HDV efficiency program development

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G20 Transport Task Group:

Deep Dive to Support Heavy-Duty Vehicle Efficiency Labeling and Standards Meeting #6

icct
THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

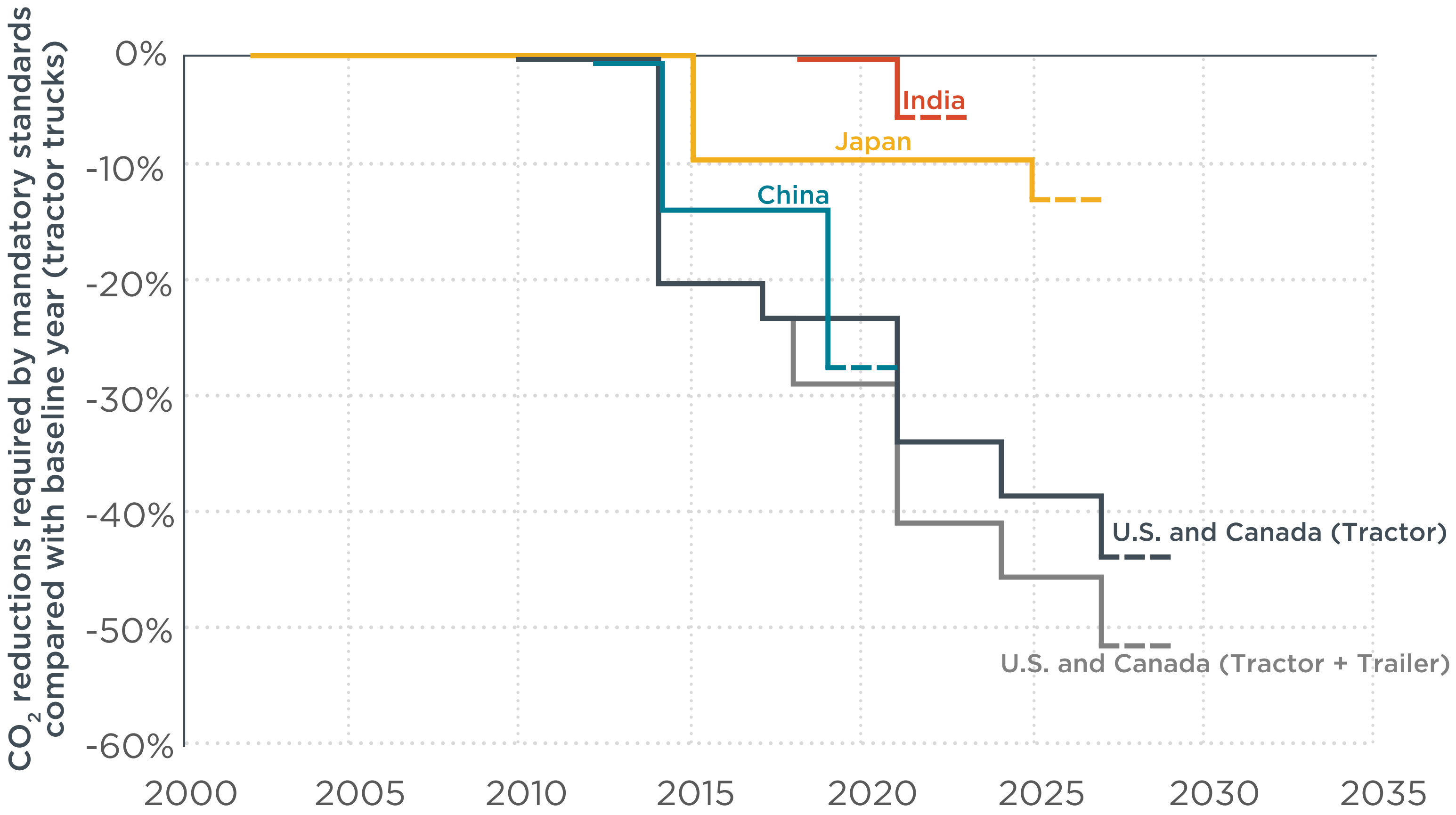
Outline

1. Overview of HDV CO_2 standards around the world

2. Standard design: CO_2 targets are just part of it.
   a. CO_2 determination: Vehicle simulation and testing procedure
   b. Segmentation and duty cycles
   c. Baseline determination
   d. Flexibilities
   e. Incentives for emerging low carbon technologies
   f. Trailer and engine standards

