TEV cars are quite normal in appearance by modern standards. Indeed, it is part of the TEV project strategy to use mass-produced cars. Among other benefits, this will drastically reduce the TEV system’s development time. In the long term, most TEV cars will be powered by electric motors on the track. On the road, they might be hybrids and powered by engines. There are many options.

A basic feature of TEV vehicles is that they are equipped with rubber tires which are used both on the roads and on the tracks; more on this later.

In addition, each car has a computer-controlled system for the accelerator and brakes that override the driver’s pedals. These types of controls have already been developed by the automotive industry and some are already in production.

The use of conventional cars gives TEV a practical advantage over transportation proposals that require specially-designed vehicles. The modern car is an extraordinarily well-developed appliance, having had billions of dollars spent on its chassis, suspension, power-steering, air-conditioning, anti-lock brakes, traction-control, electric windows, remote door locks, air-bags, sea-belts and other systems. So, it makes perfect sense to develop a track system based on and compatible with the modern car.

Electric vehicles and other options

The ideal TEV car from an environmental viewpoint is a pure EV, having a battery, an electric drive-train and the special controls that permit it to drive in track mode. It will burn no fuel and produce no local pollution. It is likely that most of the TEV cars in the future will be of this type. However, as mentioned, the TEV concept is flexible enough to accommodate fuel-burning cars; not just a hybrid vehicle that can run on petroleum fuel on the roadway and switch to electric power on the track but also a 100% engine powered car on the track.

A nice feature for EVs is that efficient, utility-powered electrical air-conditioning is available while on the track.
Restricted vehicle access to TEV track

A deliberate constraint on the TEV car design is that the vehicles must be “track compatible.” For example, large vehicles like trucks or buses are not acceptable because of the enormous cost to build large tunnels and other infrastructure components. Mini-buses built like the stretched limousine shown earlier, will be fine. Vehicle size will also be limited to some degree but will be defined in the Design Review stage of the TEV project.

Also banned are vehicles with protrusions such as roof racks, strapped-on packages and trailers of all kinds (except ones that are specially certified for use on TEV) and all open-bed vehicles such as pickups and all motorcycles. Approved vehicles will carry radio registration devices that the track computer can read, just like the systems presently used for toll-booths.

Public service vehicles

The design of public service vehicles will follow the same principles as the car design. However, since most Mini-buses and Robo-cabs will be single-mode vehicles that never leave the track, they will be electrically powered almost all the time. A small battery or generator will provide emergency services but in normal operations, they will use NO petroleum based fuels at all.

Rubber tires versus other drive systems

All dual-mode vehicle concepts, TEV or otherwise, must obviously use rubber tires when they travel on normal roads. However, some inventors have been tempted to use a separate support and propulsion system for high-speed travel on the track such as steel-wheels-on-steel-rail or magnetic levitation (Maglev). TEV uncompromisingly uses rubber tires for both road and track for strong technical and economic reasons.

Steel wheels certainly have the immediate technical appeal of low rolling resistance – about 6 times lower than older types of rubber tires. However, the fault of this virtue is that they are also very slippery, which results in problems such as a tendency for wheel-spin during acceleration, an inability to climb hills, and, most dangerous of all, a very poor braking capability. For example, a modern high speed train can take three kilometers or nearly 2 miles to come to a stop in an emergency - even more if the track is wet, icy, or covered with leaves.
By contrast a TEV car could stop from its cruising speed of 200km or 120mph in 60 meters, little more than half a football field. Poor braking performance is unacceptable for a high-density people-transporter. In addition, steel wheels are very noisy, emitting a continuous high-frequency whine caused by continuous slippage between wheel and track.

Rubber tires, on the other hand, have *superb traction and braking capabilities*. Best of all, they already exist as part of the modern car and are already equipped with incredibly sophisticated technology such as disc brakes and ABS anti-skid systems, torque vectoring systems and more. No radical new developments are needed.

Also, modern tire technology has already nearly halved the rolling resistance of older rubber tires by using silica based compounds, higher tire pressures, and altering the design of the treads and sidewalls. These new tires run cooler and are ideally suited to high speed travel of 200km (120 miles) per hour. What’s more, if tire companies were to design tires specifically for the smooth TEV track surface, we could expect even lower rolling resistances. Lastly, tire pressures could be raised automatically when driving on the track.

But the clinching technical argument is that the higher rolling resistance of rubber tires is not as big a drawback as it seems because, at high speeds, it is *aerodynamic drag*, not rolling drag that becomes the dominant energy consumer. Calculations show that the rolling resistance to be only about 6% the total drag of a TEV car doing 200km/h, so that further reduction in rolling drag has diminishing returns. (Note: The use of close convoys change this calculation a little but not enough to change the conclusion).

Rubber tires are also **much quieter** than steel wheels, and “run-flat” rubber tires, essential for the TEV system, are already commercially available. Finally, they are easy to replace when worn.

Maglev (magnetic levitation) may be a technically attractive system for very high speed trains (although even in that application it has not been commercially successful). Maglev is a very complicated approach for a simple people-mover system and would add huge costs. Cars would need to have both a rubber-tire system for road travel and a Maglev system for track travel. The track would require costly embedded coils or magnets, or some other equally expensive arrangement, throughout the entire network, as well as a separate linear induction motor drive arrangement. It is simply not compatible.
And how one would one safely transfer from one support/propulsion system to the other at full cruising speed before exiting the track? It certainly would not be either easy or safe. Then there is the drawback huge cost. The Maglev from Pudong airport to Shanghai cost a mind-blowing $50 million per mile. Clearly, Maglev is not a practical option to TEV at present. In truth, it probably never will be.

The rubber tire, therefore, is a surprising but worthy winner. It is a thoroughly practical solution: reasonably efficient, flexible, simple, inexpensive, reliable, quiet, and immediately available without a major development program.

One drawback to using rubber tires is that the “road” surfaces of the track might wear out over time and need replacement. However, this drawback can be minimized using mechanized replacement techniques described later. (See Chapter 7).

For the technically inclined, these are some comparative coefficients of rolling resistances – the drag force is expressed simply as a percentage of the vehicle weight. (my apologies to dimensional purists).

- Conventional rubber tires 10.0
- New low-resistance tires 5.0
- Future TEV tires (estimated) 4.0
- Steel wheels on steel rail: 1.5

Automated parcel delivery

For companies in the package delivery business, now growing madly due to the influence of the internet, the delivery of physical parcels weighing 5g or 10 pounds directly to the homes of buyers is still a necessity. It is also a process that is very difficult to automate.

TEV can solve this problem too by integrating the self-drive car software into the TEV Robo-van so that the vehicle can deliver parcels door to door with no driver. The vehicle would call the home owner’s mobile phone, make a delivery appointment, and then stop outside of the house at the agreed hour. After receiving the equivalent of a signature, the robot would hand over the package. Drones are the competition here it seems. But TEV is more practical, we believe.
4 Computer software

Once a car is accepted for travel on the TEV track, the central computer takes over the driving and controls everything from the initial safety check of the cars, the acceleration up to cruising speed, the grouping into convoys, the exit of the car at its programmed destination, and even the electronic billing of the customer for use of the track and the electricity consumed.

This sounds like a huge development task but, remarkably, most of the required software has already been developed by the car companies. Their original aim in the 1980s was to develop “automated highways” where cars were to drive on autopilot on normal highways shared with other vehicles.

However, it should be obvious to all that autonomous vehicles driving at high speeds on public highways, relying on four small contact patches of rubber for steering and braking is far too dangerous, especially in ice, snow, fog, and rain. But if the vehicles are confined to a restricted TEV track, especially one with a roof, the concept immediately becomes not only safe and practical but very attractive. We believe that autonomous vehicles on public roads should be limited to relatively slow speeds. For high speeds, one should use TEV tracks exclusively.

The good news is that the engineers’ control software, which has been much improved since the 1980’s can easily be transferred to TEV which is a far less demanding application. Cars driven robotically on normal highways require control in two dimensions, that is, speed control plus steering control, the latter being necessary for passing other vehicles. The TEV software, most of the time, requires control in only one dimension, speed, which is a much simpler and much safer task.

The TEV central computer is always aware of all traffic conditions on the track network, making it able to redirect traffic away from trouble spots, or bring all cars to a halt in seconds in an emergency. To accommodate the computer controls, each car is modified to have “fly-by-wire” electronic control systems – specifically for brakes and accelerator. Again, most of these systems have already been well developed by the car industry.
5 Passenger capacity comparisons

The *carrying capacity* any people-mover system is measured by the number of passengers that can be moved each hour past a given point. The TEV capacity calculations involve the following rough assumptions:

- The TEV cars are compact in size having a length of about 14 feet (4 meters) with four seats and room for luggage. (The shorter the car, the higher the passenger carrying capacity of the track).

- On the TEV track, the cars are grouped into *convoy* with about one meter (3 feet) between cars during the cruise mode. (The convoy concept is one of the biggest contributors to high capacity).

