Joint workshop by the Joint Research Centre of the European Commission and the International Energy Agency

The future role of trucks for energy and the environment

Tuesday 8 November 2016 *Centre Albert Borschette - Rue Froissart 36 1040 Brussels*

Workshop Summary, 14.11.2016

BACKGROUND

Session 1

Key themes of the workshop emerged in the opening session. Contributors highlighted several points, including: (1) the role that freight in general and road freight in particular plays in the economy, (2) key drivers of demand for road freight, (3) modal shares of GHG and pollutant emissions, (4) enablers and barriers of efficiency and conservation measures to reduce energy consumption as well as GHG and pollutant emissions, and (5) considerations in designing policies to enable these reductions.

Economic and Environmental Indicators

The freight sector plays an integral role in the global economy, and with strong growth projected in developing and emerging countries, freight activity can be expected to increase commensurately. Maritime freight accounts for the lion's share of global activity (measured in tkm), but road freight accounts for more than two-thirds of freight sectoral emissions, and similarly high shares of all pollutant emissions (except SOx). Road freight's large and growing share of GHG emissions in the energy and transport sectors[1] stands in stark contrast to the lack of prioritization the sector has received in (Intended) Nationally Determined Contributions ([I]NDCs). Only 43% of (I)NDCs provide transport-specific mitigation measures, and only 13% mention freight. Of those that mention freight, only 4% highlight the potential for improved vehicle utilisation to reduce emissions. Science-based targets and initiatives to reduce freight emissions are desperately needed not only at the national level – 179 global multinationals have set targets for reducing emissions associated with freight movements, but they are struggling to see how to get there.

Policy Formulation

Speakers emphasized the need to craft "holistic" policies that address the fundamental drivers of freight activity, energy use, and environmental impacts (notably GHG and local emissions). Policy must force markets toward efficiency, both through regulations and through strong, stable and consistent market-mechanisms that reward leading manufacturers of energy efficient technologies (both component makers and OEMs). They must promote improvements both at the systemic and the vehicle/fuel levels. Policies must address local pollutant emissions, which are an immediate threat to the health of residents of cities, particularly in developing and emerging economies, and must go beyond reducing tailpipe CO2 emissions to extend to the entire well-to-wheel scope of GHG emissions. Indeed, the case for strong policy action can be bolstered by demonstrating the co-benefits of promoting efficient vehicles, operations, and low-carbon fuels – all of which have the potential to reduce both air pollution and GHG emissions. Policies must also simultaneously take advantage of immediate and near-term opportunities to improve real-world vehicle

[1] According to one presenter, HDVs currently contribute about 30% of all road transport CO2 emissions in the EU. Another presenter cited the World Energy Council as stating that transitioning global transport is one of the hardest challenges society faces to overcome to decarbonising energy systems.

and logistics efficiencies, and steer the sector toward the long-term goal of zero-emission and decarbonised provision of goods and services.

To the extent that harmonisation of standards (especially emissions standards) is possible, given the differences in national truck markets and existing regulations, it is preferable. This is the case both from an OEM's standpoint – as harmonisation provides clear and standard specifications for manufacturing and enables industry to harness economies of scale – from a regulatory perspective – as it can streamline the regulatory design and implementation process – and from a social one – as it prevents the 'race to the bottom' dynamic wherein old, non-compliant vehicles are sold to poorer countries.

Consideration must be given to potential rebound effects of policies, and for other unintended impacts. Finally, policies must address root causes of demand (i.e. final consumers who desire products and services), and for instance must be capable of addressing the increased demand engendered by internet orders in the developed world. Carbon taxes are an example of a policy that would address this root cause, and pricing that encourages consumers to accept flexible delivery times could help shippers to optimise routes. In the context of growing incomes and technological change, holistic, long-term and transformative interventions can leverage the potential to increase efficiency by shaping land use in general and the design of cities in particular, as cities account for a growing share of final consumption.

