

# MISSION

REACHING NET-ZERO CARBON EMISSIONS FROM  
HARDER-TO-ABATE SECTORS BY MID-CENTURY

# POSSIBLE



SECTORAL FOCUS  
HEAVY ROAD  
TRANSPORT



The **Energy Transitions Commission (ETC)** brings together a diverse group of leaders from across the energy landscape: energy producers, energy users, equipment suppliers, investors, non-profit organizations and academics from the developed and developing world. Our aim is to accelerate change towards low-carbon energy systems that enable robust economic development and limit the rise in global temperature to well below 2°C and as close as possible to 1.5°C.

In November 2018, the ETC published ***Mission Possible: Reaching net-zero carbon emissions from harder-to-abate sectors by mid-century***. This flagship report is available on our [website](#). This report describes in turn:

- Why reaching net-zero CO<sub>2</sub> emissions across heavy industry and heavy-duty transport sectors is technically and economically feasible;
- How to manage the transition to net-zero CO<sub>2</sub> emissions in those harder-to-abate sectors of the economy;
- What the implications of a full decarbonization of the economy are for the energy system as a whole, in particular in terms of demand for electricity, hydrogen, bioenergy/bio-feedstock, and fossil fuels, as well as carbon storage requirements;
- What policymakers, investors, businesses and consumers must do to accelerate change.

**This Sectoral Focus presents in more details the underlying analysis on heavy-duty road transport decarbonization that fed into the ETC's integrated report *Mission Possible*.** It constitutes an updated version of the consultation paper with the same title published by the ETC in July 2018.

**We warmly thank all experts** from companies, industry initiatives, international organizations, non-governmental organizations and academia, who have provided feedback on this consultation paper. Their insights were instrumental in shaping the *Mission Possible* report and this updated Sectoral Focus.

The *Mission Possible* report and the related Sectoral Focuses constitute **a collective view of the Energy Transitions Commission**. Members of the ETC endorse the general thrust of the arguments made in this report but should not be taken as agreeing with every finding or recommendation. The institutions with which the Commissioners are affiliated have not been asked to formally endorse the report. The list of our Commissioners at the time of publication can be found in the *Mission Possible* report.

**In 2019, the Energy Transitions Commission will continue to engage actively and work with key policymakers, investors and business leaders around the world**, using our analysis and the unique voice of the ETC to inform decision-making and encourage rapid progress on the decarbonization of the harder-to-abate sectors. We are keen to exchange and partner with those organizations who would like to progress this agenda. Please contact us at [info@energy-transitions.org](mailto:info@energy-transitions.org).

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# TABLE OF CONTENTS

- Reaching net-zero carbon emissions from heavy-duty road transport ..... 2**
- 1. Overview of the challenge ..... 4**
  - A. Demand trends by mid-century.....4
  - B. Carbon emissions – and other environmental impacts.....5
- 2. Reducing CO<sub>2</sub> emissions by curbing traffic volumes ..... 7**
- 3. Improving energy efficiency ..... 9**
- 4. Decarbonizing trucks and buses..... 10**
  - A. Decarbonization solutions: technical feasibility comparison ..... 10
    - Energy efficiency ..... 10
    - Storage efficiency..... 10
    - Charging rate ..... 11
    - BEVs vs. FCEVs..... 11
  - B. Decarbonization solutions: carbon intensity comparison ..... 12
  - C. Decarbonization solutions: cost comparison..... 14
  - D. Use of biofuels in heavy-duty road transport..... 18
  - E. Transition pathways ..... 18
- 5. Cost of full decarbonization of heavy-duty road transport ..... 20**
- 6. Conclusions and policy implications ..... 22**
- 7. Existing initiatives..... 23**
- 8. Recommendations ..... 25**
  - A. Research and development ..... 25
  - B. Public policy ..... 25
  - C. Industry collaboration and commitments..... 26



# REACHING NET-ZERO CARBON EMISSIONS FROM HEAVY-DUTY ROAD TRANSPORT

Heavy-duty road transport includes both heavy-road passenger transport (e.g. buses) and heavy-road road freight defined as all activities that are linked to the movement of goods, including everything from raw materials to food and electronics<sup>1</sup>. All together, these activities account for **2.5Gt of CO<sub>2</sub> emissions annually**, which represents 7.3% of total global energy system emissions<sup>2</sup>. But, under a business-as-usual scenario, this could rise to 4.6Gt of CO<sub>2</sub> emissions annually by mid-century<sup>3</sup>, as total road freight volumes rise rapidly in many parts of the developing world, and up to 11.6% of remaining emissions, as emissions fall in other easier-to-decarbonize sectors of the economy such as power generation. It is essential to drive heavy-duty road transport to zero carbon emissions by 2050 to enable the world to achieve the Paris Agreement's targets. However, until now, there has been less focus on decarbonization options for road freight transport than for the automobile sector.

The analysis carried out by the Energy Transitions Commission for its 2018 report *Mission Possible*<sup>4</sup> indicates that the long-term path to heavy-duty road transport decarbonization is relatively clear. As with automobiles, **electric drivetrains deliver huge increases in vehicle efficiency compared to internal combustion engines (ICE) and will likely become the dominant technology**. This shift to electric drivetrains will, in addition, help alleviate the adverse local pollution impacts of ICE trucks and buses in cities. Battery storage limitations may, however, mean that electric drivetrains are combined with hydrogen fuel cells for the longer-distance freight sector, unless catenary overhead charging is deployed on a significant scale.

Based on a review of the existing literature, we estimate that **the total cost of operation of electric drivetrain vehicles will fall below those of ICE vehicles during the course of the 2020s**, even if there were no carbon price applied to road transport fuels, due to cost reductions in the price of batteries and availability of low-cost electricity. The cost advantage would arise first for city buses and for lighter, shorter-distance trucks, eventually extending to very long-distance trucks by the end of the decade. This would leave no need for long-term use of biofuels<sup>5</sup>. Meanwhile, CNG is unlikely to play a major transitional role, given the pace at which electric vehicles could become cost-competitive and the need to develop dedicated infrastructure that could rapidly be stranded. But, several features of the trucking industry (e.g. fragmented industry structure, a focus on upfront rather than total operating costs, and the use of second-hand vehicles in lower-income countries) will slow the progress to full decarbonization unless effective policies are put in place.

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<sup>1</sup> OECD & IEA (2017), *The Future of Trucks*

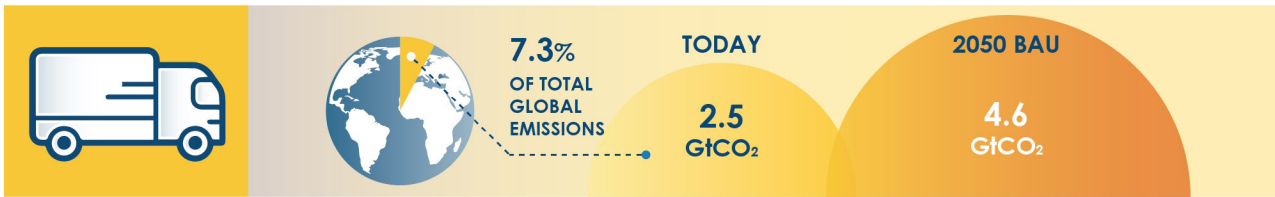
<sup>2</sup> IEA (2017), *Energy Technology Perspectives*

<sup>3</sup> IEA (2017), *Energy Technology Perspectives*

<sup>4</sup> Energy Transitions Commission (2018), *Reaching net-zero carbon emissions from the harder-to-abate sectors by mid-century*

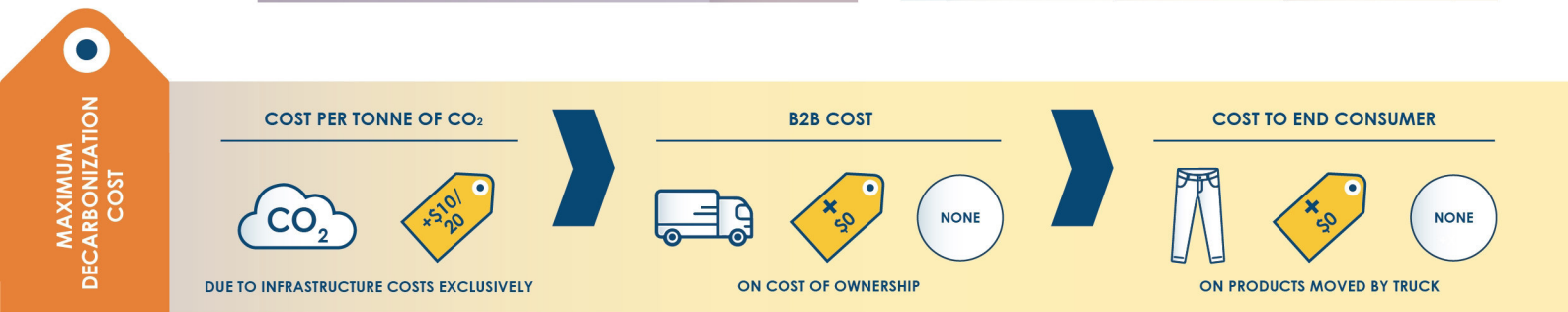
<sup>5</sup> Supply of biofuels is likely to be constrained for sustainability reasons. Use of biofuels should therefore be prioritized in sectors with little or no alternative decarbonization solutions, especially aviation. See Chapters 6 and 7 of the *Mission Possible* report for further details.

