The Oil Drum
DISCUSSIONS ABOUT ENERGY AND OUR FUTURE

Multiple Birds – One Silver BB: A synergistic set of solutions to multiple issues focused on Electrified Railroads

Posted by Prof. Goose on July 15, 2008 - 11:05am
Topic: Alternative energy
Tags: electrical transmission, electrification, national defense, non-oil transportation, original, peak oil mitigation, railroads, silver bb, urban rail, wind [list all tags]

This post was written by Alan Drake in response to an indirect query from an elected official. We wanted to put it up on The Oil Drum and let the infamous "TOD Meatgrinder" help vet the proposals--so we hope you will help Alan out. From what Alan tells me, this is a real shot at influencing public policy.

Problems:

- Excessive Oil Consumption by the USA, much higher than OECD average
- Economic, Energy, and Environmental costs with related National Security issues that result from excessive oil consumption
- No Real Plan to Significantly Reduce Greenhouse Gas Emissions
- Lack of Non-Oil Transportation: there are no alternatives for essential transportation that don’t use oil
- Inadequate Railroad Capacity
- Speed and reliability of today’s Rail Freight cannot compete with Truck Freight for many cargoes
- Weak Electrical Grid with limited inter-regional transmission and stability problems
- Lack of markets and transmission capacity for remote Prime Wind Farm Sites
- Chronic Under-investment in long lived, beneficial infrastructure

The Silver BB

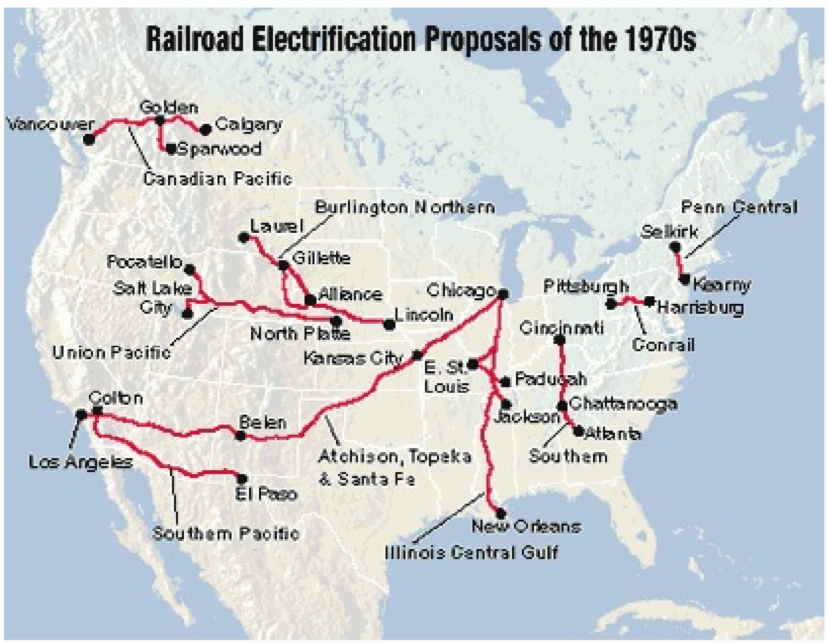
- Electrify 36,000 miles of mainline railroads
- Expand Railroad capacity and speed by adding double tracks, better signals and more grade separation
- New 110 mph tracks for passengers and freight added to existing rail ROWs as a second step
- In many, but not all cases, use the railroad ROW as new electrical transmission line corridors
- Promote the use of rail lines, usually spur lines, as wind turbine sites with rail transported cranes and materials
- Take advantage of the lower marginal economic costs of railroads, where the more we use it, the less it costs per unit. A diffuse economic benefit for many sectors of the economy.

The consensus on The Oil Drum is that there is no single “Silver Bullet” to deal with our related energy, oil and climate change problems, Rather a series of “Silver BBs” will be needed. This essay is about a cost effective, medium term, multi-faceted, synergistic Silver BB arguably our best one.

The USA has almost no Non-Oil Transportation and no real plans to create a parallel alternative to our existing Oil Based Transportation system. This is a deliberate policy choice because other nations, such as France, are moving aggressively to create a comprehensive Non-Oil Transportation system (see Appendix One).

Electrifying our freight rail system will provide a Non-Oil Transportation alternative in an oil emergency, whether acute or chronic. Regardless of oil prices or availability, there would be a backbone of essential long distance transportation that requires no oil. And the USA, with Peak Oil arriving, appears to be moving rapidly towards a chronic oil price and affordability emergency.

This was the aborted response to the last oil crisis:

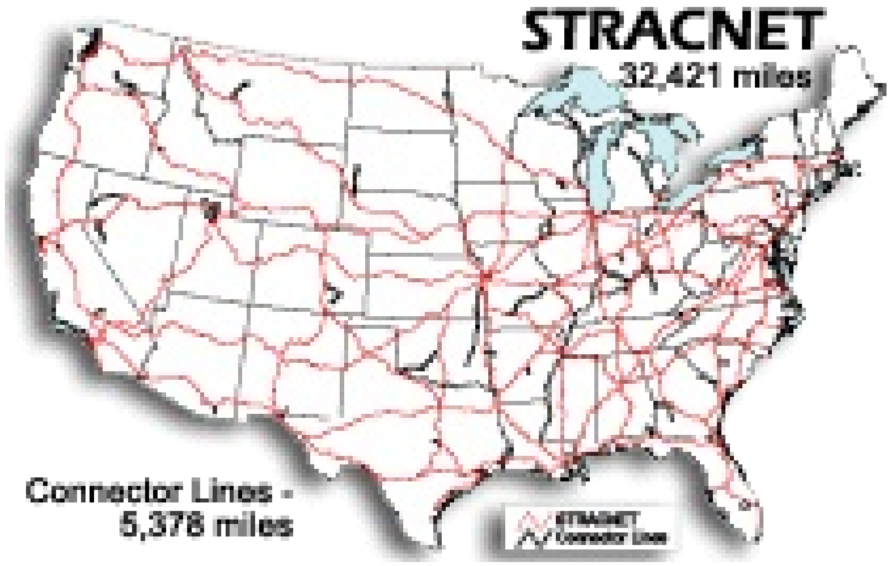


Properly done, relatively small federal incentives can stimulate a roughly $90 billion investment in a short time period with a wide range of benefits, in large part due to the rapidly shifting economics of oil use.

