# HDV efficiency program development

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IEA Energy Efficiency Training Week

GFEI day

Paris

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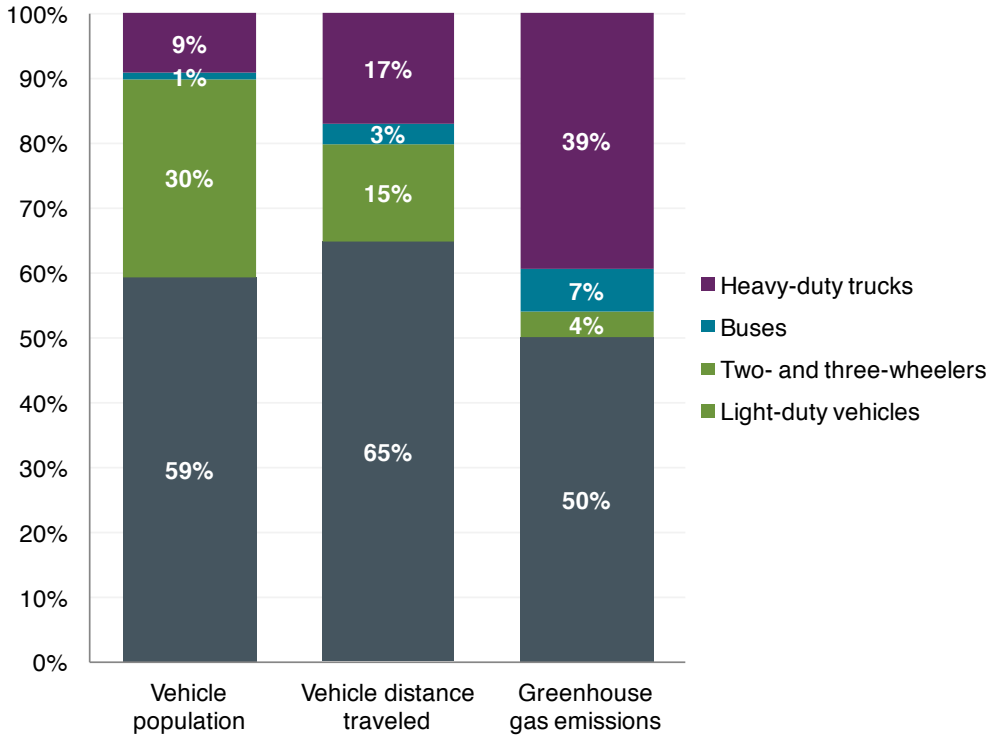
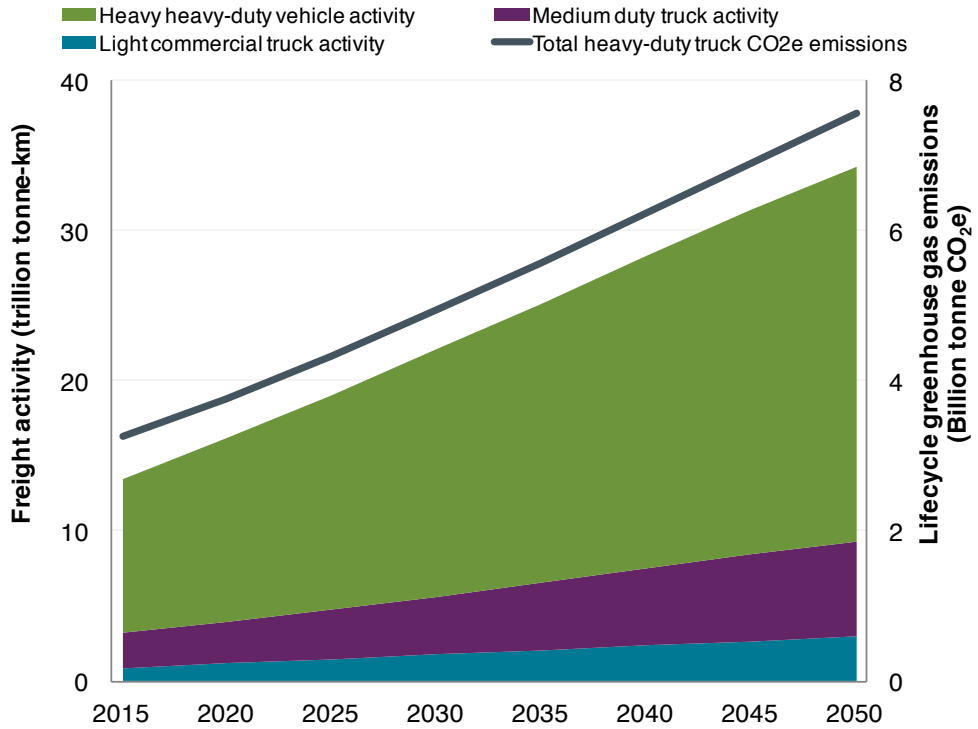
# Why policy makers should pay attention to HDVs

## HDVs represent 10% of global fleet but nearly 50% of on-road GHG emissions . . . and growing




Global vehicle stock, distance traveled, and life-cycle road transport greenhouse gas emissions by vehicle type in 2015.




Projected global freight activity and life-cycle greenhouse gas emissions from 2015 to 2050.


Moultak, Marissa, Nic Lutsey, and Dale Hall. 2017. "Transitioning to Zero-Emission Heavy-Duty Freight Vehicles." The International Council on Clean Transportation
https://www.theicct.org/publications/transitioning-zero-emission-heavy-duty-freight-vehicles

# Agenda

- Why regulate HD efficiency?
- What are the key elements of HD efficiency programs?
- Certification methodology
- Vehicle segmentation

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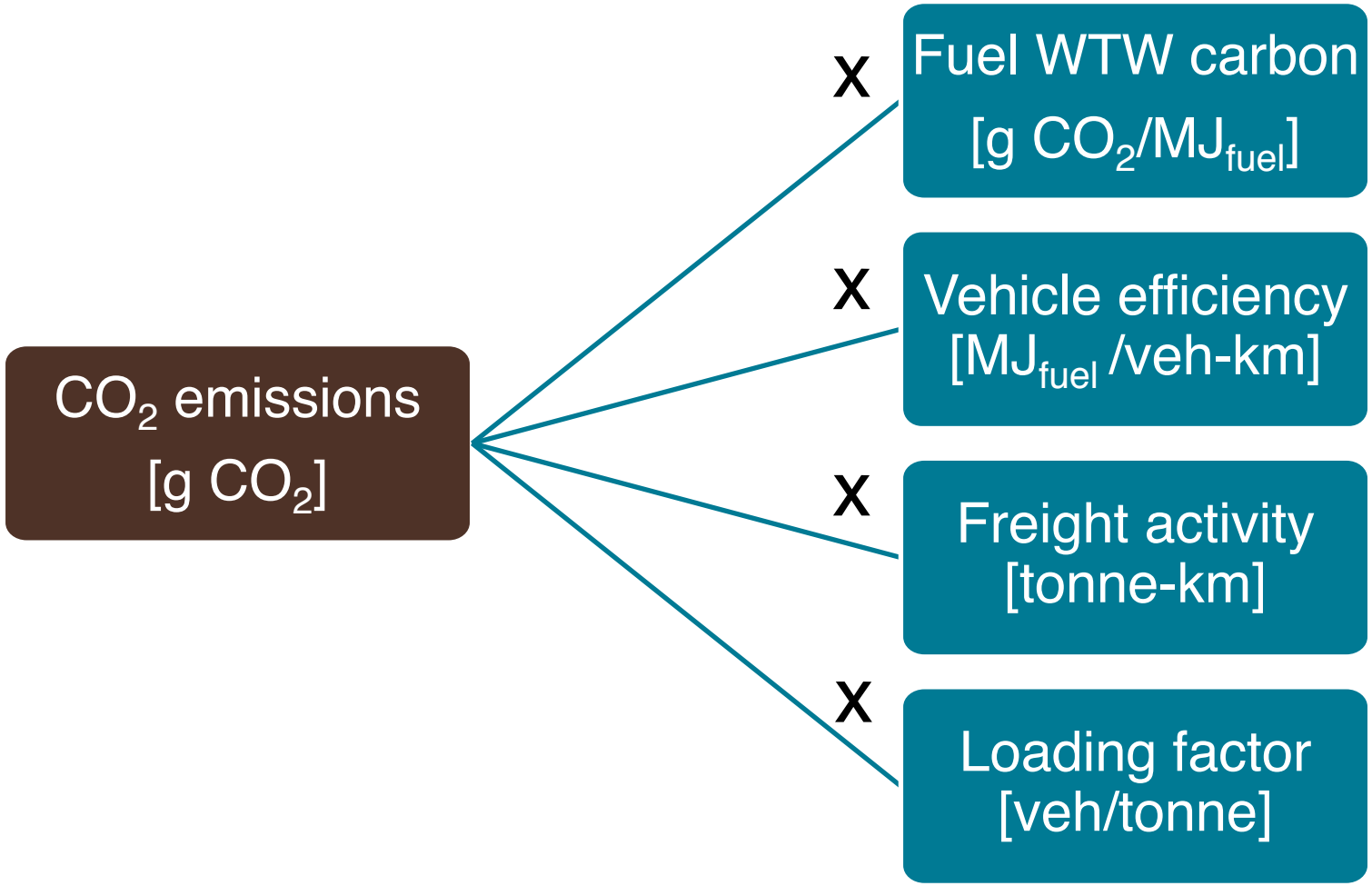
# Why regulate HD efficiency?

## Drivers for $CO_2$ emissions from on-road freight and market barriers

# Drivers for tailpipe $CO_2$ emissions from road freight transport

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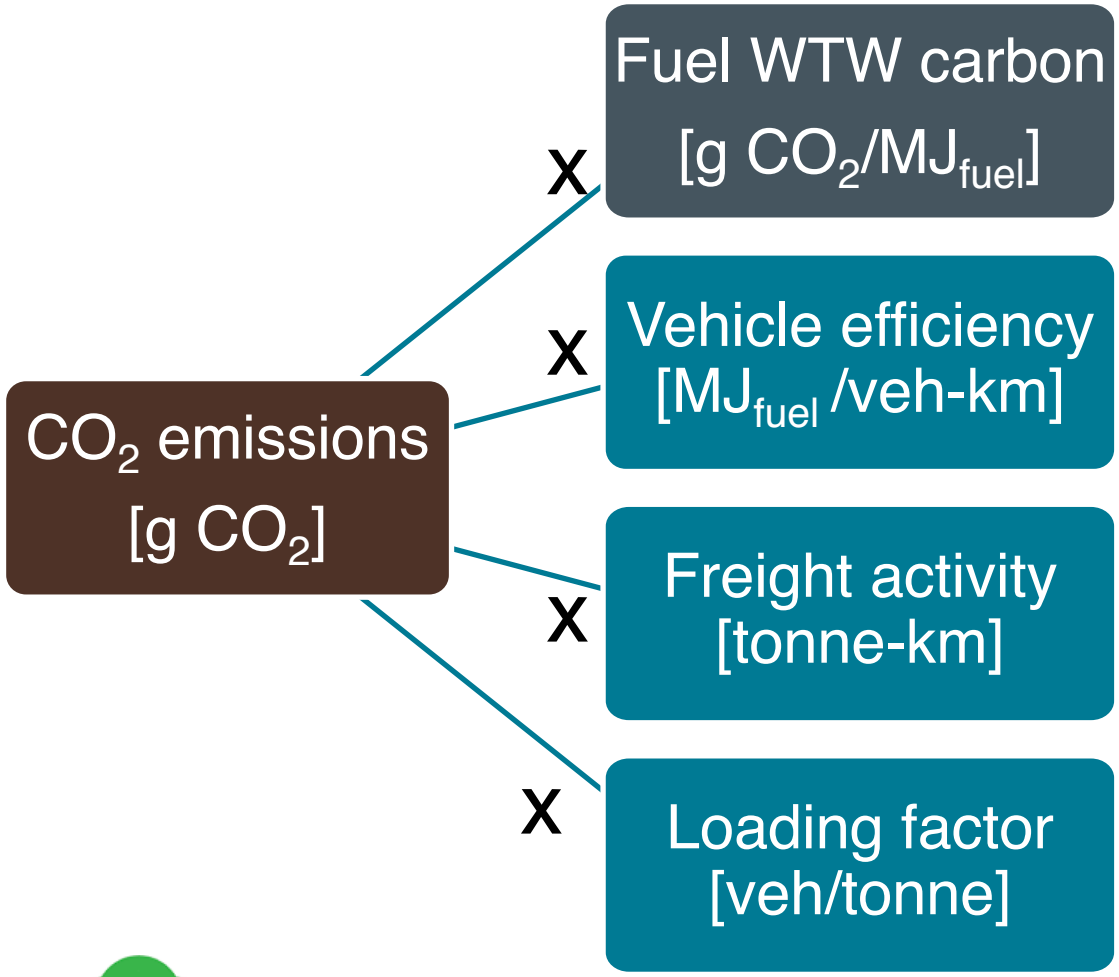
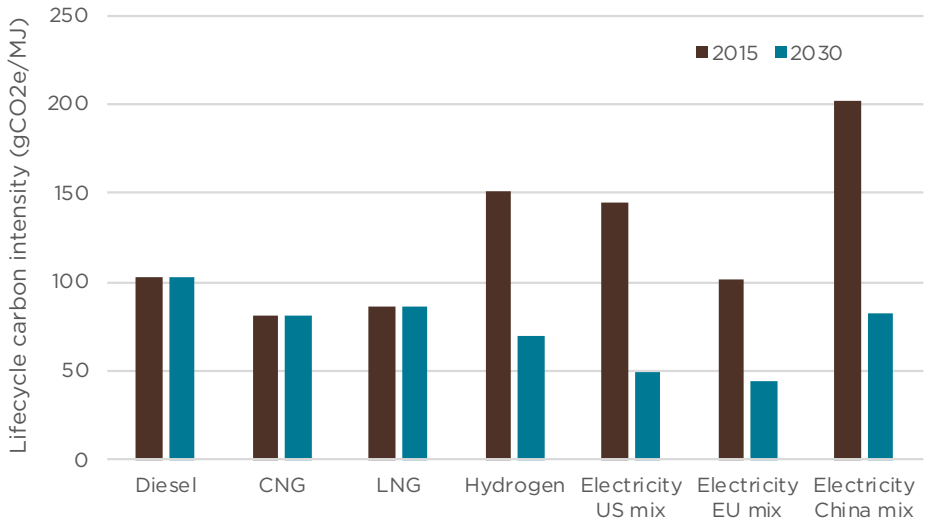
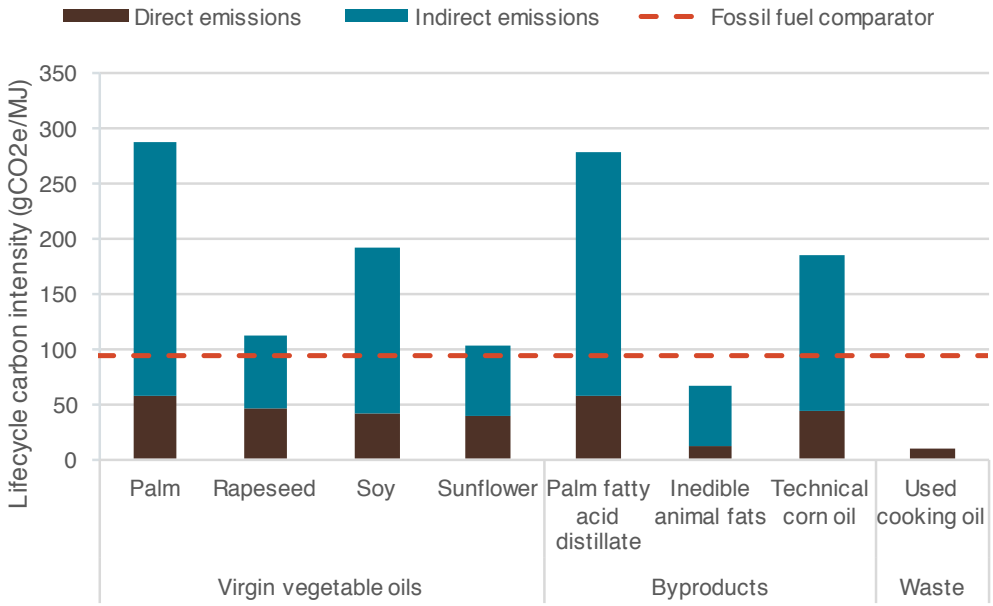
# Life-cycle carbon intensity of different fuels