# HOW TO REACH NET-ZERO CO<sub>2</sub> EMISSIONS FROM HEAVY ROAD TRANSPORT



REACHING NET-ZERO CO<sub>2</sub> EMISSIONS FROM HEAVY ROAD TRANSPORT IS POSSIBLE BY COMBINING 3 MAJOR DECARBONIZATION ROUTES:

		MAXIMUM CO <sub>2</sub> EMISSIONS REDUCTION POTENTIAL	TECHNOLOGY APPLICABILITY / AVAILABILITY OVER TIME			
			2020	2030	2040	2050
1 DEMAND MANAGEMENT	Logistics and operational efficiency	-30%	[Progress bar from 2020 to 2050]			
	Modal shift to rail or shipping		[Progress bar from 2020 to 2050]			
2 ENERGY EFFICIENCY	Improvements in engine efficiency	-30/45%	[Progress bar from 2020 to 2050]			
	Improvements in aerodynamics and tyre design		[Progress bar from 2020 to 2050]			
3 DECARBONIZATION TECHNOLOGIES	Liquefied natural gas (transition fuel)	-5%	[Progress bar from 2020 to ~2035]			
	Biofuels (transition fuel)	-100%	[Progress bar from 2020 to ~2035]			
	Hydrogen fuel-cell vehicles	-100%	[Progress bar from 2020 to 2050]			
	Electric battery vehicles (with or without catenary wiring)	-100%	[Progress bar from 2020 to 2050]			



## TOP 3 ACTIONS TO ACCELERATE THE TRANSITION FOR...

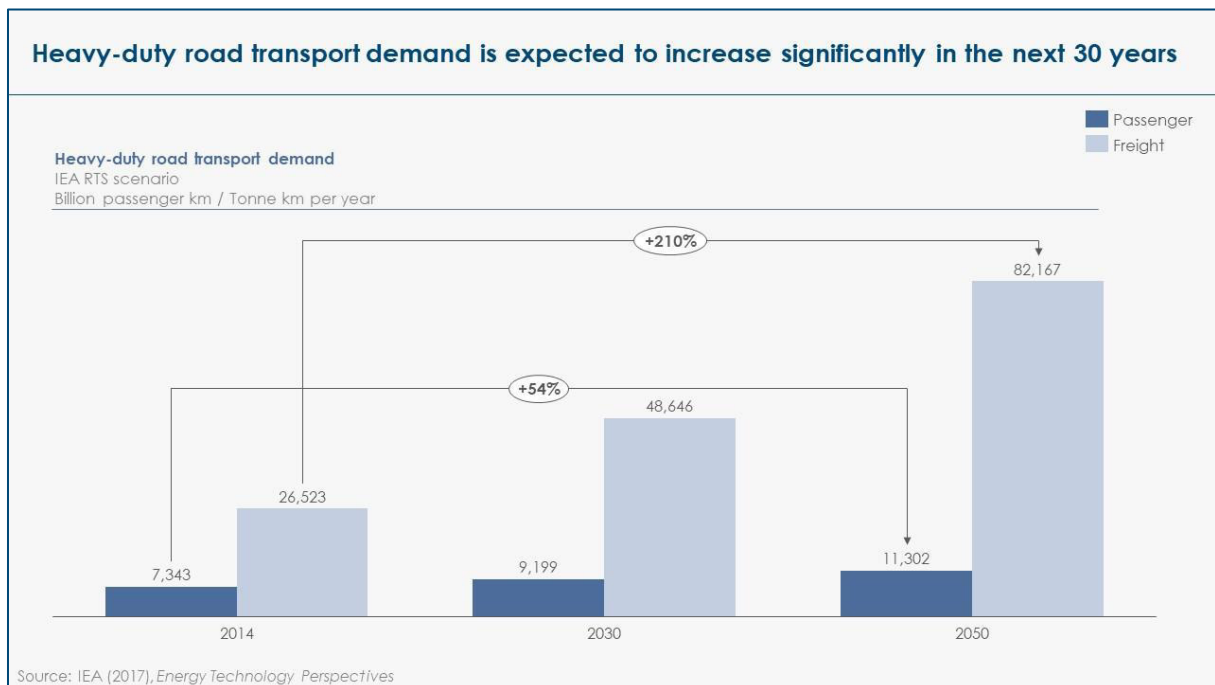
- |  |  |   |
|--|--|---|
| <p><b>INNOVATION</b></p> <ul style="list-style-type: none"> <li>Improve battery density and charging speed</li> <li>Reduce the cost of electrolysis</li> <li>Reduce the cost and improve the efficiency of hydrogen fuel-cells and hydrogen tanks</li> </ul> | <p><b>POLICY</b></p> <ul style="list-style-type: none"> <li>Decarbonize power and strengthen power distribution networks</li> <li>Support infrastructure deployment in high-speed charging, hydrogen refueling and overhead wiring</li> <li>Cities: commit to 100% zero-carbon bus fleets by 2035</li> </ul> | <p><b>INDUSTRY/BUSINESSES</b></p> <ul style="list-style-type: none"> <li>Fleet owners and operators: adopt best practices and technologies for energy efficiency and logistics efficiency</li> <li>Major logistics companies and retailers: commit to 100% zero-carbon trucking</li> <li>Automotive and energy companies: develop high-speed charging and hydrogen refueling infrastructure on major freight roads</li> </ul> |
|--|--|---|

# 1. OVERVIEW OF THE CHALLENGE

## A. DEMAND TRENDS BY MID-CENTURY

**Heavy-duty road freight volumes**, measured in tonne-kilometer, are strongly driven by rising prosperity and are therefore **expected to triple by mid-century** in a business-as-usual scenario [Exhibit 1]. **Heavy-duty road passenger volumes are less income-elastic** and are forecasted to increase by 54% in the same timeframe.

This growth will be **concentrated in major emerging economies**, such as India, the ASEAN economies and Africa, as growth somewhat slows in mature economies such as the European Union, the USA, and even China<sup>6</sup>. Non-urban long-distance traffic is forecast to grow more rapidly than short-distance within-city traffic, making it particularly important to develop decarbonization options for the long-distance segment<sup>7</sup>.



**Exhibit 1**

<sup>6</sup> IEA (2017), *Energy Technology Perspectives*

<sup>7</sup> IEA (2017), *Energy Technology Perspectives*

## B. CARBON EMISSIONS – AND OTHER ENVIRONMENTAL IMPACTS

Transport accounts for roughly one quarter of today's global carbon emissions, with approximately 7.4Gt of CO<sub>2</sub> in 2014 for all transport modes, and 4.5Gt CO<sub>2</sub> for heavy-duty transport only (heavy-duty road transport, shipping and aviation)<sup>8</sup>. Today, **heavy-duty road transport accounts for more than half of the heavy-duty transport emissions**, with 2.5Gt of CO<sub>2</sub><sup>9</sup>, which represents around 7.3% of total global emissions from the energy and industrial system. According to the IEA's Reference Technology Scenario, heavy-duty road transport emissions could grow to reach 4.6Gt per annum in 2050. As shown in Exhibit 3, India, China and South-East Asian countries represent by far the largest share of projected emission increases.

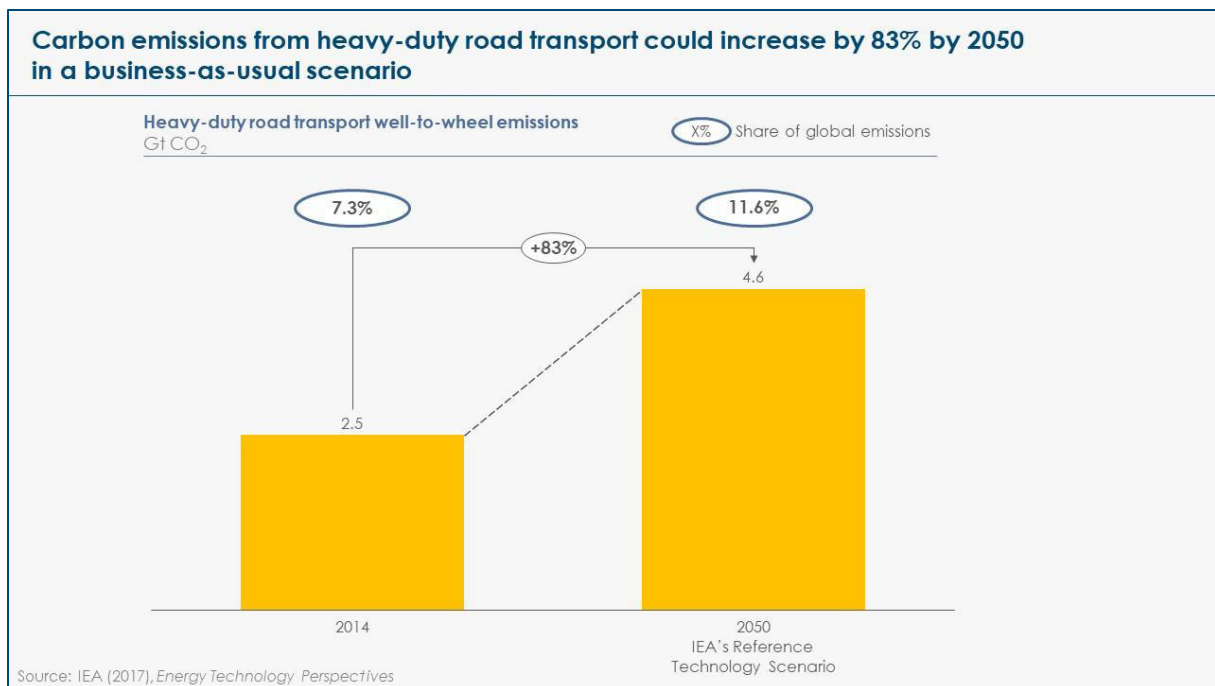


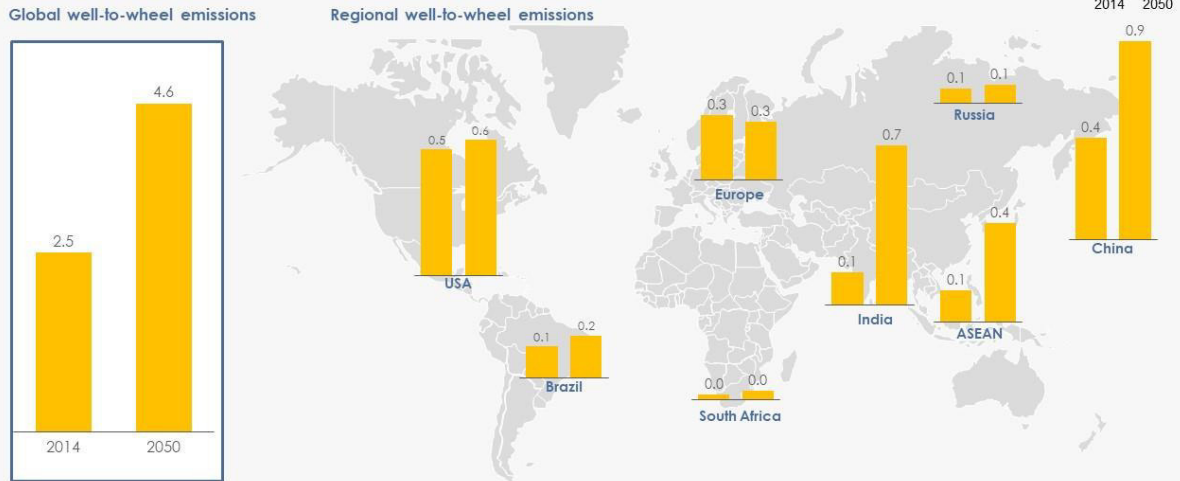
Exhibit 2

<sup>8</sup> IEA (2017), *Energy Technology Perspectives*

<sup>9</sup> IEA (2017), *Energy Technology Perspectives*

## The growth in heavy-duty road transport emissions is concentrated in Asia

Well-to-wheel emissions from heavy-duty road transport  
Gt CO<sub>2</sub>, IEA Reference Technology Scenario



Source: IEA (2017), *Energy Technology Perspectives*

### Exhibit 3

Heavy-duty road transport also contributes to **non-CO<sub>2</sub> emissions**. More than one-third of the transport-related NO<sub>x</sub> emissions are produced by trucking. Recent scandals about NO<sub>x</sub> tests for diesel cars have led to a heightened awareness of this issue, and even though latest diesel trucks deliver significantly lower NO<sub>x</sub> emissions, many cities are likely to apply increasingly tight constraints on the use of ICE trucks and buses within cities.