Leadership across Policy, Industry, and NGO Realms

Session speakers provided a glimpse into the diversity of perspectives on road freight from policy makers, industry, and NGOs. A consensus emerged that addressing the sector's growing oil consumption and emissions calls for leadership not only by policy makers but also by industry and NGOs.

In the policy realm, an overview of the VECTO tool, developed by the European Commission, provided insight into its capabilities and the efforts taken to ensure that it is representative and robust. Although VECTO can be used to estimate with high accuracy and precision the efficiency impacts of vehicle technologies, including alternative configurations and retrofits (e.g. low rolling-resistance tyres, aerodynamic skirts, etc.),[2] it cannot be used to gauge the energy use and GHG reduction impacts of the broader system within which trucks operate (as discussion in Session 3).

In the realm of vehicle technology, consensus estimates emerged on the potential for near- to mid-term efficiency improvements of 30%-50% per tonne-km with incremental technologies (i.e. those that are already on the market, and in many cases have very short payback periods). The industry representative on the panel noted that efficiency gains of 20% are realisable 'in the immediate term', and that the potential benefits are attractive to truck operators, as 40% of the total costs for road freight services are for fuel. He called for policies that reward industries with the most efficient technologies, claiming that once 15% market share has been achieved, RD&D costs of new technologies can be recuperated and supply chains secured.

The NGO perspective focused on pinpointing key barriers to adoption of energy efficient vehicle technologies and practices. These comprise: (1) Governance – public policy makers must prioritize and make the case for decisive and effective policies (e.g. by illustrating substantial co-benefits) (2) Market fragmentation – for instance, in China, up to 90% of freight is carried by small operators with up to 1 truck only (3) Inadequate access to finance – leading to old, inefficient fleets. For example, more than half of the truck fleet in ASEAN countries are more than 15 years old. The aggressive and competitive nature of the road freight sector drives transport buyers to provide contracts of ≤1 year. This makes long-term income less reliable and investment in new technologies a greater risk. Longer contracts from shippers would improve the likelihood of operators investing in newer technologies. Even individual truck owners would prefer to drive a newer, cleaner truck, but while the interest is there, the finance is not. (4) Unavailability of data – a call was made to consider ways to mandate or incentivize the collection of minimum parameters needed to track and model freight operations, namely: origin, destination, tonnage of cargo, dimensions (i.e. length, width, height), and timing constraints (i.e. shipping order dates and delivery deadlines).

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[2] The VECTO tool designates among 17 vehicle classes, with varying inputs for axle and chassis configuration, Gross Vehicle Weight (GVW), and across five mission profiles.

Session 2

Discussion of the potential of various 'incremental' and 'transformational' vehicle and fuel technologies was framed by considering the barriers to adoption, on one hand, and GHG reduction potential, on the other, of alternative technologies.

Incremental technology – options and barriers

The set of 'incremental' technologies was defined as having a GHG reduction potential of <10% in all cases, and mostly 'low', in some cases 'medium' barriers to adoption. Technologies that could be mandated very quickly, and lead to immediate GHG emission reductions, include tractor and trailer add-on devices that improve ***aerodynamics***, material substitution leading to vehicle ***light-weighting***, fuel-switching and improved efficiency for ***refrigeration*** devices, ***low rolling-resistance tyres***, ***improved transmissions***, and higher-quality ***fuels and lubricants***. Operational improvements, such as ***driver training*** that focuses on saving fuel, or even on-board ***driver-feedback*** devices, ensuring proper ***tyre pressure*** is maintained, and ***telematics*** to reduce trip distances and time spent in traffic, face low-medium barriers and individual lead to similar ranges of GHG reduction (1%-10%). Improving road quality and designing smoother roads would be a necessary measure to realise the benefits of many of the vehicle efficiency technologies in the real-world, particularly in developing and emerging economies. However, road improvements are expensive and must be balanced with other considerations (e.g. overloading as a primary cause of rapid road degradation, allocation of budgets to road improvements over other priorities such as improved rail networks, etc.). Academic and industry speakers presented a range of estimates of the potential for these measures to improve real-world efficiencies, both in isolation and as demonstrated in specific projects in various combinations.

