Low emission vehicles

In a nutshell

Summary overview							
It is best practice to improve the fuel consumption and emissions of waste collection vehicles. Priority technology options include: • stop/start and idle shut-off; • low rolling resistance tyres; • hybrid vehicles; • dedicated natural gas/biomethane vehicles or dual-fuel vehicles (diesel/gas); • electrically powered vehicles.							
Waste management area							
Cross-cutting	MSW - strategy	MSW - prevention	MSW - collection	MSW - EPR	MSW - treatment	CDW	HCW
Applicability							
This best practice is broadly applicable. The presence of filling or recharging stations is less of an issue for refuse collection than other types of transport because vehicles are usually operated over a limited distance and the fleet is run from a centralised waste depot where refuelling can take place. Compressed natural gas (CNG) is available in all EU countries. Biomethane may not be available in many regions, but wet organic waste (e.g. food waste) can be used to produce biogas that can be upgraded to transport biomethane.							
Specific environmental performance indicators							
• Average fuel consumption of the waste collection vehicles (litres/100 km). • Share of vehicles that are Euro 6 in the total waste collection vehicle fleet (%). • Share of waste collection vehicles that are hybrid, electric, natural-gas- or biogas-powered (%).							
Benchmarks of excellence							
All new refuse collection vehicles purchased or leased by the waste management organisation are Euro 6 and are fuelled by either compressed natural gas or biogas, or are hybrid-electric.							

Description

Municipal use of heavy goods vehicles (HGVs), primarily refuse collection trucks, accounts for approximately 4 % of HGV CO_2 emissions in the UK (Ricardo-AEA, 2012). A typical 26-tonne rigid HGV collection truck will consume between 57 L and 141 L per 100 km of diesel, reflecting inefficient low-speed and stop-start driving. Apart from the characteristics of the vehicles, fuel consumed for waste collection varies depending also on the levels of source separation (i.e. separate collection) achieved, since more separated fractions require more collection routes. Values can range from 3.3 L/tonne of waste (when source separation of waste is 25 %) to 3.8 L/tonne of waste (when source separation is 52 %) (Di Maria et al., 2013).

Priority measures identified by Ricardo-AEA to reduce GHG emissions from municipal HGV use are summarised in Table 1.

Table 1. Priority technology options to reduce greenhouse gas emissions from refuse truck operations proposed in Ricardo-AEA (2012)

Rank	Measure	Life-cycle CO_2e saving	Payback time*	Additional considerations
1	Stop-start and idle shut-off	5 %	<1–2.5 years	Small air quality and noise reduction benefits in congested urban areas. Marginal increase in life-cycle impact due to additional components.
2=	Hybrid electric vehicles	15–25 %	4–16 years	Air quality and noise reduction benefits particularly if able to in electric-only mode. Life-cycle impacts of batteries need to considered.
2=	Dedicated natural gas vehicles	5–16 % (CNG) 61–65 % (biomethane)	6–18 years	Significant particulate emission and noise reduction benefits requires additional refuelling infrastructure. Substantially lar CO_2e reduction benefits with biomethane.
3	Electrically powered truck bodies	10–12 %	9+ years	Electrically powered refuse truck bodies can reduce noise a air pollution.
4	Low rolling resistance tyres	1–5 %		May have slightly shorter lifespan than standard tyres but C and fuel cost savings are expected to outweigh any negativ environmental impact

*Based on current technology, marginal capital costs, fuel cost savings and low-high mileage sensitivities.

Source: Ricardo-AEA (2012).

Ricardo-AEA (2012) conclude: "The analysis indicates that one of the most effective strategies to achieve well to wheel CO_2e emission reduction in this [HGV] sector is to encourage a large scale shift to the use of gas as a fuel to replace diesel". Compressed natural gas (CNG) contains methane, which has a high hydrogen to carbon ratio, and therefore 20–25 % lower CO_2 emissions, per unit of lower heating value compared with petrol and diesel (Tassan et al., 2013). Perhaps more significantly, use of natural gas as a transport fuel significantly reduces air pollution emissions, such as NO_x and particulate matter (PM), compared with petrol and especially diesel. This effect is particularly beneficial in urban environments where refuse collection trucks operate, and where air quality is a major environmental and health concern. Biodiesel reduces GHG emissions but increases air pollutant emissions compared with diesel, whilst the climate change and air pollution performance is highly dependent on the method of electricity generation in the region of use.