- The cruise speed on express tracks is 200km/h (120mph). High cruise speed is also a big contributor to capacity.

- The maximum "load factor" is arbitrarily restricted to 75%. That is, convoys of 30 cars followed by gaps of 10 car spaces.

  *Note: The early work on automatic highways used the term “platoon” instead of convoy and that term has stuck in the literature. The dictionary definition of “platoon” is a small group of soldiers, usually under a lieutenant. The definition of “convoy” is a group of vehicles travelling together. With respect, we will stay with the term convoy here.*

TEV capacity is huge

If a TEV track were loaded to its full capacity (100% load factor), with all the cars in one continuous convoy traveling at full 200km (120mph) speed, the number of cars passing a given point would be 39,600 cars per hour. But, we will here arbitrarily take the practical maximum track loading to be 75%, our practical maximum capacity is **29,700** cars per hour; say 30,000 for short. To show how enormous this capacity is we must compare it with other transport systems.

Compare with highways

A useful rule in the UK Highway code for spacing of cars on a regular motorway is to leave two seconds between cars, one second for
human reaction time and one second for deceleration. From this we can compute that the official maximum capacity of a single lane of expressway is around 1,688 cars per hour. Note that this is for a dry road; wet roads will result in half that number, perhaps.

If you compare this number with the TEV number above, you might be shocked: a single, slim TEV track has the astonishing capacity of more than 17 lanes of freeway.

But even that is only half of the story. We can stack two TEV tracks in the space of a single lane of motorway because TEV vehicles have a low profile. In this case, the capacity of a pair of TEV tracks would be about 34 times greater than the single lane they appropriated.

This solution has real and practical application for bridges and tunnels. Just imagine the effect of converting one lane of a bridge or tunnel into a major city with a double-deck TEV track. You could drive into Manhattan, underground, get out of your car and send it back to your home in New Jersey without causing any traffic jams. Clearly, TEV changes the rules because of its enormous capacity.

The capacity of the TEV format is one of its truly revolutionary aspects. Indeed, it irreversibly changes the economics of public transport. The closest parallel is the shift from copper-wire to fiber-optic cable for data transmission.

**Cost per mile per unit of traffic capacity**

If the construction cost per unit of capacity is compared, the TEV superiority widens even further. A modern interstate highway with 3 lanes each way can easily cost $10 million per mile (we will use American units here) to build even in open countryside. The cost in town is literally prohibitive. By contrast, a TEV track with one lane each way will likely carry more than ten times the traffic, cost a tenth the money to build per unit capacity, and have a tenth of the environmental impact - both during construction and operation. That is very impressive!

To be fair, the one great virtue of the traditional road system is its flexibility; a road will carry everything from bicycles to huge trucks. But that is what makes it difficult to manage – look at web videos of Mumbai roads to see the point. The virtue of TEV is exactly the opposite: by focusing on carrying only people and light freight it avoids most of the compromises of flexible road travel. Thus, its capacity is
dramatically improved. The conventional road system will continue to exist forever in a TEV world, of course, but will carry a lower proportion of the traffic as time passes.

**Observations confirm the calculations**

Author’s note: On several occasions, we have stood on bridges that crossed major 6-lane motorways and counted the traffic flow during periods of maximum traffic. For example, we checked the M6 near Manchester in the UK, and the Pennsylvania Turnpike near Philadelphia in the USA. On every occasion, the measured capacity per lane was lower than the 1688 vehicles per hour estimated above. In fact, the average capacity was more like 1200 vehicles per hour. One of the reasons for the low capacity was obvious: the two “slow lanes” were usually occupied by heavy trucks trying to pass each other, with long empty spaces behind each truck. The other drivers, not wanting to share these lanes with the trucks gravitated to the “fast” lane, which then became clogged with cars driving far too close together for safety. TEV gets it superior capacity by closing the wasteful gaps and having all vehicles maintain the same high speed.

**High speed train capacity comparison**

But what about advanced trains; how do they compare in passenger carrying capacity?

One of the most advanced high-speed train in service today is the French TGV (Train `a Grande Vitesse). This beautiful masterpiece of engineering cruises at over 290 km/h (180 mph) on a network of dedicated high-speed rail tracks. It also goes more slowly on older, conventional track. It is a successful and popular innovation in France, and not only competes strongly with the airlines, but reportedly has paid back its own construction cost in the first 10 years.
of operation. It is, therefore, a prime yardstick for comparison when future passenger services are discussed.

*Note: Just to challenge the impression that high speed trains are the wave of the future, it should be mentioned that only two of these lines in the world were profitable in the year 2015, the Paris-Lyon line and the Tokyo-Osaka line. Both were built in the early days when money was cheap. Now, most high speed lines are subsidized.*

The capacity of a single track of a high-speed train, in terms of people carried per hour, depends only on *the number of seats per train and the number of trains per hour*. Since the train stops and starts in stations along the track, the maximum cruising speed is not a direct factor in the capacity calculation as it is with the TEV system.

Some TGV trains have single-deck cars with a capacity of fewer than 500 persons. However, there are also double-deck cars that carry 800 persons with yet newer designs coming. We will use the 800-passenger version as our yardstick here and assume that all seats are filled.

The published maximum frequency of TGV train service at peak hours is 16 trains per hour which, when multiplied by 800 passenger seats per train, makes the capacity per track equal to 12,800 passengers per hour – equivalent to 3,200 cars per hour. Per our capacity definition, that is approximately equal in capacity to two lanes of motorway.

But that is not the biggest limitation of the high-speed train. There is a much more fundamental one, which is that the train stations must be placed *far apart* or else the average speed drops precipitously. To illustrate, if a TGV train has to wait 5 minutes at stations that are 50km (30 miles) apart, the *average* speed of the TGV train drops to 200km/h (120mph) which is the same as a TEV car that doesn’t stop at all. Stopping on a track is a tremendous waste of time and capacity.

Another example: in the USA, the Acela train from New York to Washington DC, achieves 240km/h (150mph) in places but averages only 134 km/h (84mph) for the complete journey. TEV which averages nearly 200km/h (120mph) would be faster point to point. Not only that, you could start your journey when you like and would not have to go into town to catch the train. That would make TEV much quicker.
This low average speed problem is partly avoided by having long distances between train stations. *Fast trains, therefore, are inter-city expresses* – much like airlines. They cannot compete with TEV vehicles anywhere except between major cities. They may fit the city lifestyle of France, Japan and China. However, since most middle-class people of the world prefer to live in the suburbs or in the countryside outside city centers, our calculations say that, for them, *TEV will be much faster door to door than any railway, including high speed rail.*

But that is not all. By using new, small tunnels or by reusing old railway lines and tunnels, TEV vehicles can go quickly into the heart of old, established cities as easily as it goes into the countryside. It is a vastly more flexible system for the ordinary person to use than a train. And don’t forget, you may be able to stack two TEV tracks in one railway tunnel.

**How do commuter trains compare?**

Most people would assume that the commuter train, crowded with harassed passengers, has the highest passenger-carrying capacity of all. However, they would be wrong. Even though it is cramped, uncivilized and unhealthy, the commuter train still can’t come close to TEV for capacity. Again, this is because the train must *stop on the line* in a series of stations which ruins its capacity.

To match the maximum capacity of a single TEV track, a commuter rail line would have to provide one train, with 500 passengers on board, about *every 15 seconds.* Obviously, this would be impossible because the train must stop in each station for much longer than this. Observation in a London Underground suburban station showed that, at peak travel times, a train rolled by every 10 minutes or so. In that case, the capacity of that rail track will be about 3,000 passengers per hour, the equivalent of 750 cars and only half the capacity of a single lane of highway. This makes the commuter train the worst people mover on all counts.

**Results and conclusions on capacity**

For a fair comparison between train, road cars and TEV cars, we must compare passengers carried per hour per lane. With each road car and TEV car having four seats, this is the result:
<table>
<thead>
<tr>
<th>System</th>
<th>Speed (mph)</th>
<th>Vehicles per hour</th>
<th>Passengers per hour</th>
<th>Equivalent road lanes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highway One lane</td>
<td>70</td>
<td>1688 cars</td>
<td>6,752</td>
<td>1</td>
</tr>
<tr>
<td>Commuter train One track</td>
<td>variable</td>
<td>6 trains</td>
<td>3,000</td>
<td>1/2</td>
</tr>
<tr>
<td>High Speed Train One track</td>
<td>180</td>
<td>16 trains</td>
<td>12,800</td>
<td>2</td>
</tr>
<tr>
<td>TEV One track</td>
<td>120</td>
<td>29,700</td>
<td>118,800</td>
<td>17</td>
</tr>
</tbody>
</table>

One surprising result is that the high-speed train only has a capacity equivalent to only two lanes of highway traffic. The 16 trains per hour figure corresponds to a rate of one train every 3.75 minutes. *That is, if a train stops in any station for more than this it will hold up the following train.* That seems a bit crazy but it works. However, 3.75 minutes seems to be a bit quick for a handicapped person to find his seat on the train.