A Major Benefit - Reduced Oil Use

Oil can be saved from the diesel that railroads use today (231,000 barrels/day in 2006) and from truck freight (2,552,000 barrels/day in 2006) by switching to electrified rail. Trucks carry about a quarter fewer ton-miles than rail, but with 11 times the oil.

The USA has 177,000 miles of railroads, with the Department of Defense classifying 32,421 miles as strategic (STRACNET). These selected rail lines correlate closely, but not exactly, with what are considered “main line” railroads. DoD only selected one rail line when two main lines parallel and a few main lines are not considered strategic. 36,000 miles should cover all of the main lines.



The Pareto Principle (also known as the 80/20 rule) suggests that the 36,000 miles of main line railroad should carry 80% of the railroad ton-miles, and burn 80% of the fuel (there being no electrified freight lines in the USA), or 185,000 barrels/day.

Electrifying 36,000 miles of US railroads could take as little as six years with “Maximum Commercial Urgency” (see Appendix Two). The Russians electrified the Trans-Siberian Railroad in 2002 and to the Arctic port of Murmansk in 2005, so there are no technical obstacles to electrifying American railroads. [See Appendix Three for an overview of foreign electrified rail lines].

However, this calculation of 185,000 barrels of oil/day saved seriously underestimates the fuel saving potential, especially in an oil constrained future, Transferring just 8% of the truck ton-miles to electrified rail would save another 204,000 barrel/day. Transferring half would save 1,276,000 barrels/day, plus the 185,000 barrels/day for 1,461,000 barrels/day saved (roughly equal to ANWR at its peak, but electrified rail does not deplete - which ANWR inevitably will). Transferring 85% of truck freight to rail, and electrifying half of US railroads, which the author considers to be possible with a large enough investment (see Appendix Four), would save 2.3 to 2.4 million barrels/day. That is 12% of USA oil used today for all purposes, not just transportation.

This dwarfs any other “silver BB” being actively discussed that can be implemented quickly. And best yet, no new technology is required. This analysis shows that the major oil savings are in transferring freight from trucks to electrified rail. Electrified rail passenger service is an added, but unspecified, bonus.

Electric Grid and Renewable Energy Benefits

Electrification will likely require substations every 20 to 30 miles, depending on the voltage chosen and the traffic density. In the more remote areas, the railroads will not be able to tap into the local grid and will have to bring their own high voltage lines with them, as Amtrak does on the Northeast Corridor from Washington DC to New Haven Connecticut. This will require new electrical maintenance work crews at the railroads, with supporting infrastructure, hired and built from scratch.

One innovative alternative is to use the existing railroad ROWs as electrical transmission corridors and have electrical utilities sell “Power at the Wire” to the railroads, if the railroads prefer that option. What would be a headache and a problem to the railroads - providing both high and medium voltage transmission along their ROW - is a scarce and valuable asset to the electric utilities.

The utilities will deal with one landowner instead of 10,000, two or three years to build instead of twelve years: a new customer immediately underneath their wires and special tax and financing incentives. The railroads can chose to go into the electrical transmission business if they so wish, or just supply their own needs, or buy “power at the wire” and let someone else perform their core competency while the railroads do theirs.

I would suggest both HV AC and HV DC transmission in many corridors, with HV DC being the long haul, high volume (only 5% loss per 1,000 miles) transmission and HV AC being the regional feeder and the feeder to the trolley wire.

A secondary benefit of these new transmission corridors will be to provide new markets for renewable, especially wind generated, electricity. In particular, HV DC could supply markets that are over 1,000 miles away.

Rail spur lines could also serve as sites for long rows of wind turbines. Today, the size of wind turbines is often limited by the capacity of local roads and bridges to support the large cranes involved, even though “larger and taller” is better in wind turbine economics. Rail mounted or rail delivered cranes to a series of wind turbines could potentially install 5 MW wind turbines now seen only at sea.

Rail spurs always connect to main line railroads and the HV transmission on these main lines could ship power to markets in distant cities and states.

If we wants significant improvements to our nations electrical grid within a decade, to support a more reliable grid and more renewable generation, electrified rail corridors are the best, and perhaps the only, hope.

More discussion in Appendix Five.

Energy and Environmental Benefits

Transferring freight from truck to electrified rail trades 17 to 21 BTUs of diesel for one BTU of electricity. Simply electrifying existing rail freight would trade 2,6 to 3 BTUs of diesel for one BTU of electricity.

Transferring 100% of inter-city truck traffic (impractical) to electrified railroads, plus electrifying all (not 80%) of the existing rail traffic, would take about 100 TWh/year or 2.3% of total US electrical demand. Electrifying 80% of railroad ton-miles and transferring half of current truck freight to rail would take about 1% of US electricity. 1% is an amount that could be easily conserved, or, with less ease, provided by new renewable generation and/or new nuclear plants.

Such dramatic savings from shifting trucks to electrified rail means that electricity from modern coal plants, the worst environmental option to power electrified railroads, is still a large net environmental positive. The ability to use non-Greenhouse Gas sources of electricity, renewable and nuclear, creates the very real possibility of both Non-Oil and Non-GHG Transportation systems.