Biomethane provides the same engine performance as CNG, but can reduce life-cycle GHG emissions by up to 180 % if a feedstock such as manure is used to produce the biogas. Greater than 100 % GHG avoidance can be achieved if emission credits associated with avoided counterfactual waste management are attributed to biogas uses including as biomethane transport fuel (the economic drivers for anaerobic digestion). Diverting food waste or manure to anaerobic digestion may avoid considerable GHG emissions that arise during composting and manure storage, respectively, depending on the prevailing alternative fate of those waste feedstocks. However, if accounting for upstream emission credits in this way, based on a consequential life-cycle assessment approach, it is imperative that double-counting is avoided – i.e. the waste management organisation accounts for the upstream emission savings from anaerobic digestion *either* in relation to waste treatment *or* transport fuelling (see BEMP on life-cycle assessment of waste management).

There are already over 1 million gas-powered vehicles on Europe’s roads (Tassan et al., 2013). This best practice therefore focuses on the use of CNG- and biogas-powered refuse collection trucks, or the use of hybrid-electric vehicles. Best environmental performance can be achieved by use of biomethane from organic waste, but where this is not yet available, converting collection fleets to run on CNG provides a useful step towards that goal. Alternatively, hybrid-electric vehicles significantly reduce transport impacts, and drive technological progress towards electrification of road transport which could lead to considerable future environmental benefits.

Dual-fuel vehicles

Typical 26-tonne refuse collection trucks run on diesel and can be readily converted to dual-fuel vehicles via simple modifications to the compression-ignition cycle via software remapping and injection modification. In dual-fuel vehicles, diesel is still required as a pilot fuel to initiate combustion under compression, but gas can then be injected as the main combustion fuel. The ratio of gas used in dual-fuel engines varies depending on the engine load and knocking issues under high compression, but can reach 90 % for integrated systems or 60 % for non-integrated systems.

Dedicated gas engines

Alternatively, HGVs can be selected with dedicated engine technology, such as Otto cycle stoichiometric combustion with a multipoint injection system, enabling 100 % gas fuelling and a superior overall environmental performance. Smaller petrol-driven collection vehicles can be converted to run on either 100 % gas, or as dual-fuel vehicles where the spark-ignition engine can switch between petrol or gas (Tassan et al., 2013).

Natural gas is becoming a relatively common transport fuel in Italy. In March 2015, there were more than 3 000 CNG stations in operation in Europe, most of them in Italy (1 054), Germany (920), Austria (178), Sweden (155), Switzerland (138), the Netherlands (134), Bulgaria (105) and the Czech Republic (82) (metanoauto.com, 2015).

Biomethane is becoming more common as a transport fuel in Germany and Sweden. The technology for the utilisation of gas for transport has been refined to a point where it is commercially viable. One main barrier to the use of gas in transport is the large storage volume required, or restricted range, compared with petrol and diesel engine vehicles. This is exacerbated by the fact that conversion of petrol and diesel engines (rather than ground-up design of dedicated gas engines) leads to suboptimal efficiency, and there remain relatively few gas filling stations in most countries (metanoauto.com, 2015). However, these barriers pose less of a challenge for refuse collection vehicles that travel limited distances around a central waste (refuelling) depot. Furthermore, biomethane may be produced within the waste management network, enabling an energy and carbon cycle in line with the concept of a circular economy. BSR, the public waste management company of Berlin, operates a fleet of 150 refuse collection vehicles running on biomethane produced from organic waste collected in the city (BSR, 2015a).

Hybrid-electric vehicles

Electric propulsion systems also have considerable potential to improve environmental efficiency, but are further from commercial application than gas fuels, although hybrid systems are becoming commercially available and can reduce environmental burdens significantly (Nehlsen, 2013).

Nehlsen (2013) reports on the testing of hybrid and conventional diesel-powered refuse collection trucks in Bremen (Figure 1). In addition to the main diesel engine, the hybrid vehicles were fitted with a smaller (2 L) diesel engine that runs at optimum speed to charge high-power capacitors that in turn power electric motors for hydraulic operations.

Source: Nehlsen, 2013

Figure 1. A “Rotopress Dualpower” refuse collection truck during testing in Bremen, Germany

Maintenance costs are lower for hybrid vehicles because the hydraulic system is powered by low-maintenance electric motors, and because regenerative braking reduces brake pad friction.

