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FREIGHT TRUCKS, MITIGATING GHG EMISSIONS AND THE DANGER OF INCREMENTALISM

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A. Introduction[1]

Freight trucks generate a large and almost certainly increasing share of total greenhouse gas (GHG) emissions in the US and Canada, particularly carbon dioxide (CO_2). Mitigation efforts that have sharply diminished particulates and some emissions (such as NOx and SOx) have had little impact on CO_2. Many ideas for mitigating carbon emissions are currently under discussion. They range from simple and relatively inexpensive to complex and very expensive. Some are patches on existing modes; some would transform large segments of our transportation systems. Some of these ideas are fascinating. Many would surely be useful.

But throughout much of this work, several key elements are missing. Often, the discussions fail to consider the systemic implications of proposals to mitigate GHG emissions. There is little research that assesses and compares the impact of different proposals to reduce carbon throughout the entire energy-transportation system. There is more but still insufficient work on cost, particularly as the impact of change radiates out through the system, and little on start-up time to get projects underway. In addition, the bottom line matter of implementation – that is, developing strategies to actually put in place a policy regime for mitigating freight transportation-generated GHG emissions – is infrequently discussed. Much is said about <u>what</u> might be done; very little about <u>how</u> to do it.

A comprehensive report released by US Department of Transportation in April 2010 illustrates the strengths and weaknesses of much current literature.[2] In two volumes totaling more than 600 pages – a synthesis report and a technical report – it provides an extensive and detailed survey of "greenhouse gas reduction strategies and impacts". The DOT report describes in depth ways to reduce emissions and cites latest research. But each method is viewed in isolation, analysis is limited to the potential direct impact on fuel consumption and GHG emissions and wider systemic implications are not considered. Its conclusion on "Policy Options" does not touch on costs, either direct or indirect, on externalities that might be created or on what kind of public-private sector actions would be necessary to realize these ideas. It is an interesting and well researched compendium of methods for reducing GHG emissions. But in no sense does it deal with "strategies" to actually accomplish this goal.

Freight transportation and climate change involve complex networks, and changes at any point affect the rest of the network. Freight transport must be viewed as a single system and not as collection of different transportation modes and unconnected elements of the supply chain. Much of what has recently been written consists largely of lists of mitigation methods with little attention given to how the transportation-energy systems work. This research, moreover, is overwhelmingly national in scope while the basic problem of climate change and the structure of key sectors of our economy – automobiles, food production, and energy to name just a few – demand the perspective of an integrated continental system.

Thinking about mitigating transportation generated GHG emissions in a wider systemic context suggests, I believe, the dangers implicit in incrementalist approaches. What seems to be a logical, step by step movement in the right direction may actually take us where we really do not want to go. The problem is not the step by step approach. It is taking step after step without a clear sense of where we want to go and how we should get there. We need a clearer sense of where we want to wind up before we leap into examinations of different vehicles.

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[1] This paper extends and expands a paper I prepared for The Conference Board of Canada: "Freight Trucks and Climate Change Policy: Mitigating CO2 Emissions", The Conference Board of Canada (February 2010)

[2] Department of Transportation, Transportation's Role in Reducing U.S. Greenhouse Gas Emissions, Report to Congress, U.S. Department of Transportation, April 2010

This brief paper first examines several methods to mitigate truck generated GHG emissions that seem terribly obvious – making cleaner trucks, using alternative fuels, and producing more of what we eat locally. It seeks to tease out some of the possible systemic implications of each of these proposals and finds that starting down these paths without a clear idea of where we might be heading may lead to unforeseen and possible undesirable results. It suggests that we may be asking the wrong questions, trying to fix the wrong problem. Perhaps instead of asking how to make trucks cleaner, we should ask how our transport system can be organized to use fewer trucks.

The paper then moves on to examine several broader themes often neglected in discussions of ways to mitigate truck generated GHG emissions -- scale, timing, cost and, perhaps the largest of these, infrastructure. If mitigation proposals lack sensitivity to these issues they remain abstract and academic. Similarly, if these proposals fail to include a focus on implementation – how they can be pushed through the political-legislative-regulatory pipeline – then, again, their potential utility is greatly diminished.

The various proposals for ways to mitigate truck generated GHG emissions rarely include comparative assessment of what others are doing and what might be learned from them. Conclusions drawn from cross cultural/political comparisons can be overly simplistic to be sure. But it is odd not to try to learn from what others have done or are trying to do to achieve goals we have posted for ourselves.

This essay concludes with a riff on the US railroad industry. It suggests that what we are facing today – technology-driven system-wide transformation – is similar in scale and scope to what the US confronted with the rise of the railroad industry. It asks if we might learn from that experience.

This essay is not a plea for some sort of centralized energy-transportation planning system. It is, rather, a plea for more collaborative and sustained conversation among competing visions of the future and notions of how to get there. It asks for a more cumulative learning process in which individual researchers and research institutions develop longer-term commitments to explore these issues and to develop a true community rather than seeing each report as an individual, isolated contracted project that is completed, ignored and discarded.

B. Cases

B1. Cleaner Trucks – a very good idea?

One can scarcely argue with suggestions to make freight trucks cleaner. Freight trucks are a large and almost certainly increasing source of GHG emissions, particularly CO_2. But viewing proposals to make trucks cleaner in a wider context illustrates the potential hazard of incremental change even in a positive direction.

Projections by government agencies and a wide array of research organizations indicate that barring a major structural transformation of our transportation system the number of trucks on our highways will almost certainly increase substantially, that truck energy use will continue to rise and that truck generated GHG emissions, particularly CO_2, will increase as well.

Over the past thirty years, freight traffic has shifted substantially from rail, water and pipelines to more energy intensive trucks and air transport. In 1970, trucks carried 18% of intercity freight ton-miles; by 1998, trucking's share had increased to 28%.[3] Reasons include an expansion of freight

[3] U.S. Department of Transportation, Bureau of Transportation Statistics, 2002. Transportation Statistics, op. cit., Table 1-41, quoted in David L. Greene and Andreas Schafer, Reducing Greenhouse Gas Emissions From U.S. Transportation,

trucking after economic deregulation of the trucking industry in the 1980s; widespread adoption of just-in-time manufacturing and retailing practices by business shippers and receivers, increasing highway congestion; and structural changes in the economy that produce higher-value, lower-weight, and more time-sensitive shipments better served by trucking. [4]

Forecasts agree that freight truck traffic will increase over the next years. The US Federal Highway Administration estimates that if the US economy grows at annual rate of between 2.5 %-3% annually over the next 20 years (a relatively conservative estimate), truck-borne freight will increase by nearly 70% by 2020 and double by 2035.[5]

Impressive reductions have been made in emissions of most tailpipe pollutants — hydrocarbons, nitrogen oxides, carbon monoxide, and particulate matter. In large measure, these changes are due to tightening emissions standards. Trucks certified under the U.S. EPA's SmartWay program (which Canadian regulations track), for example, use 10% to 20% less fuel than older models, a saving per truck of some 2,000 to 4,000 gallons of diesel a year.[6] New truck engines have filters that reduce particulate emissions to almost nothing and emit much less nitrogen oxide and trucks engines which meet new 2010 regulations should reduce nitrogen emissions to zero. But this has no effect on carbon emissions.