Overview of HDV CO_2 standards around the world

Tractor-trailer CO2 standards around the world



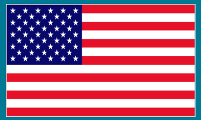
Missing from this chart:

The European Commission 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 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

Details of HDV standards developments around the globe

(Presentation of EU HDV CO_2 standards proposal will take place on a separate future call)

	 			
Type	FE & CO_2 (ex. Canada); CAFE	FE; individual vehicle	FE; CAFE	FE
Vehicle scope	GVWR > 3.85t 19 sub-categories, by vehicle type / duty cycle and GVW	GVW > 3.5t 66 sub-categories, by vehicle type / duty cycle and GVW	GVW > 3.5t 25 sub-categories, by type (bus/lorry) and GVW	>12t 10 sub-categories, by GVW, axles, and type (rigid or tractor)
Timeframe (full implementation)	Baseline: 2010 (Phase 1) Phase 1: 2014, 2017 Phase 2: 2021, 2024, 2027	Baseline: 2010 China I: 2014 China II: 2016 China III: 2021	Baseline: 2002 First phase: 2015 Second Phase: 2025	Baseline: 2018 (enforced by first step of standard) 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. 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

Standard design: CO_2 targets are just part of it.

The standard design can impacts significantly the CO_2 benefits

Setting a fuel consumption or CO_2 target is just one aspect of the regulatory design. Other aspects include:

a. CO_2 determination: Vehicle simulation and testing procedure
b. Segmentation and duty cycles
c. Baseline determination
d. Flexibilities
e. Incentives for emerging low carbon technologies
f. Trailer and engine standards

Regulatory design

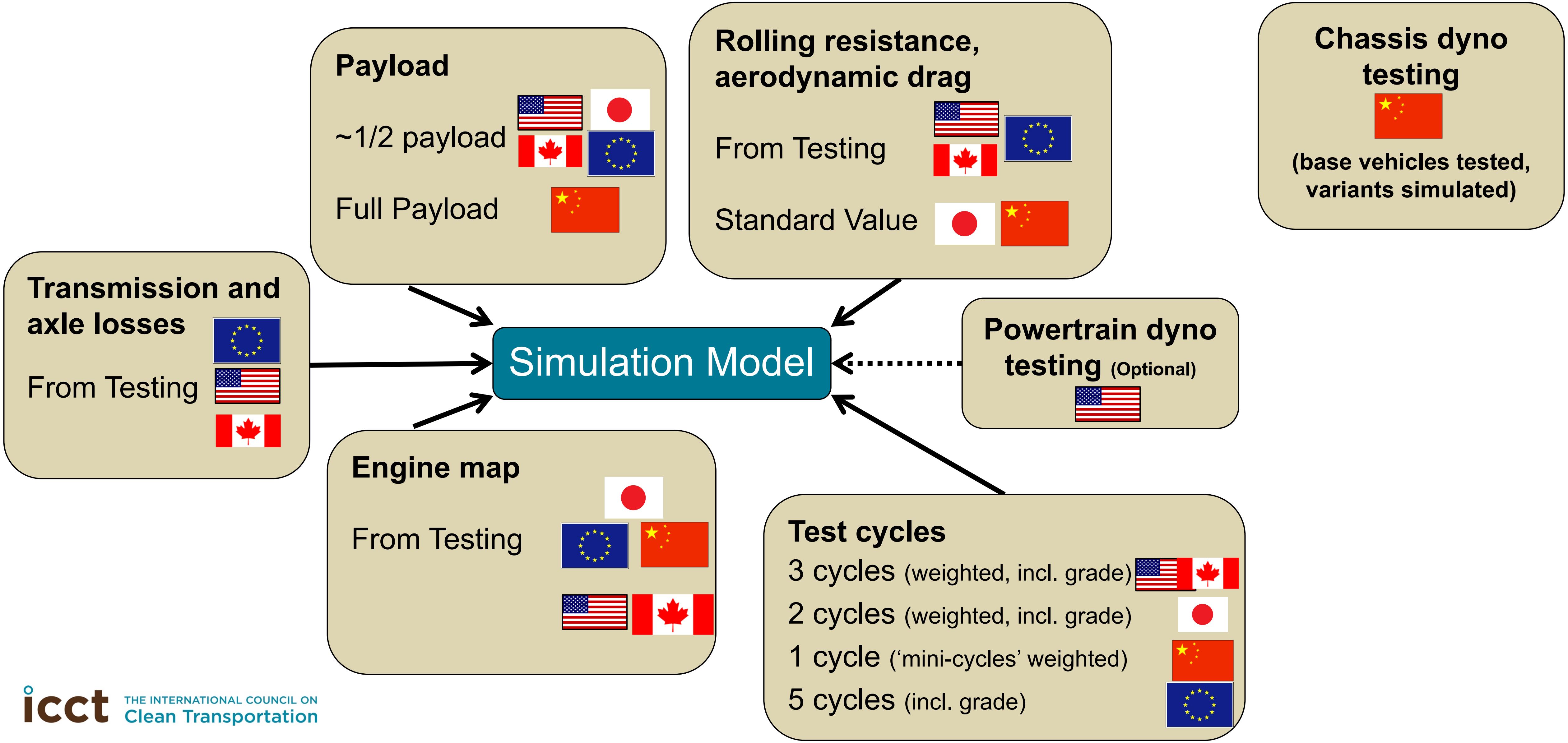
CO_2 determination: Vehicle simulation and testing procedure