Data source: Moultak, Marissa, Nic Lutsey, and Dale Hall. 2017. "Transitioning to Zero-Emission Heavy-Duty Freight Vehicles." The International Council on Clean Transportation https://www.theicct.org/publications/transitioning-zero-emission-heavy-duty-freight-vehicles




Data sources: European Commission proposal for recast Renewable Energy Directive to 2030; Valin et al. (2015); Searle et al. (2017); Malins, C. (2017)

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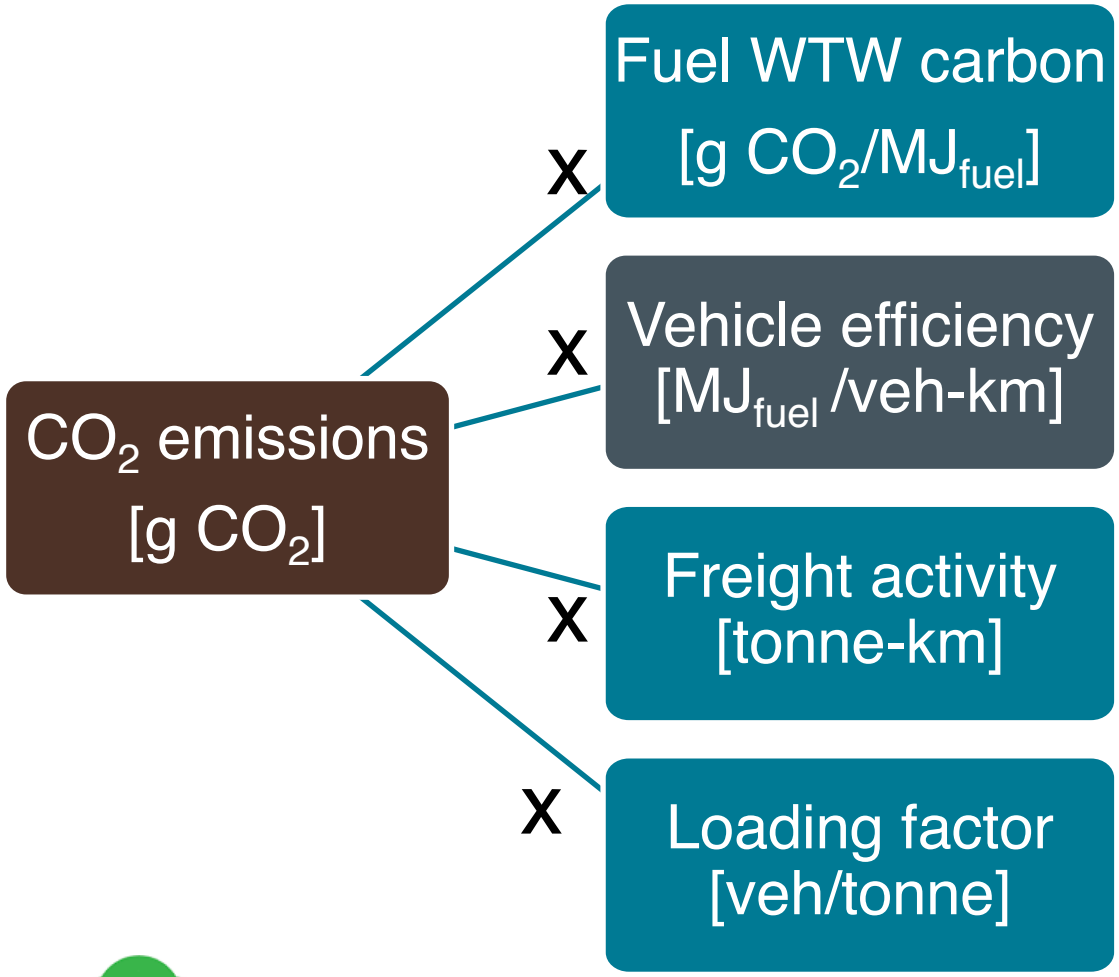
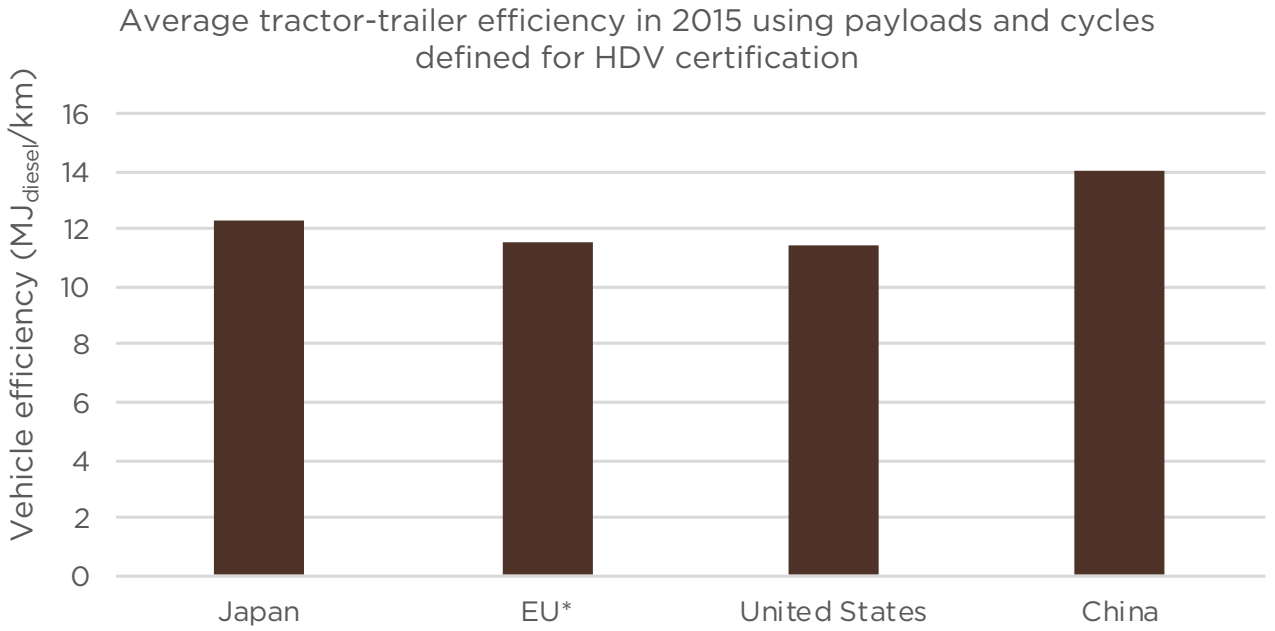
# Tractor-trailer efficiency for different regions in the year 2015




| | 2015 fuel consumption in region's metric* | Notes on cycle and payload |
|---|---|---|
| Japan | 2.84 km/L | GCVW = 38 t, Payload = 50% loading (~10 t). Cycle: JE05 (55%), 80 km/h (45%) |
| EU | 33.1 L/100km | GCVW = 40 t, Payload = 19.3 t, Cycle: Long Haul |
| U.S. | 7.3 gal/1000 ton-mi | GCVW = 36 t, Payload = 17.2 t, Cycle: 95% constant speed cycles |
| China | 40 L/100km | GCVW = 40 t, 100% loading (~24 t), Cycle: C-WTVC (90% motorway) |

* With the exception of the EU, the fuel consumption corresponds to the mandatory limits set in HDV standards. The EU vehicle efficiency is based on ICCT's own work. The EU will propose HDV $CO_2$ standards in May 2018.

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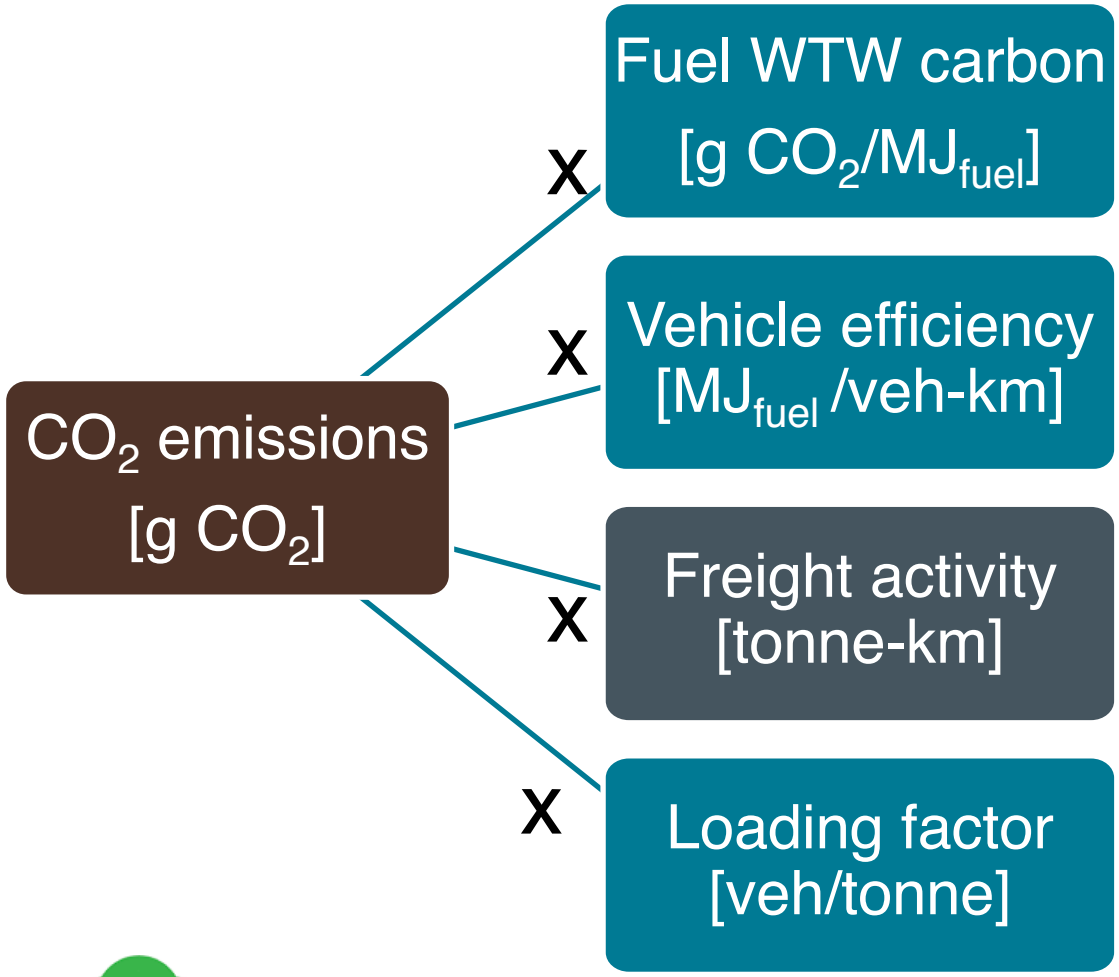
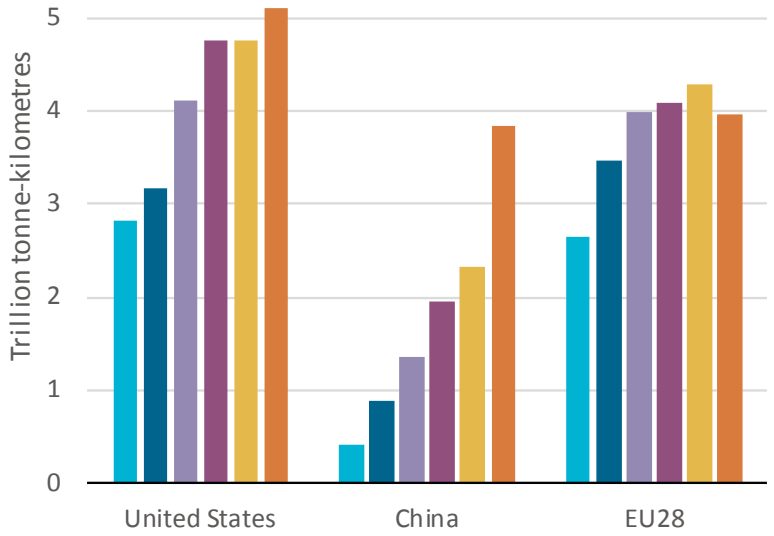
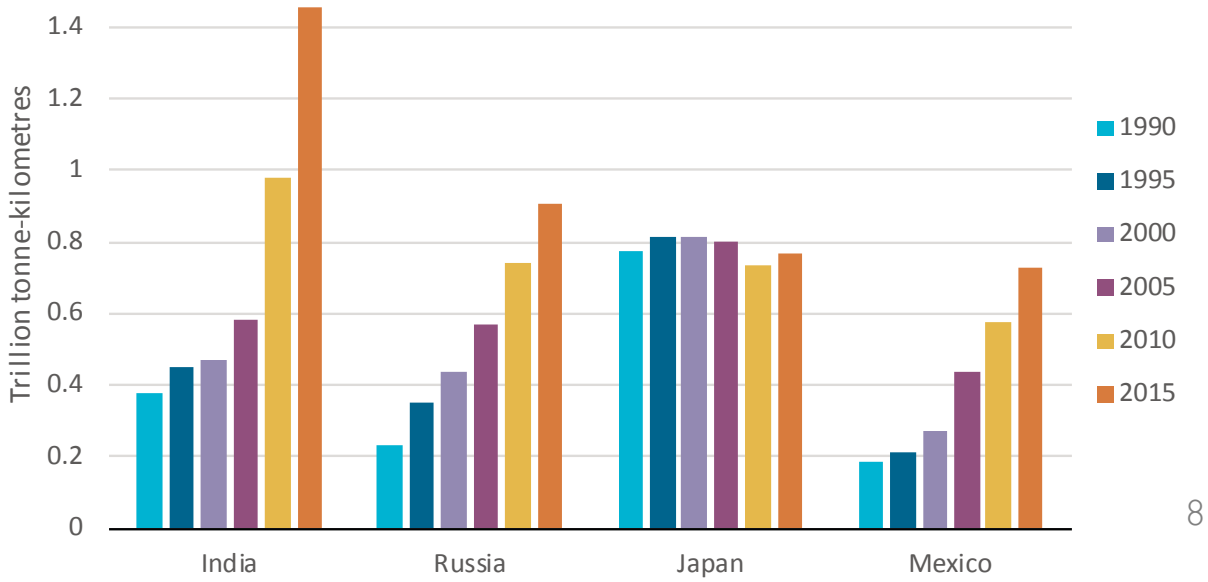
# Freight activity is generally linked to GDP. In the EU and Japan, there is some incipient evidence of decoupling