The primary barriers to exploiting the 30%-50% efficiency improvements mentioned above included: (1) the facts that trucks are custom-made for a wide diversity of missions, not mass manufactured, and that sales volumes for any given vehicle-engine configuration are limited (particularly as compared with the LDV market), together imply that RD&D costs are less easily recuperated, and that economies of scale cannot be harnessed as effectively as is the case with LDVs. (2) Powertrain and engine efficiency improvements (including the potential for WHR) are converging on physical constraints, and hence further improvements on compression-ignition (ICE) systems will become increasingly expensive.[3] Finally, fuel quality issues must be addressed in developing countries as a means of both reducing local pollutant emissions and enabling more efficient engines and powertrains to enter the truck fleet.

Debate on the potential vehicle efficiency technologies to translate to real-world efficiency improvements focused on the utility of the VECTO tool for fleet operators. A presenter argued that VECTO is useful only as a tool for 'putting a sticker on a truck', and is of limited use to fleet operators who would like to gain a precise and accurate picture of their current fuel consumption and the potential for technological and operational modifications to cut real-world fuel use and GHG emissions. The speaker from the European Commission countered that not only can VECTO be used by regulators to estimate fuel consumption impacts of various combinations of vehicle and engine specification, but also the impacts of aerodynamics, low rolling-resistance tyres, and light-weighting. This speaker elaborated by explaining that VECTO has two modes: an *engineering mode* that can be used by operators, who can give the details of their truck fleet vehicle and mission profile to OEMs, who can then use VECTO to model actual CO_2 emissions and fuel consumption, and a *declaration mode* that is useful for regulations and efficiency labelling. But this speaker acknowledged the limitations of the tool, chiefly that it can neither capture systemic improvements (such as routing or reduced empty running), nor the GHG implications of transformational technologies (e.g. electrification, hydrogen).

Transformational technology options and barriers

Decarbonising trucking will require that alternative fuels substitute for diesel. After brief initial discussion on the viability of lower-carbon alternatives, such as natural gas and biogas, the greater focus was given to

[3] For instance, as manufacturers close in on achieving 50% brake thermal efficiency, they are approaching a hard thermodynamic limit.

the potential for electricity versus hydrogen as energy carriers and pathways for complete decarbonisation. Scepticism was raised on the viability of both alternatives, but in general the champions of hydrogen seemed to be the minority, dissenting camp.

Dual-fuel vehicles can take advantage of CNG/LPG, though these powertrains must contend not only with upstream leakage of methane, but also with 'methane slip', which reduces efficiency. However, Daimler asserted that current HPDI systems can already reduce methane slip significantly. Trucks running on dedicated (single-fuel) CNG or LPG need not contend with methane slip. While the carbon reductions benefits of switching to conventional natural gas substantial, they are insufficient to achieve decarbonisation, and as such can only serve as transitional technologies that contribute in certain contexts to reducing emissions. Utilizing biogas (e.g. landfill gas) can lead to net-zero or even negative well-to-wheel emissions, but the volumes that could potentially be collected and converted are extremely limited. Hydraulic hybridisation could improve efficiency of trucks running on conventional compression-ignition engines, and offers a simple mechanical engineering solution that requires no rare earth metals. Hybrid-electric powertrains would require rare-earth metals in batteries and motors, but could serve as the first step toward research and development, establishing supply chains, and achieving cost reductions that enable eventual electrification.

Electrification could proceed along many pathways, starting with missions and vehicles with the greatest cost competitiveness. Daimler has already begun to market electric light commercial vehicles, and expects to bring the first models of electric medium freight trucks to market next year. They envision that market introduction of electric heavy trucks could proceed within the next 5-10 years. The gap in purchase cost for electric vehicles will however remain for 'quite some time'.