Freight transportation has become more fuel efficient in terms of fuel use per ton-mile of freight moved. But the growth in freight transportation activity outpaces the decline in per vehicle emission rates.[7] More trucks on the road mean more energy use and (absent very widespread use of alternative fuels) more CO_2 emissions.

Carbon emissions in the transportation sector are forecast to increase by almost 50% over the next 20 years—a faster rate than in any other sector of the economy. If this prediction holds, transportation will be responsible for 36% of US carbon emissions in 2020. Among all transportation sources, GHG emissions from freight trucks have increased most rapidly.[8]

> Since 1990, GHG emissions from medium and heavy-duty trucks have increased 77 percent, growing at three times the rate of emissions from light-duty vehicles. This is the product of decreasing fuel efficiency—as measured per ton-mile carried—and steadily increasing demand for freight trucking. Between 1990 and 2005, CO_2 emissions per ton-

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Prepared for the Pew Center on Global Climate Change (Arlington, VA: Pew Center on Global Climate Change, 2003) p. 7

[4] Transportation's Role in Reducing U.S. Greenhouse Gas Emissions, op cit. p. 2-11

[5] United States Government Accountability Office, Freight Transportation: National Policy and Strategies Can Help Improve Freight Mobility (Washington, DC: Author, 2008), p. 3. See "Executive Summary—The Bottom Line," Research and Innovative Technology Administration, Bureau of Transportation Statistics, http://www.bts.gov/publications/freight_in_america/html/executive_summary.html

[6] Betty Beard, "Keep on truckin', but 'greener,'" The Arizona Republic (Mar. 27, 2008) See SmartWay Transport Partnership: Innovative Carrier Strategies (http://www.epa.gov/smartway/transport/what-smartway/carrier-strategies.htm)

[7] "Despite improvements in operational efficiency and implementation of fuel-saving technologies, overall sector energy use continues to increase. GDP growth, tightening of CAC regulations and increased levels of service are all driving GHG emissions higher. Changes in fuel composition and vehicle technology have contributed to a decoupling of air pollutant emissions from energy use (and a further decoupling is expected due to tightening air pollution standards in the near term), but GHG emissions continue to rise." Canada Foundation for Sustainable Development Technology, "Transportation — Industrial Freight Transportation", SD Business Case, Version 1, Sustainable Development Technology Canada, November 2009 p.1 http://www.sdtc.ca/en/knowledge/BC_TRANS.pdf, See the recent study by the Transportation Research Board on increasing fuel consumption by this class of vehicles, TECHNOLOGIES AND APPROACHES TO REDUCING THE FUEL CONSUMPTION OF MEDIUM- AND HEAVY-DUTY VEHICLES, Committee to Assess Fuel Economy Technologies for Medium- and Heavy-Duty Vehicles, Board on Energy and Environmental Systems, Division on Engineering and Physical Sciences (2010) http://www.nap.edu/catalog/12845.html, p. 9

[8] Greene and Schafer, Reducing Greenhouse Gas Emissions From U.S. Transportation, p.10.

> mile carried increased almost 13 percent, while actual ton-miles carried increased 58 percent.[9]

Natural Resources Canada forecasts that transportation energy demand will increase by 90% between 1990 and 2030, far outpacing demand growth in other sectors. At this rate, by 2050, transportation will overtake industry to become Canada's highest energy-consuming sector.[10] And freight trucks will lead the parade:

> Despite a 42 percent increase in VMT over the period, light-duty vehicle GHG emissions are projected to decline nearly 12 percent, in response to expected increases in fuel economy from corporate average fuel economy (CAFE) regulations, advanced technologies, and alternative fuels. Freight trucks, on the other hand, show a projected 20 percent increase in emissions, even though freight truck VMT grows at a similar rate to light-duty vehicles.[11]

It certainly would appear that making trucks cleaner is a good idea, and many proposals to mitigate truck produced GHG emissions are under consideration. Proposals run through the entire range of the "five Rs": retrofit (add after-treatment device to remove emissions from the engine exhaust), repower (replace existing engine with a new engine), refuel (use fuels that require little or no modification to the engine such as emulsified diesel or biodiesel or those that require engine conversion or replacement such as natural gas), replace (replace older, higher polluting equipment with newer equipment that meets more stringent emission standards), and repair/rebuild (reduce freight emissions during regular engine service intervals through routine maintenance or major engine overhauls.)

A lot can be done with fairly little. Several studies note that combinations of aerodynamic styling, proper tire pressure and good driving habits can save a lot of fuel and so cut GHG emissions. Changes in design that reduce aerodynamic drag by 20%, for example, can result in a 10% fuel saving.[12] No new technology is required: "Commercially available aerodynamic and rolling-resistance improvements can be applied today, both to new trucks and in-use trucks, to reduce fuel consumption and global warming pollution."[13] Auxiliary units that power air-conditioners and heaters enable drivers to be comfortable and safe without running the diesel engine when their trucks are stopped. Low-resistance tires also improve truck performance.[14]

> Considering only products that are commercially available today, tractor-trailers can be equipped with aerodynamic devices and high-performance tires and wheels yielding a greater-than-12-percent reduction in fuel consumption. For a typical long range truck traveling over 100,000 miles per year, this would translate to an annual savings of 2,000

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[9] Transportation's Role in Reducing U.S. Greenhouse Gas Emissions, op cit. p. 2-11

[10] Natural Resources Canada, "Moving Forward on Energy Efficiency in Canada: A Foundation for Action—Transportation: Scope" [online]. Website content (Ottawa: Author [cited January 7, 2010]). www.nrcan-rncan.gc.ca/com/resoress/publications/cemcme/transport-eng.php.