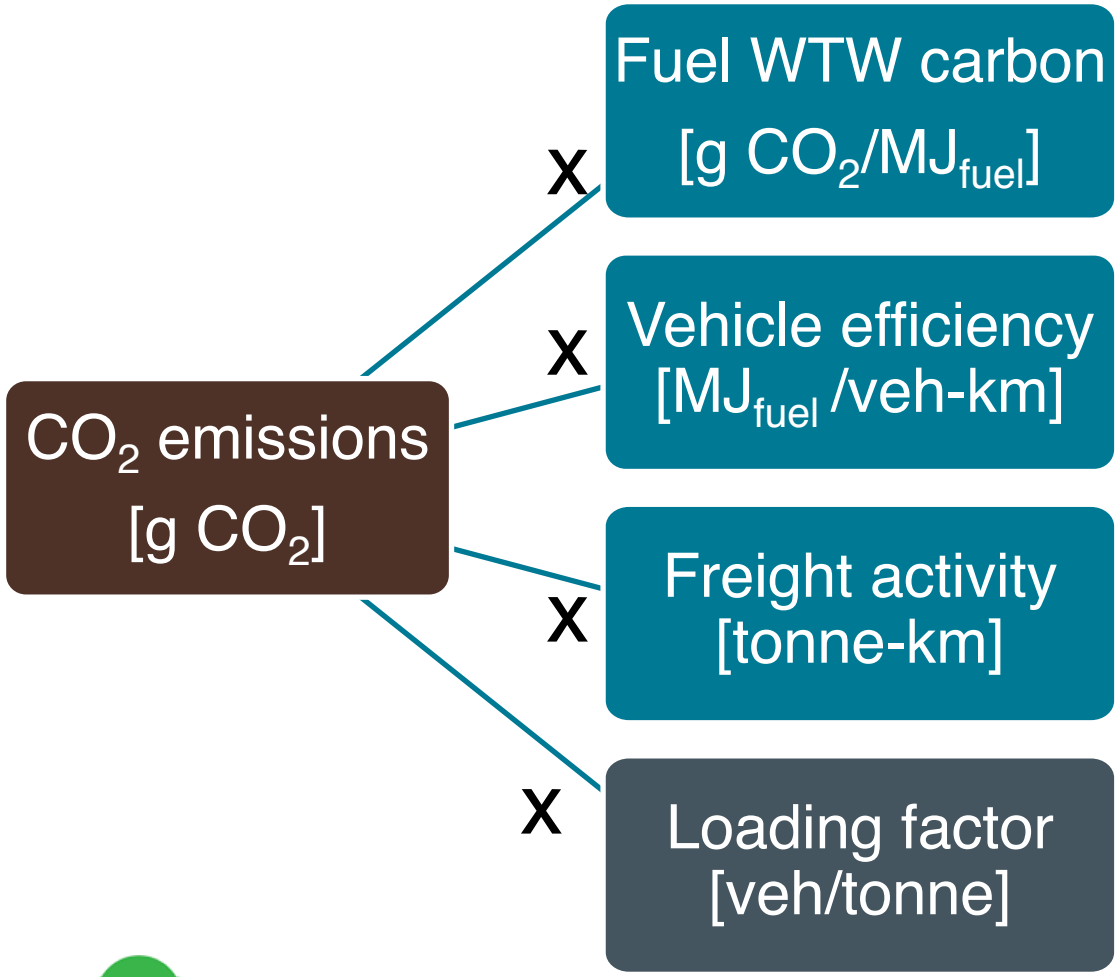


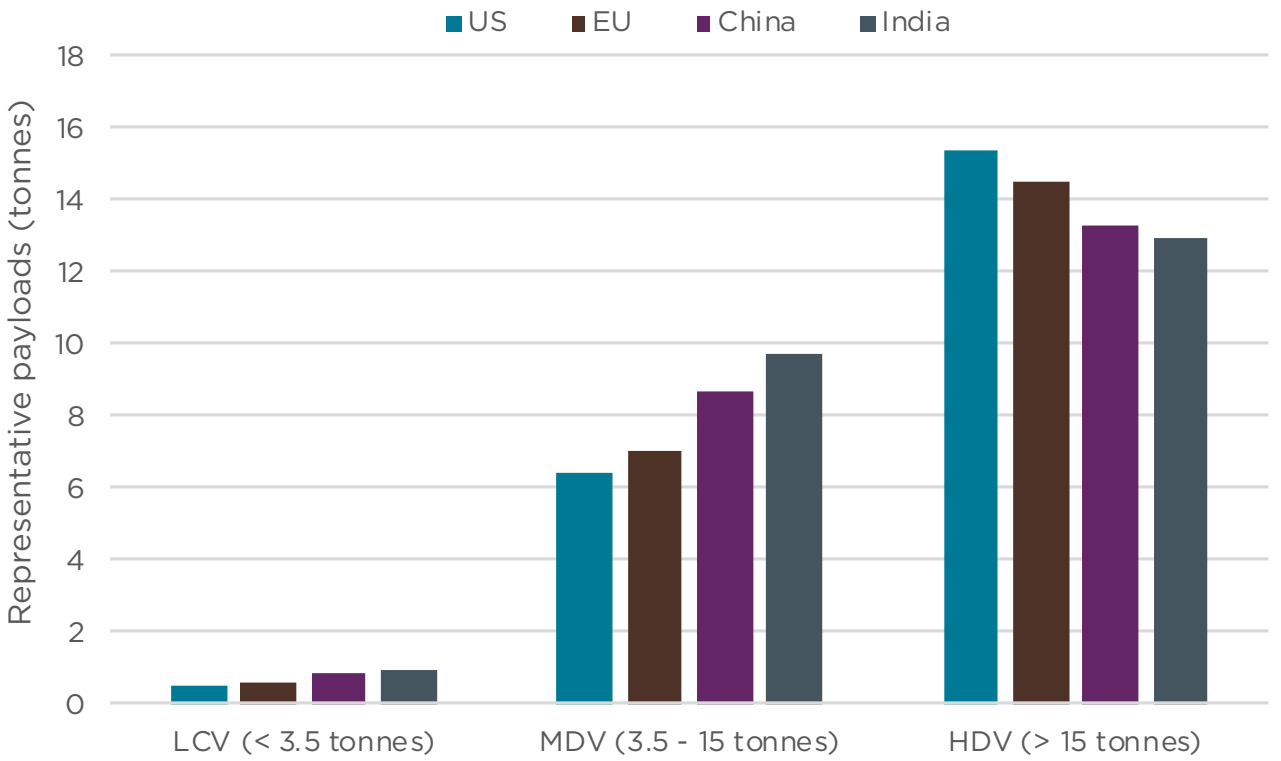




International Energy Agency. "The Future of Trucks. Implications for Energy and the Environment." OECD, August 4, 2017. https://www.iea.org/publications/freepublications/publication/the-future-of-trucks---implications-for-energy-and-the-environment.html.

# Maximizing vehicle loading can reduce $CO_2$ emissions, but has clear boundaries.




Data source: International Energy Agency. (2017). *The Future of Trucks. Implications for energy and the environment.*

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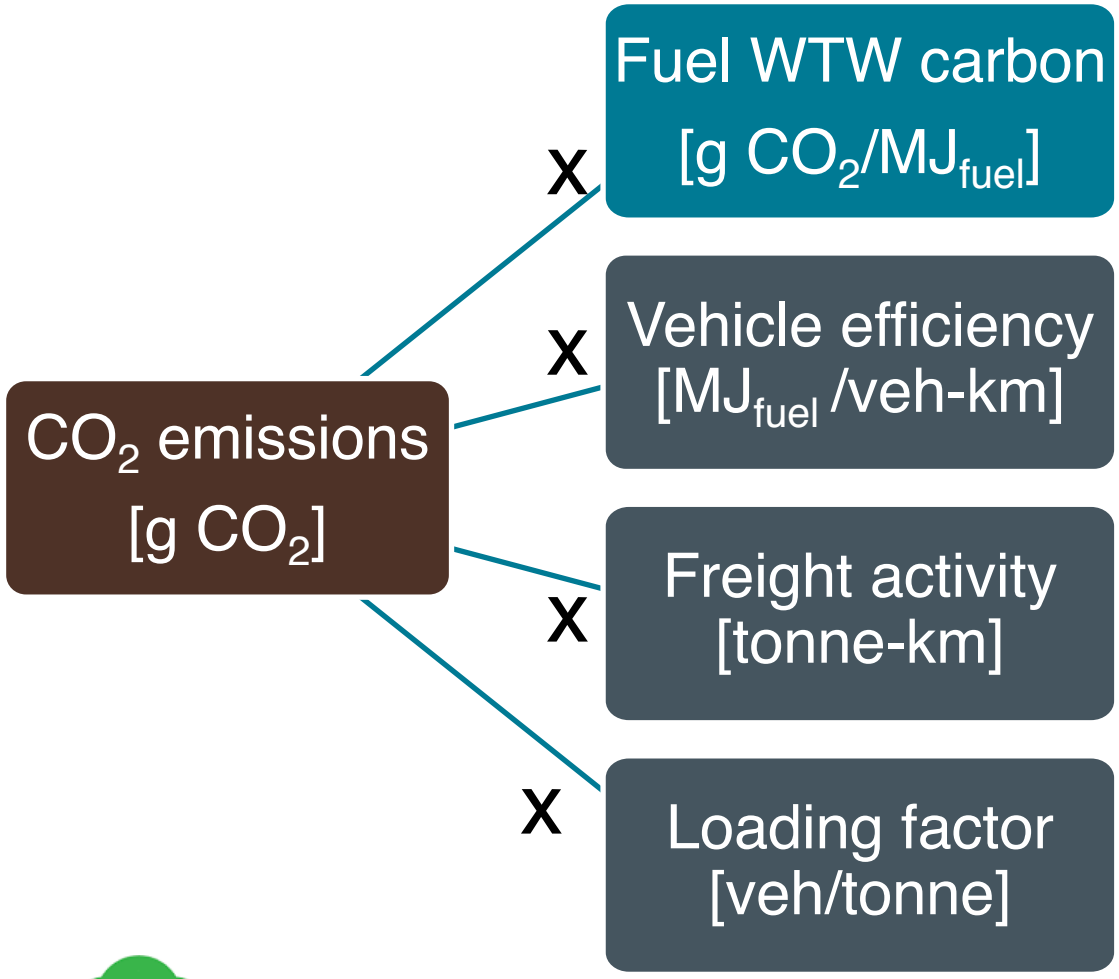
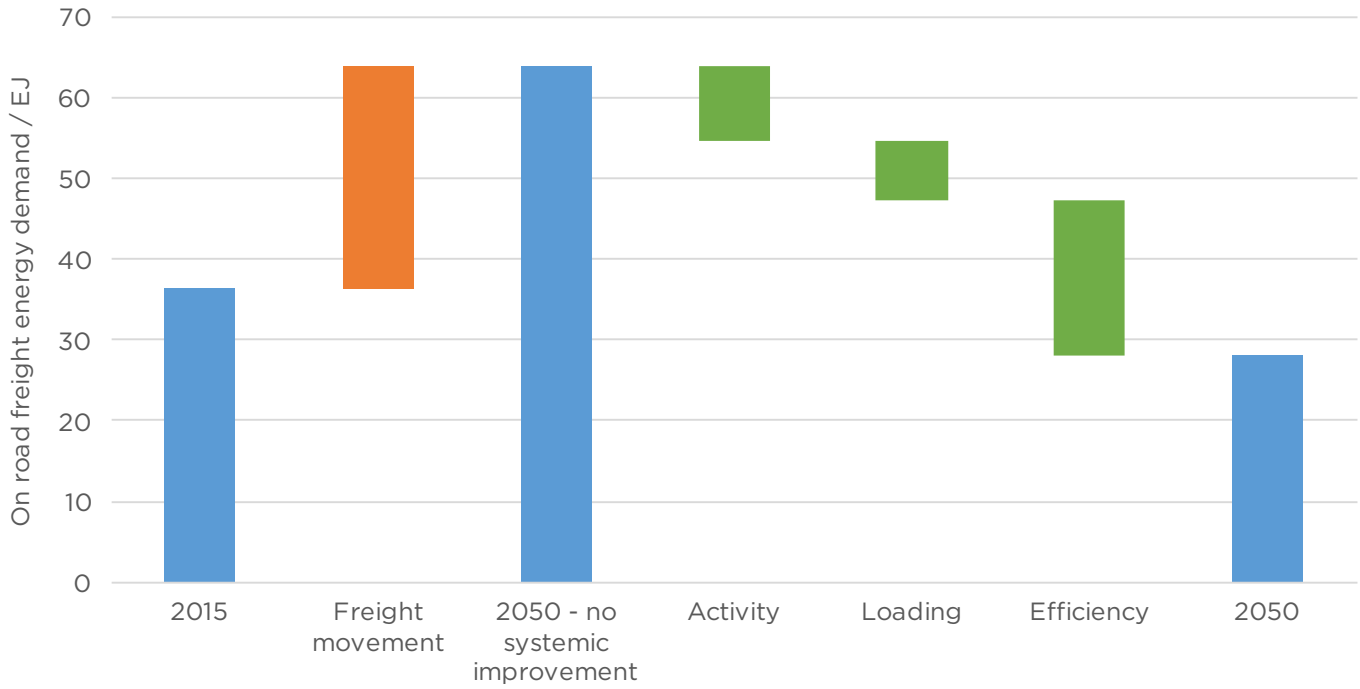
# Vehicle efficiency is the biggest lever to reduce freight's energy demand




Data source: International Energy Agency. (2017). *The Future of Trucks. Implications for energy and the environment.*

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# Why regulate HD efficiency?

**Market barriers for the market uptake of fuel efficient technologies**

# How can we improve the fuel efficiency of HDVs?

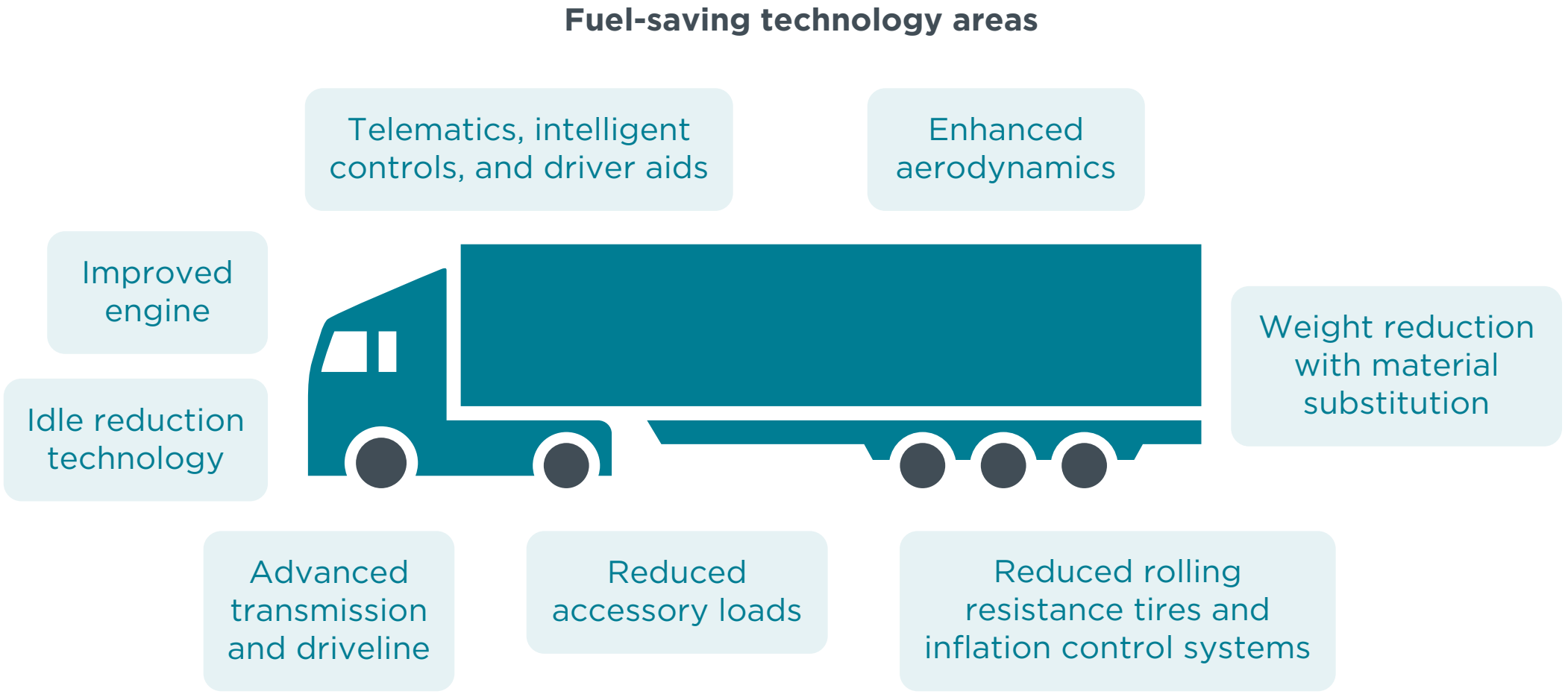
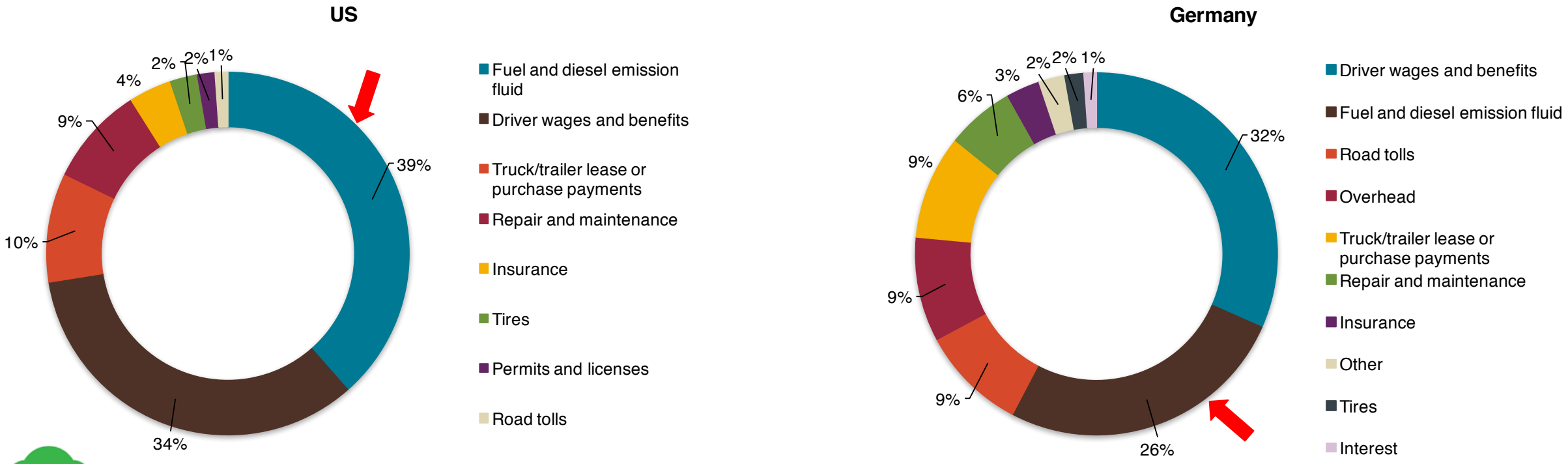