Another surprise is that the commuter train is a terrible waste of resources. *The priceless rights-of-way that trains use to get into the city could be put to a much better use by TEV.* TEV mini-buses could supply all the peak passenger traffic at a much higher speed while
other TEV vehicles, like parcel vans, could use the same track during other times of the day.

But the most remarkable conclusion is that the simple, low-cost, TEV track is the equivalent of 17 lanes of highway, a vastly greater capacity than either freeways or high-speed trains or commuter trains combined. *Its combination of speed and capacity truly puts it in a class of its own. No contest: TEV wins!*

Critics may quibble with the assumptions of the TEV calculation; that the gaps between cars should be a little more, or the load factor should be a little less, and so on. On the other hand, it equally likely that the cars could be made shorter, the speed could be made higher and the load factor raised to 100% in special circumstances. Further, two TEV tracks can easily be stacked in the space of a single highway lane, which would double the capacity to 34 equivalent lanes! Surely that ends any debate. For capacity, there is nothing close to the TEV system.

However, just to be conservative, let us arbitrarily reduce the claimed capacity equivalence of TEV from 17 lanes of highway down to 10 lanes – just to make a nice, round number.

Few would then argue with the conclusion that *one TEV track is equivalent to at least 10 lanes of highway.* That is enough advantage to justify construction of the TEV system.
6 Energy consumption of TEV vehicles

Suppose we developed a magic battery that gave electric cars the same performance as conventional gasoline-powered cars. Would that option be as good as TEV? Absolutely not. **TEV would still be far better.** Why? Because those EVs will take up the same space as other cars and we would still have the same old traffic jams, traffic lights, intersections, accidents, road repairs, bad drivers, parking problems, bad weather and all the other causes of stoppage.

*By the way, do you know how many people have died on American roads in the last 50 years? The answer is around 2 million. Add to that millions more with serious injuries.*

TEV’s energy efficiency is very high because there is virtually no stopping and starting on the track. It is improved further by the combination of smooth track surfaces, low-resistance tires, streamlined car bodies, banked turns, direct supply of electrical power to the motors, and aerodynamic drag-reducing techniques made possible by convoys.

![Image of a car]

Modern cars can have very low drag coefficients but still look normal

Because of these “natural” advantages, we would reasonably expect TEV vehicles to consume less energy per passenger-mile than conventional cars on a normal road system – even if those cars had magic batteries. However, we would certainly not expect TEV cars to be competitive with super-streamlined, high-speed trains running on steel wheels, would we? Let’s find out.
A Japanese “Bullet Train” traveling at 160 mph is reported to consume only 55 watt-hours of energy per kilometer per passenger – and that is only counting half the seats as occupied by passengers. The French TGV train is said to consume the same amount of energy per kilometer, but at 180 miles per hour, and with all the seats occupied. In both cases, the consumption figures equate to a continuous power draw of 10kW per counted seat which is a very useful comparative measure to have. So now let’s compare TEV with super-trains on that measure.

To match the figure of 10 kW per seat, a four-seat TEV car would have to draw just 40 kW of continuous power at 200km/h (120 mph). With some simple engineering calculations, we can estimate the approximate power consumption of a TEV vehicle, recognizing that some of the drag forces are difficult to compute, especially (a) the possible **increase in** aerodynamic drag of the cars within the partial enclosure of the track and (b) the very substantial **reduced** drag from the “drafting” effect of convoys. Therefore, we will ignore both these factors, expecting them, at least partially, to cancel out.

Two drafting NASCAR vehicles doing 200mph. Note that they are only a couple of feet apart.

We will assume that the TEV car is a compact car, weighing a substantial 2000 pounds, having a frontal area of 20 square feet and a **very streamlined** shape with a low drag coefficient (Cd) of 0.15 - which is achievable in practice (eg: GM Precept) and, therefore, should be made the target.
Note A brand-new opportunity to reduce aerodynamic drag on TEV cars that is not available to road cars is to raise the vehicle another 6 inches or so (150mm) above normal ground clearance on its suspension. We can’t calculate here if that would make a significant improvement but there is the option if it works. Another is to make the “ground” under the cars an open grating to allow free passage of air. There are a lot of virtues in having a dedicated track.

The GM Precept experimental car built in 1999 had an aerodynamic coefficient of 1.5 to 1.7. It looks practical.

Back to the calculation: The resulting aerodynamic drag force at 120 mph would be 116 pounds of force. (American units). The rolling drag of the special low resistance tires, is estimated to be only 8 pounds of force. Therefore, we get a total drag force of 124 pounds. This drag force of 124 pounds, at 120 mph, equates to 40 brake horse power or about 30 kW. Allowing for some energy conversion losses, the actual power consumed by the vehicle would, therefore, be about 40 kW – an amount identical to the TGV train doing 180mph and double that of the Japanese Bullet Train doing 160mph.

Thus, the total amount of electricity used by the TEV car is low. For example, a journey of 120 miles could be done in one hour with an energy consumption of just 40 kWh which, even at 10 cents per kWh would only cost $4.00 in “fuel” costs. (Note: The actual production
cost of electricity can be as low as 2 cents per kWh, as shown later, so it is an exaggerated cost).

By contrast, a fuel-burning car on a normal road, consuming gasoline at a frugal 30 miles per gallon would use 4 gallons on the trip – going a great deal slower than 120mph. Using American gasoline prices at $3.00 per gallon at the time this report is written, fuel would cost $12.00 - or 3 times more than our clean EV. Using expensive European petrol prices of $6.00 per gallon, it would cost $24.00 – 6 times more. Of course, petroleum prices in Europe are largely made up of taxes, as are electricity prices. Still, it shows that the cost of TEV travel is lower than present systems and not inevitably higher, despite faster speeds.

Note that pure EVs will be more energy efficient driving on the TEV tracks than driving on the roads on their battery power. The reason is that the electricity goes almost directly from the electrified track to the drive motors. Energy is not wasted going through a charger and battery. A vehicle that drives on its battery loses a substantial amount of energy as the current passes through the charger and the battery before reaching the drive motors. Incidentally, the faster the charge rate the less efficient it is.
7 Track design

The basic definition of a TEV track is: a single-lane, electrically powered, limited-access, electric roadway with no intersections other than ON ramps and OFF ramps.

A TEV track is quite narrow: just the width of the car plus some extra space necessary to permit passengers to exit their cars in an emergency. To eliminate the possibility of the cars being thrown off the track in any foreseeable event, including terrorist attacks, there are crash barriers on either side to keep the vehicles safely contained.

This contrasts with conventional trains which can derail rather easily with truly disastrous consequences. In 1998, the advanced German ICE train damaged a wheel and crashed into a bridge abutment killing over 100 people and injuring over a hundred more. It was only doing 120mph. In TEV vehicles, by contrast, occupants are so well protected by advanced, highly tested, safety equipment such as air bags and crush zones that, even in a terrorist attack, few people would be injured or killed. It is not intuitively obvious but TEV cars will be much safer in a crash than trains.

Fundamental to the purpose of the TEV track is to make travel intrinsically safe. Therefore, there are no objects on the track that can cause high frontal impact or nasty accidents:

- no trees, telephone poles, walls, ditches
- no head-on crashes, two-way traffic (except as discussed later)
- no intersections, crossroads, railway crossings, traffic lights
- no farm tractors, motorcycles, bicycles, school buses
- no sheep, cattle, pets, wild animals, pedestrians
- no heavy trucks, trailers, flatbed trucks, open pickups
- no drunk drivers, speeding drivers or bad drivers of any kind

All this is possible because TEV is, by design, a highly-segregated transport system, concentrating on carrying the most precious cargo of all, people, plus some light freight to help pay for construction and maintenance.
Stacking of tracks

A pair of TEV tracks can be placed side by side as in a two-lane road. However, they can also be stacked one on top of the each other in double-deck fashion. The double-deck arrangement has benefits of structural strength, useful when making long bridges or other spans, and is perhaps nicer for passengers who, on an elevated track, might enjoy the extra, two-sided visibility. On the other hand, the tracks themselves may not look as nice from the outside in certain locations. Probably, the arrangements will vary per local needs. Double deck arrangement would make very economical use of existing or new tunnels.

Also, as mentioned earlier, a double deck track arrangement could be made with freight vehicles running below at a slower speed, say and passenger cars above running at high speed. This might turn out to be the ideal infrastructure for the future.

TEV tracks can also be laid down in several unusual ways, as follows:

Using old railway tracks, on the ground or elevated

This is one of the lowest-cost options and has huge potential. In most developed countries, there is a large existing network of railway tracks that not only cross the countryside but also drive right in to the centers of major cities. Often these tracks are shockingly underutilized.