In addition, road freight within cities can, in some circumstances, adversely increase **local heat levels**, contributing (along with local pollution) to greater use of air conditioning, which drives further CO<sub>2</sub> emissions, as long as electricity generation continues to be fossil-fuel based.



## 2. REDUCING CO<sub>2</sub> EMISSIONS BY CURBING TRAFFIC VOLUMES

Opportunities to curb demand growth are more limited in the transport sector compared to the industrial sector. Economic development drives higher demand for services which sustain good standards of living: freight transport is driven by global economic growth and passenger transport by higher mobility demand in emerging economies. This is also true in heavy industry, but demand for raw materials can be mitigated by reducing the amount of materials required to offer the same level of services – e.g. reducing the amount of virgin steel required to build a house – whereas it is more difficult to apply that same logic to cut demand for mobility services.

Nonetheless, there are non-negligible opportunities to moderate the growth of heavy-duty road traffic volumes and related CO<sub>2</sub> emissions. An illustrative scenario assessing the potential impact of demand-side measures in trucking suggests that **a non-negligible contribution to carbon emission reductions might be possible (about 1.3Gt CO<sub>2</sub> by 2050)**, through two major drivers: modal shift to rail and platform management efficiency improvement [Exhibit 4]. 2050 business-as-usual emissions from heavy-duty road transport could be reduced by up to 28%. This potential is particularly important in the short term, to help mitigate carbon emissions until zero-carbon trucks and buses can be widely deployed.

In many countries, there is potential to **shift long-haul road freight to more carbon-efficient rail or inland/coastal shipping**, which could respectively trigger 85% and 25% reduction in carbon emissions on the shifted traffic<sup>10</sup> [Exhibit 5]. Modal shift could also reduce road wear-and-tear, saving on road infrastructure maintenance costs. In some countries, such as India, where rail freight subsidizes passenger rail, there is also a clear political incentive to shift more transport to rail, for instance, in dedicated freight rail corridors<sup>11</sup>, as the increase in revenues could be used to further improve passenger services.

**Logistics and operations efficiency improvements** could also appreciably reduce heavy-duty road transport emissions. Information and communications technologies make it increasingly possible for truck fleet operators to ensure fuel-efficient driving and optimized routes. Further supply chain collaboration could improve load factors. Some studies have estimated that, at the truck level, savings of up to 15% could in principle be achieved through fleet optimization and route management (e.g. eliminating backhauls and consolidating loads)<sup>12</sup>, and an average of 5% thanks to driver fuel-efficient driving training and maximum speed reduction<sup>13</sup>. For example, the China Green Freight Initiative (CGFI) is China's national voluntary program, which aims to improve energy efficiency and reduce emissions from road freight<sup>14</sup>. The program design is inspired by the Green Trucks Pilot Project launched in Guangzhou, Guangdong province, in 2012. It focuses on green management of the fleet (such as through better loading practices), the deployment of green technologies (such as the development of green truck standards and issuance of a catalogue of energy-saving technologies) and green driving (establishing driver-training programs to promote eco-driving, for instance).

It is inherently difficult to make a global estimate of how much demand could be reduced by the application of the sort of demand-side levers described above. **Implementation will necessarily be driven at the local, or at most the national, rather than the global level.** The

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<sup>10</sup> Vivid Economics and ETC (2017), *Economic growth in a low carbon world*

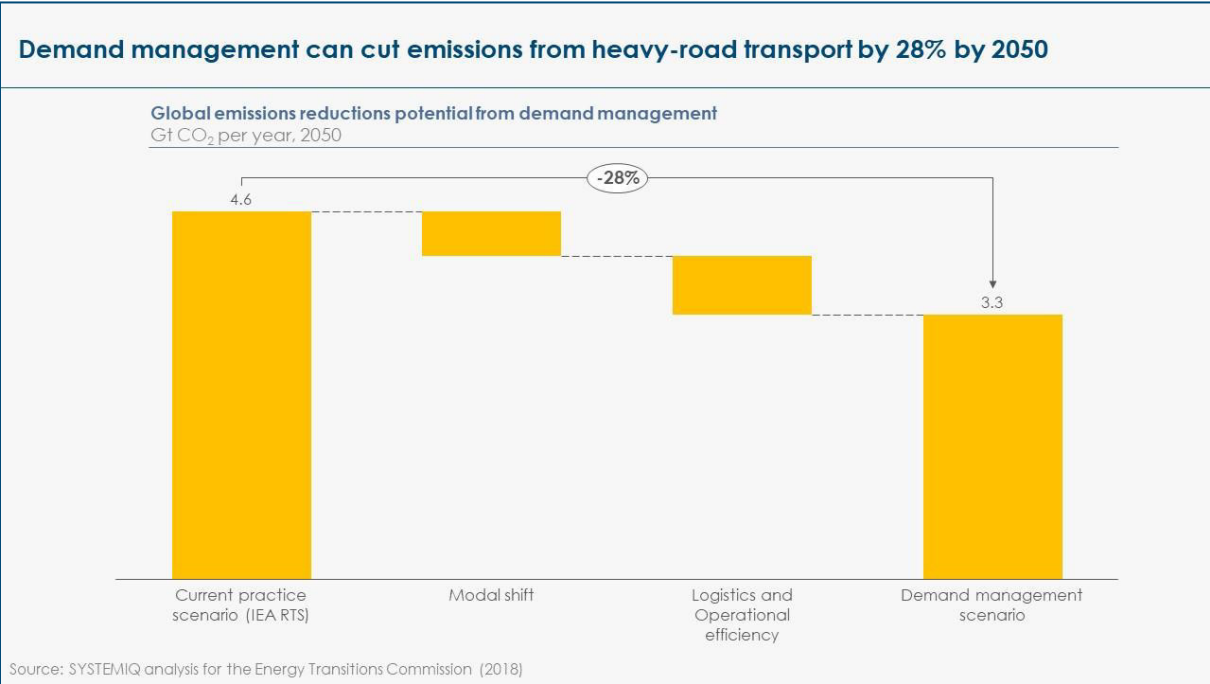
<sup>11</sup> In India, Rail Freight Corridors are planned to be freight-only corridors connecting industrial hubs in the North and ports on Eastern and Western coasts to ensure a more reliable, economical and faster transportation of goods. More details available at: <http://www.makeinindia.com/article/-/v/connecting-the-country-dedicated-freight-corridors>

<sup>12</sup> RMI (2014), *Reinventing fire: transportation sector methodology*

<sup>13</sup> RMI (2014), *Reinventing fire: transportation sector methodology*

<sup>14</sup> Clean Air Asia, n.d., China Green Freight Initiative (CGFI)

potential for modal shift will be dependent on local geographical specificities and on the existence of rail or fluvial infrastructure, which could demand significant investments. The fragmentation of the trucking industry in many countries will also limit the scope for supply chain coordination or the application of best practice operational control. Companies managing large bus and truck fleets will be able to enforce fuel-efficient driving and capacity utilization, but with many trucks owned and managed by small companies, average efficiency may continue to fall well short of the theoretical maximum.



**Exhibit 4**

### Changes in mobility patterns could unlock up to 1.3 Gt of carbon emissions reduction in heavy road transport

Category	Action	% of demand to which it applies	% of traffic affected / shifted	% emission reduction on affected / shifted traffic	Gt CO <sub>2</sub> saved vs. 2050 BAU emissions
<b>Modal shift</b>	Shift from road freight to rail	54% (long-haul)	35%	-85%	0.5
	Shift from road freight to shipping	54% (long-haul)	5%	-25%	0.0
<b>Logistics &amp; operations efficiency</b>	Platform management	80%	100%	-15%	0.6
	Efficiency-based driver training and maximum speed reduction	80%	100%	-5%	0.2
<b>Total</b>					<b>1.3</b>

Source: SYSTEMIQ analysis for the Energy Transitions Commission (2018), Vivid Economics and ETC (2017), *Economic growth in a low carbon world*

**Exhibit 5**

### 3. IMPROVING ENERGY EFFICIENCY

**Improvements in internal combustion engine design, in aerodynamics and in tire design** have and will continue to produce increases in the overall energy and thus carbon efficiency (i.e. grams of CO<sub>2</sub> per tonne kilometer) of diesel and gasoline trucks. Given the great heterogeneity of the truck fleet, it is difficult to establish an overall measure of the pace of efficiency improvement, but available data suggests slower improvement in the heavy-duty vehicle fleet than in the light-duty vehicle fleet: whereas over the last 20 years European vans and passenger cars have achieved an average emission per kilometer reduction of 2% and 3% per annum<sup>15</sup> respectively<sup>16</sup>, the trucking industry has gone through a period of efficiency improvements until the 1990s, but stagnated in recent decades, with, for instance, the fuel consumption of UK heavy goods vehicle decreasing from 8.8 miles per gallon in 2004 to 8.5 miles per gallon in 2016<sup>17</sup>.

The main explanation for this trend is that **trucks have not yet been subject to the same comprehensive regulatory regime as automobiles or vans**. This issue is taken seriously by the European policy makers – on 17 May 2018, the European Commission presented a legislative proposal setting the first ever CO<sub>2</sub> emission standards for heavy-duty vehicles in the EU, which was signed by the European Council in April 2019<sup>18</sup>. Average CO<sub>2</sub> emissions of new cars registered in the EU will have to be 15% lower in 2025 and 37.5% lower in 2030, compared to the emission limits valid in 202. The CO<sub>2</sub> emissions of new vans will need to be 15% lower in 2025 and 31% lower in 2030.

However, with the potential for energy efficiency improvement subject to absolute technological limits, it is likely that the pace of improvement achievable with ICE vehicles will progressively slow down. This point may be reached earlier for trucks than for cars given, for instance, the more limited opportunity to improve performance via light-weighting (given the dominant role of cargo weight rather than vehicle weight in truck operations). Overall, the Rocky Mountain Institute identified a 45% aggregate efficiency gain potential from design levers only<sup>19</sup>.