**Figure 2:** Tractor-trailer fuel-saving technology areas

Sharpe (2017). Barriers to the adoption of fuel-saving technologies in the trucking sector.

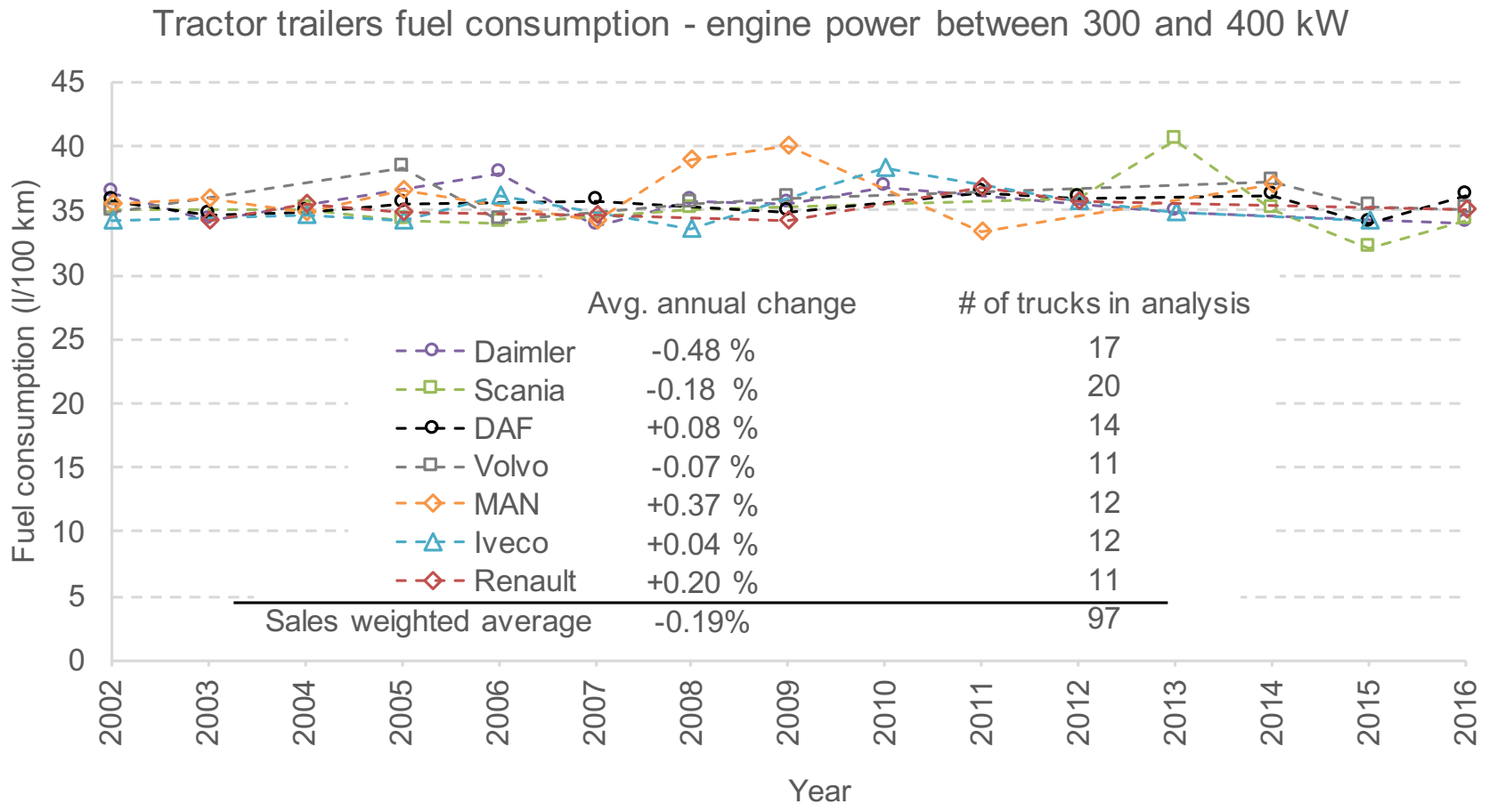
# The motivation for saving fuel is clear

In most regions, **fuel** is the largest (or second largest) expense in the trucking sector




Sharpe, Ben. "Barriers to the Adoption of Fuel-Saving Technologies in the Trucking Sector." The International Council on Clean Transportation, July 7, 2017. http://theicct.org/barriers-to-fuel-saving-technologies-trucking-sector.

# There is no certified fuel consumption data available. Unofficial data suggests limited efficiency improvements in the past




Muncrief, Rachel. "Shell Game? Debating Real-World Fuel Consumption Trends for Heavy-Duty Vehicles in Europe." ICCT Staff Blog (blog), April 24, 2017. http://www.theicct.org/blogs/staff/debating-EU-HDV-real-world-fuel-consumption-trends.

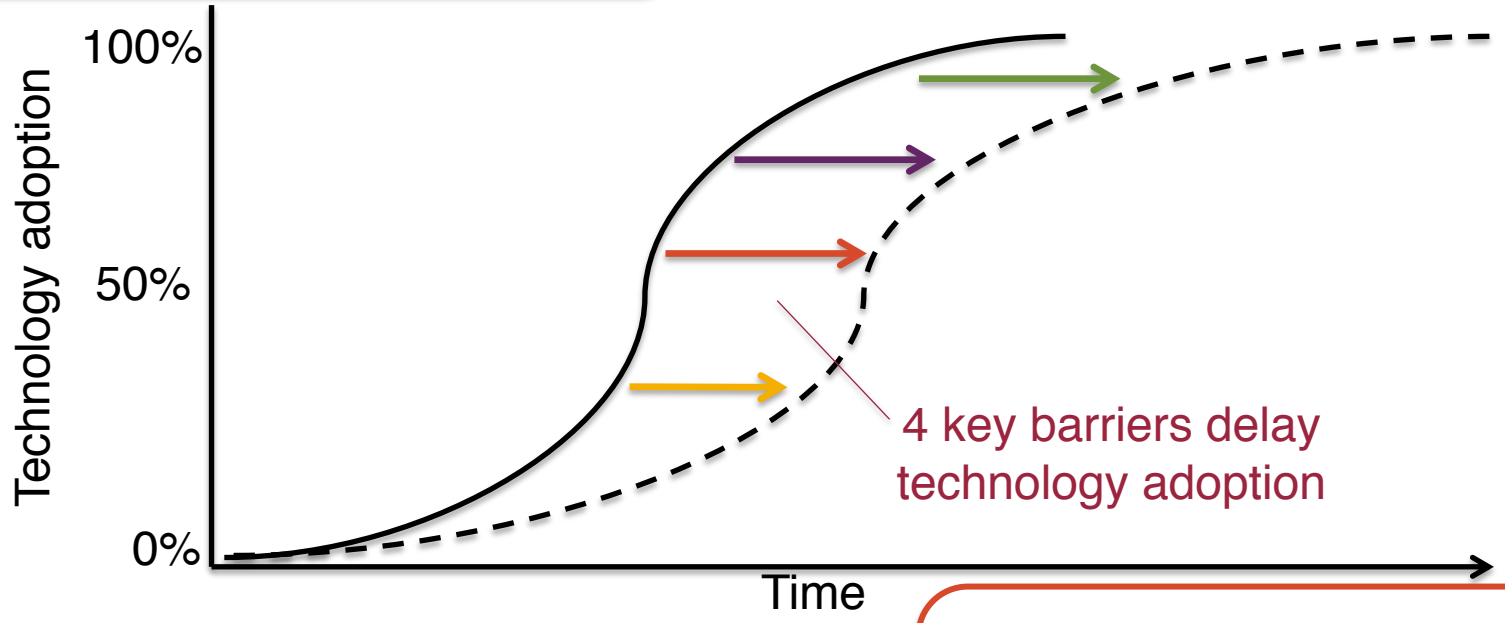
# 4 key barriers delay technology uptake

**Uncertain return on investment**

Will the technologies perform as expected?
What will fuel prices be in the future?

**Capital cost constraints**

Can the fleet get access to additional capital?




**Split incentives**

Are the equipment owner and operator different entities with different motivations?
Who makes the technology purchase vs. who pays for fuel?

**Lack of technology availability**

Are the technologies available in the market?
Available from a preferred supplier?

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Sharpe, Ben. "Barriers to the Adoption of Fuel-Saving Technologies in the Trucking Sector." The International Council on Clean Transportation, July 7, 2017. http://theicct.org/barriers-to-fuel-saving-technologies-trucking-sector.

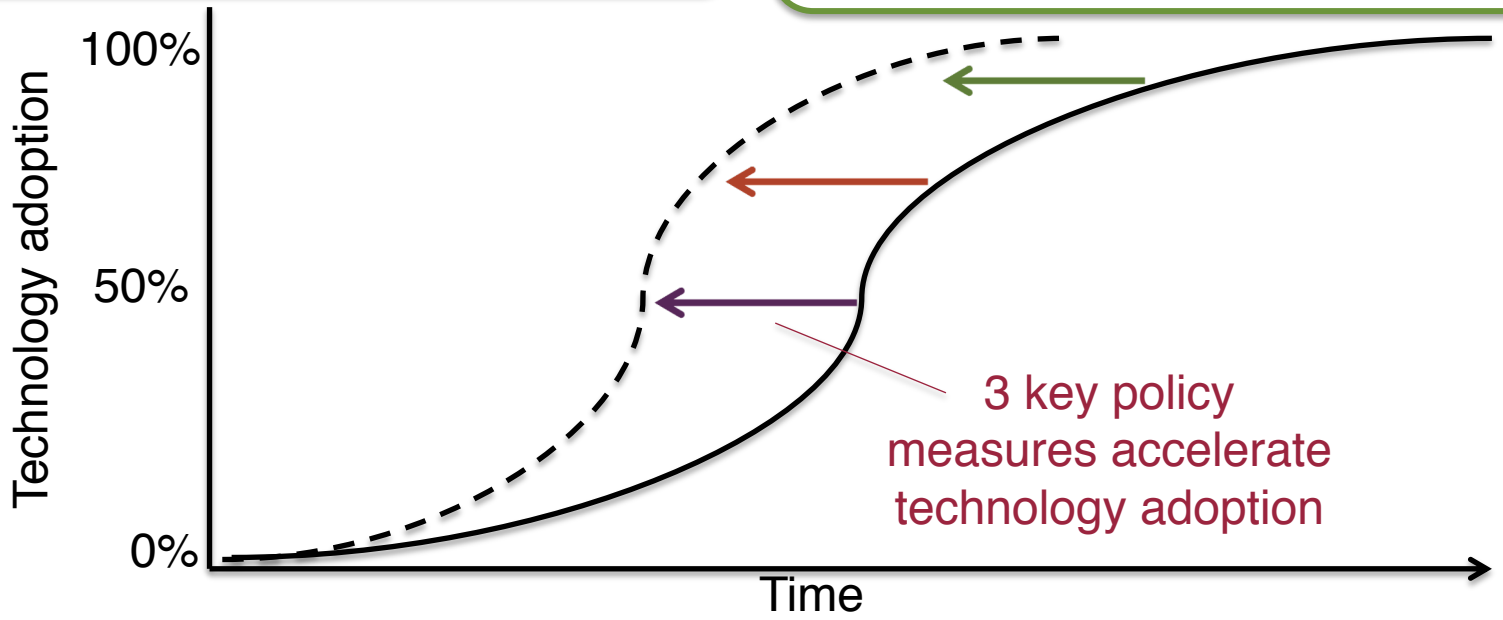
# 3 types of policy measures can combat barriers and accelerate technology adoption

**Fuel efficiency standards**

Setting and enforcing mandatory efficiency performance targets for heavy-duty vehicles

**Market-based approaches**

Providing fleets and shippers better information for making decisions around fuel-saving technologies and strategies




**Fiscal measures**

- Taxing fuels and vehicles to encourage the purchase of more fuel-efficient vehicles
- Supporting infrastructure and incentive schemes for advanced technology and alternative fuel vehicles