This topic was covered in calls #2 and #3.

Recording call #2: https://vimeo.com/252227039 (Password: ZB9a4YuW)

Recording call #3: https://vimeo.com/256666466 (Password: 4py3eu14)

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



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.**

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.

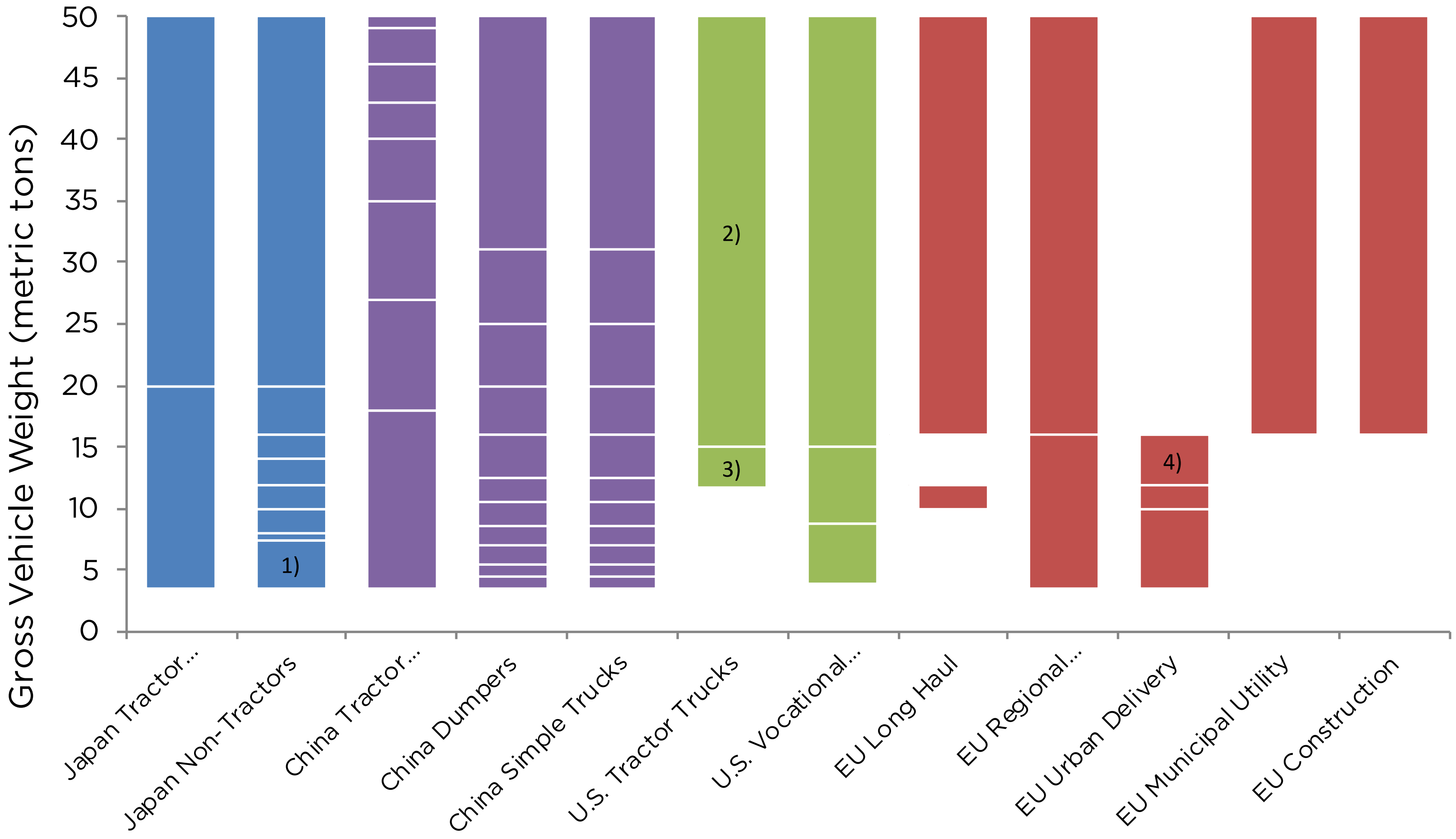
Regulatory design

Segmentation and duty cycles

This topic was covered in call #4.

