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Rapid Electrification of Long-Distance Diesel Trucking: Shortest Path to a Zero Carbon Transport System?

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ABSTRACT:

Trucking is a major sector, essential to modern goods transport, and almost universally powered by diesel fuel. A rapid conversion to direct electric drive, taking advantage of existing fleets and extensive networks of infrastructure, could be the shortest pathway to a petroleum-free transport system, not just for goods but for people movement and so deserves priority for further study.

FIGURE 1 Visualization of electrification of dedicated long-distance truck lanes. The turning of the wind turbines on the hill could literally help turn the wheels of the truck, a petroleum-free solution. (Photo by author.)

INTRODUCTION

Electrification is a highly energy-efficient method of propulsion for heavy vehicles. When renewable energy is used to power vehicles, greenhouse gases are greatly reduced.

The modern freight system is extremely dependent on long-distance trucking. Although many long-distance routes can be replaced with trains in theory, the cost and time to bring new rail systems to bear is not expedient, and the "last mile" problems would remain to be solved. Efforts to make trucking more fuel efficient can provide impressive gains over time *(1)*, but would it be more effective to focus on making the entire long-distance trucking system petroleum-free?

A novel idea emerges: Conversion of the existing trucking fleet to direct electric drive by a connection to the grid allows the efficient reuse of this major system, which in theory could be accomplished relatively quickly and efficiently. The existing trucking fleets could be re-used, but the highways system, bridges, and distribution centers which have evolved around long-distance trucking should not need to be built from scratch to implement a new mass electrification scheme. A visualization is presented in Figure 1.

Electrification of fixed-route transport systems using any kind of grid-connected vehicles (GCVs) allows for petroleum-free, carbon-free movement of both goods and people, with concomitant health, fiscal, greenhouse gas (GHG) reduction and a plethora of additional environmental co-benefits. Trucks, buses and trains can all be electrified, although trucks have only rarely seen this combination. Electrification is the most energy-efficient method of their propulsion.

Although rail is roughly 5X more energy efficient than trucks per ton transported, rail cannot serve all functions, and the timeline and cost to replace long-distance trucking with a rail-based system may be much greater than that of a multimodal electrified system.

Conversion of rubber-tired fleets utilizes existing highways and bridges, power networks and distribution systems, for additional infrastructure and operational efficiencies. A renewable energy system should develop in concert with network growth. Even if such vehicles are powered by coal, benefits are obtained and carbon emissions are reduced. Once the infrastructure is in place for long-distance trucking, it could potentially be converted to rail were a rail implementation ever scheduled.

Thus such provision can be a transitional step to growing the rail network. In the interim, trucks can in theory replicate rail capacity just as bus rapid transit can approximate the functionality of a metro system, replete with dedicated lanes making overhead wire connections more viable, particularly at high speeds.

Waiting is dangerous

Waiting for the promise of new propulsion paradigms such as hydrogen sacrifices energy efficiency and may never come; as a case example, in 1980 a trolleybus system was foregone in expectation of hydrogen buses being "around the corner," with a terrible human and environmental cost.

A proposed ideal first step in building the network would be providing an electrified truck link from an urban port to a more remote distribution center, thereby obtaining maximal utility from a single link while alleviating noise and air pollution associated death and disease in population centers.

Why not invest in the best known? The laws of themodynamics are not changing, and a short timeline is needed. Based on the tremendous energy efficiency and operational advantages of such electrification; its compatibility with existing major investments in roadway and power distribution; and its ability to be powered directly be renewable energy; grid-connected vehicles such as those using overhead wires and third rails are examined here as potentially the best possible and quickest route to a large-scale solution.

Unfortunately, relying on market forces is a dance with death which we cannot afford to lose. There is plenty more carbon fuel available, with enormous implications for carbon emissions. *(2)* To continue using carbon-based fuels rather than investing in complete alternatives risks a “perfect storm” of ever-decreasing ablity to change course, coupled with ever-mounting life support problems on spaceship earth.

ELECTRIFICATION STRATEGIES

Electrified trucks known as “trolleytrucks” have been in use for mining for over a century, but on-road use has been quite rare.

Rail electrification is a well-established method of achieving independence from oil, carbon reductions, and other public health benefits. Electrified bus lines – trolleybuses – are also well established technology, with over a century of successful use in North America.

Electrification of ports has emerged as a major public policy initiative in California: everything from cranes, to trains, to the ships themselves which burn dirty bunker fuel to run onboard generators. Even Truck stops have been targeted for electrification due to the public health benefits. *(3)* Yet there has been virtually no discussion of electrification of trucking. Trucking dominates cargo shipping in North America. Land use, highway systems, bridges, distribution centers, have all evolved around trucking.