(Author’s note: For example, I stood on a bridge over railway lines in Putney, London, during the morning rush hour. The road traffic on the M25 ring-road around London was, as usual, choked with traffic and the subway system (the Tube) was also jammed with commuters. But the rails below were completely empty for many minutes before a lone commuter train trundled by. Then nothing happened for another long period. It may have been 10 to 15 minutes. Then another train rolled by, and so on. During non-rush hours, the rails are hardly used at all).

To waste such an asset as a fully paid-for right-of-way into the very heart of London for such a crude 19th Century mode of transport as a commuter train is a tragic lack of insight.

Cannibalizing underused railway tracks outside cities and converting them to TEV tracks is another important resource for the TEV system. Don’t mourn the loss of such an archaic system; you will be far better off, especially when you must travel at some lonely hour on a dark
night. Remember that there is almost nothing a train can do that TEV can’t do better, faster, safer, cheaper and in more comfort.

**Replace the “fast lane” of a freeway**

Here is yet another way of cannibalizing underused assets: a TEV track is placed in the “fast lanes” of a 6-lane highway, one track in each direction and a strong crash barrier is installed to protect the TEV vehicles from the other road traffic. This option has a big advantage because there are obviously many existing rights-of-way already available. The huge capacity of the TEV tracks will not subtract from the capacity of the highway, it will add enormously to it at very low cost. Bridges, tunnels, etc., become incredibly cheap. With two tracks replacing two single lanes, the yield is the equivalent of 10 extra highway lanes each way if full speed can be maintained. In practice, the speed of the TEV vehicles might have to be reduced where the freeway is curved too sharply, but the concept itself is an achievable goal. See this animation on: www.TEVproject.com

**On elevated tracks**

This is the preferred option for new tracks when crossing farms or parkland or passing through low-density suburbs. It provides for minimum environmental impact for both local people and for animals. It also allows the double use of land, like farming, which would be valuable in crowded countries like India. Preferably, the track should be supported on slim pillars which are all that is needed for the relatively lightweight structure. Proper landscaping, including a lot of trees, will be necessary to reduce the visual impact to a minimum, but that is surely an advantage rather than a drawback. Once again, the tracks may be either single-deck or double deck, depending on capacity requirements. Elevated tracks also work when used down the center or sides of a multi-lane highway or along a power line corridor. In China, for example, many cities have power line corridors that approach all the way into the city centers. These corridors have plenty of room for track installation.

**In “cut and cover” tunnels**

TEV tracks can also be placed in relatively economical cut-and-cover tunnels under existing roads, carrying people in and out of cities. This will do wonders to make cities more livable. The same technique can
be used for tunnels under public parks or other scenic sites. The tunnels are so small for their carrying capacity that their cost is a tiny fraction of any other tunnel system.

**In small-bore tunnels**

Another exciting opportunity is the creation of *bored tunnels under our cities*. These would provide an underground network that would virtually eliminate the city’s once intractable traffic problems at a stroke. Just imagine the result: elimination of unnecessary road traffic in city centers; absence of traffic jams; absence of road noise; absence of diesel fumes and pollution. What an amazing change that would be. But most importantly, it would not be done by restrictions which say that you can’t drive here or you can’t park there. It would be a city of opportunities where you can go where you like and have easy parking when you get there if you prefer your own car rather than a Robo-cab.

For people who worked in the city, it would be a dream come true. They could zip from the commercial center to the airport in minutes, day or night. They could live in the suburbs without having a dreadful commute each day. They could dress up nicely in the evening and drive into town in their own cars or in economical Robo-cabs in civilized comfort, to visit theatres, museums, restaurants or galleries without bothering any of the people who happen to live in areas in between. *Have mercy on the people who live in between!*

Modern tunnel-boring machines are extraordinarily efficient machines and have reduced the cost of tunneling significantly. The cost of a tunnel is closely related to the amount of material – or “muck” as they call it – that is removed, so the larger the tunnel, the costlier it is per mile. However, a very small tunnel is costly too because the muck cannot easily be removed. Thus, the least costly tunnels are ones with a diameter of about 6m (20 ft), an ideal size for two lanes of TEV – plus some extra room for pipes, cables, and other utilities that will bring in a lot of extra revenue. Rights of way are extremely valuable assets. A twin tunnel also provide space for a life-saving escape path normally required in modern tunnels.

Therefore, the cost of boring these TEV “micro-tunnels” is much cheaper than digging large road tunnels for highways. A bad example of old-fashioned tunneling is the notorious Boston “Big Dig” tunnel that cost nearly $14 billion for 7.5 miles of tunnel, or about $30,000 per inch. By contrast, the 50 mile “ring main” tunnel under London,
designed to distribute water around the city, has a mechanically bored tunnel about 8 feet in diameter that cost less than $10 million per mile to dig. TEV tunnels would hopefully have a cost closer to this latter figure, at least for cities with clay soil like London. For the equivalent of, say, a 10-lane highway, that is very cheap!

So, we can bore lots of these “micro-tunnels” under many cities and bring the TEV system into the heart of metropolitan areas without disturbing the people on the surface, all at a reasonable cost. Furthermore, existing tunnels under rivers and channels such as the English Channel Tunnel or the Lincoln Tunnels in New York City could have their capacity vastly increased by converting to the TEV format. That would save another pile of money. Road or rail bridges across large spans anywhere would likewise have their capacity transformed at a trivial cost.

**Track enclosures**

Theoretically, TEV tracks can be made fully open to the sky and that might be a suitable low-cost approach for some long runs in remote areas like the American prairies. However, for most applications, a roof on the track will be a worthwhile enhancement both for the travelers on the track and for the local population.

For travelers, a roof is a great benefit in snowy regions because it keeps the tracks clear. Energy wasteful snow-plowing is unnecessary and the tracks are usable under almost all weather conditions, even if their roofs become covered with snowdrifts. Sprinkling salt on roads is very corrosive to steel structures and can be avoided on TEV tracks.

In rainy regions, a roof keeps the track dry, enhancing tire friction and eliminating water spray. In very sunny climates, a roof shelters the cars from solar radiation and reduces air conditioning loads to conserve energy further. It all adds up.

In sunny climates, like Dubai for example, the roof could be a location for solar panels which could produce some of the electric power needed for the local area. Powering the vehicles would be vehicles inside would not be practical. An enclosure would also keep the sand out.

For the local people who live near a TEV track, an enclosure would have the added benefit that it reduces road noise which is mainly tire and wind noise. The use of sound absorbent materials inside the
enclosure would trap most of this. In addition, the sides of the enclosure can be partially or completely enclosed with glass windows or even mirrored glass windows. The latter would not only make the noise disappear but also make the cars “disappear” visually.

In case you thought that high speed trains were nice, quiet, civilized things, you might like to check on the noise made by an ICE train doing 300km per hour in Germany in this YouTube link:

http://www.youtube.com/watch?v=e_MSRb79qOU&feature=related

TEV with its rubber tires will be quieter but we don’t know by how much. Therefore, TEV tracks may be equipped with noise-blocking side windows when passing through built-up areas or sensitive countryside. It will all be up to local planners to decide.

**Track construction and repair**

The tracks structures have a relatively light construction compared with roadway bridges because they do not have to carry heavy-truck traffic. Ideally, track sections can be mass-produced in factories and brought to the site for installation – a much quicker and less disruptive method than that used in road building, not to mention the greater precision and quality control. The speed of construction for TEV would be breathtaking compared with conventional highways, especially in built-up areas. See the construction video on the TEV project site.

Maintenance and repair of the track roadway, called “friction surfaces” is also easier to do than with conventional roadway maintenance. The surfaces of the track are twin ribbons of “roadway” on which the tires run. These would not be manufactured on-site with the slapdash methods of roadway construction, but in a clean factory with engineered accuracy.

The friction surfaces would be designed in conjunction with the vehicle tires to minimize both noise and rolling resistance while still retaining good grip for acceleration and braking. Preferably, they would be delivered to the site from the factory as long strips and attached to the track structure with bolts or other removable attachments. Repair does not involve noisy jackhammers, but is rather a matter of taking up the old friction strips - which are recycled back to the factory - and installing new ones. All this is done “on the fly” with automatic “pick-and-place” machines traveling on the track itself inside the enclosure. Other procedures are possible.
Repairs will be very rare due to the intrinsically low wear-and-tear of the friction surfaces (no heavy trucks, no freezing, few heavy-braking loads) - plus the development of super-durable, ceramic wear surfaces like tungsten carbide. And when it needs repair, that repair will be accomplished far more quickly and efficiently than normal road repair methods. Indeed, one of our calculations suggests that the replacement of a pair of 100 foot strips of friction surface could be achieved in less than a minute, making possible a continuous roadway replacement rate exceeding a speed of one mile per hour! The consequent cost reduction potential compared with conventional road repair is obviously huge.

**Powered tracks and non-powered tracks**

A *very dramatic simplification* of the TEV concept is to have electric power supplied only to the high-capacity tracks. The shorter, slower commuter tracks don’t really need external electrical power because the vehicle batteries are more than adequate for short trips. The EVs would recharge either at home or on a main track depending on the driver’s preference.