Hybrid trucks tested in Bremen (Nehlsen, 2013) had the same total weight as conventional trucks (26 tonnes), but 1.5 tonnes less waste capacity owing to the weight of the hybrid system (especially batteries). The effect of additional journeys was considered in the fuel and GHG balance per mg of waste collected, as described above, although Nelsen (2013) notes that there may be routes where a truck’s full capacity is not required and on which hybrid trucks would not require an additional refuelling stop. Carefully integrating hybrid vehicles into optimised collection rounds is therefore essential to obtain maximum efficiency savings.

Environmental benefits

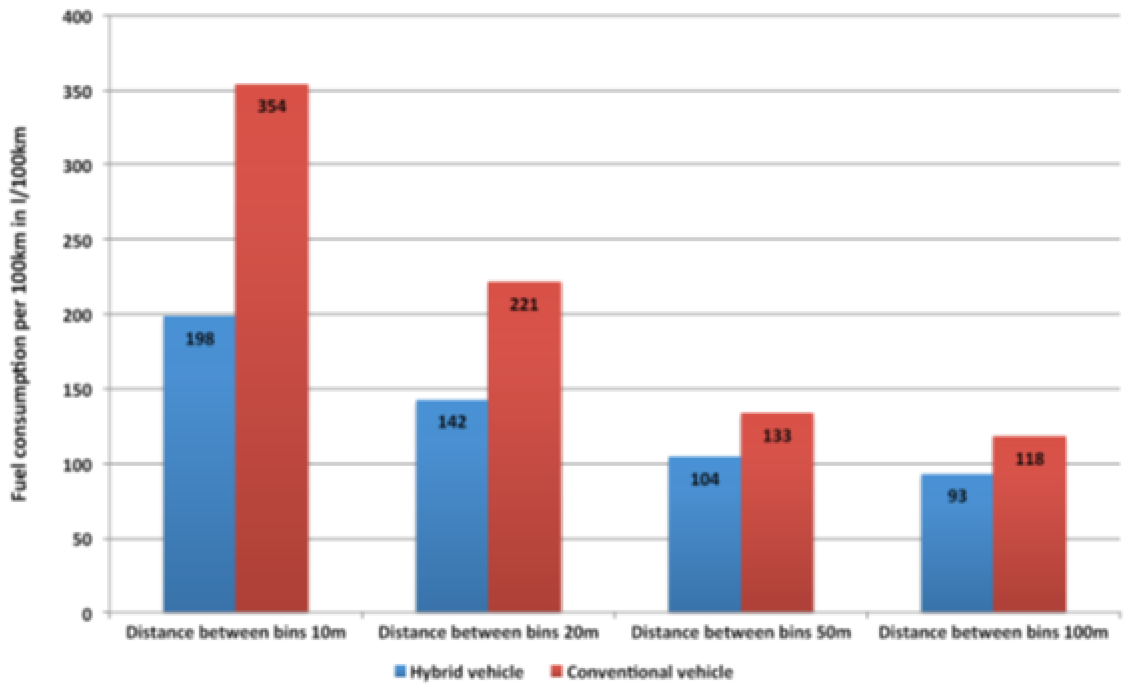
GHG emissions

Direct CO_2 emissions from combustion are significantly lower for CNG-powered trucks compared with diesel-powered ones, by up to 16 % (Ricardo-AEA, 2012). However, life-cycle GHG savings are somewhat lower than this owing to upstream burdens of CNG extraction, processing and transport, including leakage (CH_4 has a GWP 25 times higher than CO_2), and may in fact be negligible (Rose et al., 2013).

Biogas can achieve life-cycle GHG reductions of 65 % compared with diesel-powered vehicles (Ricardo-AEA, 2012), and up to 180 % if LCA boundaries are expanded to account for avoided counterfactual manure or food waste management (Tassan et al., 2013), as explained above.

Stop-start and idle shut-off can reduce GHG emissions by 5 %, and alternative-fuelled (electric) bodies can reduce GHG emissions by 10–12 % compared with conventional diesel refuse trucks (Ricardo-AEA, 2012).

Nehlsen (2013) reports that the overall fuel consumption per mg of waste collected decreases from 4.2 L to 3.5 L of diesel for the diesel-electric hybrid system, a 16 % saving, on average considering all factors (decreased load, transport to depot, etc.). However, the efficiency advantage of hybrid systems is strongly dependent on the route and collection characteristics, and is greatest during the stop-start collection stage of rounds, achieving reductions in fuel consumption of up to 40 % in the case of bin stops separated by short distances of 10 m (i.e. urban areas) (Figure 2).