[11] Ibid., p. 2-16

[12] Technology Roadmap for the 21st Century Truck Program: A Government-Industry Research Partnership, December 2000, p. 6 (www.osti.gov/bridge/servlets/purl/777307-BKSUFs/native/777307.pdf) Two useful studies on truck emissions are Rocky Mountain Institute's, "Transformational Trucking Initiative Report (June 2009) which reviews methods to increase trucking efficiency using existing technology (http://move.rmi.org/files/capabilities/transformationaltrucking/RMI_TTruckingInitiativeReport_090622_v1.pdf) and Union of Concerned Scientists, Delivering the Green; Reducing Trucks' Climate Impacts will Saving at the Pump (http://www.ucsusa.org/assets/documents/clean_vehicles/delivering-the-green.pdf)

[13] Delivering the Green, Op. Cit, pp. 5, 2

[14] For a similar approach to reducing carbon emissions through relatively simple actions, see Thomas Dietz, Gerald T. Gardner, Jonathan Gilligan, Paul C. Stern, and Michael P. Vandenbergh, "Household actions can provide a behavioral wedge to rapidly reduce US carbon emissions," Proceedings of the National Academy of Sciences in the United States of America, 2009 106:44, pp. 18452-18456 (www.pnas.org/content/106/44/18452.full.pdf+html)

> gallons of diesel fuel.... Retrofitting existing tractor-trailers offers significant fuel and cost savings for all but the oldest and lowest-mileage trucks, while choosing the most efficient tractor trailers when buying new allows for the greatest savings overall.[15]

Another recent report observes that "feasible technological improvements" in truck efficiency combined with the use of multiple trailers can potentially raise ton-mile efficiency "by a factor of 2.5 with respect to a baseline of 130 ton-miles/gal."[16]

The use of multiple trailers may become much more widespread. A traditional rig hauling one trailer gets about 6.5 miles per gallon of diesel – about 130 ton-miles per gallon. A more aerodynamically styled rig could get 12.5 miles to the gallon – some 275 ton- miles per gallon. An aerodynamically styled rig pulling two trailers would lose in fuel consumption – getting only 8.7 miles to the gallon – but would gain greatly in ton-miles with 335 ton-miles per gallon. And, say advocates, with no loss in safety.[17]

So far, this sounds very useful and productive. But we must examine the implications of even such "good" decisions as making trucks cleaner. We must try to envisage the systemic impact of a decision that would focus efforts at mitigating GHG emissions on cleaning trucks.

Recall that our discussion takes place in the particular context of high levels of congestion and decay that currently exist in our highway system. Congestion, maintenance deficits and border issues all led to the widespread recognition of an emerging "perfect storm" in our highway system – well before 9-11 intensified problems. An assessment of several reports describing this emerging infrastructure crisis concludes:

> The JIT–lean inventory advanced manufacturing system developed since the 1970s that enables North America to compete successfully with Asian and European manufacturers is now reaching its capacity limits. The supporting transportation infrastructure is now inadequate to handle the projected volume growth of North American supply chains freight flows.[18]

Given the congestion and the maintenance deficit that now exists in our highway infrastructure, even a modest resumption of economic growth will increase freight traffic and clog up critical junctions in the North American road systems. More trucks – so long as they burn some form of hydrocarbon fuel – will almost surely increase total truck produced GHG emissions. Congestion, slowing traffic and increasing idling, makes the problem worse.

The point is that by reducing concern about GHG emissions that might otherwise have inhibited the growth of the fleet, focusing mitigation efforts on cleaner trucks is likely to lead to more trucks on the highways. Focusing mitigation efforts on cleaner trucks might as well slow the impetus to develop new non-truck transportation technologies and reduce efforts to shift more freight to other transport modes. Also, we must anticipate that one element of a cleaner truck approach will be the widespread use of heavier trucks and trucks with multiple trailers.

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[15] Union of Concerned Scientists, Delivering the Green; Reducing Trucks' Climate Impacts While Saving at the Pump, 2008, pp. 5, 2

[16] Rocky Mountain Institute, Transformational Trucking Initiative Report (June 2009) p. 3 (www.move.rmi.org/transformationaltrucking)

[17] "14 Things You Probably Never Considered About Making Trucks More Efficient," Rocky Mountain Institute (www.treehugger.com/files/2009/04/14 thing s you p.pnp) 04.18.09

[18] Guy Stanley, Review of Recent Reports on North American Transportation Infrastructure, North American Transportation Competitiveness Research Council, Working Paper 3 (September 2007) http://natcrc.org

So the bottom line: a commitment to reduce truck generated GHG emissions by making trucks cleaner is likely to worsen the crisis of congestion and will thus intensify pressure for a huge expansion of the highway system – perhaps even for building a new system with limited access or even limited to trucks.

At the end of the day, perhaps focusing on making trucks cleaner and constructing a new truck based highway system is the best way to build a sustainable freight transport system for the next decades. But to reach this decision, we have to work our way through the entire set of implications that will result. It's not enough to talk only about cleaner trucks. In the same breath, we have to talk about new highways that would accommodate these new trucks. We have to talk as well about the environmental impact of this construction, about how to build political coalitions to make this happen, about how long it will take to do this and about how to pay for it.

The decision to make trucks cleaner seems so obvious. But step by step changes to make trucks cleaner may take us in the wrong direction and lock us into an enormous expansion of the continental highway system. **Maybe we're asking the wrong question, trying to fix the wrong problem. Instead of asking how to make trucks cleaner, should we ask how we can organize our transport system to use fewer trucks?**

B2. Alternative fuels: Another good idea?

Alternative transportation fuels are those fuels used for transportation other than gasoline or diesel.[19] They include methanol, alcohol, biodiesel, coal-derived fuels, hydrogen, electricity, compressed natural gas, and liquefied petroleum gas. Some are produced from renewable sources including biogas and biofuels such as ethanol (derived from biomass), biodiesel, and biobutanol.

Biofuels can be divided into categories based on feedstocks and lifecyle GHG thresholds. Conventional biofuels include ethanol derived from corn-starch. Advanced biofuels are derived from renewable biomass other than corn-starch and capable of achieving a 50 % GHG reduction. Cellulosic biofuels are produced from any cellulose source capable of achieving a 60% GHG reduction. Biodiesel results from the transesterfication of organically-derived vegetable oils or animal fats. Biogass refers to a gas produced from the degradation of organic matter such as biomass, manure, sewage, or municipal waste. Technologies are currently underway to develop other types of biofuels such as biobutanol or from photosynthetic organisms that grow in aquatic environments such as algae.[20]

Trucks would be much cleaner if they did not burn gasoline or diesel fuel. Exploring alternative fuels seems another incontestably good course to pursue. Once again, however, when we try to assess these ideas in a wider systemic context, many questions emerge.

First, regarding the supply side, many questions are raised about actual cost of producing alternative fuels and the system-wide impact of moving resources for this purpose.

Whether corn was "diverted" to use into as ethanol feedstock and whether this led to increased prices in many foods has led to arguments among many experts. The production of corn based ethanol cannot be blamed for the entire increase in food prices in 2006-07, but no one suggests either that production of ethanol would not affect demand/price of various feed stocks. Clearly, estimates of total cost of an alternative energy source should include the full energy cost of

[19] EIA. "Renewable and Alternative Fuels Basics 101" available at http:www.eia.doe.gov/basics/renewalt_basics.html
[20] Thanks to my colleague Dr Claude Chereau

producing these new energy sources, including fertilizers, the use of tractors and other farm implements, the costs involved in production of fuel and in transportation.