This arrangement would save a huge amount of money on infrastructure and maintenance.
8 Power for the track

Should electrical power be supplied to TEV vehicles by old-fashioned contact rails or by new-generation induction? This will be a fundamental decision for TEV so here is some background.

The usual method for charging an EVs is to plug it in like an appliance. Mobile phones, on the other hand, can be equipped with inductive charging where you just place the phone on a charging pad.

Recently, electric vehicles have been equipped with induction coils so that you can park your EV over a charging pad at your local supermarket and charge your battery while you shop. Induction pads are also being implanted under the road surface at bus stops so that electric buses can stop and be boost charged.

**Dynamic induction is in the development phase.**

Even more interesting for the TEV system is that engineers are now working on a system called *dynamic induction* where EVs will be charged *continuously* on a modified road. This concept requires a multitude of induction pads to be buried under the road surface. It sounds perfect for a TEV track because the pads could be laid on the floor of the track without burial. However, it also sounds expensive.

To put things in perspective, charging a convoy of EVs travelling at 120mph, with each vehicle drawing 40kW, is a much harder task than charging a parked car at 3 kW. But a lot of work is being done with induction to achieve this exciting breakthrough.

**Catenaries, pantographs, and high speed trains**

Modern high-speed trains, like the French TGV train, which carries 750 passengers, are not old fashioned products. They use innovative technology in every phase of their operations. However, they don’t use induction. A train picks up electricity from a high-voltage overhead “wire” using conductive strips of carbon like those that have been used on trains for decades.

The power needed for a single TGV train is enormous, over 12 megawatts. Those 12 million watts is enough to propel 300 TEV cars at full cruise speed, with each car consuming 40kW. (We can note with
a smile, that the TEV cars will have 1200 available seats, 60% more than the train has. But back to the subject!

Is the TGV technology old-fashioned? Of course not, it’s a highly-refined concept that is modern, sophisticated, practical and efficient. *It works well in the real world* at very high speeds and power levels.

The TGV power system works like this: there is usually only one pantograph per train which draws *megawatts of power from a single overhead “wire” with a diameter of a mere 15mm (3/4 inch)*. This wire is kept at a constant height by suspending it from a catenary support-wire above. All the power to the train goes through a **single carbon shoe** on the train pantograph.

Ingeniously, the contact wire is zigzagged between support poles by about 300mm (11 inches) so that, relative to the train, the wire appears to move gently from side to side to equalize the wear on the carbon shoe.

Most people would assume that the hard-working carbon shoe would only last a few trips across France. Not so: the carbon lasts between 9 and 12 months of operation at high speed! So, this is excellent engineering; sophisticated and robust, which is now use all over the world on high speed trains. The main point here is that we must not think of conduction as “old fashioned”.

**“Twin-rail” conduction**

Commuter trains and Metro systems tend to use a different type of conductive power. These trains pick up power from a conductive “third rail” placed near the ground. Carbon “shoes” slide along the rail to bring power to the drive motors. Again, this sounds old-fashioned but it is still good engineering and works extremely well, especially in subway trains where space is limited inside the tunnels. (Due to the curious but fundamental phenomenon called “skin effect” these third rail systems are always DC and never AC).

So, would a conductive “third rail” system work for individual cars on a TEV track? Given that the TEV track would need *twin-rails*, like the Paris Metro (because the cars in both cases run on rubber tires) the answer is yes. A conductive rail system should work very well on a TEV track, with high reliability, high efficiency, and low cost. We will assume for now that the power would be DC.
A top-contact carbon shoe for a London metro train. It is self-aligning and can be retracted by remote control, just like TEV. Simple and effective as good design always is. The “shoe” is the lower plate.

Usually, fast trains are powered by high voltage AC, typically 30,000V, provided by substations located up to 25km (15 miles) apart.

To summarize: there are many options and tradeoffs for engineers to review and debate but none of them appear to be very difficult to implement.

**Dynamic induction**

Dynamic induction is very new so we don’t know much about its pros and cons. Dynamic induction technology for TEV is vastly more complicated than a stationary charging pad for a single EV. It involves inducing a large amount of power, continuously, for convoys of vehicles at 40 kW per vehicle.

It presumably will have hundreds of induction pads per mile so the cost of the track will probably be high. To be successful, the system must demonstrate that it can supply energy with efficiency, reliability, and safety - including protection from electro-magnetic fields - and do so at a low cost. It is a clearly an ambitious concept.

The main questions are:

- Will dynamic induction work? Yes, we believe it will.
- Will it be efficient? Not as efficient as conduction, we think. We hear of 85% as being achievable but that is not good enough for a major transportation system.
- Will it be reliable? Yes, we believe that it could be very reliable.
• Will it be made safe from high EMF fields? Yes, we think so
• Will it be expensive? Yes, and this is the big worry. But, if it worked for many years without costly maintenance, it might amortize itself. We don’t yet know the failure mode of the pads.
• Will it be flexible and grow with a TEV system having an increasing amount of traffic? That is difficult to calculate. Does this mean adding more pads or not?

The last factor is important because as traffic grows, the amount of power to the track must increase. With a conduction system, this is done simply by adding more power supplies or substations to the existing track. With an induction system, it presumably means adding more pads.

**Linear induction**

There is also another type of induction system that might be best of all. It was designed by the brilliant engineer Eric Laithwaite. A later variation patented by someone else is shown below.

![Linear induction system diagram](image)

In this version, high voltage power must still be supplied to the train by some means so this embodiment is not ideal for a TEV system.

However, a converse version, also devised by Laithwaite, having static inductors along the track and a metal reaction plate attached to the vehicle, seems much more practical. The metal plate would of course have to flex from side to side to accommodate the lateral movements.
of the rubber tired vehicle. Also, some means would be necessary to keep the metal reaction plate in the center of the air gap and not touching the inductors. It is an intriguing concept because it is basically like an AC motor that has been opened and made flat and therefore probably very efficient. The beautiful principle of the system was explained by Laithwaite: the vehicle simply “surfs” on the moving electromagnetic wave.

Perhaps a version of this principle would be the best form of dynamic induction because all the electronics are on the track and none on the vehicles.

**Which system is better in the real world?**

A “twin rail” system will certainly do the job of propelling convoys of cars at high speed if it designed properly. Passenger trains have operated with third rails at 100mph in southern England for decades and TEV is a much lighter duty than that. Each TEV vehicle would have its own pair of contact shoes designed for its own needs, which is only 40kW or so. It should be reliable because it is simple. Finally, it will not induce large magnetic fields so there are no EMF safety issues. It needs proving, of course, so testing is required.

On the other hand, induction, having no moving parts, is extremely attractive, especially the linear induction motor version. It is also very elegant and modern. But we need more information on it, particularly its cost and efficiency.

So, we can’t tell yet which system will win. But if all else fails, we have a good default solution in the Twin-rail. It is proven, has high reliability, high efficiency and is low in cost. One cannot overstate the importance of those five criteria. It also has other benefits:

- It has no moving wear parts except replaceable carbon shoes which owners will replace at their own cost
- Composite aluminum/steel conductive rails are commercially available already (see Siemens catalog)
- It does not need years of research to implement
- Experts in the field already exist in the railway industry
- It can be constructed anywhere - even in the developing world - which is crucial.
- Failures are easy to fix and unlikely to be catastrophic
- Parts are easy to repair and replace
- It does not require the burial of complex coil systems and electronics under a road surface. (But note that a TEV track would be ideal for fitting induction pads above the ground).
- It is very flexible in design
- It is compatible with pre-assembled TEV track modules as shown on the TEV website
- It produces no powerful electro-magnetic fields

Prototype testing

That is a tough list of criteria that induction must match. But perhaps a new form of induction will surprise us and win the day. In any case, we must stay neutral and carry out a serious test program to find the best solution. We will be living with it for a long time.

New concepts take much longer to implement than most people recognize. So, let’s have a proper competition between the systems and see which is the best. That means a TEV test track.
9 Automatic parking

Parking places in cities, airports and other crowded places anywhere in the world are almost impossible to find at reasonable prices. This makes the TEV concept look impossible for parking private cars nearby. Where would all these cars park? But the TEV system can offer several fundamentally superior arrangements for solving city parking problems.

The first way is to put most of the parking underground. This allows parking to be built nearby without the political squabbles about rights of way on the surface. That is, *most of the TEV Parks in a city could be are simple underground tunnels* and not buildings at all.

There is plenty of potential parking space under the urban landscape. A single tunnel 22 feet in diameter would house 4,000 cars per mile of tunnel. If we need more parking, we just dig some more tunnels.

**Other parking examples**

The second way is to recognize that the driverless TEV cars don’t have to park near the place where they drop you off. They are free to move off under automatic control to suitable TEV-Parks wherever these are available, nearby or miles away outside the city.

The computer doesn’t have to look for a parking space because it knows exactly where they all are. You don’t need to know or care where the car is parked. It will return to any Station to pick you up when you call for it.