Recording call #4: https://vimeo.com/261558268 (Password: n9ye7k)

Segmentation comparison by GVW around the world



1) Further divided into four subsegments by maximum payload, 2) Further divided into six subsegments by roof height and cab type, 3) Further divided into three subsegments by roof height, 4) Each EU segment further divided into two to seven subsegments by axle, chassis, and body configuration and weight

Segmentation and duty cycles – 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, nor duty cycle. 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.

- The development of duty cycles for fuel consumption certification must be a data-driven process. A good characterization of the vehicle fleet is necessary. Similarly, the topography and typical traffic conditions of the road network are also required.

Regulatory design

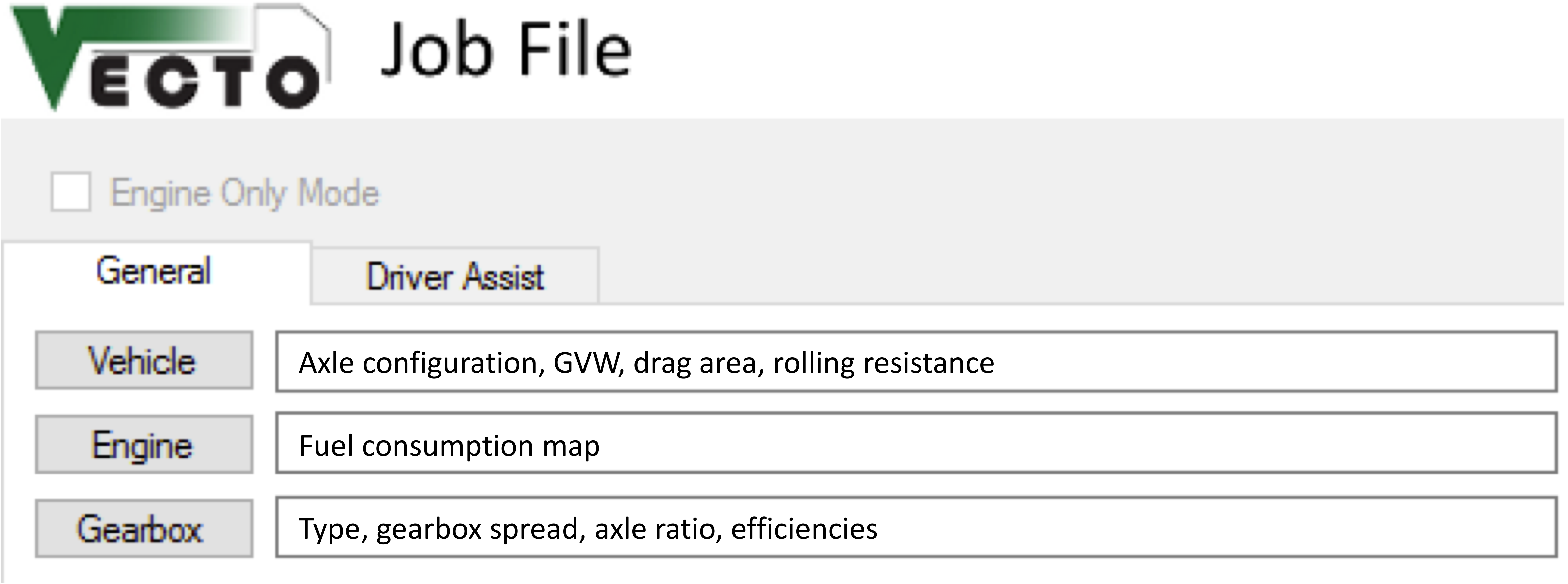
Baseline determination

This topic was covered in call #5

Recording call #5: https://vimeo.com/266179381/ (Password: 67n7jt)