Siemens presented progress it has made in various demonstration projects – on a test track north of Berlin, on a stretch of highway north of Stockholm, and on a 1-mile stretch of highway from the Los Angeles-Long Beach ports – of Electric Road Systems (ERS). According to cost comparisons, the operation costs of ERS are between 1/4 and 1/3 of those of pure battery electric trucks, including the amortized costs of installing and maintaining the infrastructure. ERS systems couple catenary lines running at 600 Volts direct current with an overhead retractable pantograph installed on trucks. After having investigated the potential of inductive rails on roadways or conductive charging in pavements, catenary lines proved to be the only durable, cost-effective and technically viable way to electrify heavy-duty applications.

According to the vision of ERS advocates (including Siemens, BMUB, UBA, BGL, IRU, and Sweden's Transport Administration), ERS enabled lanes could penetrate first in short-distance, local freight applications as a means of radically reducing local pollutant emissions, for instance at ports (as in the LA-Long Beach demo site) and mines. With sufficient regulatory and potentially also fiscal support from local, regional, or national policy makers, ERS infrastructure could then branch out to medium- and long-distance highways with the highest freight activity. Trucks operating along ERS routes could be equipped with hybrid-electric powertrains, fully electric batteries, or hydrogen storage tanks and fuel cells, to ensure flexibility of operations for a short range without catenary power conduction (i.e. when not on ERS lanes).

According to the vision of ERS proponents – which include not only Siemens, but also BMUB, UBA, BGL and IRU –, the early applications will be in shuttle applications, where trucks go back and forth a lot, for instance at ports (with the added benefit of radically reducing local pollutant emissions for the nearby communities) and mines. For ERS technologies based on proven power transfer infrastructure, like contact lines, the regulatory approval process should not pose a significant challenge. In fact, Germany's Federal Highway Research Institute (BASt) and Sweden's Transport Administration have both investigated the contact line ERS and given the green light for application on highways. Following shuttle applications, and aided by cross-border coordination by national policy makers, ERS infrastructure could then branch out to medium- and long-distance highways with the highest freight activity.

Some participants were sceptical about the capacity for various actors to align in a sufficiently rapid and coordinated manner to build catenary lines for ERS. Regulatory hurdles were seen as major barriers – litigation, planning, construction, land rights, environmental considerations, etc. may delay large scale projects so that they take decades to realise. Some of the same sceptics of ERS noted the advantages of hydrogen, chief among these its potential to serve as a vector for energy storage of grids that will rely heavily on variable renewables and will have highly variable and mismatched generation and demand profiles. Among sceptics of hydrogen, the usual litany of barriers to the viability of 'green' hydrogen were cited, as well as the contention that the coordination and regulatory hurdles faced by ERS apply even more for the build-out of hydrogen generation, transmission, and distribution systems.

Aside from the debate on which decarbonisation pathway seems more viable for trucking in general and long-distance, high-volume trucking in particular, the other highly contested issue in Session 2 concerned the GHG reduction potential of high-capacity vehicles, and whether reliance on these vehicles led to a mode shift away from freight rail. The debate revolves around whether such a mode shift actually occurs; those advocating high-capacity vehicle adoption argued that the goods shipped have little to no overlap with those shipped by rail, and hence the concern over modal shift was entirely unfounded. Sceptics, citing the dearth of good data, wanted more convincing proof of these claims.

Proponents of high-capacity vehicles saw political acceptance as the principle barrier to its adoption in countries where it does not yet exist (and above all in Europe). Other barriers include licensing, safety concerns (including the potential for vehicle roll-over, lack of access to tunnels, and less secure operations in cold weather or on steep grades). Further concerns voiced included the potential for damage to roadways and bridges, and the need for new and expanded infrastructure (including weigh stations and refuelling ports).