Land use could be another key issue. Farm-grown fuel crops – such as palm oil – might displace forests and other lands that soak up carbon. One biofuels critic writes that "Indonesia, for example, destroyed so many of its lush forests and peat lands to grow palm oil for the European biodiesel market that it ranks third rather than 21st among the world's top carbon emitters." He notes that "food crops that get diverted to fuel usually end up getting replaced somewhere. For example, ethanol profits are prompting U.S. soybean farmers to switch to corn, so Brazilian soybean farmers are expanding into cattle pastures to pick up the slack and Brazilian ranchers are invading the Amazon rain forest…"[21]

Most critics deal with the supply side of the biofuels equation. But the demand side is equally problematic.

One example is the need for vehicle modification or replacement. Most alternative fuels, other than biodiesel and ethanol at blends of 10 to 15% or less, cannot be used directly in today's vehicles without modification. A US Department of Transportation report notes that "Most low-carbon fuels such as higher ethanol blends or natural gas, require at least minor modifications to vehicle design. Some, notably electricity and hydrogen, benefit from or require the development of entirely new vehicle propulsion technologies."[22]

Truck owners and operators may resist change. Bad experiences and operating on tight margins can make owners risk averse. Tractors pulling different trailers on a daily basis, short-term ownership, and split ownership of the tractor and trailer create mixed economic incentives. Replacement is expensive and while increases in fuel prices spur interest in fuel efficiency, fluctuating prices and uncertainty about future prices can stall investments. Access to financing can present a challenge to small fleets and single-truck owner-operators. This means large capital expenditures for anyone using alternative fuel trucks and raises questions about the use of regulations or taxes to force replacement or subsidies to encourage the change-over.

Delivery of alternative fuel – the downstream side – raises as many questions as production. The evolution of the network of gasoline stations – with low gasoline prices, company subsidized "mom and pop" outlets and primitive technology including delivery by tank truck – offers few insights into what will amount to a very great change in our transportation infrastructure of pipelines, storage tanks and delivery facilities. The Census reports that there were 121,466 gasoline stations in the US in 2002. The Department of Energy anticipates that there will be 10,000 battery charging stations in the US (paid for in part by DOE grants) by the end of 2011.[23] The construction of infrastructure to manage the transport and distribution of alternative fuels is surely going to be an enormous task.

It is not enough just to build the new facilities. Service is crucial as well. Ensuring adequate inventories of replacement parts and training people to repair the new hardware and software is essential, and likely to be both time-consuming and expensive. And what about disposing of old batteries?[24] If the devil is in the details, here many devils lurk.

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[21] Michael Grunwald, "Seven Myths About Alternative Energy" *Foreign Policy* (Sept/Oct 2009)
[22] DOT, p. 3-23
[23] http://www.census.gov/econ/census02/data/us/US000_44.HTM#N447 and Brian Dumain, "Can the Volt Charge GM?" Time, July 26, 2010, p. 41
[24] We could go on here into an array of lithium battery issues. See David Rothkopf, "Is a Green World a Safer World?" (Foreign Policy, Sept/Oct 2009)

Finally, what happens to the old gasoline-diesel infrastructure – the pipelines and storage tanks that can't be adapted to new fuels and the continental network of gasoline stations? And what happens to the people who made their living from the traditional gasoline-diesel fuel economy and will be displaced by the new system? Who is responsible?

Separating freight transportation from hydrocarbons is obviously necessary for many reasons – strategic and financial as well as environmental. But we aren't going to succeed by focusing on one or another alternative fuels as the first step forward. We have to think in terms of the fundamental transformation of our energy-transportation system.

B3. Produce, buy locally – still another good idea?

Buying food produced locally has become a widely touted goal in environmentally minded communities. "I don't eat anything that comes from more than 100 miles away" is a cool riff on this theme. A New York Times reporter writes "Increasingly efficient global transport networks make it practical to bring food before it spoils from distant places where labor costs are lower. And the penetration of mega-markets in nations from China to Mexico with supply and distribution chains that gird the globe — like Wal-Mart, Carrefour and Tesco — has accelerated the trend. But the movable feast comes at a cost: pollution — especially carbon dioxide, the main global warming gas — from transporting the food."[25] Buying locally seems like a reasonable if modest way to reduce GHG emissions from long distance freight movement.

But "Buy Local" and "Buy American" are bad policies for many reasons – and bad advice with regard to transportation and carbon emissions. We can grow more stuff closer to home and reduce long distance transportation requirements, but we might wind up using more fertilizers and irrigation. Investigation shows that production has a greater environmental impact than delivery. How far a tomato or apple is moved is less important to its carbon footprint than how it is grown. The authors of a study on buying food locally find that production differentials are keys to differences in carbon production: "While long range transportation of food by air or sea accounts for only a fraction of total greenhouse gas emissions generated by various transport modes, transportation itself is not even the main cause of greenhouse gas emissions. The most energy-intensive segments of the agricultural production chain are instead related to the production stage (fertilizers, pesticides, irrigation, energy required to power machinery, etc.)."

These authors cite a 2005 study by the United Kingdom Department for Environment, Food and Rural Affairs which shows, they say "that 82% of the estimated 30 billion food miles (the distance traveled between producers and consumers) associated with U.K.-consumed food are generated within the country, with car transport from shop to home accounting for 48% and heavy goods vehicles for 31%. Air and sea transport each amounted to less than 1% of food miles. In the worst case scenario, a U.K. consumer driving ten kilometers to buy Kenyan green beans emits more carbon per bag of beans than flying them from Kenya to the U.K."[26]

Land use questions should also come into play here – that is, as we have seen above with regard to the production of palm-oil, the diversion of land from one use to another can have a significant impact on carbon footprints.

There is a crucial time element as well. Agriculture in poorer areas might be highly environmentally offensive – think of burning forests to open new crop land – but unless these communities can get richer, by selling things to us, they will not be able to become greener. So

[25] Elisabeth Rosenthal, The Food Chain: Environmental Cost of Shipping Groceries Around the World (New York Times, April 26, 2008

[26] Montreal Economic Institute, "Will Buying Food Locally Save the Planet?" (Economic Note, February 2010) pp. 2, 3

perhaps buying their products now, even with a larger carbon footprint, constitutes a kind of green investment for the future.