Source: Nehlsen (2013).

Figure 2. Fuel consumption for a hybrid truck and a conventional 26-tonne refuse collection truck tested in Bremen, Germany

Emissions affecting air quality and health

Gas burns more cleanly than petrol or diesel, resulting in significantly lower emissions of particulate matter (PM), nitrogen and sulphur oxides (NO_x and SO_x), and volatile organic compounds (VOCs), amongst others (Table 2; Figure 3).

Table 2. Reductions in emissions affecting air quality for CNG vehicles compared with petrol- and diesel-powered vehicles

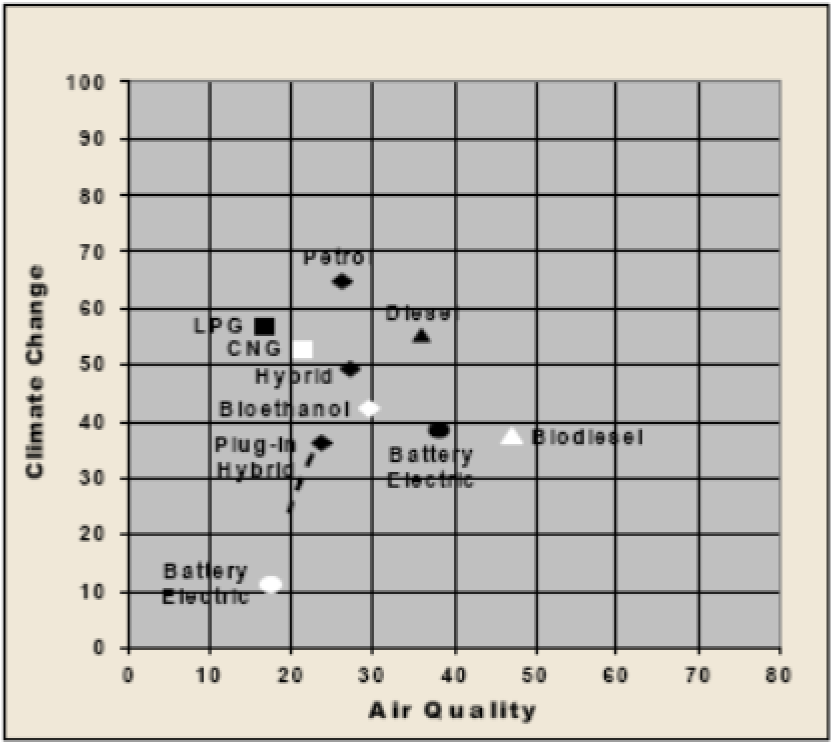
	SO_x	NO_x	VOCs	PM	Ozone promoters	Aromatic compounds
CNG vs. petrol*		52 %	92 %		96 %	99.9 %
CNG vs. diesel**	44 %	44 %	21 %	25 %		

* Tassan et al. (2013).

** Rose et al. (2013), life-cycle reductions relative to diesel-powered refuse collection truck.

Rose et al. (2013) note that SO_x and PM emissions are mainly reduced at the feedstock and fuel production stages, while CO, NO_x, VOC and PM emissions are significantly reduced at the fuel dispensing and vehicle operation stages. At the location of vehicle deployment, a 54 % reduction in overall air pollutant emissions can be achieved, representing a significant benefit in urban areas.

Figure 3 shows that replacing petrol and diesel with alternative propulsion systems usually reduces both GHG emissions and air pollution, except in the case of biodiesel which leads to higher air pollution.



Source: LES (2011)

Figure 3. Performance of different vehicle propulsion options in terms of GHG emissions (y-axis) and emissions affecting air quality (x-axis).

Side effects

The life-cycle environmental balance of biogas produced from crops is much worse than biogas produced from waste, owing to nutrient losses during crop production (eutrophication), the need for agro-chemical inputs (multiple impacts) and possible indirect land use change incurred by agricultural land expansion (GHG emissions, but also biodiversity effects) (Boulamanti et al., 2013).

Biomethane upgrade of biogas is associated with methane leakage of around 1–2 %, which can have an important effect on the GHG balance of biomethane as a fuel (Ravina and Genon, 2015). Biomethane upgrade also requires significant electricity, which may be provided by an on-site combined heat and power plant fuelled by biogas, or imported from the grid. Cheshire (2014) reported electricity consumption of 1.06 kWh and 0.6 kWh per kg of methane, respectively, for biomethane upgrade and compression for use as a vehicle fuel, for a small-scale upgrade plant.