On arrival at such a Station, the car goes into a short-term parking zone and waits for you, for a fee. To avoid the high cost of short-term parking, most people will wait to recall the car until they are close to the Station so there is no problem with this arrangement. If the owner doesn’t turn up, the car will be sent back into long-term storage at a lower parking rate.

The so-called “impossible” problem of city parking is, therefore, not impossible at all. For TEV, at least, it is not even difficult. In a city, the cars never need to come up to the surface. They never take part in any traffic jams. They do not pollute the city air. They occupy no parking space on the surface. They make no noise. They need no fueling stations or the attendant dangers and smells of tanker trucks. Bad weather does not affect them. They can be used at any time. They
can get in and out of the city at high speed, even in rush hour. In effect, they are completely invisible yet provide a level of convenience and service to their owners that *no other mode of transportation can hope to match*.

Of course, another option is to send your car back to your own house and park there. That too is a possibility in a TEV world. Sheer capacity makes all this possible.

Note that everything that the private cars do, cabs and minibuses can do also. Since public transport vehicles also use the underground tracks, the surface roads can be free of the stench of diesel buses. The result is that the surface can largely be returned to pedestrians with more trees, landscaping and room for wildlife. The air will be cleaner and the noise level lower. This is what the future cities should be like.

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10 Stations and Stops

A criticism that can be made of bi-modal transport systems is that the rate of exit of vehicles from the track will be too slow, creating choke points at the exits and, therefore, derating the useful track capacity. That is not true for the TEV system, as we will now show.

Schematic of a TEV station

The sketch above shows a medium-sized TEV Station with eight bays. The same bays can be used either to Embark or Disembark depending on demand. In the Disembark mode, cars enter from the left and are directed to one of the eight bays. Passengers step out promptly on to the platforms (C), walk up the small ramp (B), and exit the Station via the low overpass (A).

If an average 15 second interval is allowed in the bays for embarking, the Station can handle 32 cars per minute or 1,920 cars per hour – which is more traffic than one lane of motorway can supply. At this rate, the cars can enter the Station continuously at an average speed of 5.4 miles per hour.

The bays are computer controlled and flexible. They may be segregated into private cars and cabs in some bays and Robo-buses
in others. On one day the traffic may be heavily biased in favor of buses (e.g.: sports fans going to a stadium); on another day, it might be biased in favor of private cars and cabs (theatre or concert fans).

There are many variations on this theme that can add capacity. For example, if batches of two or three cars at a time are allowed into each bay, the capacity is immediately doubled or tripled, and so on. In a very large Station, if such were ever required, there could be 20 bays, serving batches of, say, 6 vehicles at a time. The capacity in that case would be nearly 30,000 cars per hour which, with four people in each car, could theoretically fill a 60,000-seat sports stadium in half an hour. Obviously, there is no limit here.

The vehicles shown in the sketch, which can include a mix of Rob-cabs, Robo-buses and private cars, leave the Station to the right and can either go back on to the track, or to an automatic TEV park, or anywhere else the owner decides. For example, a private car could drive itself to a TEV park near a car dealer for scheduled maintenance while its owner is at work, or it could run through an automatic car wash before parking itself. The possibilities are endless.

![An overhead view of an underground station from our animation video. With multiple bays, multiple vehicles per bay, and automatic parking the capacity can be enormous](image)

The Station is flexible in its response to changing situations. For example, at any one time, the bays may be given completely different assignments such as Embark or Disembark or Handicap Use or Emergency Use and so on. The system lends itself to a degree of flexibility that is unheard of in public transport systems. To minimize
human confusion, the bays at one end might be segregated to one mode while the bays at the other to the other mode. The computer would have no problem organizing all of this.

**Special cases**

The TEV Station can not only handle an enormous amount of traffic, but can do so with a wonderful, disciplined grace; the cars arrive and disappear as if choreographed. This is quite unlike the usual chaos, for example, in a typical airport arrival area. With TEV there is no traffic noise, no diesel fumes, no ugly parking lot, and no dithering drivers who are lost or don’t know where to go.

A special case for a Station is a city hospital. The TEV system would permit very fast delivery of emergency patients to any hospital, local or distant, saving many lives. Thus, area hospitals could coordinate their services efficiently.

Likewise, TEV could initiate another revolution by connecting several regional airports to reduce noise footprints or to relieve flight congestion. For example, a city like London could have Heathrow, Gatwick, Luton and other local airports coupled together with a transport system that could get a passenger from one to the other in a matter 15 or 20 minutes. That would create a single, enormous “virtual” airport. If bad weather or other incident should close one airport, the others could pick up the slack. Even a backup airport 100 miles away such as Birmingham would cause less than an hour’s delay with a TEV system. In fact, this application might be ideal for a prototype test program for the TEV system.
11 Energy supplies for the future

If we succeed in building any kind of electrically powered transport system how do we provide it with the huge amount of electrical energy it requires? The generating capacity of the planet will be far too low, and many more power stations must be built, especially in the developing countries, to catch up with the more advanced countries.

And what kind of power stations will they be? They can’t be coal or oil, or natural gas or ethanol or methanol or any carbon-based fuel, because these all make greenhouse gases. If we want to avoid burning all hydrocarbon fuels there are only two present possibilities, wind farms and nuclear energy.

1. Wind farms. The big new wind turbines, over 5 megawatts in size, are impressive machines so wind farms may finally live up to their promise – especially if used on a large scale in remote areas like the Midwest of the USA. In densely populated places like Europe, however, it is far more difficult to justify. Cost per kilowatt-hour is dropping slowly but from a very high base price. Wind power is the most successful of the renewable technologies, albeit partly due to subsidies, and almost certainly will contribute to energy production in the future. However, the wind is obviously not consistent enough to supply the primary base load source of electricity for TEV. We must have backup power generation of some kind and that effectively increases the cost per kilowatt hour.

2. Nuclear energy. Whether we like it or not, safe nuclear power is probably the only option that can presently be guaranteed to produce the vast quantity of energy required by the world on an acceptable schedule, with or without TEV. In any rational energy plan, therefore, nuclear power must be considered as a major contributor. That is bad news in the eyes of some people who class nuclear power as evil. But nuclear isn’t evil or good; it is just a means of producing energy. The good news is that it is now safer than ever - even if we use the old-style pressurized water reactors that we now have. But the even better news is that there are new ways of producing nuclear energy being developed that are vast improvements over this old technology. More on this in a moment. In the meantime, we should not forget why nuclear energy is such a strong contender: it makes cheap electricity, produces no carbon dioxide and generates around a million times
more energy per gram of fuel than coal or oil. In other words, it works!

Author’s note: I am not a fan of PWR reactors. But the dislike is not because they are unsafe but because they are inefficient: they waste 99.5% of their uranium fuel. Other designs, discussed later, can use virtually ALL the fuel and are a better choice.

Other sources of renewable energy such as solar power are frankly inadequate to make a large contribution to the supply of TEV energy in the short-term or medium-term, especially in temperate climates. While their development should continue to be encouraged for special duties, they can’t be depended on for base loads.

So, whether we like it or not, in the short to medium term most of the energy must come from nuclear power. There really isn’t much point in railing against atomic energy because there isn’t much of a choice. In the longer term, we may develop truly benign energy sources, perhaps based on the ideas of Nicola Tesla. But in our time, we will probably have to compromise and fix one problem at a time. Put it this way: nuclear power, even from inefficient PWR reactors, is far better than burning 5 billion tons of coal a year.

I hope that the declining number of anti-nuclear environmentalists will come around to a common-sense agreement on this point, because we don’t have a time to play politics. This is what James Lovelock, a revered leader of the environmentalist movement, has said on the subject:

“Only one immediately available source does not cause global warming and that is nuclear energy”.

“We have no time to experiment with visionary energy sources, civilization is in imminent danger”.

“Opposition to nuclear power is based on irrational fear led by Hollywood style fiction, the Green lobbies, and the media”.

“nuclear energy …has proved to be the safest of all energy sources”.

And from Patrick Moore, the co-founder of Greenpeace:
“In the early 1970s when I helped found Greenpeace, I believed that nuclear energy was synonymous with nuclear holocaust. Thirty years on, my views have changed, and the rest of the environmental movement needs to update its views, too, because nuclear energy may just be the energy source that can save the planet from another possible disaster: catastrophic climate change. Nuclear energy is the only large-scale, cost-effective energy source that can reduce these emissions while continuing to satisfy a growing demand for power. And these days it can do so safely”.

Nuclear power

Are the conventional PWR nuclear power plants, like the present US designs, safe enough to do the job? The answer is yes. The existing plants have worked very well and have proved themselves to be extremely safe. Not a single person has died from radiation in the entire 50+ years of the US atomic energy program. Furthermore, a lot has improved in design of plants over the last 25 years. We can proceed at once to scale up nuclear power production.

For comparison, over the same 50 year period, over 2 million people have died on US roads. On that basis, calling nuclear power unsafe is hysterical.