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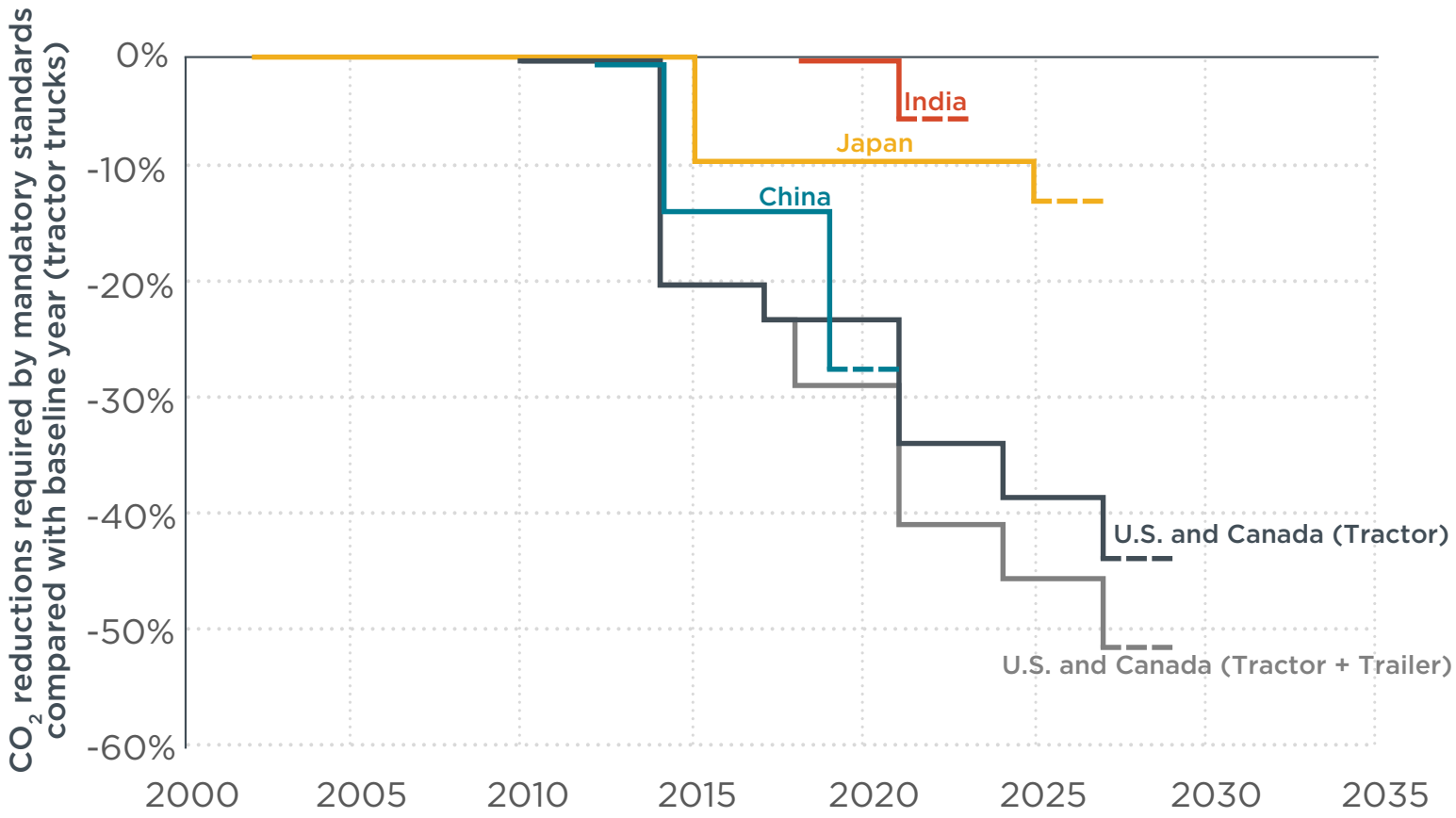
# What are the key elements of HD efficiency programs?

**Policy options**

# Tractor-trailer $CO_2$ standards around the world




**Missing from this chart:**

Europe just announced its proposal for HDV $CO_2$ standards for the years 2025 and 2030. They aim to reduce $CO_2$ emissions of the regulated categories in 15% and 30% by 2025 and 2030 respectively, compared to 2019.

Source: Delgado, O., & Rodriguez, F. (2018). *CO2 emissions and fuel consumption standards for heavy-duty vehicles in the European Union*. The International Council on Clean Transportation. Retrieved from https://www.theicct.org/publications/co2-emissions-and-fuel-consumption-standards-heavy-duty-vehicles-european-union

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# Details of HDV standards developments around the globe

(HDV $CO_2$ standards for the EU were proposed yesterday)

| |  |  |  |  |
|---|---|---|---|---|
| Type | FE & $CO_2$ (ex. Canada); CAFE | FE; individual vehicle | FE; CAFE | FE |
| Vehicle scope | GVWR > 3.85t<br>19 sub-categories, by vehicle type / duty cycle and GVW | GVW > 3.5t<br>66 sub-categories, by vehicle type / duty cycle and GVW | GVW > 3.5t<br>25 sub-categories, by type (bus/lorry) and GVW | >12t<br>10 sub-categories, by GVW, axles, and type (rigid or tractor) |
| Timeframe (full implementation) | Baseline: 2010 (Phase 1)<br><br>Phase 1: 2014, 2017<br>Phase 2: 2021, 2024, 2027 | Baseline: 2010<br>China I: 2014<br>China II: 2016<br>China III: 2021 | Baseline: 2002<br>First phase: 2015<br>Second Phase: 2025 | Baseline: 2018 (enforced by first step of standard)<br><br>CSFC: 2018, 2021 |
| Certification | Component testing and simulation. Separate engine standard. | Chassis dyno (base vehicles) or whole vehicle simulation (variants). | Engine testing (map) and vehicle simulation. Second phase includes aero and tires testing. | Constant speed fuel consumption (CSFC) standards.<br>Track testing at 40/60km/h |
| Flexibilities | ABT scheme | None. Not-to-exceed standard. | Initially a credit system. Not in place any longer. | None. Not-to-exceed standard. |
| ZEV incentives | Super-credits | None | None | None |

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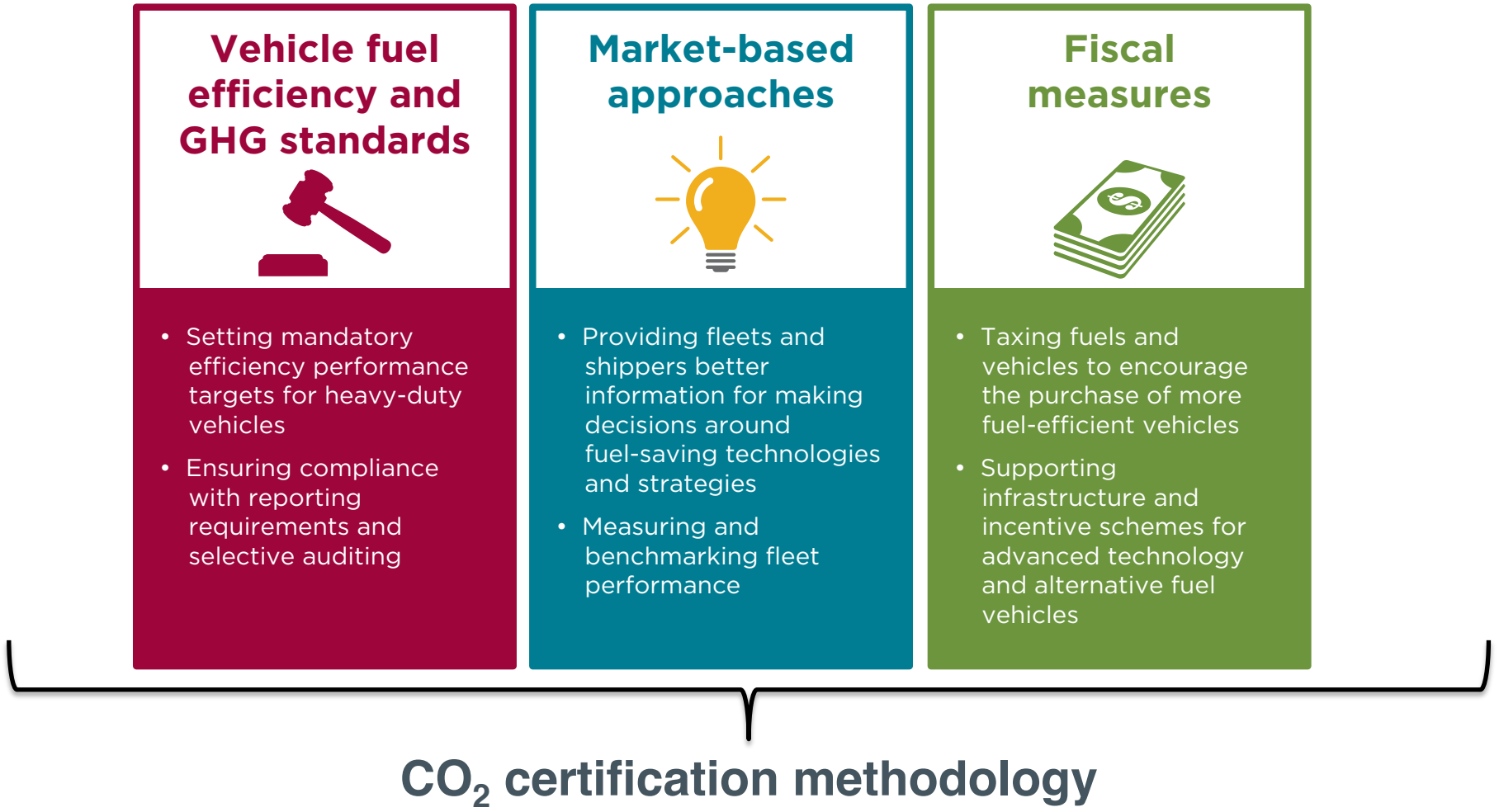
# Policy options for improving HDV efficiency

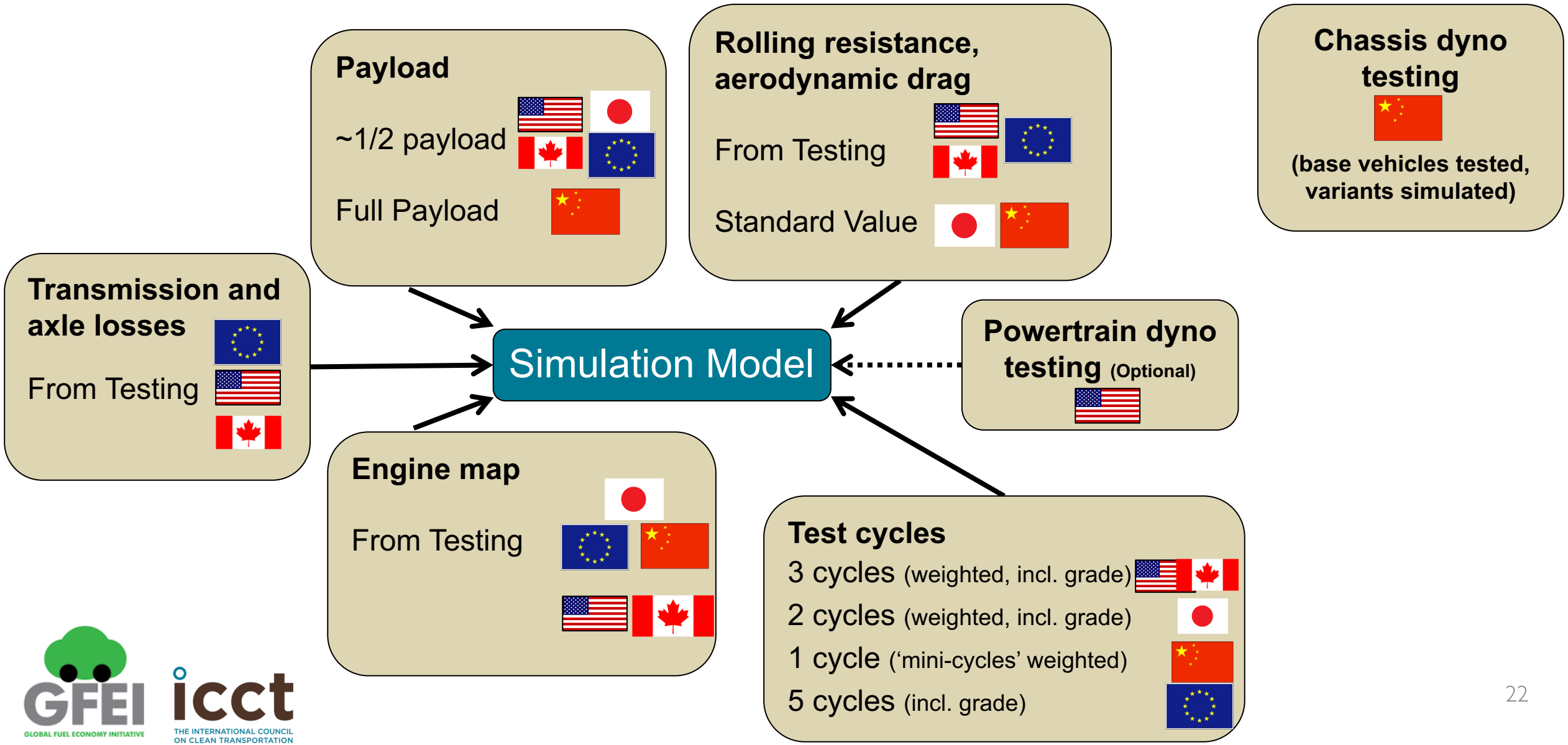



Sharpe (2017). Freight Assessment Blueprint.

# Certification methodology

## Vehicle simulation

# Most regions use HDV simulation in combination with component certification to determine $CO_2$ emissions

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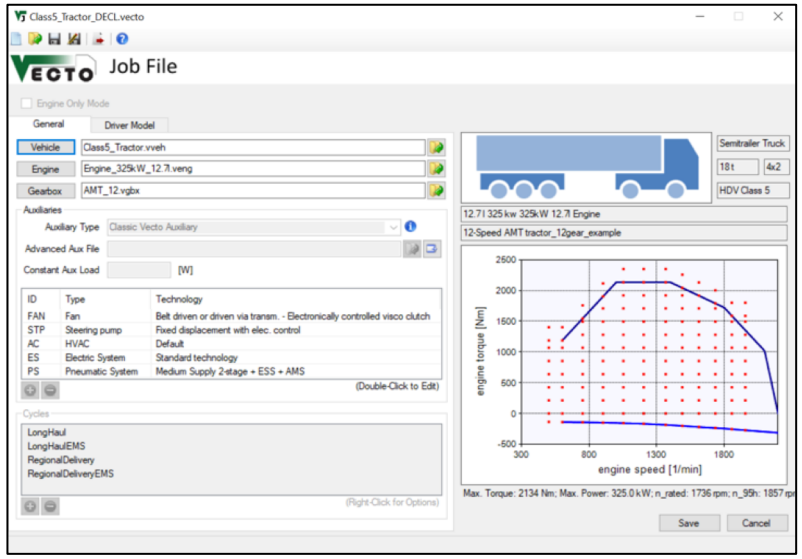
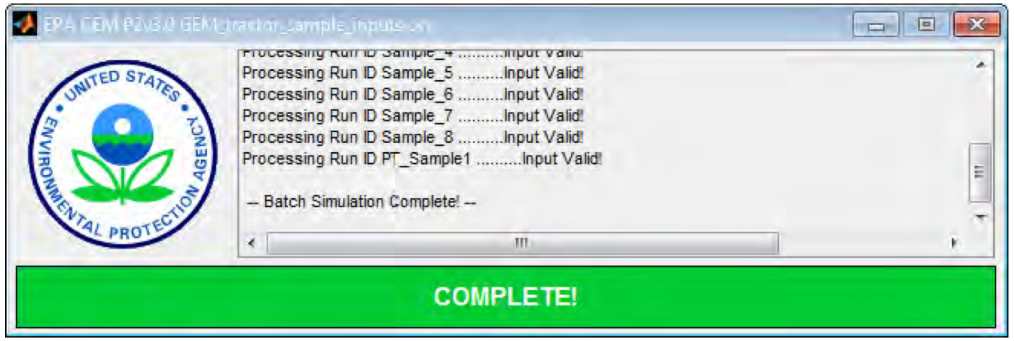
# **ICCT White paper:** Fuel consumption simulation of HDVs in the EU: Comparisons and limitations (2018)




- A new comparison study of the latest releases of GEM and VECTO
- Although focused on VECTO, it describes the model architectures of both GEM and VECTO
- The results of this new study are the focus of this presentation
- Publication expected in February 2018