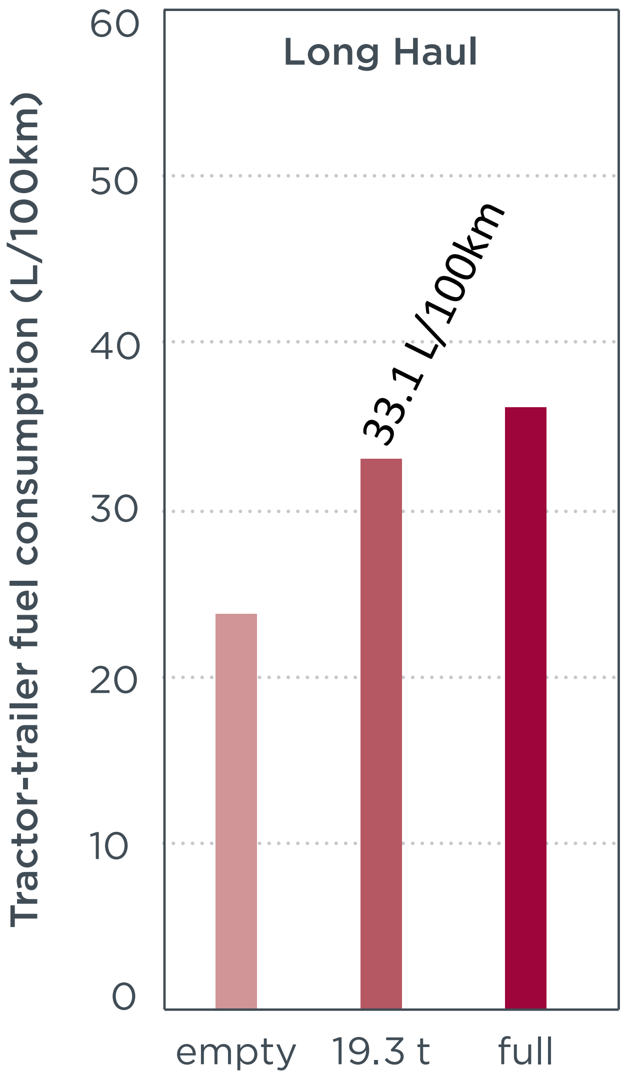
Setting the baseline consist in estimating fleet-representative component performance metrics

The baseline determination does not require to collect real world on-road data, but must rely on the certification procedure. That is vehicle simulation from certified component data.



Example of ICCT’s baselining exercise.

Baseline specifications	Tractor-trailer
Gross vehicle weight (t)	40
Vehicle curb weight (t)	14.4
Axle configuration	4×2
Aerodynamic drag area (m²)	6.0
Tire rolling resistance (N/kN)	5.5
Engine emissions	Euro VI
Engine displacement (L)	12.8
Engine power (kW)	350
Engine peak BTE (%)	44.8
Transmission type	AMT
Transmission gear number	12
Transmission gear ratios	14.93–1.0
Rear axle ratio	2.64
Accessory power (kW)	5.6



http://www.theicct.org/EU-HDV-fuel-efficiency-tech-2020-2030

Regulatory design

Flexibilities

Flexibilities can be useful tools to reduce the cost of efficiency standards while guaranteeing CO_2 reductions

Regulatory flexibilities typically come in three different forms.

1. Averaging (A): Targets are defined as a fleet-average, and not on an individual vehicle basis.
2. Banking (B): Manufacturers can accumulate (bank) credits when over complying with the banking threshold
3. Trading (T): Manufacturers can “trade” the credits to another manufacturer

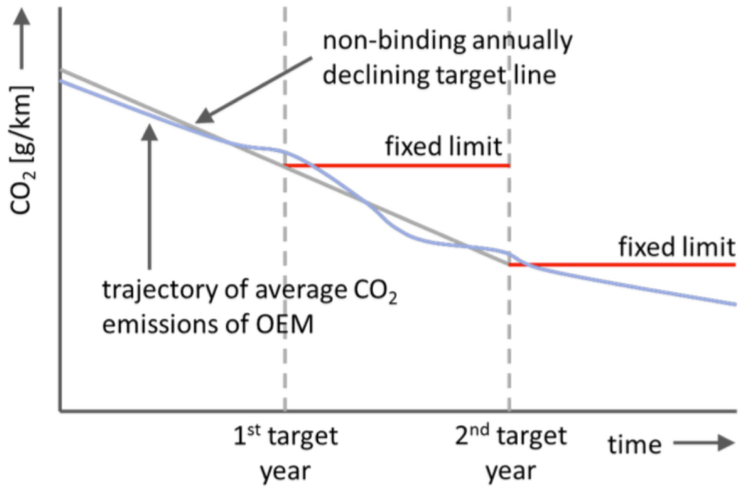
A well-designed ABT program can also provide important environmental and energy security benefits by increasing the speed at which new technologies can be implemented.