#### **Box 1 – NACFE: Driving change in a fragmented industry**

Improving the fuel efficiency of trucks could reduce carbon emissions from the sector by 30-45%. Achieving this potential is particularly crucial to reduce emissions over the next 10-15 years, as ICE vehicles powered primarily by fossil fuels are still likely to dominate the market. It could also save millions in fuels for the trucking fleets. The North American Council for Freight Efficiency (NACFE) works with the trucking industry, technology providers and manufacturers to double US freight efficiency. They aim to accelerate adoption of efficiency technologies by increasing confidence in those technologies and highlighting their benefits, sometimes on the back of commercial scale testing. NACFE has already published 15 Confidence Reports that evaluate over 60 fuel efficiency technologies. They disseminate this knowledge and raise awareness through workshops which bring together key industry players and technology leaders to facilitate shared learning on efficiency technologies.

<sup>15</sup> ICCT, 2019, *CO<sub>2</sub> emission standards for passenger cars and light-commercial vehicles in the European Union*

<sup>16</sup> Recent scandals, initially focussed on diesel particulate and NO<sub>x</sub> emissions, have also provoked questioning about whether the pace of “real world” improvement in carbon efficiency is as fast as test results suggest, but it is clear that significant real improvement is still being achieved.

<sup>17</sup> UK Department for Transport data series

<sup>18</sup> European Council of the European Union, April 2019, *Stricter CO<sub>2</sub> emission standards for cars and vans signed off by the Council*

<sup>19</sup> Rocky Mountain Institute, 2014, *Reinventing Fire: Transportation Sector Methodology*

## 4. DECARBONIZING TRUCKS AND BUSES

While there is significant potential to increase energy efficiency through incremental improvements to internal combustion engines and vehicle design, actual emissions reduction – as against a slower pace of growth – requires a shift to either alternative fuels or an electric drivetrain. The latter route will and should dominate, since the use of electric drivetrains (whether battery or hydrogen powered) will be increasingly technically feasible, will achieve the greatest carbon emissions reductions, and will become a lower-cost option for an increasingly wide range of buses and trucks sizes and distances during the course of the 2020s.

### A. DECARBONIZATION SOLUTIONS: TECHNICAL FEASIBILITY COMPARISON

Achieving significant emission reductions in heavy-duty road transport requires **either the use of alternative low-carbon fuels within internal combustion engines, or a shift to electric drivetrains with energy storage in battery (BEVs) or hydrogen (FCEVs) form**. Electric drivetrains deliver the advantage of far greater in-vehicle energy efficiency, but the key technical issue is whether energy storage densities and charging rates can be sufficient to make them a feasible alternative to diesel or gasoline trucks for long distances.

#### ENERGY EFFICIENCY

**Electric drivetrains can deliver energy efficiency of around 95%**, compared to at most 40% for ICE trucks. Hydrogen fuel cell trucks face the additional energy loss of hydrogen-to-electricity conversion but can still achieve total efficiencies of around 60%. The cost implications of this fundamental efficiency advantage is considered in subsection (D) below.

#### STORAGE EFFICIENCY

**The major technical advantage of ICEs is their energy storage efficiency**, with a major weight advantage versus batteries (11kWh per kilogram for gasoline vs. 0.3kWh per kilogram for current lithium ion batteries) and a volume advantage versus hydrogen (9kWh per liter for gasoline vs. 2kWh per liter for hydrogen). The ICE advantage in terms of energy storage efficiency is however partially offset by the lower weight of electric engines, which are far simpler equipment.

A crucial issue is whether **the weight and volume disadvantage of energy storage for electric drivetrains** makes a shift to electric trucks unfeasible for long-haul trucking. Our model, assessing the combined engine and energy storage weight and volume required for a truck with a range of 700 km between recharging/refueling, shows a significant overall weight penalty for battery EV truck (3 tonnes vs. 1.5 tonnes ICE) [Exhibit 6]. This additional weight (2-3 tons) would impose an operating cost penalty of reduced cargo capacity, but it does not seem so great as to make battery electric trucks unfeasible, even over very long distances (maximum of 1.5m<sup>3</sup>, in comparison with an average cargo volume of 80-100 m<sup>3</sup> for long-haul trucks).

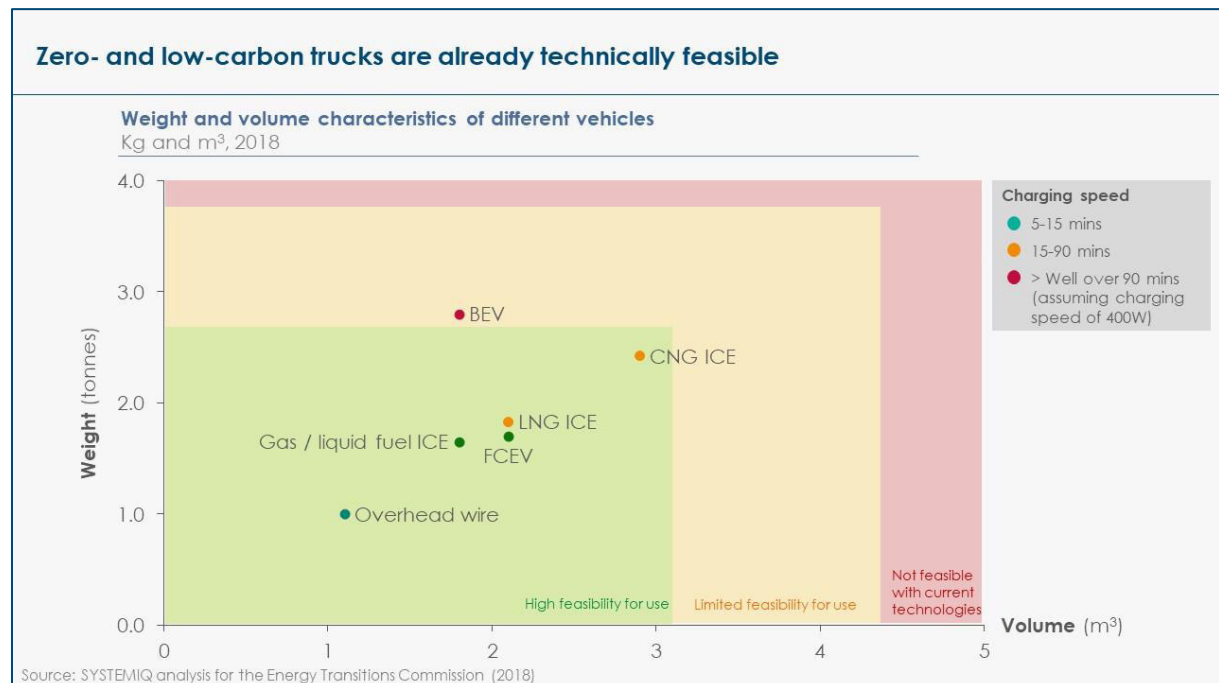


## CHARGING RATE

Indeed, the bigger challenge for very-long-range trucking would seem to be the feasible charging rate. At a charging rate of 400kW per hour, the 600-kWh battery required to support a 700-km range would take **90 minutes for full recharge**, which could only be operationally acceptable in conditions where trucks regularly returned to depots overnight. The Tesla Semi claim of a 20-to-30-minute full recharge (which might be more acceptable given the necessity for occasional driver rest breaks) implies a charge rate of 1600-kW per hour, far beyond anything that is currently available on the market. If multiple battery packs are used and can charge separately from one another, but simultaneously, the challenge of charging speed can be considerably reduced: there is speculation that Tesla might have chose to split its Semi's battery pack in 4 smaller packs to solve the charging issue.

## BEVS VS. FCEVS

**For the shorter-haul vehicles involved in local delivery, with regular return to depots overnight, pure battery electric trucks are evidently already technically feasible.** Considerations of storage efficiency and charging speed, however, may imply that – until and unless battery densities and charging rates can be significantly improved – the optimal technical **solution for very-long-range trucking will be FCEVs or the deployment of catenary overhead wiring** on major motorway routes. Hybrid solutions in which electric drivetrains and batteries are combined with range extending hydrogen fuel cells (powered by relatively small fuel tanks) are also a feasible possibility. Overhead wiring or hybrid vehicles would also make very-long-range battery electric trucking feasible with much smaller battery sizes. All of these solutions, however, imply important infrastructure costs. Both BEVs and FCEVs markets already generate a lot of interest and competition among automotive companies [Box 2].



**Exhibit 6**

## Box 2 – Automotive companies are racing to put electric and hydrogen trucks on the road

The trucking industry is witnessing a surge in competition from truck manufacturing companies to lead the adoption of new electric and hydrogen fleets. Tesla and Nikola have already announced new models, while Daimler's Mercedes-Benz truck division is developing commercial trials. Chinese manufacturers are targeting potential export markets to hold their electric truck sales volume dominance.

- **Nikola** recently unveiled a new version of its hydrogen-powered electric semitrailer truck that will be aimed at European customers. This could be the first European zero-emission commercial truck and may also serve other international markets including Asia and Australia. Nikola is currently working with Norwegian firm Nel Hydrogen to deploy more than 700 hydrogen stations across the U.S. and Canada by 2028, and European stations are planned to come online around 2022 aiming to cover most of the European market by 2030.
- Meanwhile, **Tesla** continues to develop its all electric long-haul truck Tesla Semi. The company has not yet released the actual specifications of its battery for the Semi, but its roadmap includes the commercialization of two versions of the vehicle, a 800-km long range and a 480-km short range versions. Elon Musk, CEO, has stated that the vehicle would likely have a range close to 970km per charge.
- **Daimler's Mercedes-Benz Electric Truck** division is currently conducting trials of an all-electric truck for on-road testing, expecting to continue over the next year. The test will be conducted over a 100km daily tour with a 25-tonne truck that includes a refrigeration unit for food. The company has been working with this technology since 2010 and has been producing a first series of fully electric trucks since 2017.