However, as mentioned, PWRs represent old technology and there are better types of reactor now available. We should be developing these at full speed. What are these options?

One better option: the Pebble Bed Reactor

The first alternative to the PWRs is the Pebble Bed reactor (PBR) which was the invention of Dr. Rudolph Schulter of Germany in the 1940s. One feature of this reactor is that it cannot have a core meltdown under any conditions – even if the cooling system is deliberately shut off during full power operation. In that respect, it is “intrinsically safe”. It is also a bit more efficient.

At present, China has the only operating pebble bed reactor in the world. Here is the opinion of Qian Juhui, President of the Nuclear Power Institute of China and made some time ago:

"Nobody in the mainstream likes novel ideas. But in the international nuclear community, a lot of people believe this
(PBR) is the future. Eventually, these new reactors will compete strategically, and in the end they will win. When that happens, it will leave traditional nuclear power in ruins."

Energy production is so crucial to our ongoing civilization it is necessary to develop all practical alternatives and let them compete. Right now, we may have to go with a few conventional PWRs. Later, when the Pebble Bed Reactor is fully developed, we may switch to that option.


Possibly the best option: The Liquid Fuel Thorium Reactor

However, in the opinion of many experts even the Pebble Bed Reactor is not the best nuclear option for the medium and long term. One of the most impressive and exciting systems available belongs to a completely different type of reactor called a Liquid Fluoride Thorium Reactor (LFTR) - or “Lifter” for short.

This amazing development was the idea of Dr. R.C Bryant and was championed by Dr. Alvin Weinberg in the 1950s and 1960s. Weinberg had earlier invented the PWR but preferred the Lifter design which uses a liquid fuel - molten thorium salts - instead of the solid fuels used on PWRs. The US government, on the other hand, preferred to finance uranium reactors. It was wartime and they wanted to produce plutonium to make atomic bombs. Lifters do not easily produce plutonium and this is one of its major advantages.

The LFTR design is so simple and so safe that it not only makes our present nuclear PWR reactors obsolete, it probably makes all other large scale energy production methods obsolete too - including burning coal and some natural gas. This reactor can be refueled on the fly and thereby run continuously. It can also be shut down easily.

The LFTR provides another tremendously important benefit: it is 200 times more efficient than the PWR reactor. That old PWR technology wastes 99.5% of the uranium fuel. The Lifter, on the other hand, consumes nearly all its fuel. It may not be an exaggeration to say that the Lifter will be the main source of electrical energy for the next century, giving us time to build newer and even better technologies.

Thorium is so plentiful in the earth’s crust that we will never run out of it and thorium reactors are so safe that we could put them inside cites,
where the actual power is used and thereby save the 10% loss of energy that is typically wasted in long power lines.

Here are some of its other Lifter advantages:

- It is unpressurized so there can be no explosions
- It uses no water cooling
- It is intrinsically stable and safe
- It produces no plutonium (bomb material)
- It is refueled continuously
- If power is lost the fuel drains out by gravity into a safe tank
- (Once again) It is 200 times more efficient than the PWR
- One trainload of thorium (15,000 tons) is enough to supply the entire world’s electricity needs for one year.

Please take the time to listen to the following YouTube video on the subject. It may change your entire outlook on nuclear energy:

[http://www.youtube.com/watch?v=D3rL08J7fDA](http://www.youtube.com/watch?v=D3rL08J7fDA)

**We must start with PWRs**

Wonderful though the thorium reactor is, it will take a few years to develop fully. So, we must be pragmatic and use what we have. After all, anything is better than burning 5 billion tons of coal a year so we may well have to rely on PWRs in the short term. If this sounds terrible it is partly because there are many myths about conventional PWR nuclear plants that have been created by its opponents.

The objective truth, based on actual operations over many decades, is that the PWR is a very clean, safe and environmentally friendly method for making electricity. So let us expose some of these myths with some more quotes from Patrick Moore:

**Myth 1: Nuclear energy is expensive:** It is in fact one of the least expensive energy sources. In 2004, the average cost of producing nuclear energy in the United States was less than two cents per kilowatt hour, comparable with coal and hydroelectric. Advances in technology will bring that down further in the future.
The cost of nuclear energy is lower than that from oil or gas and doesn’t generate greenhouse gases as those do. With mass produced thorium

**Myth 2: Nuclear plants are not safe.** Three Mile Island was in fact a success story; the concrete containment structure did just what it was designed to do – prevent radiation from escaping into the environment. And although the reactor was crippled, there was no injury or death among the nuclear workers or nearby residents.

Chernobyl was….an accident waiting to happen. This early model Soviet reactor had no containment vessel, (and) was an inherently a bad design. The multi-agency U.N. Chernobyl forum reported last year that 56 deaths could be directly attributable to the accident, most of those from radiation and burns suffered while fighting the fire. Tragic as those deaths were, they pale in comparison to the more than 5,000 coal-mining deaths that occur world-wide every year. No one has died of a radiation-related accident in the history of the U.S. civilian nuclear reactor program.
Myth 3: **Nuclear waste will be dangerous for thousands of years.** Within 40 years, used fuel has less than one-thousandth of the radioactivity it had when it was removed from the PWR reactor. And it is incorrect to call it waste, because 95% of the potential energy is still contained in the used fuel after the first cycle. Now that the U.S. has removed the ban on recycling used fuel, it will be possible to reduce the amount of waste.

Myth 4: **Nuclear reactors are vulnerable to terrorist attack.** The six-feet-thick reinforced concrete containment vessel protects the contents from the outside as well as the inside. And even if a jumbo jet did crash into a reactor (after breaching) the containment, the reactor would not explode. There are many other types of facilities that are far more vulnerable.

Myth 5: **There is a shortage of uranium fuel.** On the contrary, there is a glut of uranium in the world, with enough known reserves to last a century or more. With the availability of breeder reactors, there is enough uranium to last many more centuries. Also, scientists have calculated that there is enough uranium is sea water to last billions of years and could be extracted at an economic price. By then, we should have an even better technology.

- Author’s note: Thorium is even more plentiful in the earth’s crust, and thorium reactors are much more efficient, so one small mine, digging up a mere 15 thousand tons of thorium, which is about one train load, could power the entire world for one year replacing billions of tons of coal.

Most U.S. oil consumption, over 70%, goes to transportation, so the electrification of transportation - cars, trucks, trains, buses, ships, and aircraft - is the single biggest factor in reducing dependency on oil without producing greenhouse gases. This is where TEV can make a huge contribution, so long as we can get the electricity.

It is difficult to put a PWR reactor on “idle” at night when the demand for power is low. Therefore, such plants have an enormous “spare” capacity during off-peak hours. This capacity could be sold cheaply to encourage people to use the “off-peak” power available at night.
How do we solve the energy problems of the developing nations?

Poorer nations will need help for many years to come. Money subsidies, however, are notoriously inefficient because they can be siphoned off by corrupt officials into secret bank accounts. An energy subsidy using Lifters may be an ideal alternative.

Ideally, by the end of the 21st century, technology may have advanced enough to allow us to produce energy on a vast scale with a completely different and even better method. But, in the meantime we will do well just to avoid regressing.

Where does the hydrogen economy fit into our future?

A minor cult has developed in the Western world around the concept of a “hydrogen economy”. In this scenario, the future lies in burning hydrogen as a fuel instead of fossil fuels. This attractive concept is extremely misleading because, unlike real fuels, hydrogen does not exist naturally.

Many media people repeat the mantra that hydrogen is the most common element on earth and that we have plenty in plain water. Of course there is hydrogen in water, but it represents energy that is already spent. It is like saying that there is plenty of carbon in the greenhouse gas carbon dioxide. But you can’t burn that carbon to make energy because it has already been burned. Likewise, water is the ash that is left over after burning hydrogen.

Simply put, oil, coal, natural gas, uranium and thorium are all primary fuels. They are all found in the earth, to be dug up and consumed. The energy they yield to us is already stored inside their chemical structure and bursting to get out, so to speak. But there are no hydrogen gas fields in the world, waiting for us to find. None! All hydrogen must be manufactured. And when it is manufactured, using electricity, it contains less energy than the electricity that was consumed to make it. Duh!

The so called “hydrogen economy”, therefore, is a delusion. A sensible use of hydrogen would be to use cheap nuclear power, generated at night, to extract hydrogen from water and store it somewhere. It would be expensive but very clean. Perhaps it could be used to power jet aircraft where the outside temperature will keep the hydrogen cold and prevent it from evaporating to waste.
Hydrogen can be used to power conventional heat engines directly in place of gasoline. In fact, several prototypes of hydrogen powered cars are running around at present. They drive much like normal cars and produce no carbon dioxide in their exhaust gases. But they are a fiction as we see later.

So why don’t we solve the problems of global warming and global oil dependency by converting to hydrogen-burning cars? The answer is that it is not efficient.