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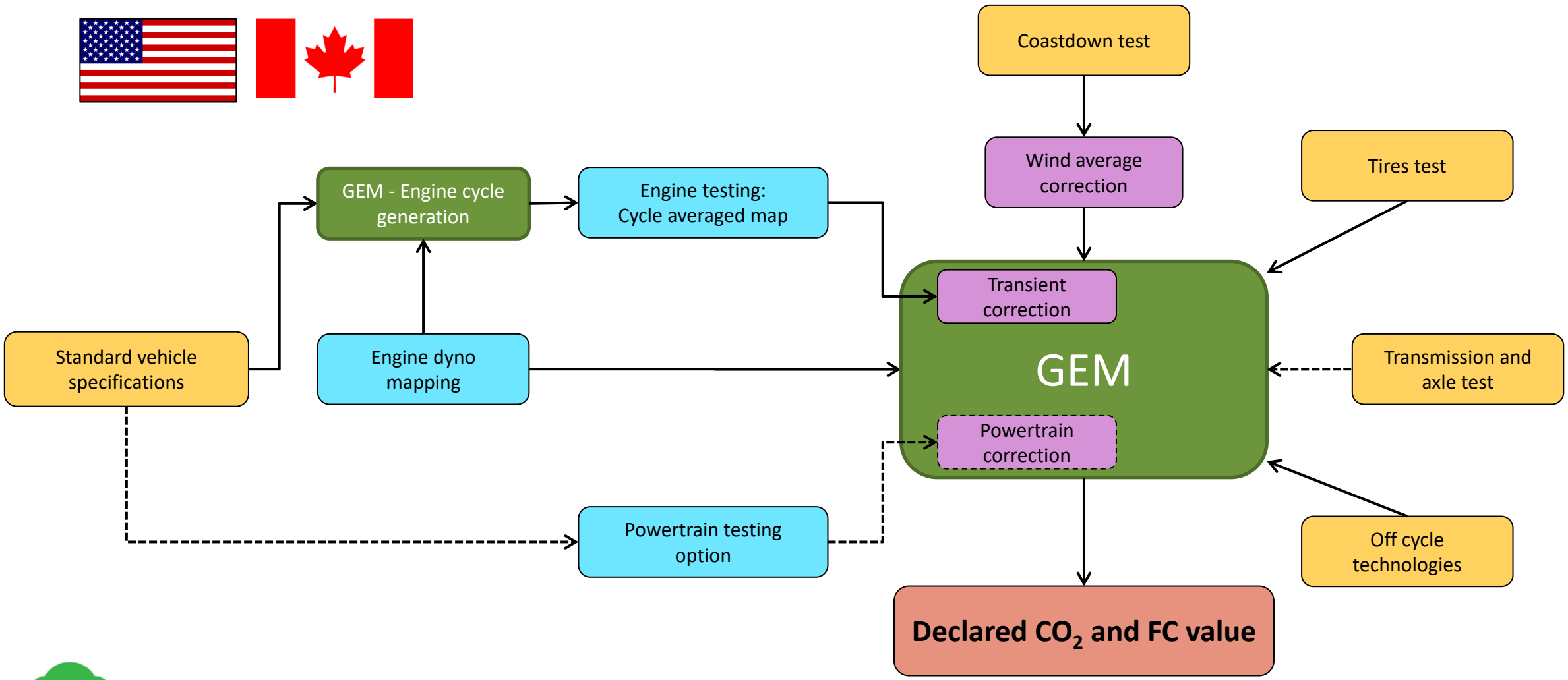
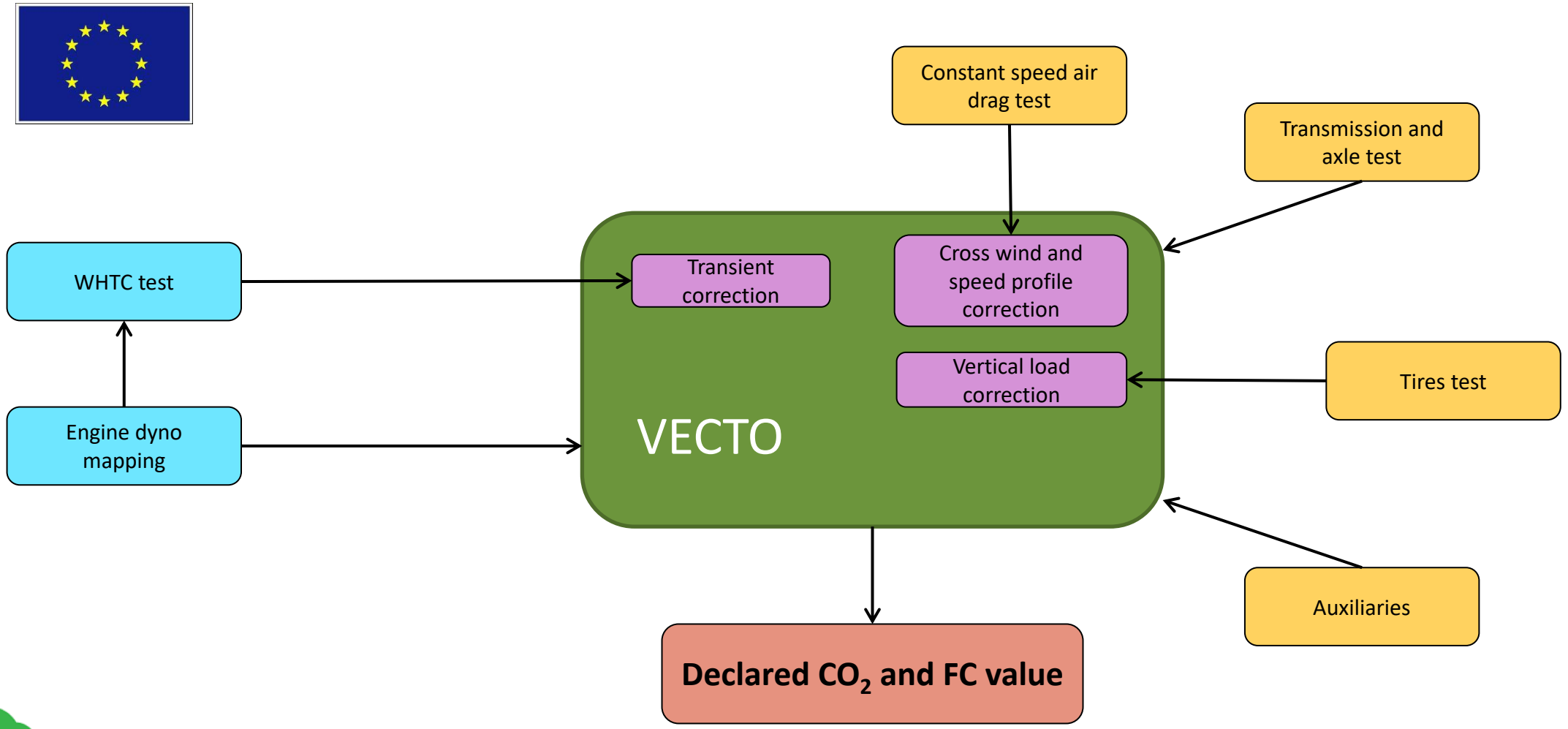
Rodriguez, Felipe. "Fuel Consumption Simulation of HDVs in the EU: Comparisons and Limitations." White Paper. The International Council on Clean Transportation, March 6, 2018. https://www.theicct.org/publications/fuel-consumption-simulation-hdvs-eu-comparisons-and-limitations.

# US and Canada HDV fuel consumption certification



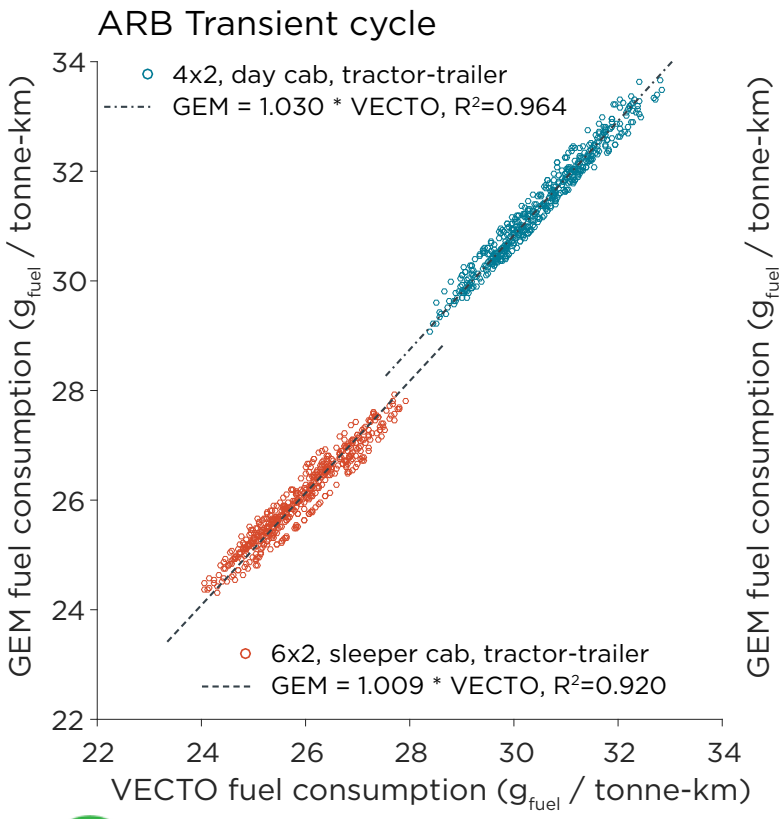
# Europe HDV fuel consumption certification

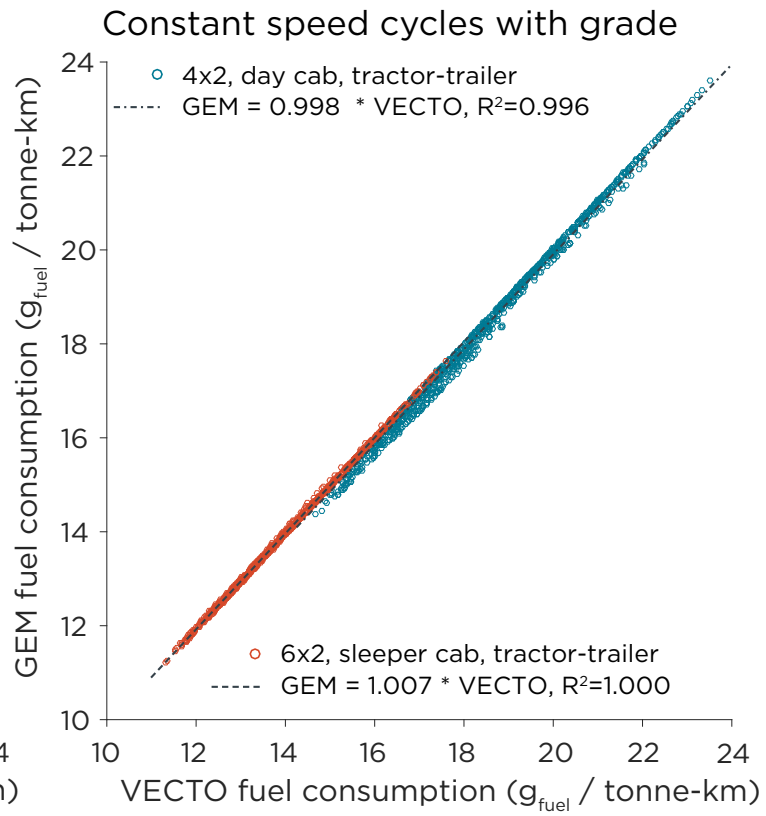



Input data | Output data | Dyno testing | Correction | Simulation

# Comparison results: Constant speed cycles with grade

**Absolute error < 2%**




- Despite the differences in model architecture (forward vs backward-looking), driver model, and shifting strategy; both VECTO and GEM produce similar fuel consumption results.

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# Vehicle simulation tools – Summary

- **Both GEM and VECTO can be adapted to account for the differences across regions.** VECTO's engineering mode provides a user friendly interface to modify drive cycles, payloads, and vehicle details. GEM can also be modified accessing the source code, however, this implies more effort.

- **VECTO and GEM show very good agreement** when simulated over a large set of identical vehicles

- The accurate simulation of $CO_2$ emissions of HDVs is more dependent on the component input data than on the selected model (VECTO vs GEM). **Harmonization of component certification benefits the implementation of future regulatory measures.**

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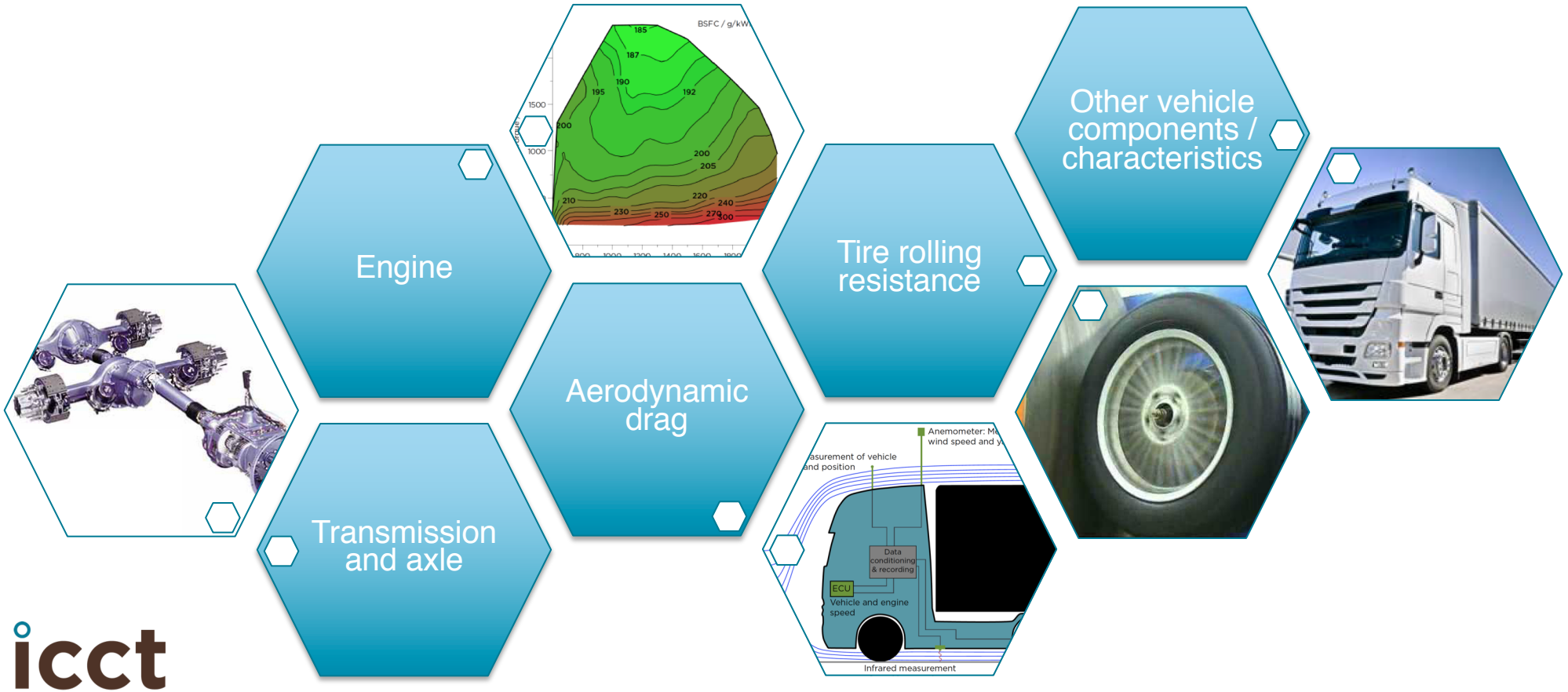
# Certification methodology

## Component certification

# Certified component performance data

There are five key components that are measured to provide the necessary input for the simulation tools

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# Regulations for component certification in the EU and the US

- **Regulation (EU) 2017/2400** of 12 December 2017 implementing Regulation (EC) No 595/2009 of the European Parliament and of the Council as regards the determination of the $CO_2$ emissions and fuel consumption of heavy-duty vehicles and amending Directive 2007/46/EC of the European Parliament and of the Council and Commission Regulation (EU) No 582/2011.