## B. DECARBONIZATION SOLUTIONS: CARBON INTENSITY COMPARISON

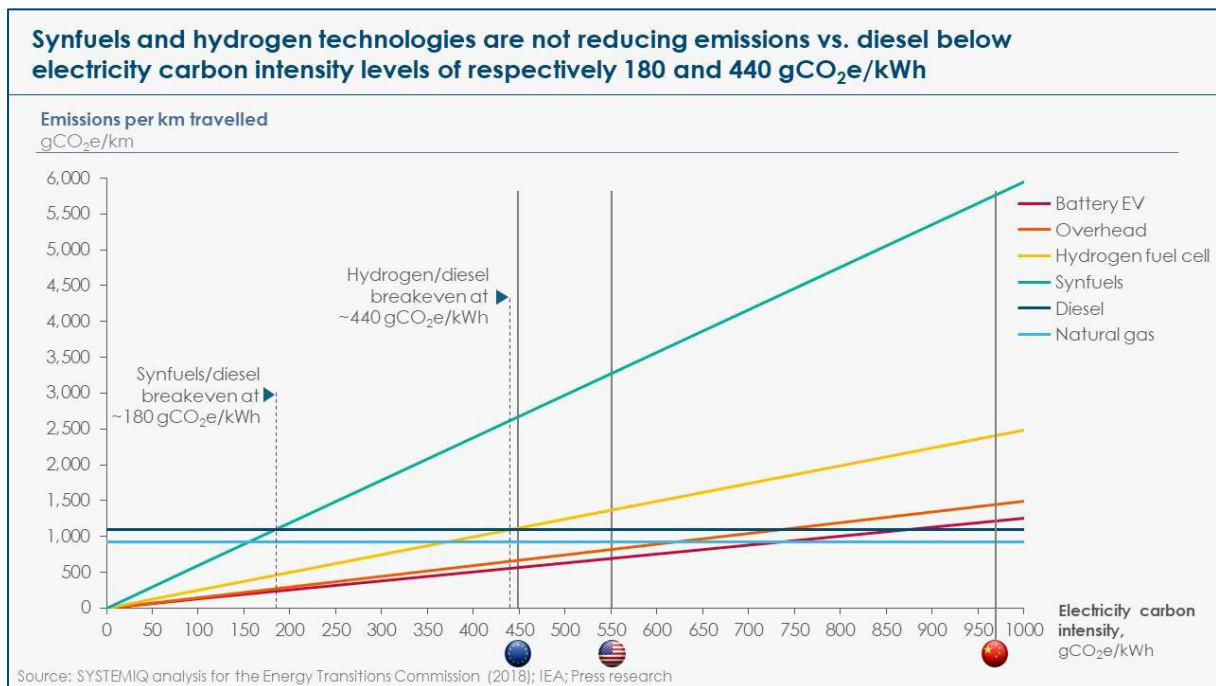
**Electric drivetrains will make the complete decarbonization of heavy-duty road transport possible only when electricity generation is totally decarbonized.** The carbon intensity of synthetic fuels also depends crucially on the carbon intensity of the electricity used in hydrogen electrolysis and (potentially) direct air capture of CO<sub>2</sub>. For biofuels, accurate carbon intensity estimates need to reflect a full lifecycle analysis of biofuel production.

An optimal transition path must therefore reflect careful assessment of full carbon intensities, and how these will change over time as electricity systems are steadily decarbonized. Our analysis suggests that:

- **Battery electric vehicles (BEVs) produce lower total carbon emissions than diesel or gasoline vehicles once the carbon intensity of electricity goes below about 875 grams per kWh.** The US and almost all EU countries are already significantly below this breakeven point (and falling), but in China and even more so in India, further electricity decarbonization is essential to ensure that a shift to BEVs (whether for cars or trucks/buses) reduces rather than increases carbon emissions.
- **Hydrogen FCEVs require a carbon intensity of electricity below about 440 grams per kWh** to produce lower total carbon emissions than ICE vehicles: many European countries are already below this level, apart from Germany, where remaining coal use in power currently maintains carbon intensity above that level.
- **For synthetic fuels, the breakeven point is about 180 grams per kWh.** This low level reflects the significant losses incurred in both the production of synthetic fuels and the

use in an internal combustion engine, which result in aggregate energy efficiency of only 20% or below.

- In principle, **compressed natural gas (CNG) trucks produce 5% less carbon emissions than gasoline or diesel trucks<sup>20</sup>**, if and only if methane leakages across the value chain were lower than 1-2%<sup>21</sup>. Methane leakages today are often significantly higher, cancelling the potential benefits of a switch to gas. Moreover, as power systems decarbonize, battery and hydrogen-based vehicles will become – and, in many cases, are already – far less carbon-intensive.
- Biofuels could in principle be fully carbon neutral, if 100% biofuels were used in internal combustion engines and if the lifecycle production process was totally carbon neutral (which will increasingly be the case as the energy inputs, especially the power inputs, to the production process decarbonize). In practice, **the true carbon intensity of biofuels will differ** according to the biomass source and its land use impact, the precise production methods, and the carbon intensity of the energy inputs to the production process<sup>22</sup>. Moreover, if biofuels are only used, as is often the case today, in a 10% fuel mix, emissions from biofuel use would be only marginally below the diesel line, and the breakeven points for the electricity-based options only marginally lower.



**Exhibit 7**

<sup>20</sup> Transport & Environment (2018), *CNG and LNG for vehicles and ships - the facts*

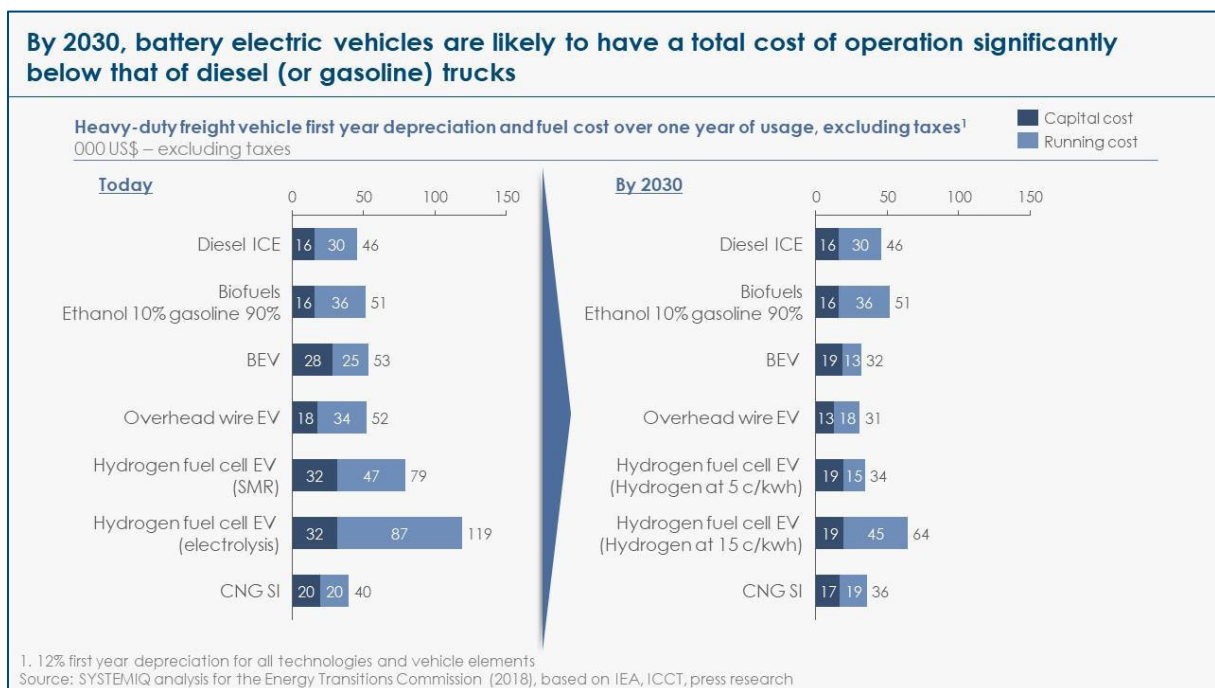
<sup>21</sup> Analysis based on light-duty CNG car example. Environmental Defense Fund (2012), *The climate impacts of methane emissions*

<sup>22</sup> For instance, the EU considers that a minimum threshold of 35% greenhouse gas savings compared to fossil fuel, based on a defined lifecycle analysis must be achieved for a given biofuel to be eligible for support under Member State renewable energy policies (Directive 2003/30/EC) and this threshold has been increased to 50% on 1<sup>st</sup> January 2018.

## C. DECARBONIZATION SOLUTIONS: COST COMPARISON

Our analysis, supported by other sources, suggests that, **by 2030, trucks with electric drivetrains will have a lower total cost of operation than diesel or gasoline trucks**, even for long-distance truck applications, with similar upfront capital costs and much lower operating costs. This reflects the fundamental efficiency advantage of electric drivetrains and is true even without the implicit carbon prices imposed by high excise duties in some countries. For light-duty trucks and buses, the cost advantage will likely be achieved much earlier.

Exhibit 8 shows the results from the ETC's cost model for a heavy-duty truck doing 150,000 kilometers per year. This analysis excludes any tax effects. Electricity prices are assumed at US\$130/MWh hour today and US\$70/MWh in 2030; hydrogen prices at respectively US\$16 cents and US\$29 cents per kWh today for SMR production and electrolysis and US\$5 cents to US\$15 cents per kWh in 2030; battery prices at US\$209/kWh today and 100/kWh in 2030, in line with the latest Bloomberg New Energy Finance survey and forecast<sup>23</sup>.



### Exhibit 8

Key results based on these assumptions are that:

- **By 2030, battery electric vehicles are almost certain to have a total cost of operation significantly below that of diesel (or gasoline) trucks**, with similar upfront costs but much lower operating costs [Exhibit 8]. The cost cost-competitiveness of BEVs is crucially dependent on the electricity price [Exhibit 10]. If renewable electricity prices are below about US\$15 cents per kWh, BEVs will be favored. This is very likely to be the case in almost all geographies by 2030<sup>24</sup>.
- **The cost competitiveness of hydrogen FCEVs is crucially dependent on the price of hydrogen**, which, if the hydrogen is derived from electrolysis, will in turn depend on the price of electricity. Recent analysis from the IEA [Exhibit 11] suggests that, with falling

<sup>23</sup> Bloomberg New Energy Finance (2017) <https://www.bloomberg.com/news/articles/2018-05-31/california-approves-record-utility-spending-for-electric-cars>

<sup>24</sup> See Energy Transitions Commission (2018), *Mission Possible: Reaching net-zero carbon emissions from harder-to-abate sectors by mid-century* – Chapter 6 for further details on renewable electricity prices.



costs of electrolysis equipment and dramatically decreasing cost of renewable energy, it will become possible to produce hydrogen for as little as US\$2 per kilogram or US\$6 cents per kWh in most favorable locations. But, these low costs would only be relevant for road transport, if low-cost international shipping and local distribution of hydrogen could be achieved. The deployment of FCEV trucks would also require the deployment of a hydrogen refueling infrastructure (although much smaller than what would be required for FCEV automobiles), with a varying impact on total operation cost depending on the financing model. In the UK, based on a US\$2-3 million per refueling station, installing 5000 new stations (vs. 8000 existing diesel/gasoline stations) would represent roughly US\$10-15 billion investment<sup>25</sup>.