C. Missing Pieces

In this era of dramatic global change in technology, production, trade patterns and competitive advantage, we should be thinking about the impact of freight transportation on climate in the widest possible framework. The key issue should not be how we might move forward incrementally, filling the deepest holes and oiling the squeakiest wheels. Rather we should ask what an efficient, secure and sustainable North American freight transportation system for 2050 might look like – a system that would enhance our standards of living and our competitiveness in global markets. We have seen in just one area – freight truck generated GHG emissions – how a limited focus on methods of mitigation can lead to unexpected and possibly undesirable results. The three cases we have discussed show how vital it is to extend analysis beyond the proposed method of mitigation itself into its wider systemic implications. Here we suggest here four elements of the "bigger picture" than seem often to be overlooked in the mitigation literature: scale, timing, cost and, perhaps the largest of these sometimes invisible issues, infrastructure.

Scale seems often underappreciated. The size and scope of the task of unwinding our fossil fuel based freight transportation system is greater than may be perceived. One analyst observes that "today, replacing only half of worldwide annual fossil fuel use with renewable energies would require the equivalent of about 4.5 billion tons of oil. That's a task equal to cresting *de novo* an energy industry with an output surpassing that of the entire world oil industry – an industry that has taken more than a century to build."[27] The critic of biofuels quoted above states that "even if the United States switched its entire grain crop to ethanol, it would only replace one fifth of U.S. gasoline consumption."

The authors of a recent article in the Milken Institute Review raise a similar issue of scale with regard to cellulosic biofuels widely viewed as a significant improvement over corn ethanol. They explain that the US Energy Independence and Security Act of 2007 sought to revise ethanol policy, mandating and providing a subsidy for the production of 16 billion gallons of cellulosic biofuel by 2022. Producing this amount of ethanol annually from cellulose, they note, "still a modest portion of America's liquid fuel needs – would be no small feat." Grasses may become a viable feedstock, but "the only practical way now to make large quantities of cellulosic ethanol is to ferment it from wood. And by our calculations, the wood required to meet the 2022 mandate would total 348 million cubic meters – an astonishing 71 percent of the bountiful United States wood harvest in 2005."[28]

The **time** dimension can be underestimated as well. Cleaner engines can be manufactured, for example, but re-equipment takes time. Of the millions of trucks on the road, many – probably most – have engines that are pre-2007. Only about 200,000 new truck engines are sold a year and the EPA says it likely will take until 2030 for all the trucks on the road to have "green" engines.[29] A recent survey reports that many carriers are now "aging their fleets due to the rising cost of new trucks and inadequate rates."[30]

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[27] Vaclac Smil, "Moore's Curse and the Great Energy Delusion," *The American*, American Enterprise Institute for Public Policy Research (November/December 2008), quoted in "The Coming North American Energy Transition", *Environments and Energy Bulletin*, Vol. 1, No 1. (February 2009)

[28] Roger A. Sedjo and Brent Sohngen, "An Inconvenient Truth about Cellulosic Biofuel" *The Milken Institute Review* (Fourth Quarter 2009)

[29] quoted in Betty Beard, "Keep on truckin', but 'greener,'" The Arizona Republic (Mar. 27, 2008)

[30] Sean Kilcarr, "New dynamics reshaping freight forecast," Fleetowner Magazine, July 27, 2010 http://www.fleetowner.com/news/topstory/new-dynamics-reshaping-freight-forecast-072710

For all of the talk about alternative fuels (not to mention money put into the projects), the US Department of Energy notes that while In the long run, alternative fuels have the potential to reduce GHG emissions from the transportation sector, they still remain a small percentage of total fuel usage. "Measured as a percentage of energy usage for the entire transportation sector (all modes), renewable fuels constituted less than 2 percent of the fuel supply in 2006 (measured by energy content). Going forward, DOE projects that renewable fuels will increase to just something more than 8 percent of the transportation fuel supply by 2030**.**"[31]

Cost is another frequently missing piece in proposals to mitigate GHG emissions.

If the chosen approach to mitigating truck produced GHG emissions is cleaner trucks and if that means restoring, improving and expanding our highway system, the costs would be stunning. Forecasts of the cost of just "maintaining" transportation infrastructure costs are astronomical. A paper issued by the National Chamber Foundation of the US Chamber of Commerce in 2005 estimated that by 2015, the cost just to maintain U.S. "pavements, bridges, and transit infrastructure" would amount to $295 billion To "improve" these systems would cost $356 billion. The report concluded that total cost to improve the system for the period from 2005 to 2015 will be $3.4 trillion but that total revenue will be only $2.4 trillion, leaving a cumulative gap of approximately $1.0 trillion.[32] Very little of this agenda for improvement has been carried out in the past few years, so the cost of the project, say to 2020, would likely be still more than this. And these figures do not contemplate building what will have to be in many cases at least an entirely new system.

It is not clear that this is possible. As two specialists in freight transportation have recently noted, "There is little hope…of solving congestion problems solely by investing in more highway capacity. According to the American Society of Civil Engineers, annual spending on highway improvements is now roughly $70 billion – a fraction of the estimated $186 billion needed to stay ahead of traffic growth.[33]

Note too that the low-hanging fruit is gone. As a study on infrastructure expansion by the American Association of Railroads notes that "most of the moderate-cost capacity expansions have already been made; future capacity expansions will be purchased at a higher cost because they will require expensive new bridges and tunnels and more track and larger terminals in developed areas."[34] We also know that as large scale infrastructure projects move forward, the cost of materials will rise. Capacity to build capacity is limited and costs will fly up.

Indirect costs, as the impact of construction or the development of alternative fuels radiates through the economy, are more difficult to assess, but equally significant in providing critical elements of a freight transportation strategy. [35]

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[31] *Annual Energy Outlook*, March 2008 Release, Tables 7 and 17. from AASHTO, Primer, 2008, p.26

[32] *Future Highway and Public Transportation Finance Phase I: Current Outlook and Short-Term Solutions* prepared by Cambridge Systematics, Inc. under contract to the National Chamber Foundation® of the U.S. Chamber of Commerce, 2005)

[33] Randy Garber and Amiya Setu, "Getting from Here to There: How Railroads can save our Highways from Gridlock", The Milken Institute Review, 2nd Quarter 2010

[34] Op. cit National Rail Freight Infrastructure Capacity and Investment Study

[35] For just one example, increasing demand for wood as a base for cellulosic biofuels might lead to significant shifts in cost functions in the economy: If the cellulosic mandates of the 2007 Energy Act are met solely by wood, we estimate that wood prices will be about 15 percent higher in 2015 and 20 percent higher in the early 2020s than they would otherwise be. Worse yet, higher priced wood will drive U.S. forest product processing offshore, increasing imports of wood-based goods, perhaps dramatically. This would increase the United States trade deficit. More important, it might well sabotage the effort to reduce climate change by creating incentives to cut down trees that serve as natural storage sinks for carbon in places where they aren't likely to be replaced. Sedjo and Brent Sohngen, Op. cit.