Appendix Six discusses this in more detail.

Economic Benefits

Electric locomotives can accelerate and brake faster because electric motors can be (and are) routinely run above their rated power for up to an hour without damage. The on-board diesel generator of a diesel-electric locomotive cannot supply this surge of power, but a trolley wire can. This extra acceleration and braking creates a 15% increase in track capacity for freight trains, as well as faster transit speeds.

In commuter train service, travel times are typically cut by 15% with electrification, which reduces labor and rolling stock costs and will increase ridership. All of these factors will reduce local subsidies for commuter rail, even at increased levels of service.

SBB (Swiss Rail) will operate up to 300 trains/day, at mixed speeds of 110 to 240 kph (66 to 150 mph) and with trains up to 1.5 km long, through a 58 km dual bore tunnel. Such volumes would be impossible without electrification. Few dual track US rail lines, operating with diesel-electric locomotives, can handle more than 100 trains/day.

Adding capacity for "rubber tires" (trucks, cars and SUVs) costs more for each additional unit (in capital or congestion costs). Adding just one lane to a freeway can cost more than the original freeway, even after adjusting for inflation. The more we use rubber tires, the more the average cost rises - a negative cost elasticity of demand.

On the other hand, rail, both freight and urban, has a positive cost elasticity of demand, Adding additional capacity lowers average costs instead of raising them, since the marginal cost of new capacity is typically lower than the initial cost per unit of capacity. Electrification by itself increases rail capacity by roughly 15% due to faster acceleration and braking and costs much less than 15% of a new rail line.

In simplest form, a double track railroad can carry 3x to 4x the freight of a single track railroad, but adding back a track torn up in the 1960s will not double costs. Some infrastructure, such as ROW and signals, can be used for either one or two tracks. Improved signals are an even more cost effective means of adding capacity than adding track.

Not only will double tracking dramatically increase capacity, it will also increase speed and reliability since trains will not have to queue for their turn or wait on a passing siding as trains come the opposite direction on a single track. This lowers labor, rolling stock and customer costs (the costs of slow transit and uncertainty about delivery dates).

Road damage is roughly proportional to the fourth power of the axle load. A 20,000 lb axle causes 16 times as much damage as a 10,000 axle, and 160,000 times as much damage as a 1,000 lb axle (wider tires mitigate the effect slightly). The net result is that 99% of the traffic damage to roads and highways comes from trucks and buses and far exceeds any fuel taxes paid. Removing as many trucks as possible (and shifting to Urban Rail with smaller feeder buses) is the best hope for keeping road maintenance affordable.

A massive capital spending program on long lived infrastructure that eliminates oil use is a nearly ideal economic stimulus. The majority of spending should be for domestic goods and services.

Rail freight is also significantly safer than heavy truck freight per ton-mile. Another economic, and human, benefit that could save thousands of lives each year. Electric rail should generate significantly less pollution, even after accounting for electrical generation.

The cost of electricity BTUs are much lower than the cost of diesel BTUs today, and are likely to stay cheaper and more stable. The only significant imports of electricity are from Canadian hydroelectric projects, which are superior to Middle Eastern and Venezuelan oil imports in several ways.

National Defense Benefits

Nations can be defeated in two ways: on the battlefield or by collapse of the Home Front. During World War I, both Russia and Germany were defeated by a collapse of their respective home fronts.

In the author's rough judgment, if the USA lost 6 to 7 million barrels/day of oil imports for 24 to 30 months, without any preparation or warning, and with a less than ideal crisis response, not only would the US economy collapse, but food distribution would become erratic as the effects of severe oil shortages cascade over time. If the USA cannot even feed its citizens, it is effectively defeated.

Military analysts will immediately think of the Islamic Republic of Arabia replacing Saudi Arabia and other Gulf States, or the Straits of Hormuz being blockaded, or submarines around the Straits of Malacca stopping the flow of oil as part of a larger conflict. These are all credible threats to our national security and survival.

There is a different threat, rarely considered. If the US dollar collapses, and the USA has to buy oil with its exports, cash instead of credit, oil imports could be reduced by 6 to 7 million barrels/day, depending upon the scenario. Such an economic scenario has the unpleasant result of the USA being defeated, but surrendering to no one. A siege without end.

A related threat is posed by the post-Peak Oil world, where world oil exports are collapsing faster than world oil production. The economies of oil exporters boom, expanding domestic consumption and reducing their exports significantly faster than their production declines. A half dozen years after world oil and "all liquids" production peaks, world oil exports (not production, but exports) can be reduced by half, two thirds, or more. A number of real world examples of this Export Land Model have surfaced in the last few years. In the author's opinion, this is the most likely scenario and a very real threat to national security - even survival.

Creating a Non-Oil Transportation System

Electrified railroads, a massive build–out of Urban Rail, much more bicycling and many more walkable neighborhoods, could insulate the USA from the worst effects of a prolonged oil emergency from any cause. Switzerland and Sweden used precisely these strategies to survive and function during six year long, 100% oil embargoes. The most crucial of these four elements of Non-Oil Transportation is electrified railroads but all four will be needed.

36,000 miles of electrified and expanded rail lines could provide a Non-Oil transportation backbone for this nation for both essential goods and some passengers. Total volumes would likely decline with the economic stress, so almost all freight (and many passengers) could be transported long distances without oil. Trucks could be used only for local deliveries and sites remote from rail sidings, just as the USA did during World War II.

The Best Policy by Every Metric

An as yet unpublished analysis by the Millennium Institute using their T21 model strongly implies that a combined policy of a maximum push for renewable energy with a maximum push for electrified transportation (railroads and Urban Rail) gives the largest GDP, the largest reduction in Greenhouse Gases and the Largest reduction in oil consumption over decade and longer time horizons,

The best Economic Policy is the best Environmental Policy and the best Energy Policy ! And such a policy combination also has extremely positive National Defense implications. With some justification it could also be called the best National Defense Policy as well.