- **Investment in catenary overhead wiring on major road routes could further reduce total cost of operation of BEVs**, with somewhat higher operating costs (due to energy losses) offset by the significantly lower vehicle costs resulting from smaller required batteries. The economics would be different, however, if overhead wiring infrastructure costs were passed on to infrastructure users. With a cost of US\$1-4 million per kilometer, installing catenaries on the UK's motorways and trunk roads would, for instance, represent an investment of US\$12-50 billions.
- Already in place **excise duties on diesel and gasoline** – which in Europe add around 65% to the pre-tax cost of fuel – will, until and unless electricity is equivalently taxed, greatly increase the cost-competitiveness of BEVs and FCEVs. Exhibit 9 shows the 2030 results for diesel, BEV and hydrogen FCEV trucks with current average European excise duties imposed on diesel. On this basis, hydrogen FCEVs would be cost competitive versus diesel trucks, while BEVs would have a total cost of operation less than half that of diesels trucks.
- **Any future breakthrough in battery chemistry, density and cost**, not captured in the BNEF forecast for lithium-ion battery prices, would further increase the cost advantage of BEVs.
- **Both biofuels and synthetic fuels are currently more expensive than diesel/gasoline.** This is likely to remain in future, even if the cost penalty declines. They are unlikely, therefore, to be a major cost-effective route to the decarbonization of trucking but might still play a role for very-long-haul applications, if sufficiently low hydrogen prices cannot be achieved. Biofuels could also potentially play a role as a transitional fuel in favorable locations with ample supply of sustainable biomass, while the recharging/refueling infrastructure necessary to the deployment of electric drivetrains vehicles is built up.

These conclusions are supported by a number of recent studies. McKinsey estimates that long-haul BEV trucks will become cost-competitive in Europe sometime between 2023 and 2031 and even in the US (with lower excise duties) by 2029 to 2031<sup>26</sup>. Regional haul (200 km) trucks and urban haul (100 km) trucks and buses will however enjoy a cost advantage much earlier, with the economics supporting large-scale deployment by the mid-2020s. [Exhibit 12]

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<sup>25</sup> SYSTEMIQ analysis for the Energy Transitions Commission (2018)

<sup>26</sup> McKinsey Center for Future Mobility (2017), *What's sparking electric-vehicle adoption in the truck industry?*

## Excise duties on diesel and gasoline will greatly increase the cost-competitiveness of BEVs and FCEVs

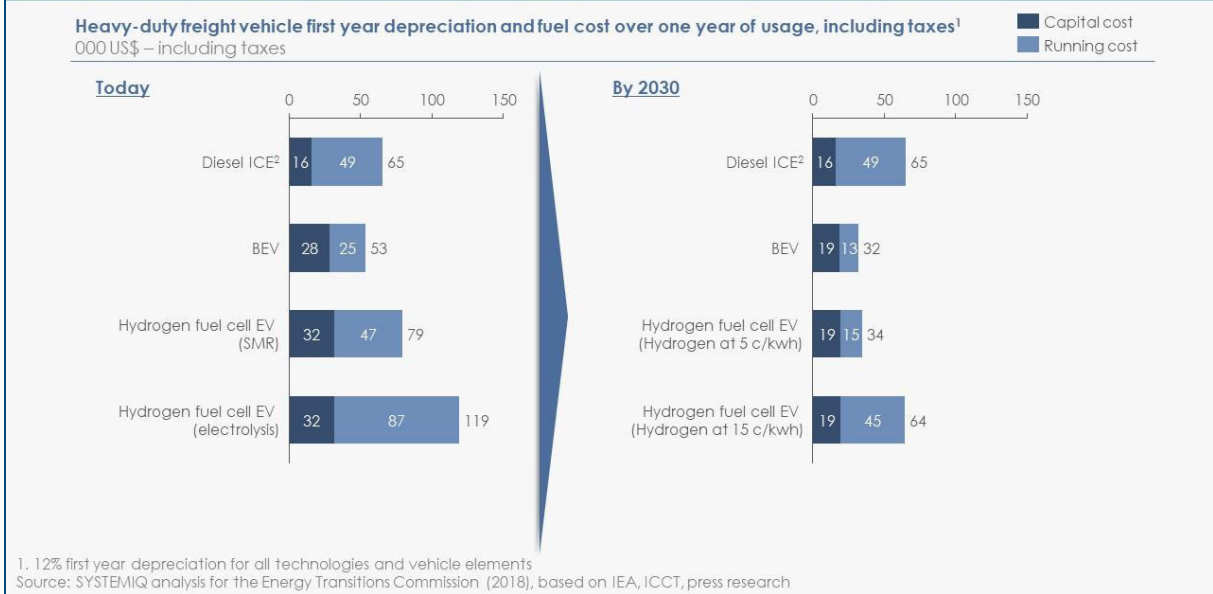


Exhibit 9

## EVs and hydrogen technologies are cost-competitive vs. diesel below electricity costs of respectively 14 and 4 cents US\$/kWh

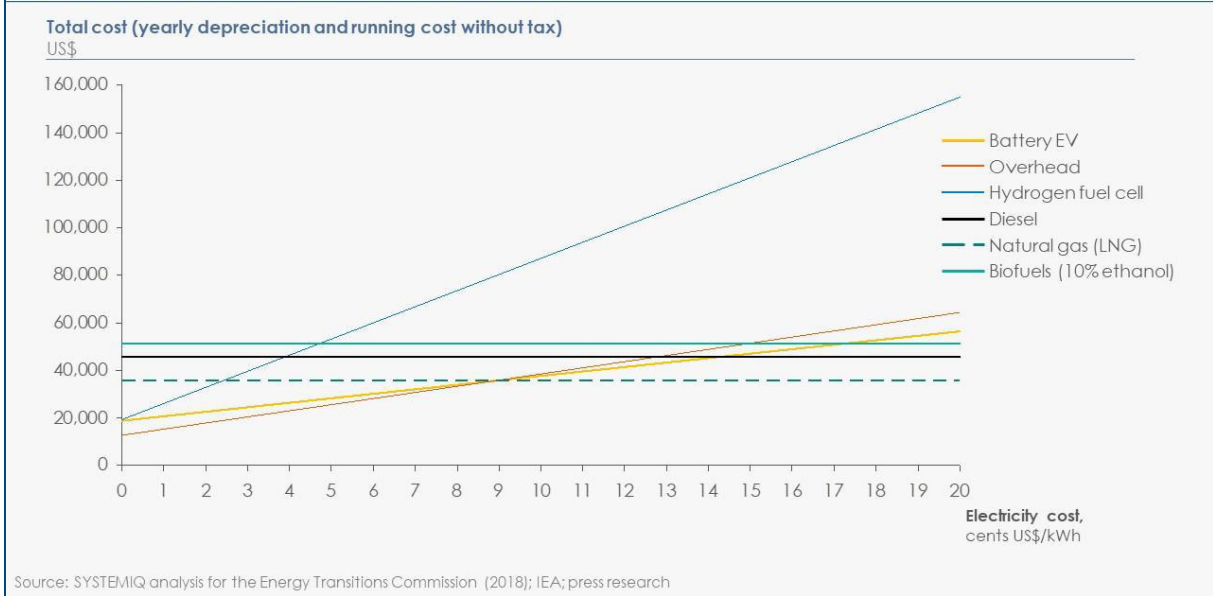
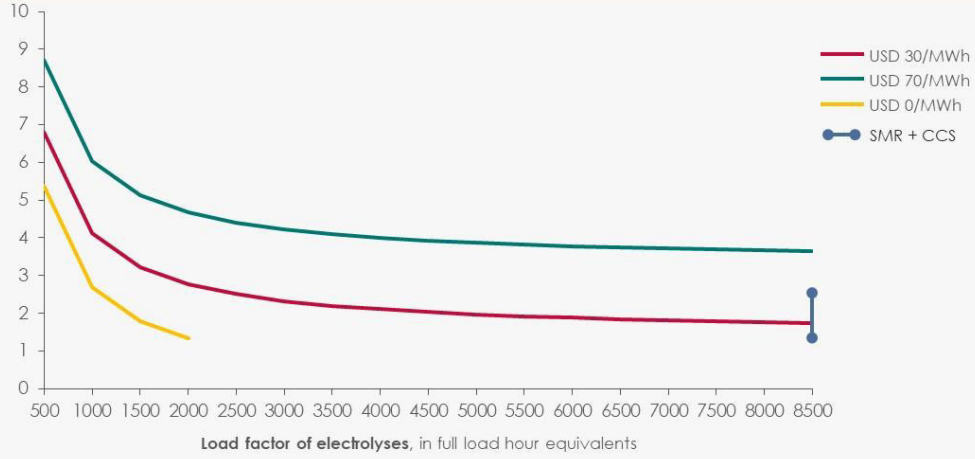


Exhibit 10

**Producing hydrogen from electrolysis may already be cost-competitive with the traditional SMR route in locations with low renewable electricity costs**

Hydrogen production cost depending on cost of electricity and load factor  
US\$ per kg of hydrogen

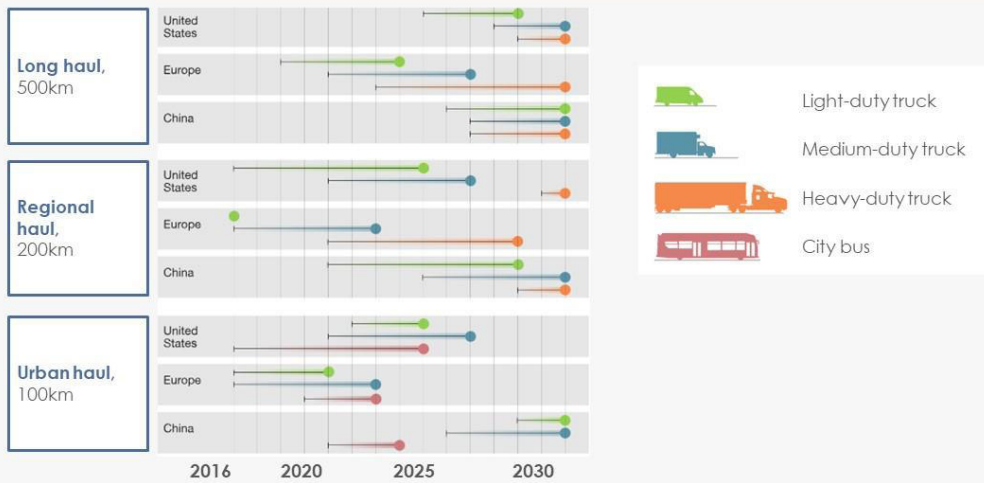


Assumptions: electrolyzers CAPEX US\$450/kW, WACC 7%, 30 years lifetime, 70% efficiency  
Source: Adapted from Philibert, C. (2017), REFI, Insight Papers, IEA, Paris, *Producing hydrogen from renewable energy*

**Exhibit 11**

**McKinsey estimates that long haul BEV trucks will become cost-competitive in Europe in the 2020s and in the US in the 2030s**

Timing of battery electric vehicle Total Cost of Ownership parity with diesel vehicle  
Year achieved range



Source: McKinsey Center for Future Mobility (2017), *What's sparking electric-vehicle adoption in the truck industry?*

**Exhibit 12**

## D. USE OF BIOFUELS IN HEAVY-DUTY ROAD TRANSPORT

Our cost analysis presented in subsection (C) above already suggests that the use of biofuels in ICEs will not be able to compete with electric drivetrains over the long-term. In addition, there are major sustainability issues related to the use of biofuels, which are addressed in detail in the ETC's report *Mission Possible* (Chapters 6 and 7)<sup>27</sup>. Tight regulations on biomass sustainability are vital to ensure that the development of biofuels does not result in negative socioeconomic and environmental impact. In that context, supply of biofuels is likely to be constrained for sustainability reasons. Use of biofuels should therefore be prioritized in sectors with little or no alternative decarbonization solutions, especially aviation and feedstock for the chemicals industry. Given the existence of alternative decarbonization routes, biofuels for heavy-duty road transport (and incidentally for light-duty road transport) should not be a priority and public support to biofuels development and deployment should transition away from road transport to higher-priority sectors like aviation.