Session 3

Conceptualizing logistics

The session on optimising transport systems began with a frame-setting presentation by Dr Alan McKinnon, who showed the realm of issues that are included in the rather fuzzy term *logistics*. His 'rectangular onion' diagram shows the hierarchy of systems involved in goods movement which can be optimised, with vehicle and fuel technologies comprising the innermost layer. Dr McKinnon defined logistics to include the four outermost layers of the 'onion: vehicle loading, vehicle routing and scheduling, modal shift, and finally logistics system design and supply chain restructure as the broadest, all-encompassing layer of freight movement. Insofar as optimisation of a subsystem does not compromise optimal performance of the whole system,[4] each of the levels in the diagram is amenable to and worthy of consideration for efficiency improvements. In closing, Dr McKinnon emphasized the undervaluation (for instance, in [I]NDCs) of the potential to improve overall system efficiency through better vehicle utilisation.

Dr Phil Greening provided a distinct framework for conceptualizing the various subsystems that comprise road freight. At a *national* level, there is a relationship between GDP and basic truck modal parameters like vkm, tkm, and energy intensity. Great variability exists at the *sectoral* level; for instance in the value density of goods (such as coal or lumber versus electronics or perishable fruits). At the *corporate* level, competition is the norm, which is typically cited as the major hindrance to data-sharing, despite the fact that data-sharing that properly ensures protection of competitive intellectual property would result both in increased system-wide efficiency and reduced bottom-line expenditures. If firms could be persuaded (if necessary, through regulation) to share their best practices and, in the words of one speaker, "compete on the shelf, but not in logistics", society as a whole would stand to benefit tremendously. At the *functional* level, improved warehouse design can facilitate optimisation of pallet loading, leading to better vehicle utilisation (in terms of both product weight and size per trip) on the order of 10%-20%. Warehouses that proved these efficiency gains were operational over a decade ago, but have not become main stream. Finally, at the *asset* level, vehicle technologies emissions and energy use can be minimized, as discussed in the previous session. Critically, improvements made at this innermost level (of vehicle technology) are diluted by inefficiencies within the systems enclosing it.

A pressing need for data

[4] An example of a measure that compromises system-level efficiency given in the workshop was the regulation of heavy-duty trucks (for instance in urban regions) that leads to a modal shift to light commercial vehicles or medium-freight trucks, which on a MJ or GHG and pollutant emissions intensity per activity (i.e. tkm) basis are less efficient, assuming the same technology.

The primary hurdle in optimising freight logistics efficiency is what one speaker characterised as a "serious, chronic lack of empirical data to calibrate our simulation models." Approximately 90% of business operators track neither the weight nor the size of their product shipments, despite the fact that product-level data on these parameters are easily available (and can be culled from a simple Google search) from manufacturers. One result is suboptimal vehicle utilisation – if a 60% load factor is an acceptable estimate of vehicle utilisation, once the weight of packaging and pallets is accounted for in the item shipment, the actual load factor is likely to be closer to 40%.

Various reasons were given and solutions proffered for why carriers are reluctant to share their data and how to incentivise them to do so. In some cases, barriers may be technical – indeed, many individual truck operators record data in their notebooks. Data must be digitalised for use by operators and researchers.

Most other barriers stemmed from firms' competitive concerns. Carriers may fear that their data will show poor performance metrics. Concerns about the security of proprietary data may cause carriers to not share, but by employing data-security professionals to protect aggregate databases such concerns can be mitigated, if not completely eliminated. Barriers to data-sharing can be countered by emphasizing the economic benefits of sharing data, by anonymising sensitive data, and by employing an unbiased supply chain orchestrator to broker goods movement while safe-keeping data.

In summary, in the absence of comprehensive data of the most basic kind, the potential for systemic efficiency measures can only be roughly estimated. More precise and accurate quantification, to say nothing of real-world implementation of logistics improvements, will require systematic data collection and analysis.

Consensus systemic solutions

As in session 2, the discussion of the potential of various systemic improvements in logistics was framed by considering the (corporate, technical, economic, and political) barriers to adoption, on one hand, and GHG reduction potential, on the other, of competing options. Measures were further delineated by those that could be undertaken by a single company versus those that would require data-sharing and collaboration across multiple firms. Although no silver bullet emerged, many options exist to reduce GHGs.