- First, hydrogen is made from electricity.
- Then it is compressed which loses more energy.
- Then it is piped to its destination which loses more still.
- Then it is burnt in an inefficient engine which loses even more.
- So only a small percentage of the original electrical energy is available to move the car.

Compare this with the high efficiency the TEV system where the electrical energy is distributed very efficiently from the power station directly to the electric drive motors on the cars. A TEV electric drive system is many times more efficient than an engine burning hydrogen.

**What about hydrogen fuel cells?**

The fuel cell car, running on hydrogen is another favorite of idealists, particularly naïve ones. *(Author’s note: I ought to know; I wrote a breathlessly positive paper on the concept in my student days over forty years ago).* One advantage is that the fuel cell has over the hydrogen engine is that the fuel cell is about twice as efficient. This is a useful improvement but still much below TEV efficiency.

All the other problems are the same as for the hydrogen engine: the distribution of hydrogen is just as difficult, the storage of hydrogen in the car is just as difficult, the driving range is better but still limited. And fuel cells do not like cold temperatures. So, it is probably true that TEV makes the fuel cell car obsolete.

The following quote by the researcher and author Jeremy Romm in his excellent book on fuel-cells called “The Hype about Hydrogen” ends that debate with brutal honesty. When a senior manager from a famous Japanese car company was asked by a hydrogen believer when their fuel cell car would be ready for production he said: “*Would you be unhappy with me if I said never?*” Never is the correct answer. Forget it.
The bottom line

Engine powered vehicles produce one third of American greenhouse gases. Other countries have a similar situation. This is a huge problem because vehicles need an energy-dense fuel like gasoline or diesel and have it delivered safely all over the land. The magic of the TEV system is that it can solve this combination problem of energy production and distribution to the individual vehicles with a simple, technical solution that is easy to implement.

TEV does not need to spend huge amounts of money and many years of research – like fuel cells and other new concepts do - because there are no breakthroughs required. TEV will work quickly and cut any county’s carbon emissions in half within about two decades. That is fast. No other plan even comes close. So, attacking this major source of pollution with the TEV system is a quick way to do something instead of just talking about it.

TEV will eliminate a huge amount of greenhouse gases for two reasons. One is because it runs on clean electrical energy but the second, and equally important, is that it also conserves energy due to its much higher overall efficiency. This is enough to justify a full scale “Manhattan Project” type of effort to get TEV and clean nuclear power into use quickly. There is no technical risk. The result will also:

- Dramatically reduce the word’s dependence on oil.
- Change the political climate and reducing the risk of wars.
- Preserve our oil supplies to make plastics and other useful products; it is too precious to burn as a cheap fuel.
- Reinforce the fundamental concept of freedom to drive anywhere, at any time, without interference from government.
Management and cost

How do we get the TEV project up and running? The following is a plan that makes commercial sense as well as common sense.

First, build a prototype TEV track a few miles around. Include an Entrance and an Exit. At the same time, modify some vehicles to drive on the track; the automotive companies will provide those vehicles themselves out of self-interest. This minor construction project would become a joyride for thousands of engineers and businessmen from all over the world even if they disliked the idea at first. In short order, a real TEV track would convert most people immediately at a trivial cost considering its value to the project.

Second, build a separate two-way 40-mile test track between two cities, For example, in Scotland, it could be between Glasgow and Edinburgh. Similar cities exist elsewhere around the world. Let each country make its own track between the cities for internal education. Then encourage car manufacturers to run their own electric vehicles on those tracks in full dual-mode format; that is, allow the cars to enter from the street, run on the track and leave to the street.

Third, allow public-service vehicles like minibuses to use this track with paying passengers. By now, everyone would see the sense of the system and how easy it was to use. The public would now want to use it with their own electric cars. The car manufacturers would have their own test tracks, of course, but this neutral “official” public track would give them great publicity.

A 40-mile prototype TEV track would become a substantial draw for the two cities involved. Interested parties from other countries would come to see and experience the new system. Local hotels and restaurants would benefit.

In the meantime, the test tracks would be racking up miles of real-world usage, allowing engineers all over the world to optimize the design of the track, the software, the road repair equipment and so on before freezing the final design of the system. In fact, the test tracks could end up being useful as a practical method of connecting two airports: if there were fog in Glasgow, for example, a plane could land in Edinburgh and passengers take the 20-minute ride to Glasgow on TEV minibuses.
The most important and last step would be to define the standards for TEV tracks formally so that every country in the world could build to that same standard and ensure that they are not left behind in the future.

**Who will pay for commercial construction of the tracks?**

The final section of this booklet is concerned with how such an extensive project as TEV can be implemented in risk-averse world. The answer is the same one it has always been: *make it pay for itself with a good return to investors*. TEV must be a financial success story before it can be a technical, environmental or political success story.

Most people think that government subsidies are necessary to bring the TEV system to life. But that thinking is out of date and not even true in many parts of the world. One reason is that many governments are already bankrupt and don’t have the money to spend. So, it is best to work under a public/private arrangement using private capital.

(Note: Having said this, there is no reason to avoid government subsidies during a deep recession. In the 1930s depression, the US government subsidized the building of road bridges all over the USA. They created lots of jobs and radically improved the road infrastructure. It is probably the BEST form of government spending possible because it increases wealth in the long term).

With respect to the preferred private capital, William Reinhardt, an expert in **Public-Private Partnerships (P3s)** in the transportation construction industry, makes the following optimistic statement:

> “Two decades of experience have shown that private investment is attracted to large, complex and expensive transportation projects that add new capacity to the US system and can be supported by a new revenue stream, usually tolling”.

Of course, government support in the form of approvals and oversight is necessary but TEV must be developed by using a public-private partnership approach. The government may oversee the project but investors should take the risks and be fairly recompensed via toll revenue. There is **plenty** of wealth available in the world to invest in a company that has a good profit potential. The good news is that TEV could become one of the most profitable investments in the history of mankind. Best of all, it should not need permanent subsides as trains do.
We would therefore propose the founding a central joint stock company having several daughter-companies each dedicated to a different country but joined in a cooperative agreement to share technology and to maintain common standards. Joint stock companies were how the railways and other radical projects of the industrial revolution were developed in nineteenth century in Britain and elsewhere. It is time we returned to using these strong and innovative entities for large projects such as TEV.

How much would TEV cost?

These are some actual construction costs in dollars per mile for the US Interstate Highway system in 1994 and 1996 dollars. Present values would be about 40% higher than those shown:

- Boston Big Dig $1000 million/mile
- New York City $333 million/mile
- Los Angeles $127 million/mile
- Los Angeles elevated $20 million/mile
- LA car pool lane $2.5 million/mile
- Pool lane tollbooths $30-50 million/mile
- Rural highway $1 million/mile
- Mountainous $15 million/mile
- Rural + urban in USA $20 million/mile

It should be obvious that TEV tracks would be far lower in cost for most of these constructions, especially difficult ones like roads into cities, or across mountains, or roads with tollbooths – which TEV replaces directly.

TEV expansion would be funded by tolls paid automatically by the users. The joint stock company would get a return on its investment by taking a percentage of the tolls. The government, likewise, would get its share of tolls as revenue. It really isn’t a difficult task as the following list indicates:
**The outline plan**

1. Set up a parent joint stock company to recruit daughter companies internationally.

2. Set up an international consortium to define a single TEV design standard for word-wide use and to manage the project.

3. Define the project targets and schedule.

4. Delegate the development of hardware and software systems to specific organizations. (For example: vehicle design to the car companies).

5. Select several locations around the world for the building and testing of full-scale prototype tracks, as described already, but complete with Stations, Stops and Entrances.

6. Build several full-scale systems and test them in the real world before releasing them for public access.

The result will be a clean, efficient, world-class transportation system worthy of the twenty first century, developed and funded by big companies from Europe, China, Japan, the USA and others. The companies might be in the business of automobiles, engineering, electricity production, electric motors, batteries, power systems.

Progress on the entire TEV development project would be reported on a continuing basis on an internet website complete with videos, technical performance reports and so on. Everyone in the world would be able to see what was going on directly. So TEV would also be an exercise in open development systems development in democracies.
Conclusion

To the reader I say: let’s stop arguing over climate change, oil dependency, pollution, and future restrictions on our freedom to drive cars. We can now DO something substantial that will make a real difference.

All we need is a system like TEV plus a safe electricity supply. Initially this could be with big generators powered by gas turbines plus conventional nuclear reactors. Then, later, we can switch to a safe, liquid-fuel thorium reactor program to support us for the longer term.

*Remember that transportation produces about a third of all the carbon dioxide in the world. But there is good news: TEV could reduce those emissions in half in the next 20 years, all over the world!* No breakthroughs are required. Just good engineering.

With TEV, your descendants will still be able to live in the suburbs, tend their own gardens, drive their own EVs and still be responsible environmentalists. It doesn’t get much better than that. So, please support TEV.

Watch [tevproject.com](http://tevproject.com) for news.

Will Jones

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