Just two major policy initiatives, renewable energy and electrified rail (Urban & freight) address every major public policy conundrum. If pursued with extreme vigor, these two policies, combined, are better than every other examined alternative.

One interesting observation is the positive effects of these two policies were not simply additive but multiplicative. There is a subtle but strong synergy between these two policies for the economy, energy and the environment.

The limitations of the Millennium Institute project did not allow for modeling increased transportation bicycling, but there is no doubt that any increase in bicycle modal share can only improve the results by every metric.

The First Step (Small)

Politics is the art of the possible. If only minimal funding of $1 billion/year or so is possible to support electrified rail, despite the enumerated benefits, then leverage is needed.

Most states are served by one or two Class I railroads, making a local monopoly or duopoly. Regionally, most of the Western USA is served by Union Pacific and/or BN-SF and the Eastern USA by Norfolk Southern and CSX. Canadian Pacific, Canadian National and Kansas City Southern provide a third Class I alternative in a few states.

This lack of competition stifles innovation. However, once one member of a duopoly successfully innovates, the other member is compelled to match them.

The issue then is to ignite the spark and get at least two of the Class I railroads (one each in the East and West) to make the first move. Such a “chain reaction” will not result in the fastest possible electrification and expansion, but it will eventually get us there.

The incentives given to the first six nuclear power plants are a model for the “chain reaction” needed. Applied to railroads, this would give incentives to the first railroad to electrify (East & West) and none for the second or third. Of course, if two or three railroads electrify at about the same time (hopefully), the incentives would be split.

One way, of many, to ignite this spark would be to grant $1 billion/year (inflation adjusted) for ten years as a 25% tax credit for electrification, with no more than 66% going to either East or West of the Mississippi River. These benefits would be granted when placed into commercial service, then – and this is a crucial point - put on both a “first come, first served” and accrued basis.

To illustrate if $3 billion worth of tax credits are issued in 2011 for $12 billion of electrification, which would be $2 billion in excess of that years tax credit budget, the overage would be issued tax credits good for the 2012 and 2013 tax years. Any work completed in 2012 would be issued tax credits usable in 2014 and beyond until the tax credits are exhausted.

This accrual of limited tax benefits would place a premium on being first to complete electrification - which serves public policy goals admirably. And railroads that failed to join the rush to electrify would be forced by competitive pressures to electrify without tax incentives at a later date.

Ten years of $1 billion (2008 $) of 25% tax credits would support $40 billion worth (2008 $) of electrification. $40 billion of electrification should electrify about 16,000 miles of US rail lines.

The First Step (Large)

The USA needs to start electrifying our main line railroads. The railroads can do it, or utilities can do it and sell “Power at the Wire” to the railroads, and use the railroad ROWs as transmission corridors, strengthening our electrical grid and providing Non-Oil Transportation.

The United States of America needs electrified rail done as soon as possible, given the growing crisis in energy and climate. The “First Step (Small)” is clearly inadequate to the looming crisis.

The preferred alternative is to get everybody to electrify everything as fast as possible. The author believes that a fixed incentive would create delay and cautious evaluation in the early years, with a mad rush as the incentives expiration nears. A carefully timed decline in incentives, rewarding first movers the most but still providing reduced incentives for laggards, would have the greatest public policy benefit, i.e. the most electrified miles ASAP.

We also need to increase capacity, speed and reliability of rail shipments to better serve the economy and to attract more shipments from trucks.

Some Possible Incentives

A declining investment tax credit - An example, a 25% investment tax credit for electrification, given only when the electrification infrastructure is operational, that is flat at 25% for the first 30 months and then declines by 1% a quarter for four years to 9% and then continues at that level for several years. The electrification tax credit would be available to either railroads or electric utilities.

Since the major oil savings come from shifting truck freight to rail, increasing capacity by just 15% from electrification is clearly inadequate. Perhaps half of this tax credit (12.5%) could be offered for double tracking, improved signals and other measures that increase rail capacity, speed and improve reliability on electrified rail lines. No tax credit should be given for improvements to rail lines that are not electrified. A slightly slower decline in the investment tax credit could be justified for these improvements. Perhaps 12.5% for five years, then a half percent/year decline to 9%..

Reduced cost of capital - Railroads are a capital intensive business. To build out electrification and to expand and improve rail service as a viable Non-Oil Transportation alternative for all types of freight will require hundreds of billions of dollars. Lowering this cost, and making the capital available as needed, is a daunting challenge that needs federal support.

One alternative is Industrial Revenue bonds - a lower cost to the railroads and a higher cost to the US Treasury. However, a series of delays are endemic in issuing these bonds. A policy decision is needed to determine whether we should encourage these or not.

Another alternative is an US Treasury guarantees for railroad or electric utility bonds issued to support electrification and improvements to electrified rail lines. Such guarantees would use the rail lines as collateral. These bonds could be issued quickly, in volume and at reduced cost to the railroads or utilities.

One needs to remember that the USA is facing a growing and ever more desperate crisis fueled by a lack of oil at affordable prices. Such a slow motion but extraordinary crisis requires extraordinary measures.

Property Tax Exemptions or Caps – The traditional reason/excuse given by US railroads for not electrifying is that the electrification infrastructure will be subject to heavy property taxes, and railroad diesel is tax free. This is an obstacle not faced by other national railroads, most of which have electrified (See Appendix Three).

It appears that both the Interstate Commerce and Common Defense clauses of the US Constitution give the federal government the power to regulate local property taxes on interstate commerce common carriers.