This discussion is not meant to conclude that any of these approaches cannot or should not be undertaken. It is meant instead as a heads-up to keep in mind the whole picture – a summons for wider systemic assessments of proposed remedies. Quinlan Carthane, a professor at the College of Europe, suggests this needed perspective in her discussion of rising concern in Europe about support for biofuels. Her critique of the EU's revised approach to biofuels titled "Good in principle, bad in practice" underlines well the need to view proposals for GHG emission mitigation in a broad economic, social, political and financial context.[36]

> First, determining the emissions profiles of first-generation biofuels requires extensive analysis stretching from the type of fertilizers used to grow the crops to the method of transporting the refined product to the intended market. Accurate calculations require full and reliable information… this poses a complication, especially with regard to plantations in developing countries. Second, meaningful calculations need to take account of both direct and indirect land-use change. The sustainability criteria in the [EU legislative] Package include provisions on environmental and social sustainability, but the Commission has not yet clarified its position on factoring indirect land-use change effects into its GHG savings profile. The Commission's eventual position will thus be critical to the relevance and reliability of the percentage savings attributed to biofuel variants. Third and finally, the measures prohibiting the conversion of high-carbon and highly biodiverse land into energy crop plantations assume the forthright compliance of producers. But as was shown, many developing countries have a long way to go to reach sustainable production methods, and in some cases, fraudulent claims of sustainability are being used to allay concern and attract investment. How the EU intends to combat this and other problems inherent in complying with and enforcing sustainable biofuels production standards on what is a global scale is of great interest.

Infrastructure is often the biggest gorilla in the room. But too often this gorilla seems to be invisible. As underlined, we can talk about cleaner trucks and devise a whole Wal-Mart of innovations to make trucks cleaner. But if we don't talk at the same time about how this will affect our highway infrastructure, it doesn't make much sense. Introducing a new system of alternative fuel would require the construction of a new infrastructure system not only of production, but also of transportation, distribution and storage.

Electric power presents different but parallel infrastructure issues. Of all alternative fuels, electricity seems to offer the most advantages. Plug In America's website waxes ecstatically about the all-electric vehicle:

> In an all-electric car, high performance batteries store cleaner, cheaper, domestically produced electricity, and an electric motor provides propulsion with zero emissions. In a plug-in hybrid, more batteries than a conventional hybrid allow local all-electric, zero-emission driving with an internal combustion engine for longer distances. Electric cars are very reliable. No oil changes, no tune ups. EVs have fewer than 1/10th as many parts as a gas car. There's no engine, transmission, spark plugs, valves, fuel tank, tailpipe, distributor, starter, clutch, muffler or catalytic converter. The best way to reduce carbon emissions is to utilize the ever cleaner, greener, more renewable grid to power transportation. Only grid-rechargeable cars can attain the end goal of zero-emissions and ensure fuel price stability.[37]

But infrastructure is the missing key to electrification in the transport industry. First, for the foreseeable future, more electricity in US means more coal. The only way the US can increase

[36] Quinlan Carthane, "A Misleading Promise? Rethinking European Support for Biofuels," EU Diplomacy Papers, 2/2009, College of Europe, Department of EU International Relations and Diplomacy Studies

[37] Plug In America, http://www.pluginamerica.org/what-are-plugins.shtm

electricity output in the near and probably middle term is to burn more coal. Are there ways to make coal "cleaner"? Some experts say that this is possible. But time and money – and government – are powerful cards in this game.

Second, did someone mention the "grid"? If we are not talking just about a few dozen, few hundred or few thousand grid-rechargeable vehicles, we have to think about a building a much more modern and robust North American electricity grid. Just as a decision to focus on cleaner trucks means a new highway system, so does a decision to go electric means a much up-graded electrical power grid.[38]

At times, building new infrastructure does not solve problems as much as push them down the line. Focusing on individual infrastructure projects, rather than looking at freight transportation infrastructure as a highly integrated, multi-modal continental system, can lead to all sorts of problems. More US-bound containers coming into Prince Rupert Port might relieve congestion in the ports of Long Beach-Los Angeles, but could add more congestion at U.S.-Canada border crossings and worsen congestion in Chicago. We can construct more highway lanes and put more trains on the rails, but if exchanges and junctions are not modified (often more difficult because they are likely to be in more densely populated areas) then you have just created more congestion at the ends of the system.

Implementation is another critical subject frequently omitted from proposals to mitigate GHG emissions is implementation – how ideas can be translated into policies.

Most of the methods advocated to mitigate truck generated GHG emissions seem to assume that proposals introduced into the legislative sausage maker will emerge as pristine as they entered and, as well, in a timely fashion. As we have continued to see in the US, proposals regarding any dimension of climate change and global warming – particularly linked to any increase in taxation – are highly controversial, if not out and out inflammatory.

America's fragmented and decentralized system of government makes the idea of a national infrastructure system (not to mention a continental system) a very hard sell. Except for remarkable events – the Interstate, for example, which was largely a creature of the Cold War – transportation infrastructure in the US is constructed from the bottom up, by states and local communities. In the past two decades, localism and fragmentation have been heightened in highway construction as Congress has taken over responsibility for allocating larger and larger shares of highway funding in the form of individual earmarks, marginalizing the role of the Department of Transportation.[39]

Complex, controversial legislation is bound to rouse swarms of lobbyists. Who could be surprised, for example, that when advocates push to eliminate gasoline and diesel based fuel systems, the oil industry would leap into the game? Those who propose change must be prepared to play through the game of politics in which log-rolling and wheeling and dealing are inescapable.

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[38] The spring 2010 issue of *The Bridge; Linking Engineering and Society* (published by the National Academy of Engineering) is devoted to The Electricity Grid. (http://www.nae.edu/File.aspx?id=18585)

[39] See a 2007 Department of Transportation report: "The inspector general counted 8056 earmarks worth $8.54 billion within last year's transportation budget. The majority of these, 6556 earmarks, directed the Federal Highway Administration (FHWA) to spend $5,675,100,200 -- fifteen percent of the agency's 2006 budget -- on projects hidden from public scrutiny in the text of laws, in conference reports and in the reports accompanying the 2005 transportation bill known as SAFETEA-LU. An earmark allows an individual member of Congress to identify a need in his district and bypass traditional federal and state planning procedures. This turns something that might previously have been a low-priority project within the state into a mandatory top priority." Source: Review of Congressional Earmarks Within Dept of Transportation Programs, US Department of Transportation, 9/7/2007 http://coburn.senate.gov/public/index.cfm?FuseAction=Files.View&FileStore_id=85049145-abf0-4af9-83c4-9189944808f7

Proposals to mitigate transport-generated CO_2 emissions can suffer from a superabundance of goals. A recent report, for example, lays out "principles or criteria should guide the formation of new federal policies for the transportation sector to address global climate change and U.S. oil dependence". These include "seriously address both the oil- consumption and climate-change challenges", "provide a clear, long-term signal to industry and the American public", "be transparent, verifiable, and enforceable", "promote shared responsibility for addressing the problems, protect and assist lower-income segments of U.S. society", "address both fuels and vehicle technologies", "stimulate innovation" and "enhance the competitiveness of U.S.-based industry". Also, "be flexible" and "be cost effective".[40] This is a heavy burden and evolving a strategy to achieve all of these objectives would be an overwhelming task. Efforts to achieve one objective may make achieving another more difficult. A feasible strategy may enunciate clear goals but must also include a sense of what can be achieved in what time-frame, of priorities among objectives and the relative cost of achieving one goal as opposed to another.