  *Official Journal of the European Union, L 349*.

  http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ:L:2017:349:TOC

- Final Rule: Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles–Phase 2 **(Federal Register / Vol. 81, No. 206)**.

  https://www.gpo.gov/fdsys/pkg/FR-2016-10-25/pdf/2016-21203.pdf

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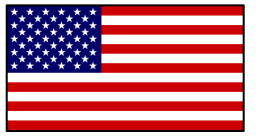

# Component certification – Summary

- The US and EU component certification methodologies have several common points.
  - Axles, tires, and engine mapping procedures are similar.
  - Key differences include the aerodynamic drag determination methodology and the engine transient correction.
- Harmonization of component certification has many advantages:
  - Facilitates transparent comparison of performance between different markets.
  - Facilitates the implementation of future regulatory measures.
  - Facilitates adapting GEM/VECTO to country-specific needs.
  - Streamlined processes and reduced cost of compliance for international manufacturers.

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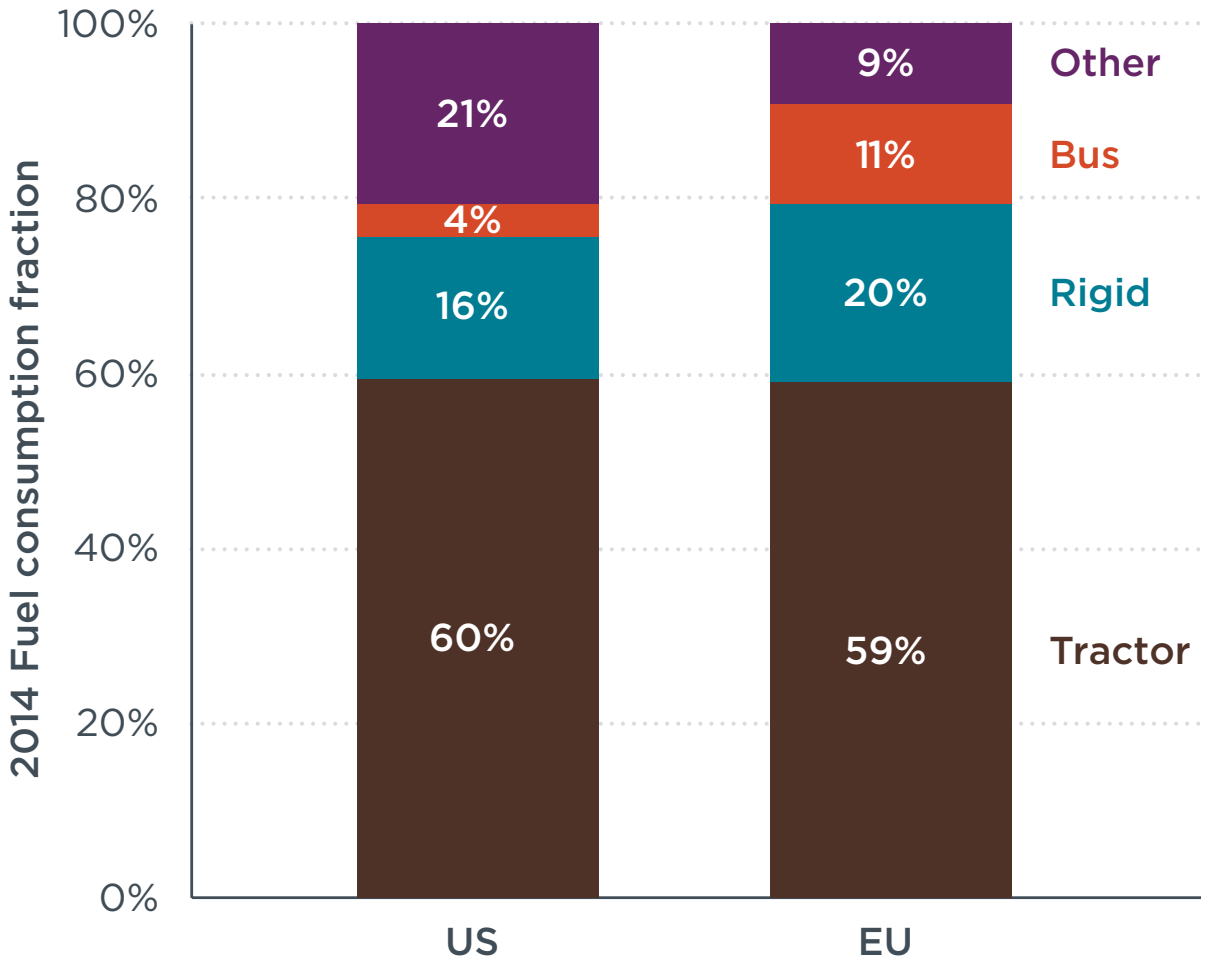
# Vehicle segmentation

**A comparison of China, India, the U.S. and the EU.**

# Objectives of the market segmentation

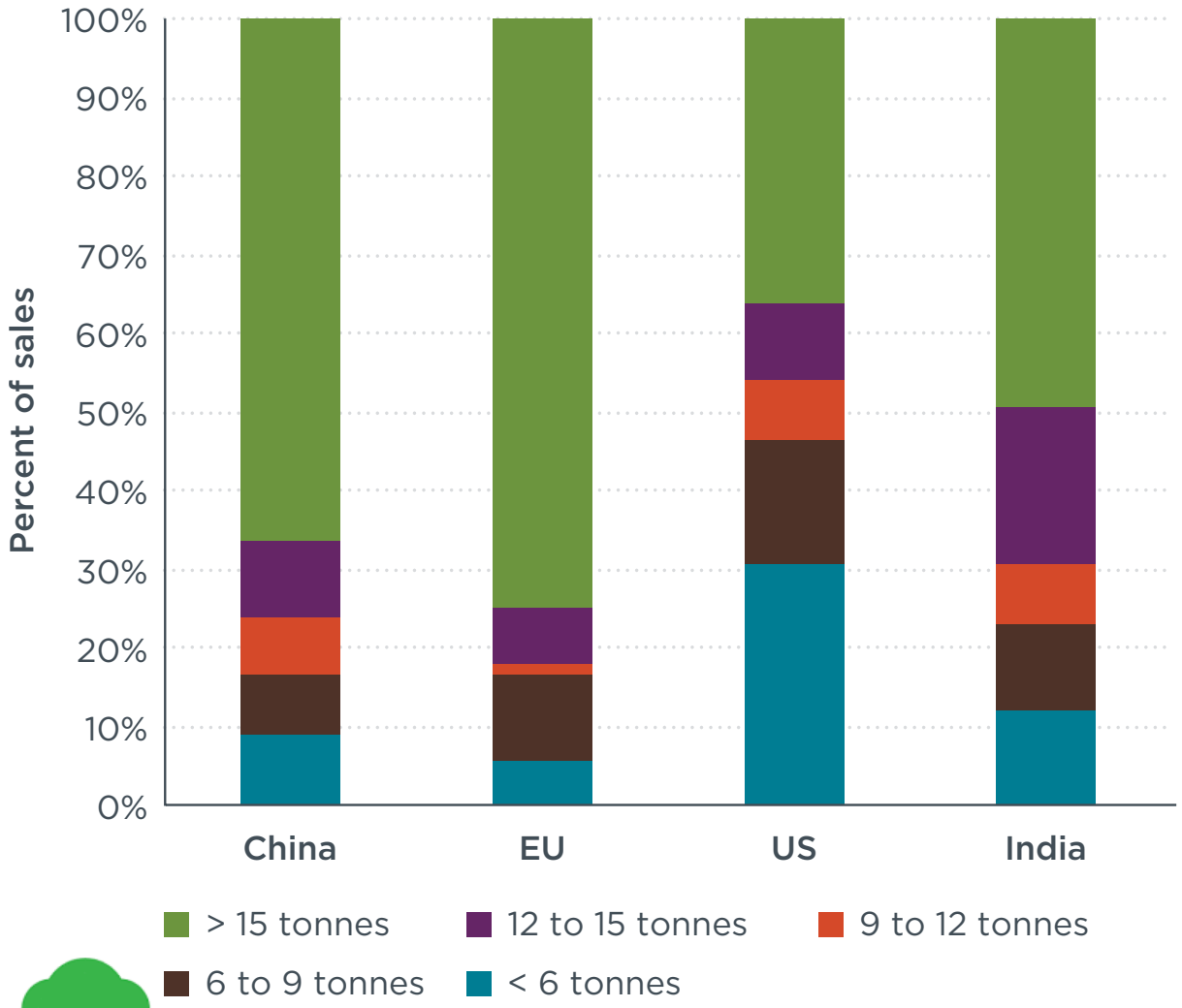
- Separate vehicles and components in groups with similar usage and fuel consumption.
- Enable the use of specific duty cycles and $CO_2$ emissions targets for each segment
- Identify the vehicle segments with high fuel consumption. The vehicle segment with the highest market share is not necessarily the same as the one with the highest fuel consumption.
- Segmentation of engines and trailers is necessary in the case of separate policy measures addressing these components.

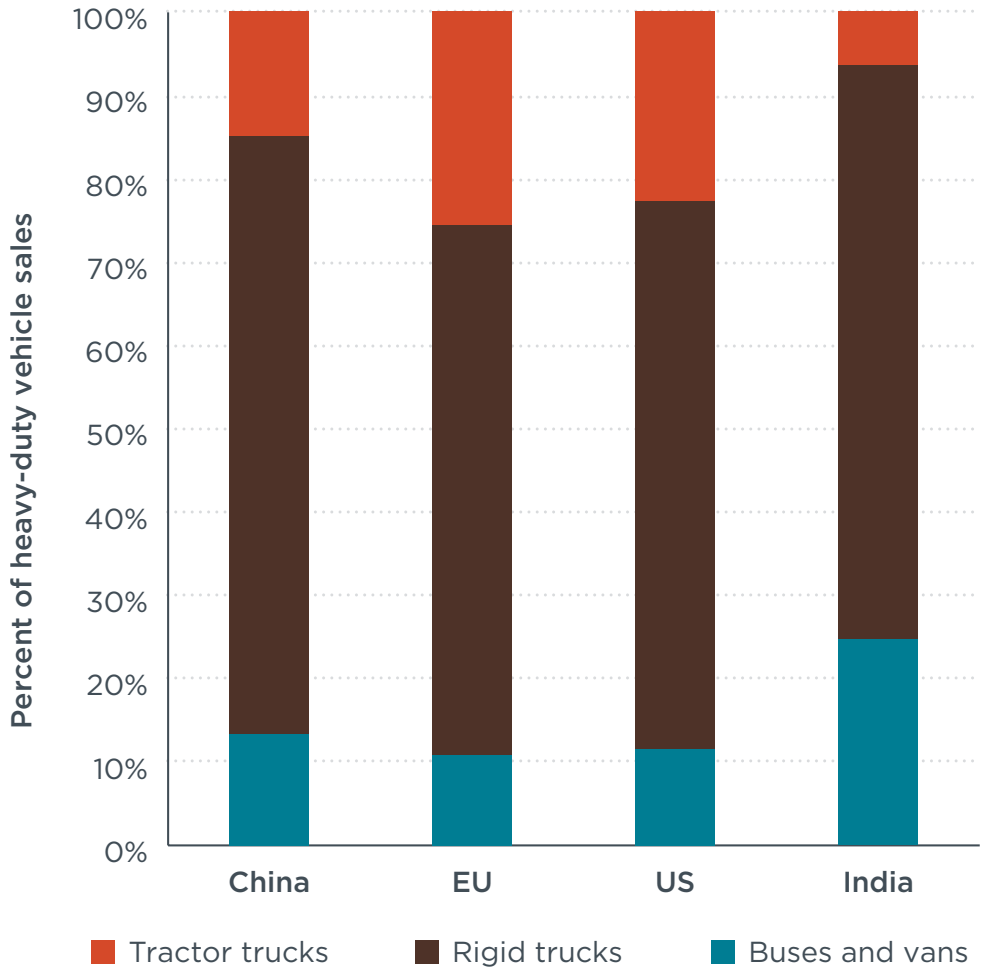





Muncrief, R., & Sharpe, B. (2015). *Overview of the heavy-duty vehicle market and CO2 emissions in the European Union*. International Council on Clean Transportation. www.theicct.org/overview-heavy-duty-vehicle-market-and-co2-emissions-european-union

# GVW and vehicle type composition for different HDV markets (2014)

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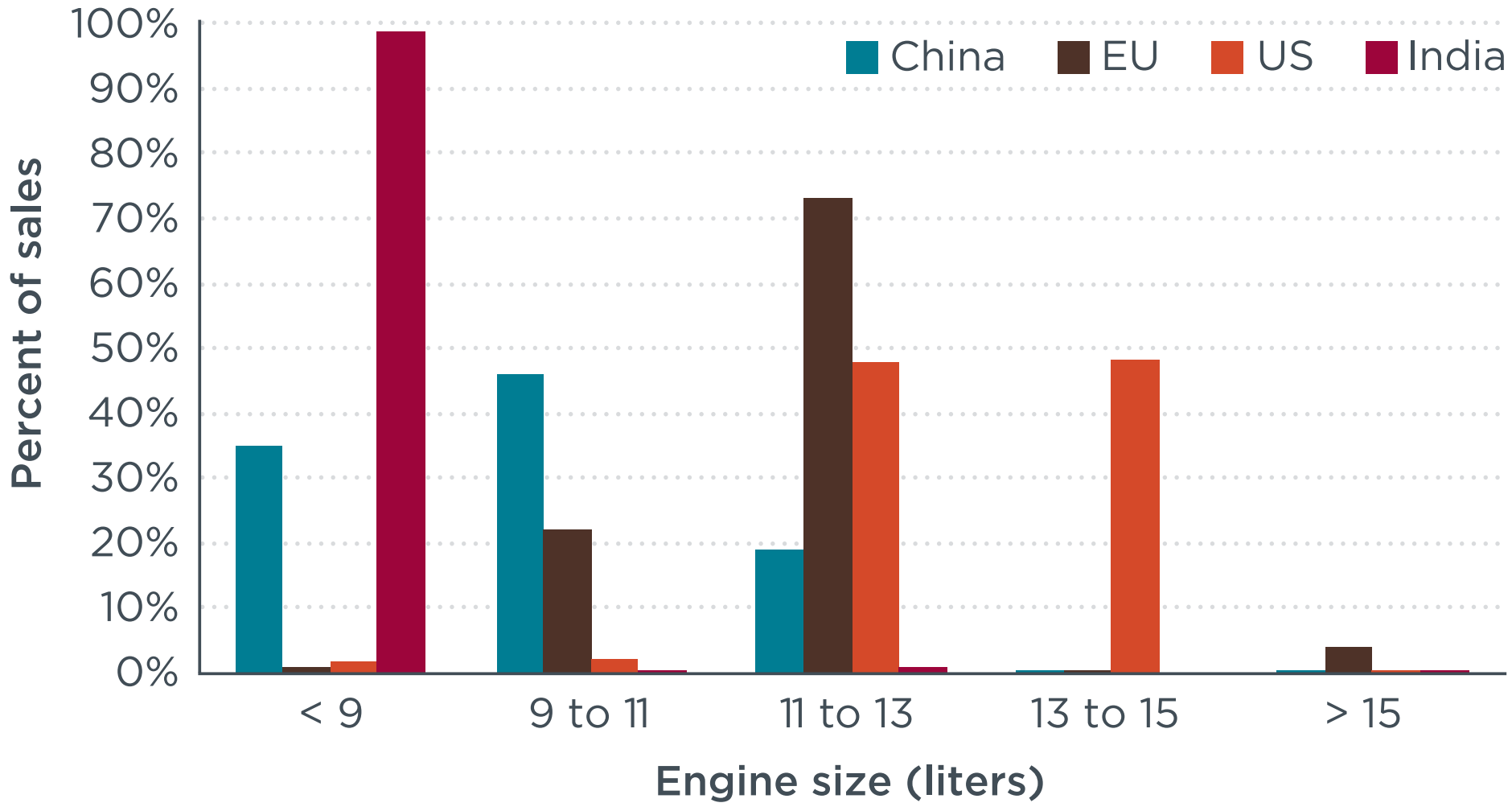
Sharpe, B. (2015). *Market analysis of heavy-duty vehicles in India*. International Council on Clean Transportation. https://www.theicct.org/publications/market-analysis-heavy-duty-vehicles-india