One approach is to give property tax exemptions on new infrastructure for a limited time. Perhaps a 30 year property tax exemption for electrification and capacity expansion infrastructure completed by 2010, with that exemption shrinking by three years for each additional calendar year.

One possibility to assist local taxing jurisdictions would be to place a cap on their prospective losses for new infrastructure. Local taxing jurisdictions that lose more than, say, 0,3% of their revenues, could have the excess above 0.3% compensated by the federal government. Such a cap would dramatically cut the cost to the federal government. And once the property tax exemption expired, they would have new property to tax. There are many other possibilities.

Refocus Highway Improvements – Vehicle miles traveled are dropping and with that, the need for additional lane miles. Refocus highway improvements on railroad grade separation and improving access to inter-modal rail-truck-barge facilities.

State and locally owned railroads (Alaskan RR, Long Island RR, various port RRs, commuter rail lines and various branch lines) would receive XX% federal matching funds. I would suggest the same percentage used to build the Interstate Highway System, 90% federal matching then, 80% now.

A never before considered funding source, that follows Senator Russell Long's famous dictum "Don't Tax You, Don't Tax Me, Let's Tax that Fellow behind the Tree" is discussed at

http://www.theoildrum.com/node/3506

This could finance the massive rush to electrification and quite a bit of Urban Rail as well. And it reasonable to expect that those taxed would strongly support lower US oil consumption.

The Second Step – Semi-High Speed Rail

CSX has proposed an upgrade for its East Coast Line from Washington DC to Miami that should serve as a model for a national system of 14,000 or so miles. CSX proposes to grade separate the entire 1,200 miles, and run regular freight trains at 60 to 70 mph on two tracks. Between Richmond and Miami, there would be one track for passenger service at 110 mph, and two semi-high speed tracks between Washington DC and Richmond.

SBB (SwissRail) has firm plans for a new express freight service, with special streamlined cars, at 160 kph (100 mph). The CSX and SBB concepts should be merged and both 100 mph express freight and 110 mph passenger service should be run on new tracks built on existing railroad ROWs.

The USA does not have enough rail passenger demand to justify more than isolated sections of high or semi-high speed rail passenger only service. The author's position is that EU and Japanese style High Speed Rail is wasteful of both scarce capital and energy at this time,

HSR costs much more per mile than semi-HSR and cannot handle medium density freight, only passengers and light parcels. CSX estimates 1,200 miles of semi-HSR will cost $15 to $25 billion which is much lower per mile than any of the varying California estimates for High Speed Rail. Energy consumption increases with the square of the speed, a 190 mph train will use 3 times as much energy as a 110 mph train, a 220 mph train 4 times as much. The USA is not France: we simply cannot afford the "best" service in this generation and we do not have the energy to waste on maximum speed.

However, if express freight demand (with refrigerated vegetables and fruit being high volume customers) is combined with passenger demand, a viable national system can be created combining passenger service at 100 to 125 mph with express freight at 90 to 100 mph on existing but upgraded ROWs. The two concepts would work synergistically, operate on existing railroad ROWs and would economically justify a widespread network. Reliable 90 to 100 mph freight service should take modal share not only from trucks, but from air freight as well, vastly expending the scope of Non-Oil Transportation.

First Steps - Other Non-Oil Transportation

Vastly expanding Urban Rail, in towns as small as 100,000 (see Appendix One) has the potential to mitigate an oil emergency as much as electrifying freight railroads. An excellent first step would be to build "on-the-shelf" projects that could start construction (and create jobs) in 12 to 36 months from a national decision.

http://www.lightrailnow.org/features/f_lrt_2007-04a.htm

A jobs program focused on Urban Rail could create oil saving infrastructure that will last over a century,

Regional passenger rail, serving travel from 100 to 300 or 500 miles, has the potential to expand dramatically with an expanded and electrified rail system, with notable oil savings. Cross-country Amtrak is unlikely to gain significant market share, except in an extremely oil constrained future. Generally, in OECD nations, rail modal share drops quickly as trip times exceed three hours.

Additional non-published work is on-going for increased transportation bicycling and encouraging walkable neighborhoods and Transit Orientated development.

Necessary, but not Sufficient

Electrifying America's Railroads is not going to be enough to solve our energy and environmental problems without many other Silver BBs. But it is difficult to model a realistic solution that does not include electrifying our railroads and shifting much of our truck freight to rail.

The question is not "if" we will electrify our railroads, but "when" and "how fast."

Best Hopes,

Alan Drake

Appendix One

France – A Comprehensive Non-Oil Transportation System

- High Speed Inter-City Rail
- Inter-City Freight Rail
- Urban Rail
- Bicycles
- Walkable Neighborhoods

President Chirac made it a national goal to electrify "every meter" of the French National railroads (SNCF) and "burn not one drop of oil." This goal was set on January 1st, 2006 with a twenty-year deadline.

France has been building their famous TGV lines for over 30 years, one line at a time. Now that the original Paris-centric system is 100 km from completion, a new network of additions, bypassing Paris, have been announced and for the first time three different TGV lines are simultaneously under construction.

France has had an aggressive tram (Light Rail) building program for over fifteen years, with only five French towns of population 100,000 or more without a tram or plans for one. Recently, France has stepped up the pace with plans for 1,500 km of new tram lines (22 billion euros) in the next decade.

And then there is vélib', rental bicycles scattered every few hundred meters in almost a dozen French cities, typically with the first half hour free. A French bicycling initiative has a stated goal of 10% of urban trips by bicycle in 2010. Bicycle lanes and paths have been built, but so far only 3% of trips are on bicycles. This statistic is up from slightly more than 1%, so it is difficult to call the program a true failure.