Advocates who insist on a single "solution" create other problems. Some of the environmentalists say there is only one way to proceed – to put a price on carbon. If this is done, the pieces will fall into place and CO_2 emissions will drop as the pricing system works its way through the transportation market. And if it isn't done, then nothing else matters. But to have any hope of success, a mitigation strategy must surely include a package of measures, some of which can be undertaken sooner and less expensively, and others longer-term and systemic. Longer-term, systemic change will be hugely expensive. Building political coalitions will be difficult, and getting new systems online, even when agreement has been reached, will almost surely take a lot of time.

What might a good balance consist of among different approaches?

For example, should a strategy focus heavily at the front end on encouraging firms to green supply chains (with tax incentives?) and include measures to encourage (require?) truckers to institute better driver training, ensure proper tire pressure and reduce idling? None of this would be enormously expensive (greening supply chains would reduce fuel costs) and together would have an immediate impact. Pushing (requiring?) aerodynamic styling (and even retrofitting older vehicles) would reduce drag, fuel consumption and emissions.[41]

Should a policy package include as well an early focus on "black carbon" and gases that form ozone? These are air pollutants rather than carbon, but their warming effect "is around 40-70 percent of that of carbon dioxide... (and)... Limiting their presence in the atmosphere is an easier, cheaper, and more politically feasible proposition for slowing climate change – and it would have a more immediate effect."[42]

Deeper systemic change would still be required (these actions would slow carbon growth but not halt it), but bringing transformational change online will take time, even if the political will to do it can be generated. More immediate actions might provide the environmental (and political) victories that could generate support from stakeholders and help create coalitions to push broader measures through the policy-making and administrative processes. The bottom

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[40] Kelly Sims Gallagher, Gustavo Collantes, John P. Holdren, Henry Lee, Robert Frosh, "Policy Options for Reducing Oil Consumption and Greenhouse-Gas Emissions from the U. S. Transportation Sector", Discussion Paper, A joint project of the Science, Technology and Public Policy Program and the Environment and Natural Resources Program, Belfer Center for Science and International Affairs, July 27, 2007 pp. 10-11

[41] See the support provided by the Government of Canada for ecoFREIGHT funding to reduce greenhouse gas emissions from freight transportation in Manitoba. (http://www.ecoaction.gc.ca/news-nouvelles/20080506-4-eng.cfm)

[42] Jessica Seddon Wallack and Veerabhadran Ramanathanm "The Other Climate Changers; Why Black Carbon and Ozone also Matter," *Foreign Affairs*, November/December 2009, p. 105

line is that we will have to think not in terms of a single method of GHG mitigation but of a package of interrelated measures that balance a range of objectives.

D. Learning from others

Little has been done to explore what others have done, in particular, in Europe. Yet in several cases – in the U.K., Sweden the Netherlands and in the European Union itself – much effort by government agencies, independent commissions and research institutions has focused on freight transportation and climate change. The brief descriptions below record discussions and policy proposals and not achievements to date. But they suggest areas to which we North Americans should turn our attention.

For example, as one element of its proposed plan to cut emissions by at least 80% below 1990 levels by 2050, the British government announced in December 2008 goals for its transport system that included "reducing transport's emissions of carbon dioxide and other greenhouse gases, with the desired outcome of tackling climate change.."[43] The Swedish Government has proposed a 25% reduction from 1990 levels in climate pollution by 2020 and has affirmed support for an overall reduction within the E.U. of 30%, by 2020. Its strategy for reducing emissions from road transportation includes creating "a transportation efficient society, energy efficient road maintenance, energy efficient use of vehicles, energy efficient vehicles, and biofuels…A transportation efficient society includes transportation efficient regional and urban planning and production chains, choice of energy efficient transportation modes, and choice of energy efficient alternatives to travel and transportation. Energy efficiency within the road transportation sector involves increasing the energy efficiency of the vehicle fleet, energy efficient use of vehicles, and energy efficient road maintenance. The biofuels area includes supply, production, and distribution of renewable fuels at competitive costs."[44] The Netherlands "are currently planning to implement an all-embracing measurement system, in which each CO2 emission caused by road traffic will be tracked and allocated to the causer. Businesses and private persons will have to pay a charge for each kilometer driven, regardless on which road."[45]

In April 2009, a paper issued by the European Commission laid out the lines that European freight transport corridor policy would follow: "Over and above everything else, the fight against climate change requires Europe-wide measures to underpin Europe's leading role in the world. Transport and transport infrastructure are areas which offer considerable potential for positive contributions. Climate change objectives should be placed at the centre of future TEN-T policy and be reflected in a truly European approach. Through a process that integrates economic and environmental objectives, is clearly oriented towards the needs of efficient freight and passenger services on a co-modal basis and involves innovation, future TEN-T policy should provide a sound basis for an effective contribution to the Community's climate change objectives."[46]

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[43] U.K. Department for Transport, "Delivering a Sustainable Transport System: Main Report" (November 2008); see U.K., "Committee on Climate Change, Building a low-carbon economy – the U.K.'s contribution to tackling climate change: The First Report of the Committee on Climate Change" (December 2008)

[44] Fredrik Hedenus, "On the Road to Climate Neutral Freight Transportation" (2007) p. 6. This study was carried out at The Centre for Environment and Sustainability, GMV, in Göteborg, Sweden, a network organization at Chalmers University of Technology and University of Gothenburg. The report was produced in cooperation with Preem Petroleum, Schenker, Volvo Trucks, and the Swedish Road Administration. (http://www.vv.se/PageFiles/9176/on_the_road_to_climate_neutral_freight_transportation_.pdf?epslanguage=sv)

[45] Deffke, U. (2009). Dutch Road Toll System Gets Surprising Green Light. Retreived September 4, 2009, from http://www.spiegel.de/international/europe/),a,608406.00.html, Quoted in Price/Waterhouse/Coopers, op. cit., p16.