## E. TRANSITION PATHWAYS

Given the likely emergence of a total cost of operation advantage for electric vehicles in all trucking segments by the late 2020s, and the relatively short (e.g. less than 10 years) normal replacement cycle for trucks, transition to a largely electrified global truck fleet over the next two decades is possible.

But three sets of implementation challenges may significantly delay the transition:

- **Building the necessary charging and refueling infrastructure – especially for hydrogen and overhead wiring – will take time and represent a significant investment.** In the UK, initial estimates suggest US\$12-50 billion and US\$10-15 billion for overhead wire and hydrogen refueling stations respectively<sup>28</sup>. While some battery recharging or hydrogen refueling will be done within depots and distribution centers, and can therefore be driven by individual companies, widespread conversion to BEVs or FCEVs will require a significant network of shared recharging or refueling facilities, and this development may only occur rapidly if encouraged and supported by public policies. Any development of catenary overhead wiring will also require public policy coordination and possibly public investment. It is likely that individual countries will prefer to opt for one or the other solution depending on local conditions to avoid building two sets of competing infrastructures.
- **Major professionally-managed trucking fleets are likely to respond rationally to the improving total cost of operation of electric drivetrains relative to existing vehicles,** gradually replacing ICE trucks with electric BEVs and FCEVs at a pace determined by typical fleet turnover. **But many smaller trucking operators, sometimes facing financing constraints, may focus primarily on upfront cost** rather than total cost of operation and may therefore replace fleets far more slowly. The fall in cost of batteries is likely to bring the upfront cost of BEVs below the upfront cost of ICEs in the 2030s, but the upfront cost of FCEVs might stay higher for the foreseeable future.
- **In developing countries,** meanwhile, many trucks are bought second-hand, sometimes from developing countries. Rapid transition to electric trucks in developed countries may therefore **create a supply of low-priced second-hand ICE trucks,** which may be used for several decades in developing economies.

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<sup>27</sup> Energy Transitions Commission (2018), *Mission Possible – Reaching net-zero carbon emissions from harder-to-abate sectors by mid-century*

<sup>28</sup> SYSTEMIQ analysis for the Energy Transitions Commission (2018)



These complexities and implementation challenges mean that **forceful public policy action** is likely to be required to accelerate the adoption of BEVs and FCEVs, even after the point when the total cost of operation for new trucks would favor those solutions. Infrastructure build-up will be essential, but other financial and regulatory incentives could also be needed, as described in Section 8.

Given the level of market readiness of BEVs and FCEVs for heavy-duty road transport, **the transitional use of “drop-in” or “close-substitute” low-carbon fuels, which can be used in existing engines, is likely to be very limited.** It might play a rapidly diminishing role over the next 5-10 years in developed countries and could potentially play a longer role in developing countries, especially where second-hand fleets are widespread. **The most likely option for a transitional “drop-in” fuel is biofuels,** as long as it is produced in a truly sustainable fashion. Synfuels currently face a significant cost penalty and would have to be produced based on electricity with a low carbon intensity level (below 180gCO<sub>2</sub>/kWh) to be carbon-reducing in comparison to traditional diesel ICEs. As for CNG, it can only deliver a small reduction in CO<sub>2</sub> emissions (which can rapidly be cancelled if there are methane leakages in the gas value chain), requires some capital investment to convert existing ICE engines (conversion cost between US\$12,000 and US\$18,000 for light-duty vehicles) and demands the deployment of a new refueling infrastructure which could rapidly be stranded.

In addition to implementation challenges related to trucking specifically, **a comprehensive decarbonization strategy for road transport** – covering cars and vans as well as trucks and buses – needs to consider (i) whether available mineral supplies, especially lithium and cobalt, place any limits on the feasible pace of electrification, (ii) issues relating to the recycling or reuse of batteries, (iii) the implications of significant road transport electrification and related charging infrastructure for the scale of investment needed in electricity generation and distribution networks. These issues are not considered in this sectoral focus but are covered in the ETC's report *Mission Possible* (Chapters 6 and 7).

## 5. COST OF FULL DECARBONIZATION OF HEAVY-DUTY ROAD TRANSPORT

The heavy-duty road transport sector appears to be, after light-duty road transport, the “easiest” of the transport sectors to decarbonize, due to the availability of technically feasible and soon-to-be cost-competitive solutions. This is reflected in the low cost of the full decarbonization of the trucking sector, compared to other transport sectors and other harder-to-abate sectors of the economy, especially in industry.

Because zero-carbon trucks should be cost-competitive as soon as the 2020s or 2030s depending on the geographies, it is safe to assume that, for heavy-duty road transport operators, **the cost of shifting to BEVs or FCEVs should by definition be null or could even be negative**, thanks to net savings arising from the higher efficiency of electric engines compared to internal combustion engines. As a result, the cost to buyers of road transport services (e.g. retailers) and to end consumers (e.g. households buying goods that have been transported by road) should also be null.

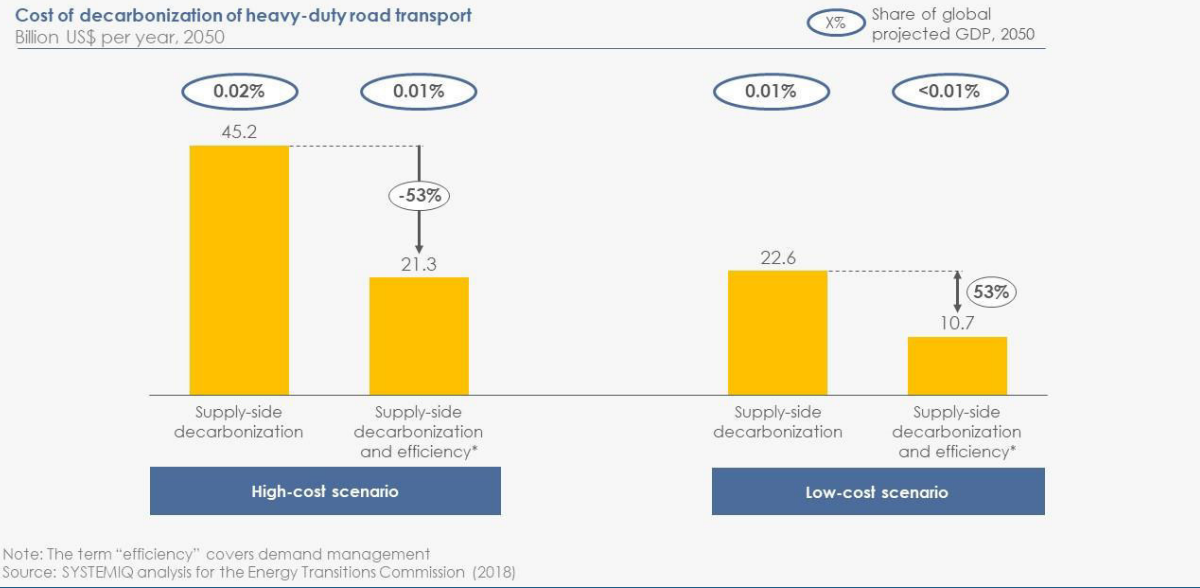
The cost to the economy as a whole of the full decarbonization of heavy-duty road transport should therefore **be limited to the sole infrastructure cost**. This paper considers infrastructure costs related directly with road transport decarbonization – i.e. recharging/refueling infrastructure. Infrastructure costs related to the increased demand for power, either directly through the use of BEVs or indirectly through the use of FCEVs using hydrogen from electrolysis, is considered in the ETC's *Mission Possible* report (Chapters 6 and 7).

The ETC calculated that the global infrastructure abatement cost of heavy-duty road transport could reach between US\$10 and US\$20/tonne of CO<sub>2</sub>. This only accounts for electric charging for medium- and heavy-duty trucks and buses, vans and short-haul trucks being served by the light-duty charging infrastructure. Based on maximum ratios of 33 slow chargers for 100 vehicles and 2 fast motorway chargers for 100 vehicles at the respective costs of US\$30,000 for a 50kW “slow” charger and US\$60,000 for a 100kW “fast” charger<sup>29</sup>, this amounts to a total maximum cost of ~US\$150bn, or ~US\$5bn per year to support a fully decarbonized electric bus and trucking industry. Applied to the global emissions of the heavy-duty road transport sector in a business-as-usual scenario, this translates into a total cost to the economy of less than 0.01% of global GDP in 2050, or less than US\$50 billion per annum [Exhibit 13].

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<sup>29</sup> Transport & Environment, 2018, *Roll-out of public EV charging infrastructure in the EU*

**With a maximum decarbonization cost of US\$45 billion per year, heavy-road transport is the cheapest harder-to-abate transport sector to decarbonize**



**Exhibit 13**

## 6. CONCLUSIONS AND POLICY IMPLICATIONS

The purpose of this sectoral focus is not to predict the precise role which different technologies will play in the decarbonization of heavy-duty road transport, nor to forecast the precise pace of transition, but to draw **broad implications for policy, industry and finance** with regards to how to prepare for and accelerate the pace of the transition. Our analysis carries the following implications:

- It is close to certain that **the primary long-term route to heavy-duty road transport decarbonization will involve a switch to electric drivetrains**, with BEVs playing a major role, even if there is no carbon price and even without major new technological breakthroughs. This implies that (i) electricity generation must be decarbonized as rapidly as possible to ensure that transport electrification delivers carbon emission reductions, (ii) further development of battery technologies is a high priority, (iii) infrastructure investment in electric charging, power grid strengthening, and low-carbon power generation is vital.
- **Hydrogen FCEVs and catenary overhead wiring of major roads are likely to play a significant role in the long-haul sector.** These two solutions require a different set of infrastructure building (hydrogen refueling vs. wiring) and individual countries or regions might need to opt for one or the other solution to avoid building two sets of competing infrastructures. This will require public policy coordination and support.
- Given the **probable role of FCEVs**, achieving further reductions in the cost and efficiency of electrolysis, fuel cell equipment and hydrogen tanks is crucial.
- **Biofuels and, to a lower extent, synfuels may have a useful but limited transitional role in the long-haul sectors, especially in developing economies**, but (i) it is essential that biofuels are produced in a truly sustainable way and (ii) synfuels for surface transport should only be supported once electricity generation has been substantially decarbonized. Any policy measure mitigating the cost penalty that low-carbon drop-in fuels currently face should be thought carefully so as to not hinder longer-term development and deployment of electric drivetrain vehicles.
- In the light of potential implementation challenges to deploy new technologies in a fragmented transport industry, **modal shift and, to a lesser extent, operational efficiencies can offer a useful, complementary emissions mitigation strategy.**

## 7. EXISTING INITIATIVES

Compared to, for instance, the aviation industry, **the heavy-duty road transport industry is highly fragmented and inherently local, reducing the scope for collective industry targets and commitments** of the sort which IATA has endorsed for aviation or IMO for shipping<sup>30</sup>. At the national level, the Nationally Determined Contributions (NDCs) submitted within the Paris Agreement process are often vaguer about plans for the decarbonization of heavy-duty road transport than for the expansion of electric mobility for light-duty transport.