During a prolonged oil emergency this new bicycling infrastructure, and the vélib', will see good use. A French Strategic Bicycling Reserve ? In the USA, only Portland, Oregon and Davis, California (to the author's knowledge) exceed the French average.

Mulhouse, France (population 110,900, metro 271,000) illustrates just how comprehensive the French program can be in a best case. This remote town where France, Germany and Switzerland meet, got its first tram (Light Rail) line in 2006. By 2012, they will have 58 km (34 miles) of new tram lines (they would also have had a tram line to Basel Switzerland if Franco-Swiss co-operation had been better).

In 2011, Mulhouse will be the temporary terminus of a new TGV line and 200 vélib', (rental bicycles) have recently been installed.

The end result is that by 2012 a resident of Mulhouse can walk out their door, grab a vélib', drop it off at the tram station or just walk, take the tram to the TGV station and be in Paris in 4 or so hours – or be anywhere in France in a long day, all with a drop or two of lubricating oil and minimal carbon footprint.

In the non-transportation area, France is installing large numbers of solar hot water heaters and geothermal heat pumps. With significant difficulty and economic loss, France could adapt to a prolonged loss of a large fraction of their imported oil.

Switzerland started building their Non-Oil Transportation system in the 1920's as a national defense policy. This policy enabled Switzerland to endure a six year 100% oil embargo during WW II with a functional industrial economy, democratic institutions and a deterrent defense.

Germany, unlike France, kept their urban rail network after WW II and has been steadily enhancing it instead of rebuilding it in a crash program. They are also building a high speed rail network, but at a slower pace than France and have world class insulation and energy efficiency standards.

Appendix Two

How quickly can the USA Electrify our Railroads ?

I contacted the premier US consultant I know of on this issue, John Schumann P.E. of LTK Engineering. He graciously gave me several hours of his time to work out a schedule for electrifying US railroads.

We assumed Maximum Commercial Urgency, the maximum effort that people driven by the profit motive can sustain on large scale projects. War time efforts are a step above Maximum Commercial Urgency since national survival is clearly at stake (the development of tar sands in Alberta Canada is a contemporary example of Maximum Commercial Urgency).

We agreed to five groups. Four would be run by the four major Class I railroads in the USA, Union Pacific, BN-SF, Norfolk Southern and CSX. Separate efforts by Kansas City Southern, the US divisions of Canadian National and Canadian Pacific, as well as Class II railroads such as Florida East Coast would be the equivalent of a fifth group. All five groups would make roughly equivalent efforts and try to create new electrification work teams at the rate of about eight teams/year/group, using a combination of in house labor and contracted labor. This is as fast as possible, within the boundaries of cost control (they would not be operating at war time urgency).

Our conclusion was that the following is an aggressive but possible effort for railroad electrification.

Year 1 – 0 (Design, Planning, Mobilization, Materials)
Year 2 – 5 x 500 miles = 2,500 miles
Year 3 – 5 x 1,000 miles = 5,000 miles
Year 4 – 5 x 1,500 miles = 7.500 miles
Year 5 – 5 x 2,000 miles = 10,000 miles
Year 6 – 4.5 x 2,500 miles = 11,250 miles

A total of 36,250 miles electrified in six years. The slight slowdown in the sixth year reflects a saturation of lines worth electrifying at Maximum Commercial Urgency. The low hanging fruit would have been picked.

Depending upon future oil prices and the efficiency of running an all-electric rather than mixed fuel railroad, the pace of electrification may slow after the main lines are electrified - or a prolonged oil emergency may compel further acceleration.

[Subsequent to our discussions, I discovered a never implemented 1979 contingency plan for British Rail that envisioned five teams electrifying 250 miles/year as a response to a prolonged oil emergency. This is 50 miles/year/team and we assumed 62.5 miles/year/team].

Appendix Three

Electrified Rail in Other Nations

As of 2000 (source Indian Railways*)

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Route km Electrified % Electrified Switzerland 3,284 3,057 93% Japan 12,668 8,939 71%

Sweden 11,797 7,440 63%

Italy 16,146 10,030 62%

Germany 40,710 16,202 40%

France 34,837 12,611 36%

Russia 88,716 38,600 43%

Ukraine 22,631 8,348 37%

U.K. 16,938 4,911 29%

Portugal 3,068 2,132 69%

South Africa 20,319 8,976 44%

India 63,140 16,986 27%

China 61,539 16,000 26%

From Azeri Railways

Azerbaijan 2,125 1,278 60%

* This is from a paper where Indian Railways argued that 27% electrification was clearly inadequate and failed to meet international standards. 20% electrification is proposed for the USA in this article.

More Recent Data

Switzerland – Switzerland voted in 1998** for a 31 billion Swiss franc 20 year program# to improve Swiss rail with one of the main goals to move freight from trucks to (hydro) electric railroads.

"*Railways handle 32% of Swiss freight traffic and 16% of passenger traffic, but they use only 3% of the total energy required for all transportation.*"
- SBB (SwissRail) Environmental Report

** Adjusted for population and currency, the Swiss plebiscite is comparable to USA citizens voting

$1 trillion to improve our railroads and reduce oil use. The Swiss have the deserved reputation as the most conservative nation in Western Europe. Making long term investments in efficiency to reduce energy dependence is seen as a conservative value.

Finland – 42% electrified.
-
France – 100% electrified by 2025.

"*Not one drop of oil will be burned.*" – President Chirac

Chile – North-South main line electrified (many years ago) and planned $2+ billion Trans-Andean link to Argentina will be electrified.

China - Plans to expand its rail system from 43,000 to 62,000 miles and electrify half of that network.

Taiwan – Just approved electrifying and partially double tracking the East Line, the last non-electrified main line.

India – 28% electrified today, recently 801 km more approved.