Averaging

- Targets are defined as a fleet-average, and not on an individual vehicle basis.
- The averaging sets usually correspond to the regulatory categories
- Averaging is one of the basic flexibility provisions as it allows to set stringent targets. In the case of not-to-exceed limits (i.e., limits that apply to each individual vehicle) requires a very granular segmentation, or a lenient stringency.

Banking

- Banking requires careful oversight and transparency.
- Credits and deficits must have a limited life (e.g., a limited life of 3 years)
- The flexibility that banking brings in terms of technology deployment timing needs to be accompanied by stringent standards
- Flexibilities should provide opportunities for OEMs to introduce technology and reduce cost, **without compromising overall environmental objective**
- In the case of step wise targets (as opposed to annual targets), the banking threshold should be defined to reflect the natural evolution of the technological improvement and prevent "over-banking" of credits.



Maarten Verbeek, et al. (2018). *Assessments with Respect to the EU HDV CO2 Legislation* (Report for Dutch Ministry of Infrastructure and Water management). TNO 2018 P10214: TNO. Retrieved from publications.tno.nl/publication/34626415/j8AF3b/TNO-2018-R10214.pdf

Trading

- As with banking, trading requires careful oversight and transparency.
- Trading imposes an administrative burden for the regulators.
- Trading can be allowed either only between the same vehicle groups or also between different vehicle groups.
- Allowing credits / debits trading between different regulatory can result in market distortions, as the product portfolio of each manufacturer is different, and the flexibility could benefit some OEMs and disadvantage some others.
- If the trading credits / debits between different categories is allowed, a careful consideration of the characteristics of the different regulatory categories is required (e.g., lifetime mileage, in-use payloads, average fuel consumption).
- Credit trading should be in units of absolute tons of CO2 over the lifetime of the vehicle (that is why you need certain assumptions)