However, **many local policy initiatives are already driving initial steps towards the decarbonization of intra-city road transport**, which will drive technological developments relevant to the whole heavy-duty road transport sector, for example:

- **Major cities announced future bans on petrol and diesel cars:** Mexico City, Paris, Madrid, Athens committed to end diesel engine use by 2025, and Paris to end gasoline engine by 2030. Britain has pledged to ban the sale of all diesel and petrol cars and vans from 2040. Trucks are specifically targeted by “clean air zones” policies: Los Angeles has launched a Clean Trucks Program, progressively banning the oldest and most polluting drayage trucks from serving the San Pedro bay and has put in place a funding mechanism to facilitate old trucks replacement. Announced future bans on diesel vehicles within several major cities will create incentives for manufacturing companies to accelerate product development of BEV, FCEV, or hybrid trucks and buses.
- **Urban bus fleets are beginning to switch to electric, most dramatically in China** [Box 3]. Shenzhen has converted all its 16,360 buses to electric in 2018 and a recent report from the Rocky Mountain Institute suggests that almost all of China’s 1 million urban buses will be electric by 2025<sup>31</sup>. The accelerated Chinese conversion will, at least initially, increase carbon emissions given the current carbon intensity of Chinese electricity. But it will also support massive scale production of large batteries, driving down costs, and leaving battery and engine companies with production capacity which, once the switch to electric bus fleets is complete, is likely to be devoted to electric truck production.

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<sup>30</sup> See Energy Transitions Commission (2019), *Aviation sectoral focus* & Energy Transitions Commission (2019), *Shipping sectoral focus*

<sup>31</sup> BNED (2018), *Electric Buses in Cities*



### **Box 3 – The deployment of urban electric buses in China**

Within eight years, the 12-million-inhabitant city of Shenzhen became the first city in the world to electrify 100% of its public buses<sup>32</sup>. In Shenzhen, the total of 16,360 buses – equivalent to London's bus fleet size – consume nearly 75% less energy than diesel buses with an average operating mileage in 2016 of 174.4km per day and energy consumption of 106kWh per 100km, resulting in savings of 366,000 tons of coal annually.

This city-level program is part of a larger government-initiative, led by the Ministry of Transport, Ministry of Finance, and Ministry of Industry and Information Technology, who have put forward a project in 2015 to replace existing traditional-fuel buses by a new-energy bus fleet. This program is driven by the aspiration to make cities pollution free. The targeted proportion of electric buses is 80% in nine cities, 65% in six cities and 30% in other provinces. As a result, across China, the number of new-energy buses has increased from less than 0.33% of the total in 2013 up to 39.5% in 2017, resulting in a reduction of 8.5Mt CO<sub>2</sub> between 2013-2017. If this trend continues, CO<sub>2</sub> emissions will be reduced by 33Mt by 2021<sup>33</sup>.

To drive implementation, the Chinese central government provides upfront investment support and grants, making the costs of electric buses on par with diesel buses, while local governments have introduced a series of subsidies and tax reductions to encourage the development and uptake of new-energy vehicles. The scale at which electric buses are now being deployed also drives cost reductions which benefit not only buyers of electric buses in China, but also buyers of electric vehicles worldwide.

Increasingly, other cities around the world are putting in place strategies to go all-electric, such as London by 2030 or New York by 2040.

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<sup>32</sup> World Resource Institute (2018), *How Did Shenzhen, China Build World's Largest Electric Bus Fleet?*

<sup>33</sup> Institute for Transportation & Development Policy (2018), *China Tackles Climate Change with Electric Buses*

## 8. RECOMMENDATIONS

To some extent, **the transition to net-zero-carbon heavy-duty road transport is more straightforward than in other sectors**, given that zero-carbon vehicles will likely be cost-competitive in the 2020s and 2030s. However, public policy needs to play a role in accelerating this transition and in supporting electric charging, hydrogen refueling or overhead wiring infrastructure.

### A. RESEARCH AND DEVELOPMENT

Even with lithium-ion liquid electrolyte batteries, it is likely to be technically possible and cost-effective to use BEVs for a large proportion of the truck fleet. Further improvements in battery technology would greatly speed the transition and increase the percentage of the fleet for which BEVs are a viable solution. If significant improvements in battery density and charging speed are achieved, it is possible that hydrogen might not be required to decarbonize even very-long-haul trucking. Until these happen, FCEVs will likely play a significant role in trucking, even if they do not play a significant role in light-duty road transport.

R&D effort should therefore focus on:

- Achieving significant improvements in **battery gravimetric density**, making possible increased ranges – breakthroughs might be achieved through the development of solid-state battery technology within the next 5 to 10 years, but a wide range of possible future chemistries should be considered;
- Improving the current trade-off between **charging speed** and battery capacity degradation over time, to enable shorter recharging times for large batteries;
- Achieving efficiency improvements and cost reductions in **electrolysis**, which will in any case be vital regardless of what role hydrogen plays in road transport, given the very significant contribution that hydrogen will have to make to decarbonization in several other sectors;
- Achieving efficiency improvements and cost reductions in **hydrogen fuel cells and hydrogen tanks**.

In these different sectors, given the existence of a market in the relatively short-to-medium term, most R&D investment is already and will likely continue to come from the private sector.

### B. PUBLIC POLICY

Given the major role which BEVs and hydrogen FCEVs will play in trucking decarbonization, light-duty transport and several other sectors, **it is essential that power systems are decarbonized as rapidly as possible**, and that plans for future low-carbon power generation capacity and grid strengthening reflect the significant increases in electricity demand even in developed economies and even if significant improvements in energy efficiency are achieved<sup>34</sup>.

- NDC plans submitted within the Paris process should explicitly describe how rapidly the carbon intensity of electricity will decline, when it will fall below the breakeven point at which road transport electrification reduces emissions, and the desired pace of road transport electrification reflecting these timescales.

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<sup>34</sup> See Energy Transitions Commission (2018), *Mission Possible – Reaching net-zero carbon emissions from harder-to-abate sectors by mid-century* – Chapters 6 and 7

- Governments/national grid operators should commission detailed analysis of the implications of widespread road transport electrification for the adequacy of electricity distribution networks and ensure that appropriate investment plans are put in place.
- Multilateral Development Banks and Development Finance Institutions should take these national strategies into account and facilitate necessary investments in the power sector, especially in developing economies.

**Carbon pricing will likely not be needed to drive heavy-duty road transport decarbonization**, unlike in all other “harder-to-abate” sectors analyzed by the ETC. But, **any subsidies to diesel or gasoline production and use – still prevalent in several emerging economies – should be eliminated**. Where high excise duties are already in place, these will help drive the pace of the transition.

**Biofuels** should only be exempted from such excise duties if derived from clearly sustainable sources and should, in any case, **be strictly regulated** to avoid any reverse socioeconomic and environmental impact. Any support to biofuels deployment should be gradually phased out to reflect that road transport does not constitute a priority use for the limited global supply of biomass, compared to aviation or feedstock for plastics.

In addition, public policy should play a major role in driving the transition by:

- **Supporting the development of the required infrastructure**, in particular:
  - Collaborating with the industry to accelerate the deployment of high-speed charging and hydrogen refueling networks, and
  - Defining a strategy for catenary overhead wiring on major freight roads, assessing costs and likely impact, deciding whether, when and how extensively to deploy catenary wiring, and estimating the resulting need for public or private investment;
- **Incentivizing modal shift from road to rail and shipping;**
- **Creating demand for zero-carbon heavy-road vehicles** via:
  - City government plans to make all urban buses zero-carbon (electric or hydrogen), ideally by 2035;
  - City government plans to prohibit ICE vehicles from city centers and national government plans to completely prohibit non-hybrid and (at a later date) all ICE vehicles, defined well in advance, to create strong incentives for the development and fleet purchase of electric or hydrogen trucks.

## C. INDUSTRY COLLABORATION AND COMMITMENTS

Many of the required investments in new lower-carbon trucks as well as in charging and refueling points at distribution center level will be driven by individual fleet operators making private decisions in the light of changing total cost of operation. But individual company commitments and industry collaboration could play a powerful role in driving change.

- **Major fleet operators** (including wholesale and retail companies with owned fleets) should make commitments to achieve **100% zero-carbon trucking** by specific dates, in a fashion comparable with the “EV100” commitments which major companies have already made with regards to their light-duty vehicle fleets.
- **Major logistics companies, wholesalers and retailers**, such as consumer goods companies, should make commitments to achieve **100% zero-carbon freight** by

specific dates, which might be achieved by a combination of deployment of zero-carbon trucking and modal shift (in particular to fluvial shipping and rail).

- Industry collaboration between truck manufacturers, fleet operators and fuel station operators, potentially supported by public subsidy, should drive rapid development of **high-speed charging and hydrogen refueling infrastructure** along major freight roads.
- **Collective industry commitments and pilot projects**, such as that launched by the North American Council for Freight Efficiency and the Rocky Mountain Institute<sup>35</sup>, should also be used to create momentum for efficiency improvements, which can be achieved in the short term, including efficient driving practices and better operational efficiency.

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<sup>35</sup> The Rocky Mountain Institute is working with the North American Council for Freight Efficiency (NACFE) and the trucking industry to double U.S. freight efficiency by increasing confidence in energy-efficient technologies and practices, highlighting their savings potential, and accelerating their adoption. The objective is to get 30% of large fleets and small owner-operators to demand fuel-efficient trucks by 2018 (<http://rmi.org>)