Iran – 148 km electrified in 2006; recently signed MOU with Russia to electrify about 400 km more.

Kazakhstan – Plans to sign contracts to electrify 2,700 km in 2009.

"Use of electric traction on railways is one of the most important technical measures to raise economic efficiency of the railway sector. For example, electric locomotives consume less energy and their exploitation takes less spending. The share of electric haulage carrier cost is 1.6 times less than on diesel traction locomotive"
- Kazakh Minister of Transportation

Korea – North – Reportedly 70% electrified in 1976.

Korea – South – 21% electrified (2000), goal is 100%.

Kyrgyz Republic – Just started electrifying ~105 km with a $100 million loan from Kuwait.

Mongolia – Seeking funding to electrify and double track 1,110 km Russia-China line (out of total 1,835 km).

Namibia & Botswana – New 1,600 km electrified rail line opens in 2009.

New Zealand – Electrification of commuter rail into Auckland approved.

Russia - Increased electrification from 43% in 2000 to 47% in 2007, including finishing electrifying the Trans-Siberian in 2002 and to the Arctic port of Murmansk in 2005. New plans call for electrifying more than 7,400 km (8.6% of current track) by 2030.

Saudi Arabia – New electrified rail line Mecca-Jeddah-Medina.

Sweden – Increased electrification from 63% in 2000 to 70% today.

Tanzania – Electrification of the main line a condition for 25-year concession

Turkey – New electrified passenger rail lines of 76 and 590 km are under construction and another new 471 km line has been announced, The status is uncertain on electrification of 1,300 km of existing rail lines previously announced.

UK – Dramatic but vague promises for massive rail electrification recently made by Government Ministers.

Appendix Four

How much truck freight can be shifted to rail?

The correct answer from several public policy perspectives is "*as much as possible, as soon as possible*".

There are several variables in this calculation:

Cost - Rail is already cheaper than trucking, but trucks have a larger modal share except for the lowest value cargoes (coal, gravel, grain). The cost differential is growing rapidly, and there is a shift from truck to rail, but not fast enough for public policy goals. Electrified rail will be even cheaper than diesel rail.

Speed & Reliability – It is critical to close the speed and reliability advantage that trucks have over rail. Electrification, double tracking, track improvements and better signals will all speed up trains and reduce the uncertainty about transit times and delivery dates.

Management Philosophy - Railroads currently want to run their tracks very close to capacity and they avoid "overbuilding" at all costs. A change in business philosophy will be required to capture higher value cargoes - cargoes from shippers willing to pay a premium rate several times coal rates. For example, Union Pacific stopped carrying UPS shipments because they did not want the operational hassle of running trains on time. US railroads will need to "overbuild" and change operating procedures to get the required capacity, speed and reliability needed to attract a majority of truck freight. Federal policy can help change this with incentives.

Semi-High Speed Express Freight - Offering express freight service (with refrigeration as needed) at 90 to 100 mph will capture large segments of the truck market and part of the air freight market. Express freight service is the essential economic driver for a 14,000-mile Semi-High Speed Rail network (more published at a later date on this). Regional passenger service at 110 mph will likely be a large but secondary benefit.

Time – Time will be required for shippers to adjust to rail. For example, WalMart has gone almost exclusively to trucking and their many regional distribution centers were built with only trucks in mind. WalMart, and other like shippers, will have to build new regional distribution centers that can accept container trains from ports and domestic factories, and the railroads will need to improve service enough to attract behemoths such as WalMart. Under the pressure of ever-higher oil prices, such changes will still likely take a decade to complete (and the abandoning some not fully depreciated real estate).

In some cases, rail will come to the factories and distributors with new spur lines. In other cases, the factories and distributors will move to rail spurs. And in many cases, "the last mile" will be by truck from a local or regional rail-truck inter-modal facility. The key to such a large scale migration is improved rail service more than a cost differential.

During WW II, public/military policy was to ship everything by rail and as little as possible by truck in order to save fuel and trucks for overseas operations. Lieut. E. L. Tennyson, Office of Chief of Transportation, US Army states that 90% of ton-miles in the 48 states were by rail during WW II.

Ed Tennyson has made the rough estimation that a $250 billion investment in rail infrastructure (electrification, double tracking, no semi-High Speed Rail) would result in an eventual transfer of 67% of truck ton-miles to rail in a high oil price environment.

I believe that, in an environment of very high oil prices, an investment of $400 to $450 billion (including semi-High Speed Rail and some new rail lines) could result in an 85% shift of existing truck freight ton-miles to rail. It is difficult to calculate the long term road maintenance savings from such a shift, but that savings alone may justify such massive investments. The bulk of rail investments have 50-year useful lives.

A nation-wide improved and electrified rail system would be a very worthwhile inheritance for the next generation facing a post-Peak Oil future.

Appendix Five

Railroad Right-of-Ways as Electrical Transmission Corridors

The railroads will have no choice but to supply their own high voltage to their substations in less populated areas of the USA. This is a major additional cost but it can also be a major benefit if the larger grid uses these new transmission lines. Most railroad ROWs are 100’ wide, which allows for multiple tracks and high voltage transmission towers.

Rail lines running through densely populated states might have the option to tap into local power lines for each substation (Amtrak did this from New Haven to Boston) but there are financial advantages to selecting the lowest cost utility and paying for only one system peak charge instead of a series of local peak charges. Generally speaking, high voltage transmission is not required for electrified railroads through densely populated states, but they may still be worthwhile.

Almost all electrical transmission in the USA today is HV AC which only requires transforming down to useful voltages. Many rail lines will have a HV AC line that conforms to regional standard voltages (345 kV in Texas for example).