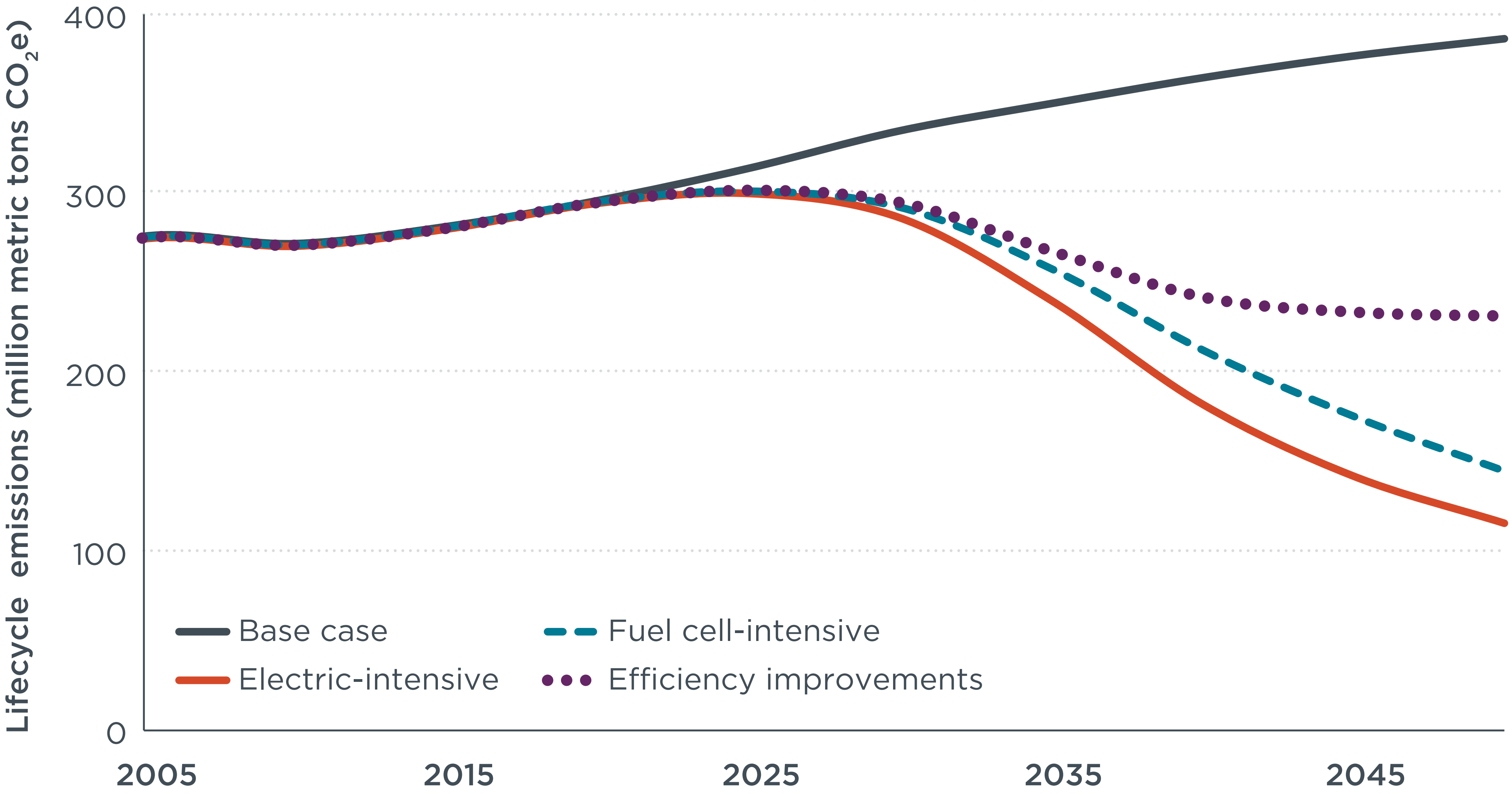
Regulatory design

Incentives for emerging low carbon technologies

HD ZEV freight: Long Haul -- simultaneously the most important and most challenging segment

Segments		Definition	Duty Cycle	Range	Payload Requirements	Battery/ Hydrogen Requirements	Infrastructure Requirements	CO_2 Footprint	Current Availability
Freight	Urban Delivery	• Light and Medium Duty trucks and vans	Low speed, transient	<200km / day	<5 ton	<100kWh <10kg H_2	Limited	10-15%	>20 models
	Drayage	• Transport freight from ports • Travel high volume freight corridors							
	Regional Delivery	• Return to base							
	Long Haul	• Tractor-trailers	High speed, constant	>500km /day	>20 ton	>800kWh >30kg H_2	Extensive	65-75%	None

De-carbonization scenario for European tractor trailers (ICCT)



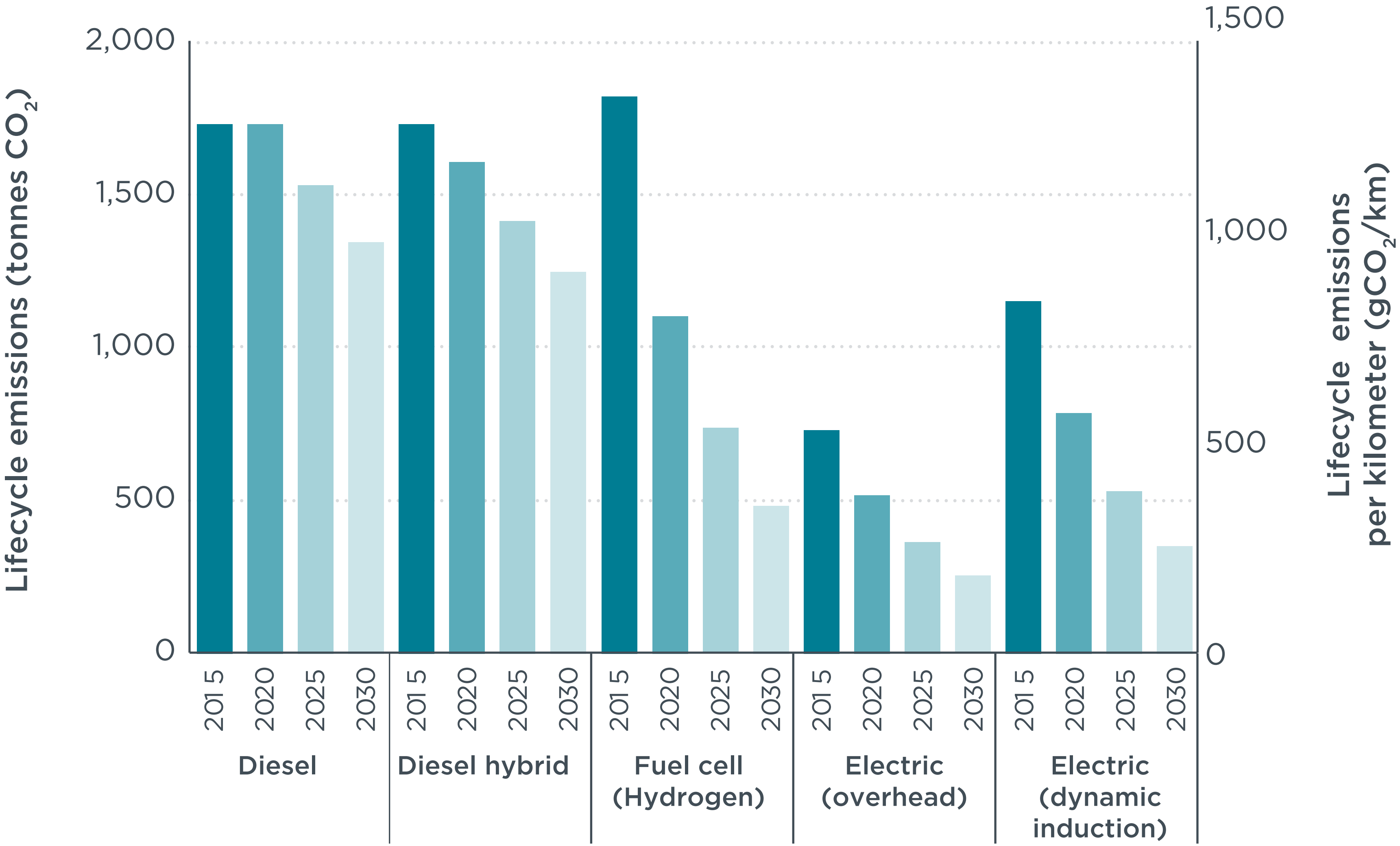
Lifecycle CO_2e emissions from Europe heavy-duty tractor-trailer fleet with base case, efficiency improvements, fuel cell-intensive, and electric-intensive scenarios.