Gone are the days when industry and towns built around rail stations as a rule. Even in towns, trucks now account for nearly all “last mile” delivery; trucks are found even on otherwise quiet residential streets, resulting in a major public safety problem for those walking and bicycling in city centers in addition to noise, air and vibration exposures to residents, raising the additional question of whether big rig/lorry trucking can be shifted to gentler modes within cities. A project funded by the European Union is exploring this very idea (Cyclogistics).

In the interim, new research on diesel emissions puts diesel squarely as a top public health issue. Trucks themselves are a primary source of these deadly urban fumes. Thus an obvious question emerges which has enjoyed surprisingly little consideration: can cargo trucking be electrified? Certainly attention has been paid to electrification of truck cabins to reduce engine idling for long haul truckers. That accounts for a tiny fraction of overall truck emissions.

Dedicated lanes for trucking have already been proposed for large corridors across the United States. With the Corridors of the Future proposal, under the US DOT, six interstate routes would get dedicated truck lanes. *(4)* Truck lanes for "slow vehicles" have already in use in the U.S. Interstate system (see Figure 2).

FIGURE 2 Truck lanes are already a reality on the Interstate system in the USA (I-15, Nevada). Photos by author.

Shared Lanes, Shared Lines

The investment in catenary, substations, etc. amortizes well with increased use. What is the potential for shared use by multiple operators and even multiple functions, such as cargo and passenger services both?

In the long-term, could passenger and freight systems share the same network of power lines? Could some vehicles and trains carry both passengers and cargo?

A shared interstate or even international trolley system for rubber-tired grid-connected vehicles (GCVs) could include both trucks and buses on shared wires. System economics improve with increased use. To coin a phrase: why not build a *trolleytire* system.

NEW INTEREST IN TROLLEYTRUCKS

Due to the pressing demands of climate change and independence from oil, along with severe public health impacts of diesel combustion for cargo transport, this idea has been discussed increasingly in recent years. The book Transport Revolutions further explored the benefits of electrification of mass transport. *(5)* This author presented at conferences and NPOs beginning 2008. *(6)* The Electric TBUS Group, a UK-based association founded in 2000 and comprised primarily of trolleybus professionals, has held discussions and created computer-generated images of the trolleytruck concept.*(7) (8)* An online article with some detail was published as well. In Sweden, a report commissioned by the Stockholm Chamber of Commerce discussed a trolleytruck system. *(9)* The renewable energy industry publication, Solar Today, made mention of the idea in its detailed article, "Freight of the Future." *(10)* Most recently, Siemens has tested an on-road cargo trolleytruck. *(11)*

History of Trolleytrucks

Electrified trucks have been used for over a centrury and have been in use widely, throughout the world, on every continent. Primarily used in mining, where fixed route hauling of heavy loads on steep slopes benefited from the power advantages of electric traction, trolleytrucks have been used on urban streets even in this decade, in Russia and the Ukraine. The creation of a new system, in which modern interstate trucking connects directly to a grid, enjoys a substantial precedent, borrowing as well from a century of road-based trolleybus implementations. On-street trolleytruck implementations for general cargo have occurred in the past, such as in St. Petersburg, Russia.

Trolleybuses Pave the Way

Although the literature on trolleybuses is relatively sparse in English, there is a substantial amount in other languages; Eurasia hosts numerous systems and tens of thousands of vehicles. Quite a lot of research on trolleytire transport is found in the Russian language. Indeed, at one time Russia had a factory producing 2000 buses per year.

Design standards for trolleybuses can be extended to trolleytruck implementation. Even operation on freeways and other controlled-access highways has been detailed in the literature, "driven by concerns about air quality and replenishable fuel." *(12)*

High speed operation may require new innovations, and new design standards such as fitting trucks with overhead connections through tight passages (tunnels and bridges), but these technological hurdles can surely be overcome.

Advantages of Trolleytrucks: Lessons from Trolleybuses:

Trolleybuses are described to have enormous benefits over diesels, which presumably would extend to any implementation of trolleytrucks as well. First, they are more energy efficient: they hold less space and weight for fuel, and can benefit from regennerative braking. Second, they last longer: roughly twice as long as diesels. Third, they have great public health benefits: they eliminate what would otherwise be harmful diesel fumes from population centers, and are only half as noisy as their diesel counterparts, a serious public health benefit as well.

Operational Benefits

Perhaps the biggest benefit to the trucking industry would be operational. Electric power allows more juice when necessary for acceleration and hill climbing, a huge benefit on hilly routes and routes with multiple stopping. The limitations of fixed line operation can be greatly overcome as typically a small battery allows disengaging from lines for short-distance independent maneuvers (usually 2km or literally last mile). The battery can be continuously kept charged by the grid during operation.