Abiotic resource depletion is associated with use of rare-earth metals in batteries for electrical and hybrid propulsion and alternative-fuelled bodies. This can be minimised through recycling of these metals. Whilst GHG emissions associated with vehicle manufacture are twice as high for a hybrid compared with a conventional diesel truck, significant GHG savings during operation mean that lifetime GHG emissions are 17 % lower for hybrid trucks (Nehlsen, 2013).

As the hybrid or CNG trucks cause less noise, they enable waste collection at times when there is less traffic (late evening, early morning), so they contribute to reductions in congestion and noise pollution.

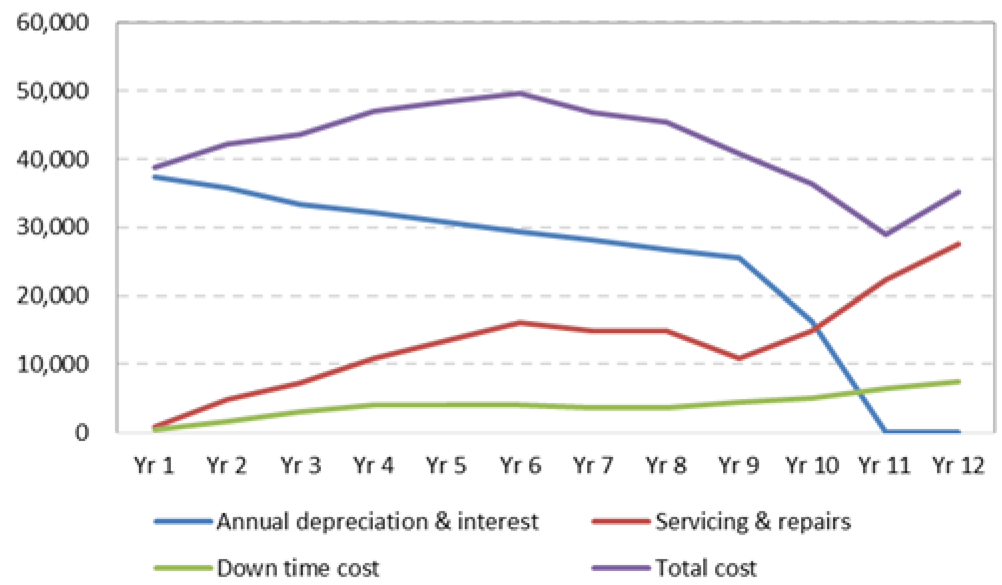
Applicability

This best practice is broadly applicable. The presence of filling or recharging stations is less of an issue for refuse collection than other types of transport because vehicles are usually operated over a limited distance and the fleet is run from a centralised waste depot where refuelling can take place.

Compressed natural gas (CNG) is available in all EU countries. Biomethane may not be available in many regions, but wet organic waste (e.g. food waste) can be used to produce biogas that can be upgraded to transport biomethane.

Economics

National Grid (2014) quotes UK Department of Transport estimates that gas-powered trucks cost between GBP 15 000 and GBP 44 000 (EUR 21 000 and EUR 62 000) more than conventional diesel trucks. Private refuelling infrastructure can cost between GBP 400 000 (EUR 563 000) to GBP 1 million (EUR 1.41 million) to install, plus the cost of a grid connection. Safety considerations mean that CNG storage cylinders can be expensive to design and build, making a significant contribution to the additional costs of a gas vehicle (Tassan et al., 2013). Figure 4 shows average annual running costs, excluding fuel, for a fleet of 150 CNG refuse collection vehicles. BSR (2015b) notes that maintenance costs are only slightly higher for CNG compared with Euro 6 diesel trucks.



Source: BSR (2015b).

Figure 4. Average annual running costs, excluding fuel, for a CNG refuse collection vehicle

However, the retail prices of CNG and biogas are considerably lower than for petrol and diesel owing to reduced duties. National Grid (2014) reports that an articulated tractor unit doing an average of eight miles per gallon of diesel (8 mpg = 35 L/100 km) costs GBP 0.62 per mile (EUR 0.54 per km), while natural gas costs approximately GBP 0.39 per mile (EUR 0.34 per km). WRAP (2010) recorded a fuel efficiency of between 6 mpg and 10 mpg for a single-modal refuse collection vehicle (skip carrier), and 3.5 mpg to 4.5 mpg for a multi-modal refuse collection vehicle. Based on National Grid (2014) data, natural gas fuel cost savings for single- and multi-modal refuse collection vehicles could equate to EUR 40 000 and EUR 80 000 respectively over 200 000 km, at least offsetting the higher purchase cost.