[46] Commission of the European Communities, TOWARDS A BETTER INTEGRATED TRANSEUROPEAN TRANSPORT NETWORK AT THE SERVICE OF THE COMMON TRANSPORT POLICY, GREEN PAPER: TEN-T: A policy review (Brussels, 4.2.2009, COM(2009) 44 final)

This paper rested on much prior work dealing with transportation and climate change. In 2006, the Commission conducted an extensive review of its earlier policy objectives and launched a new mandate. Measures proposed at this time included, among others, the promotion of "co-modality" to achieve a better integration of different transport modes into efficient logistics chains; the promotion of the use of cleaner cars and fuels; and the development of infrastructure charging to improve the management of freight transport and reduce transport's environmental impact while generating funds for investing in new infrastructure.[47]

Because most transport modes fail to fully cover their external costs, users currently pay a much lower price for their mobility than the real cost to society and the environment, keeping demand artificially high. "For efficiency as well as for fairness purposes, the costs and nuisances related to transport activities should be borne to a large extent by those who produce them," the European Commission states in its consultation document. The idea of establishing a uniform 'user-pays' system for all forms of transport is not new, but it has in the past been avoided due to the complexity of calculating external costs and to the reluctance of national governments to introduce new taxes. Which costs should be considered as transport-related externalities is the core issue – whether just air pollution, or also factors like costs related congestion or the medical costs of people involved in traffic accidents. Under the Commission's plans, congestion, noise and air pollution costs could be integrated into toll prices but charging trucks for CO2 emissions would not be permitted.

E. Final Comments and learning from history

We are facing system-wide technology-driven transformational change in our freight transportation system. What this means is that we are trying to think of ways to deal with several complex issues at the same time – facilitating freight transport and reducing its cost and mitigating truck produced GHG emissions – in an environment of constant and profound technological change.

Incrementalist thinking can obscure larger patterns of change. To build an efficient, secure and sustainable North American freight transportation system we need to bring together a much wider array of factors – trends in technology, climate change, changes in production and distribution systems and demographic changes -- to create a vision of what a North American freight transportation system should/could look like in, say, 2030 or 2050.[48] Given this, we need to ask how we can get there from here. In this world of rapid and transformative technological change, this is no small order.

Clearly, too, we must view environmental problems associated with freight transportation in continental terms, not as three separate national issues**.** Climate issues do not stop at the 49th parallel or the Rio Grande. We may speak of the need for a North American freight transportation system, but no institution exists even to think about this. North America is institution poor and funding for the one institution with a North American-wide environmental mandate, the Commission for Environmental Cooperation, remains minuscule and with no danger of a raise. Moreover, perceptions of urgency and approaches to the mitigation of transport-generated emissions differ widely among communities in North America. Aligning three national strategies that would stimulate economic growth and enhance energy security and reduce

[47] See Commission of the European Communities, Communication from the Commission to the Council and the European Parliament, "Keep Europe moving -Sustainable mobility for our continent; Mid-term review of the European Commission's 2001 Transport White Paper" Brussels, 22.06.2006

[48] See Stephen Blank with Malcolm Cairns, Drivers of Change: Envisioning North America's Freight Transportation System in 2030, Working Paper 7, North American Transportation Competitiveness Research Council (August 2008)

GHG emissions is a pretty tall order. Collaboration among the three national transportation ministries is modest and focuses more, particularly since 9-11, on security and border issues rather than wider strategic matters.

A realistic vision will emerge not from a single report but only from a dialogue among groups with different views, approaches and perspectives. Needed is an arena where different ideas about what we will need and how we will meet these needs can confront one another, where we can define with modest certainty what research needs to be carried on and where there is real learning rather than the constant reiteration of conventional wisdom.

We are still relying on shots in dark, on a series of unconnected and unrelated commissioned reports carried out by researchers who move immediately on to a new project when they complete this one. This Hail Mary approach – the hope that one last paper will finally reveal the answers – won't work. We cannot think of another project; what is needed is a process. We should consider how to mobilize assets in the research community and the private sector and embark on a multi-dimensioned dialogue on these matters.

This is not the first time technology has driven a vast transformation of the transportation system. The creation of the North American railroad system in the decades after the Civil War was the first application of such a change on a continental scale. As we confront what are likely to be economic, social and political changes on a similar scale, it is worth asking what we might learn from the earlier experience.

In the 15 years from the end of the Civil War to 1880, the US railroad system was dramatically transformed. Seven different track gauges were standardized into one, and track mileage rose from 35,000 to 115,647 miles. Ton-miles of freight carried by the thirteen major lines rose 600%, from 2.16 billion to 14.48 billion and would reach to almost 80 billion in the next decade.[49] In every dimension, from the creation of national markets and the organization of the modern company, to the widespread impetus for technological advances and even to the recreation of the American imagination, its music and literature, the railroad transformed the nation.

Americans loved and also hated the railroads, and the development of the American railroads combined the best and worst elements of the society and economy.

> Between Americans and their railroad lines there existed what was probably history's most famous love-hate relationship. The railroads were symbols of American progress, of technology, of power….At the same time the railroads represented everything ruthless and criminal in American capitalism.[50]

Building the railroad system was enormously expensive, possibly the largest infrastructure project undertaken up to that time. In the US, localism and private enterprise dominated commercial transportation infrastructure – first in canals and subsequently in rail. Governments provided huge amounts of investment capital. But companies – and railroad companies in particular – proved highly proficient at taking public funds while avoiding regulation or control. America's weak governments were no match for emerging giant companies.[51] The expansion of the rail system, with all of the benefits it provided in every aspect of the economy, also resulted in more than three decades of duplication and waste, speculation, excessive debt, corruption and, in the

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[49] Page Smith, The Rise of Industrial America, Volume Six, A People's History of the Post-Reconstruction Era (McGraw Hill Book Company, 1984) pp. 89-90

[50] The Rise of Industrial America, op. cit. pp. 110-111

[51] Charles Perrow, see Chapter 5, "Railroads, the Second Big Business" in Organizing America: Wealth, Power and the Origins of Corporate Capitalism, Princeton University Press, 2002

case of the Erie and some other railroads, chaos. It launched a struggle between governments and railway industry that led to the nationalization of the system during World War I and ultimately to the determination of Congress to lend every support to the rising competitor of railroads, the truck industry.[52]

Can we draw lessons from this experience of system-wide technology driven change?

Stephen Blank
New York
August 12, 2010

[52] See Stephen B. Goddard, Chapter 1. The First Big Business, in Getting There: The Epic Struggle between Road and Rail in the American Century, The University of Chicago Press, 1994 and Jim Cohen, "Divergent Paths, United States and France: Capital Markets, the State, and Differentiation in Transportation Systems, 1840–1940", *Enterprise & Society* (Volume 10, Number 3) September 2009