Economic Stability Benefits

Besides the benefits above, which can be quantified, additional economic benefits of electrification of the diesel fleet are enormous and beyond the scope of this paper. Externalities from diesel trucks and buses include a tremendous quantity of air and noise pollution, as well as GHG emissions. Just the electrification on one train line was estimated to save $40M/year. A trucking corridor would surely save more.

Moreover, the price and availability of petroleum (both oil and natural gas) is volatile and has severely impacted both truck and bus operations, both public and private, in recent years, and in turn the world economy. Stability in the mass transport sector would be one major benefit.

The primary sources for cost-benefit analyses and the like are agencies themselves. Transit service providers in San Francisco, CA; Seattle, WA; Vancouver, BC *(13)*; and numerous groups in Europe have conducted internal studies assessing their trolleybus systems in light of alternatives such as the diesel bus. For example, San Francisco MUNI found a 67% savings thanks to trolleybuses over diesels. *(14)*

The Comparative Disadvantages of CNG

There has been a mobilization toward long-term CNG power for trucks, due to the potential for mass fracking. Besides the environmental, health and climate changing implications of such a move, CNG imposes a substantial weight penalty on trucks that electrification would avoid; dangers of carrying explosive fuels under compression; and higher toxic emissions and human health effects than electrification would (study cited in Rafter 1995). *(15) (16)*

Possible Land Use and Livability Benefits

A final implication which can be beneficial concerns land use and property values. Due to the fixed nature of the system, land use changes accrue over time. With trolleybuses and light rail, the investment in overhead catenary wires signals a commitment to the corridor, increasing the value of the corridor. A different response might be seen if trucking increases; however, it would surely help with management of the impacts of trucking by focusing trucking corridors into specific areas, leaving residents in other areas feeling safer. The incentive to organize distribution centers for smaller vehicles and human power would be a further urban livability and environmental health benefit.

NEXT STEPS

First Steps to an International Network:

A network begins with its first segment. A modest first step would be a pilot project to remove goods from ports where trains are otherwise infeasible. A second approach would be to combine electrification with a new major projects. The proposals for long-distance trucking corridors such as Corridors for the Future provide a perfect opportunity to incorporate long-distance electrification.

Research Required

Funding is needed to commission experimental designs, and assess needs in all realms of transport implemention. Standards must be developed to assure compatibility between systems. The voltage chosen is a major first decision; the higher the voltage, the more energy efficient the line (line losses are reduced). Policy barriers need to be identified and corrected, and incentives put in place to allow a major new system to flourish.

Energy Requirements

Much controversy and uncertainty surrounds the provision of large-scale renewable energy in the future, as well as manymisconceptions. Objections to electrification on this scale include line losses, and the need for a major new source of renewable energy. This is non-trivial as the energy used by petroleum-fueled vehicles today is roughly the same as the electricity generated today. However, much can be gained from existing electricity generation, through conservation; and the needs of a mass transport network are much lower when we ignore the entire passenger car fleet. A new high quality network of electrified road vehicles could substantially reduce the use of private passenger cars over time. Objecting to the scale of the project in advance of its study is fallacious; particularly given the projected shortfalls of oil and the need to make major changes to reduce the damage to the climate.

CONCLUSION

The broad theoretical basis for converting long-distance diesel trucking to direct electrification has been explored. There is ample reason to believe such a conversion, and other supportive measures and extensions, is an expedient and perhaps the most expedient means to a petroleum-free, zero carbon, zero emissions mass transport system which could serve not onnly goods movement,but passengers as well. The projected benefits are large, and the efficient reuse of fleets and infrastructure promises a best case economic outcome. Given the crisis outlook for energy and the climate, a rapid and thorough analysis of its potential is required, and an appropriate policy response needed.

AUTHOR:

Conflicts:

None declared. Author has no investment in any transportation or energy company.

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Background:

Author first became aware of the advantages of trolleybuses in 2006 while producing the Transportation Justice Element of *El Plan Popular*, Later that Fall while presenting at the Towards Carfree Cities XI conference in Bogota, Colombia, author initiated a project with *Transmilenio* to study the maximum trolleybus implementation of that system, producing a graduate studies term paper on the topic. At same conference, author met and began communicating with Richard Gilbert, who published *Transport Revolutions*, now in its second edition, to which author contributed information and corrections. Author further investigated the potential to move cargo with modified trolleybus technology: trolleytrucks. In 2008 author presented at two conferences. Author had been aware of Peak Oil sine 2003 and actively seeking petroleum-free mass scale solutions to transportation, with a background in the study and promotion of bicycle transportation. He is presently lecturing and supporting sustainable transport, land use and environmental health research in Europe based at the University of Bologna, with affiliations to UC Berkeley.

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