Stricter vehicle emission standards are associated with higher operating and maintenance costs for HGVs. When converting an HGV to run on gas, the removal of parts of diesel system (including selective catalytic reduction) will save significant costs over the vehicle lifetime (Tassan et al., 2013). This may cancel out higher servicing costs for vehicles running on natural gas or biogas, as indicated by BSR (2015b).

Driving forces for implementation

Stricter emission standards, currently Euro VI (European Regulation 595/2009 and European Regulation 582/2011), favour gas- over diesel-powered engines because of the increasingly complex and costly emission control technology required for diesel vehicles to comply with these standards.

Refuse collection trucks are well suited to CNG and biogas fuelling owing to relatively short routes and repeated returns to waste depots where they can be refuelled.

Alternatively (electric) fuelled bodies and hybrid refuse collection trucks generate significantly less noise during bin lifting operations owing to the use of electric motors rather than a revving engine. This is a major advantage, especially in urban areas.

Green procurement guidelines by municipalities may prioritise the purchase of low-emission vehicles directly for municipality-managed collections, or the subcontracting of waste management to companies that use low-emission vehicles to reduce their environmental footprint.

Reference organisations

Renova, Sweden. A total of 37 out of 180 heavy vehicles run entirely on natural gas, and 16 refuse collection vehicles use electric-hybrid technology (Renova, 2015).

Emterra, Winnipeg Canada. In 2012, Emterra committed to using CNG trucks in Winnipeg, Manitoba, and now have almost 60 natural-gas-powered, heavy-duty waste and recycling trucks in operation (Emterra, 2015).

Waste management organisations in the German cities of Munich, Nuremberg, Offenbach, Baden-Baden and Darmstadt have tested electro-diesel hybrid vehicles over the past 4–5 years (AWM, 2014).

Veolia is operating a landfill in Claye-Souilly collecting biomethane and converting it into biofuel (Bel, 2015).

SITA UK is a landfill operator in the UK which produces vehicle fuel from landfill gas.

Production is over 5 million litres of liquid biomethane each year from the landfill site at Albury, Surrey, which can be used alongside diesel in converted waste collection vehicles (SITA UK, 2017).

Box 1. BSR, Berlin, biomethane case study

BSR processes approximately 60 000 tonnes per year of organic waste from Berlin households in a biogas plant. The biogas produced is cleaned, processed, concentrated and fed into the city gas network as biomethane. A total of 150 biogas-powered refuse collection vehicles, about half of the BSR fleet collecting approximately 60 % of the city's MSW, are refuelled from this network via gas stations in three BSR depots. As a result, annual savings of around 2.5 million litres of diesel are achieved (BSR, 2015a).

Box 2. Courbevoie, Paris, electric vehicle case study (emerging best practice technology)

In 2011, SITA introduced the first fully electric domestic waste collection truck. A partnership between SITA, PVI, a leader in electrical traction for vehicles, SEMAT, a company specialising in collection and cleaning equipment, and Li-Ion, a battery manufacturer, developed this pioneering electric refuse collection truck. The vehicle benefits from zero direct emissions and extremely low noise levels, in addition to improved cab visibility enabled by the absence of a large combustion engine under the cab (Suez-environment.com, 2015). This technology represents an emerging best practice that may not yet be commercially applicable. If and when it becomes economically viable for commercially application, it may be regarded as best practice.

Source: Suez-environment.com (2015).

Box 3. Nehlsen GmbH & Co. KG electric-hybrid case study

Nehlsen GmbH & Co. KG, Bremen are participating in the *Electric Mobility* programme by testing one waste collection vehicle with diesel-electric drive and one with plug-in components. The usability and technical, environmental and economic performance of these vehicles are being monitored across a range of operating conditions, and will be compared with conventional refuse collection vehicles. The results will be used to evaluate hybrid vehicles and optimise route planning, workload, fuel consumption, CO_2 emissions, and noise performance (Schaufenster Elektromobilität, 2015). See the "Rotopress Dualpower" refuse collection truck under Description above.

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