Single firms could optimise routing, re-time deliveries, and implement last-mile efficiency measures, each with relatively few barriers, to reduce emissions in the range of 1%-5%. In the case of retiming deliveries, encouraging consumers, in particular retails and households, to opt into flexible delivery can contribute greatly to optimizing the delivery patterns and utilisation of trucks. Enabling urban freight deliveries to happen overnight (e.g. between 7 pm and 7 am) can greatly reduce congestion, thereby lowering both fuel intensity and total consumption (via reducing delivery times on the order of 30%) and emissions.

Only low-to-moderate barriers stand in the way of home delivery of groceries, which could enable even greater GHG reductions in that sector, and vehicle fill can be improved via a wide range of operational modifications (such as warehouse redesign as mentioned in the previous section) to reduce emissions on the order of 5%-10% without substantial barriers. According to Eurostat, 25% of kilometres run by trucks were empty in 2013 in the European Union. Single firms may also be able to realise incremental (1%-5%) efficiency improvements by better integrating their shipments across multi-modal channels or through crowd-sourced logistics, though barriers to adoption in these instances are higher.

Data-sharing among firms would make possible further GHG emission reduction measures. Port-centric logistics could be optimised, enabling something on the order of 5% GHG reductions with few barriers. Some corporate and technical barriers must be overcome to enable backhauling of good shipments across many firms, which could reduce empty running, and to set up urban consolidation centres, which could similarly enable trucks to carry cargo from multiple firms, thereby reducing distances and increasing loads. But the GHG reduction potential of both these measures is likely less than 5%. If more substantial barriers could be addressed, co-loading on a larger scale (and not only for urban deliveries) could lead to further GHG reductions (~5%-8%). Finally, the physical internet – where, at least in theory, all physical resources (fleets, warehouses, ports) are shared, would theoretically enable optimal resource allocation. Work to date on this concept suggests a potential 20% systems-wide efficiency improvement.

Finally, data-sharing across multiple large- and medium-scale shippers and retailers could enable a mode shift to rail. As freight trains must have sufficient loads to merit a trip, but at the same time goods movement is driven by customer demand (e.g. at retail outlets that need to restock their shelves), cooperation along popular freight corridors would allow shippers to make more frequent hauls while still filling trains to capacity. *Procter & Gamble* (P&G), which has made great strides in shifting to rail and now moves 25%-27% of its goods by train, claims to have maximized mode shift under its current practices, but could attain 40% rail mode shares by pooling goods movement with other medium and large firms.

Best practices

Driven by innovative companies aiming to reduce the costs of "moving air" and to display innovative practices as well as by advocates and NGOs pushing for more sustainable freight operations, best practices are emerging. These come not only in 'high-tech', but also 'high-touch' operations to gain consumers' trust and prove their commitments to reducing emissions. The *Connekt* network provides a 'lean and green' platform for data-sharing coupled with protection of company IP among shippers, logistics services providers, and carriers, as a means of benchmarking and improving logistics efficiencies.

In the business world, P&G moves 18 million pallets per year (> 500k full truck loads/year) in Europe, counting only outbound operations. The company has adopted various efficiency measures throughout its freight operations, including the modal shift to rail outlined above and is also involved in the *Transformers* consortium, developing configurable and adaptable trucks & trailers. These truck and trailers prototypes are designed with the goal of achieving vehicle efficiency improvements of 15%-18% and the operations they run achieve a further 10%-15% improvement in vehicle utilisation. P&G is also pioneering on a digital collaborative platform to share data with partners, as a means of collaborating with other firms to promote modal shift opportunities and better fleet capacity utilization. This initiative is a model illustration of the fundamental principle that the success of such ventures is the alignment of the business case (typically via lower fuel and fleet expenditures) with carbon reductions.