Some rail line ROWs may also carry HV DC lines for long distance transmission. HV DC has much lower transmission losses (5%/1000 miles) but requires expensive power electronics to convert from AC to DC and then back at every node. “Northern Lights” is an ongoing project that illustrates how and where HV DC is economic today.

http://www.transcanada.com/company/northernlights.html

http://commerce.mt.gov/energy/northern.asp

The USA has several out-of-sync grids and only HV DC can transfer power between these grids.

An informal consensus was formed during the plans for electrification of US rail lines in the 1970s that the USA west of the Mississippi and Canada would be electrified at 50 kV AC and east of the Mississippi at 25 kV AC, all at the grid 60 Hz. Such voltages would require substations every 20 to 30 miles.

One can conceive of an electrified rail line operating at 55 kV AC, with a 345 kV HV AC line, interconnecting to every other HV AC line it crosses and feeding 55 kV substations every 30 miles. Local wind turbines would feed into the 55 kV line (with a 55 kV-345 kV substation conveniently near by). In addition a +500 kV DC and -500 kV DC line would be strung from the same towers (an interesting design challenge) with nodes converting to 345 kV AC every 200 to 500 miles.

Railroads could start a new business, electrical transmission (the owner of Northern Lights is a Canadian pipeline company, not an electric utility), or form joint ventures with regional utilities or just lease space on their ROWs to electric utilities.

Dual use of rail ROWs appears to be the best and fastest way to improve our electrical grid.

There is one caveat. I have received assurances from experienced power electrical engineers that this is “doable” but such assurances are not yet definitive. Unique tower designs may be required to accommodate HV DC, HV AC and electrified rail lines..

Appendix Six

Electrical Demand for Electrified Railroads and Environmental Impact

“*[Electrified] Railways handle 32% of Swiss freight traffic and 16% of passenger traffic, but they use only 3% of the total energy required for all transportation.*”
- SBB (SwissRail) Environmental Report

Electrified railroads would use 2.37% of US electrical generation (about as much as France today) if all truck freight was shifted to electrified rail, and all rail was electrified. A more realistic (very successful) rail electrification program could use 1% of US electricity in a decade and more in later years.

In 2006, the USA generated 4,065 TWh. Translating 2,552,000 barrels/day for trucks to electricity (using 18 : 1 ratio) and 231,000 barrels/day (2.6 : 1 ratio) gives 88.5 and 8 TWh respectively. This is 2.37% of US electrical generation if all truck freight was shifted to electrified rail, and all rail was electrified. Adjust downward from 100% of truck to rail and 100% of rail electrified and the USA would be very well served if an additional 1% of US electrical demand went to electrified rail

Today, 0.19% of US electricity goes to transportation - enough to run New York City subways, Amtrak’s Northeast Corridor, Long Island Railroad, subways in Chicago, Washington DC, Philadelphia, Boston and elsewhere, as well all Light Rail and streetcar systems.

Modern main line locomotives are diesel-electric. A small (2 to 5 MW) diesel generator is coupled with an electric motor for traction power. Such small diesel generators are only used on small islands and for emergency generators because of their low efficiency and high cost for fuel and maintenance.

The overall efficiency of diesel-electric locomotives (99+% of US locomotives) is slightly more than 2.6 BTUs of diesel generating 1 BTU of electricity. Both diesel-electric and all electric locomotives use an electric motor as the final drive.

Modern electric locomotives can regenerate power during braking, feeding electricity back into the grid, an energy savings that diesel electrics put into waste heat.

Gil Carmichael, former head of the Federal Railroad Administration, has stated that unit trains of double stack containers with diesel-electric locomotives are nine times as efficient as trucks in transporting freight. If one adjusts for less than ideal circumstances (such as more miles A to B by rail than by truck, some less efficient roll on-roll off trailers, some single stack containers) then 7:1 or 8:1 is more realistic. Regenerative braking in hilly terrain and built-up areas increases the diesel to electricity efficiency ratio from 2.6:1 to 3:1 (an industry rule of thumb).

So seven or eight times 2.6 to 3.0 gives about 18 to 21:1 diesel to electricity BTU ratio (I'm rounding for national average) between diesel trucks and electrified rail.

Overall, the USA grid loses about 10% of the electricity generated to transforming and transmission losses. Large industrial users, that use higher voltages, have optimized transmission and high efficiency transformers, are closer to 6% T&T losses. If railways improve the grid with more transmission lines, they would, in a sense, "make" electricity by reducing losses, so I have not allocated anything to T&T losses. Diesel also incurs energy losses in transportation before final use.

There is no other widespread economic use for falling water, blowing wind, geothermal heat or nuclear heat except to make electricity. None of these sources release large scale greenhouse gases outside the natural cycle, Therefore, the relative efficiency of each is irrelevant; only maximizing their generation matters.

Among the fossil fuels, natural gas emits 115 lbs of carbon dioxide for 1 million BTUs, oil (not diesel per se) 155 to 164 lbs and coal 205 to 227 lbs (some variance depending upon type). Locomotive diesels are in the 34% to 38% thermodynamic efficiency range. Modern super critical double reheat coal fired plants are in the 40% to 43% range, and combined cycle natural gas plants are 50% to 59% efficient.

Combining the thermodynamics and emissions of modern coal plants vs. small diesels, and factoring in regenerative braking, I conclude that coal fired electric trains should emit as much CO2 as diesel-electric trains, unless the diesel comes from Canadian tar sands (a growing source with high CO2 emissions).

All sources of electricity (except coal) are clear environmental winners for electrified railroads over diesel-electric trains. And even coal is better than diesel refined from Albertan tar sands.

The impact of shifting freight from trucks to electrified rail (as opposed to diesel rail to electrified rail) is a massive environmental improvement (1:8+ improvement) with very dramatic reductions in greenhouse gases regardless of the source