# Engine displacement distribution for HDVs in four large markets (2014)

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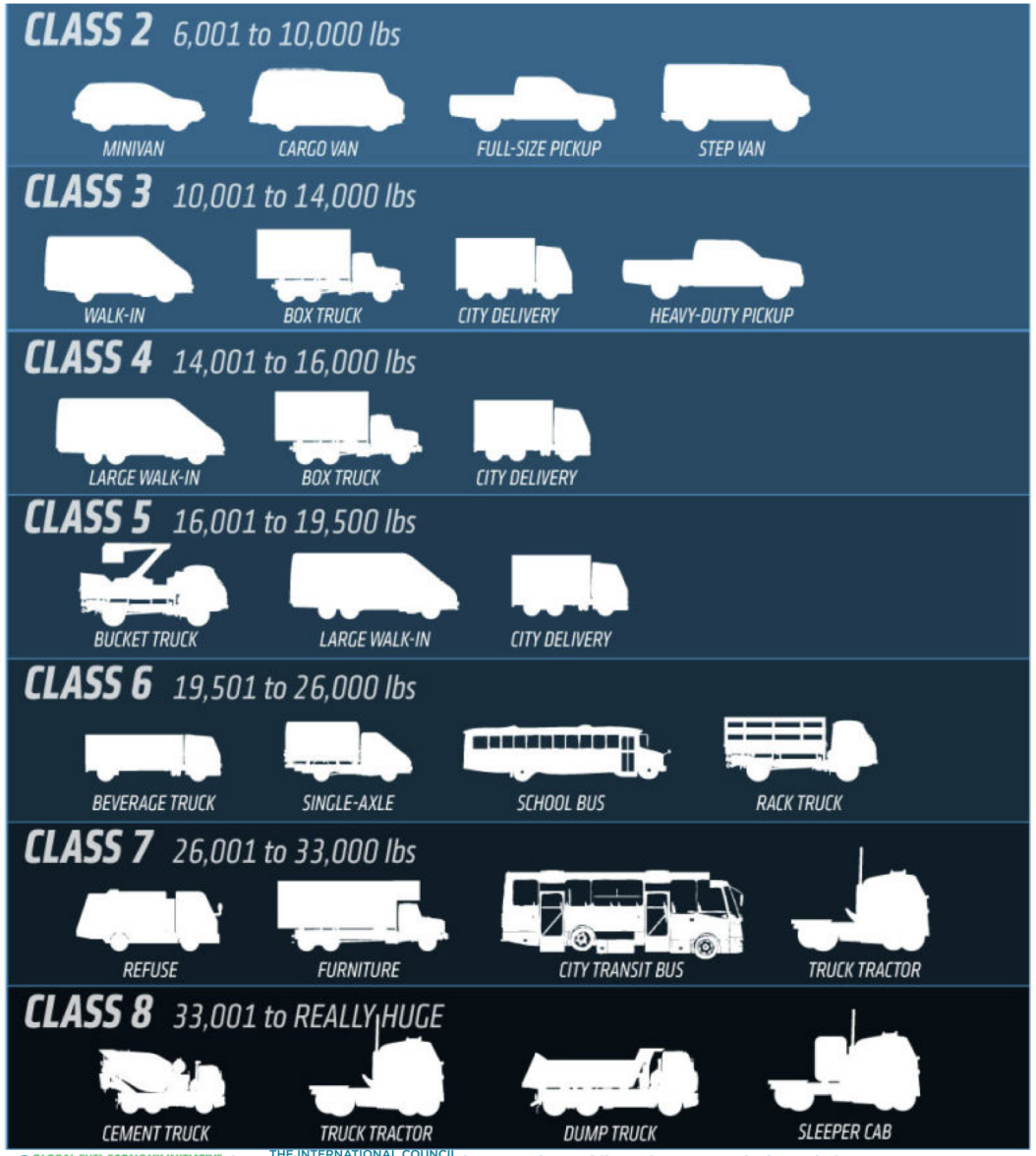
# Examples of market segmentation

## Complete vehicles

# US HDV segmentation for GHG regulation




- Vocational vehicles (Rigid, classes 2b to 8)
  - LHD (Class 2-5) — Urban Multipurpose Regional — SI CI
  - MHD (Class 6-7) — Urban Multipurpose Regional — SI CI
  - HHD (Class 8) — Urban Multipurpose Regional
- Class 7 and Class 8 tractors
  - Class 7, day cab — High roof Mid roof Low roof
  - Class 8, day cab — High roof Mid roof Low roof
  - Class 8, sleeper cab — High roof Mid roof Low roof
  - Heavy haul

Source: https://jalopnik.com/truck-sizes-classification-explained-from-tacomas-to-1613958192

# EU HDV segmentation for $CO_2$ certification

| Axle type | Chassis configuration | Gross vehicle weight (tonnes) | Vehicle group | Regulatory cycles[a] and payloads[b] used in VECTO |
|---|---|---|---|---|
| 4x2 | Rigid | >3.5 – <7.5 | 0 | Not considered by the regulation |
| | Rigid (or tractor) | 7.5 – 10 | 1 | RD (50%), UD (50%) |
| | Rigid (or tractor) | >10 – 12 | 2 | LH (75%), RD (50%), UD (50%) |
| | Rigid (or tractor) | >12 – 16 | 3 | RD (50%), UD (50%) |
| | Rigid | >16 | 4 | LH (14.0t), RD (4.4t), MU (4.4t) |
| | Tractor | >16 | 5 | LH (19.3t), RD (12.9t) |
| 4x4 | Rigid | 7.5 – 16 | 6 | Not considered by the regulation |
| | Rigid | >16 | 7 | Not considered by the regulation |
| | Tractor | >16 | 8 | Not considered by the regulation |
| 6x2 | Rigid | all weights | 9 | LH (19.3t), RD (7.1t), MU (7.1t) |
| | Tractor | all weights | 10 | LH (19.3t), RD (12.9t) |
| 6x4 | Rigid | all weights | 11 | LH (19.3t), RD (7.1t), MU (7.1t), C(7.1t) |
| | Tractor | all weights | 12 | LH (19.3t), RD (12.9t), C (12.9t) |
| 6x6 | Rigid | all weights | 13 | Not considered by the regulation |
| | Tractor | all weights | 14 | Not considered by the regulation |
| 8x2 | Rigid | all weights | 15 | Not considered by the regulation |
| 8x4 | Rigid | all weights | 16 | C (7.1t) |
| 8x6 8x8 | Rigid | all weights | 17 | Not considered by the regulation |
| | New vehicles belonging to groups 4, 5, 9, and 10 will be certified from January 1, 2019. Vehicle registrations belonging to groups 4, 5, 9, and 10 will be certified from July 1, 2019 | | | |
| | Vehicle registrations belonging to groups 1, 2, and 3 must be certified from January 1, 2020. | | | |
| | Vehicle registrations belonging to groups 11, 12, and 16, must be certified from July 1, 2020. | | | |

N2

N3

a. Long-Haul (LH), Regional Delivery (RD), Urban Delivery (UD), Municipal Utility (MU), Construction (C). Rigid trucks in the long haul cycle use an additional trailer.
b. Number in brackets is the payload in tonnes. For vehicle groups 1,2, and 3, the payload is dependent on the GVW; the percentage number in brackets refers the approximate fraction of the maximum payload that is used in the vehicle simulation.

- Possible further sub-division of the vehicle groups under development for setting mandatory $CO_2$ targets.
- Possibilities: Group sub-division based on engine power, or/and cabin type (day or sleeper).


Rodríguez, F. (2018). *Certification of CO2 emissions and fuel consumption of on-road heavy-duty vehicles in the European Union* (Policy update). International Council on Clean Transportation. https://www.theicct.org/publications/certification-co2-emissions-and-fuel-consumption-road-heavy-duty-vehicles-european

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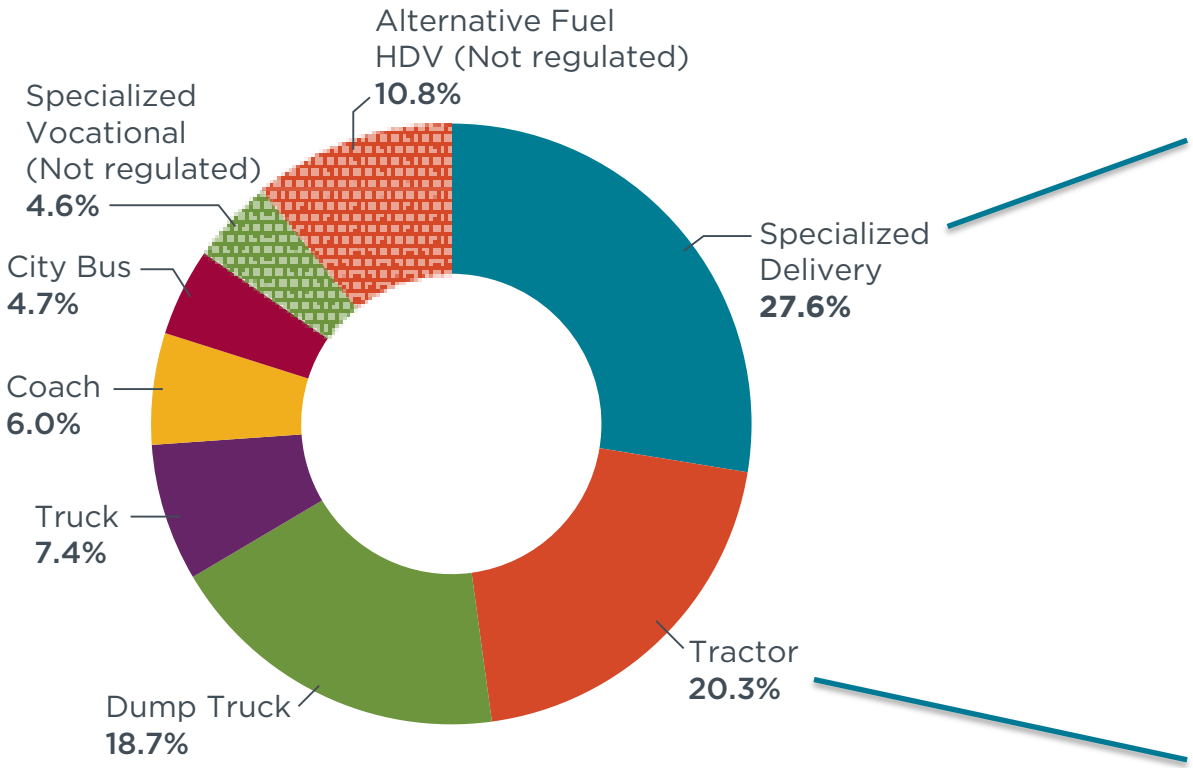
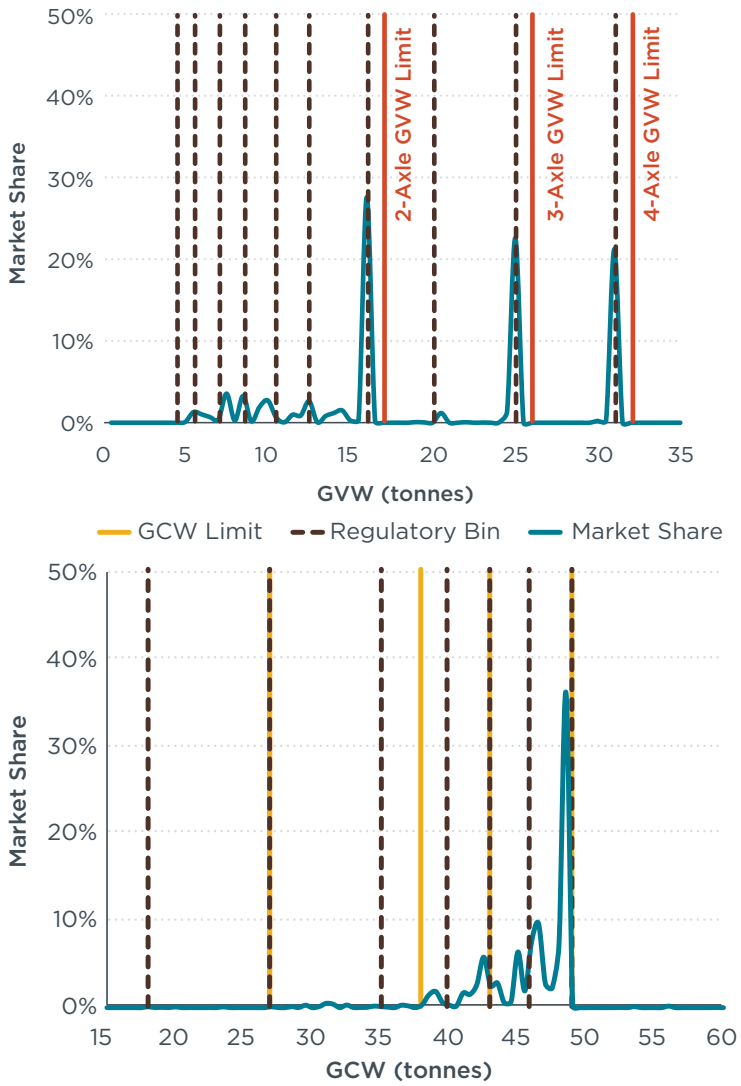
# China HDV segmentation for $CO_2$ standards



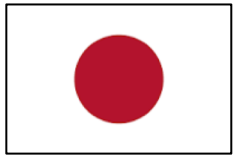




Delgado, O., & Li, H. (2017). *Market analysis and fuel efficiency technology potential of heavy-duty vehicles in China*. The International Council on Clean Transportation. www.theicct.org/publications/HDV-china-mkt-analysis-and-fuel-efficiency-tech-potential

# India and Japan's HDV segmentation for fuel consumption standards

| | GVW Bin (tonnes) | Axle Configuration |
|---|---|---|
| **Rigid truck** | 12.0-16.2 | 4x2 |
| | 16.2-25.0 | 6x2 |
| | 16.2-25.0 | 6x4 |
| | 25.0-31.0 | 8x2 |
| | 25.0-31.0 | 8x4 |
| | 31.0-37.0 | 10x2 |
| **Tractor-trailer** | 35.2-40.2 | 4x2 |
| | 40.2-49.0 | 6x2 |
| | 40.2-49.0 | 6x4 |
| **Bus** | 12.0 and above | All Configuration |

Garg, M., & Sharpe, B. (2017). *Fuel consumption standards for heavy-duty vehicles in India*. The International Council on Clean Transportation. www.theicct.org/publications/fuel-consumption-stds-hdvs-india-update-201712



Rigid freight trucks:

| | | |
|---|---|---|
| 1 | 3.5＜GVW≦7.5 | PL≦1.5 |
| 2 | | 1.5＜PL≦2 |
| 3 | | 2＜PL≦3 |
| 4 | | 3＜PL |
| 5 | 7.5＜GVW≦8 | |
| 6 | 8＜GVW≦10 | |
| 7 | 10＜GVW≦12 | |
| 8 | 12＜GVW≦14 | |
| 9 | 14＜GVW≦16 | |
| 10 | 16＜GVW≦20 | |
| 11 | 20＜GVW | |

Tractor trucks:

| | |
|---|---|
| 1 | GVW≦20 |
| 2 | 20＜GVW |

Ministry of Land, Infrastructure, Transport and Tourism (2017). http://www.mlit.go.jp/report/press/jidosha10_hh_000190.html

# Vehicle segmentation– Summary

- The market segmentation and definition of duty cycles are country specific exercises. However, experiences and concepts applied in other regions can be adapted.
- There is no perfect segmentation. A balance between complexity and representativeness is necessary.
- The market segmentation divides the vehicle fleet into different segments with similar application and fuel consumption. Typical differentiators are vehicle weight, chassis configuration, and axle configuration.
- Further segmentation can be achieved by cabin type, engine power, intended vehicle use, among others.

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