Fuel cell intensive: 50% fuel cells in 2050 / 15% electric

Electric intensive: 50% electric / 15% fuel cell in 2050.

Transitioning to zero-emission heavy-duty freight vehicles
https://www.theicct.org/publications/transitioning-zero-emission-heavy-duty-freight-vehicles

ZE-HDV are necessary to meet long-term CO2 reduction targets

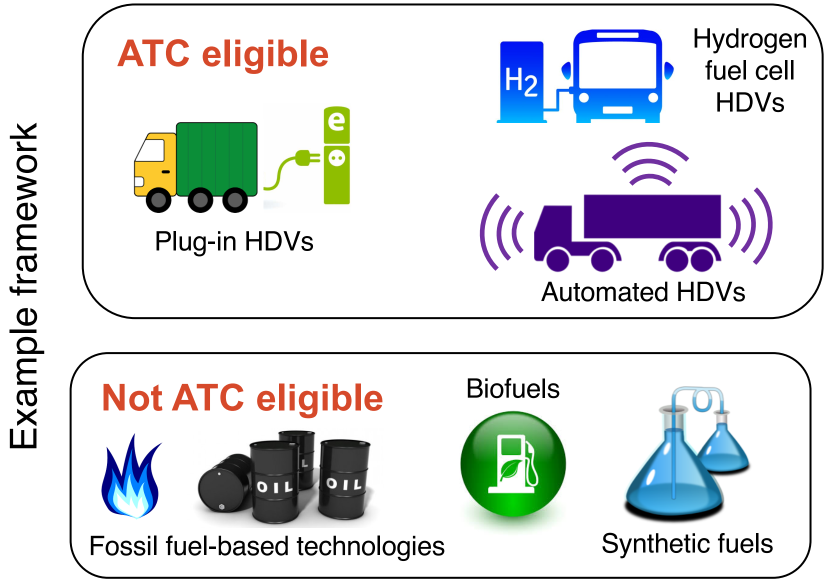


Missing from this analysis is the battery electric long-haul tractor trailer . . .

Transitioning to zero-emission heavy-duty freight vehicles
https://www.theicct.org/publications/transitioning-zero-emission-heavy-duty-freight-vehicles

Principle 1: Clearly define how the advanced technology credit (ATC) values are determined

Scenario 1: advanced technologies and credit values are explicitly defined



Advantage

- Simple to understand and administer
- Ability to assign credit multipliers to certain fuel/technologies

Disadvantages

- Can be seen as 'picking winners and losers'
- Dual-fuel and/or complicated propulsion architectures may be difficult to classify

Scenario 2: No advanced technology credits beyond that of zero rating for ZEVs

Advantage

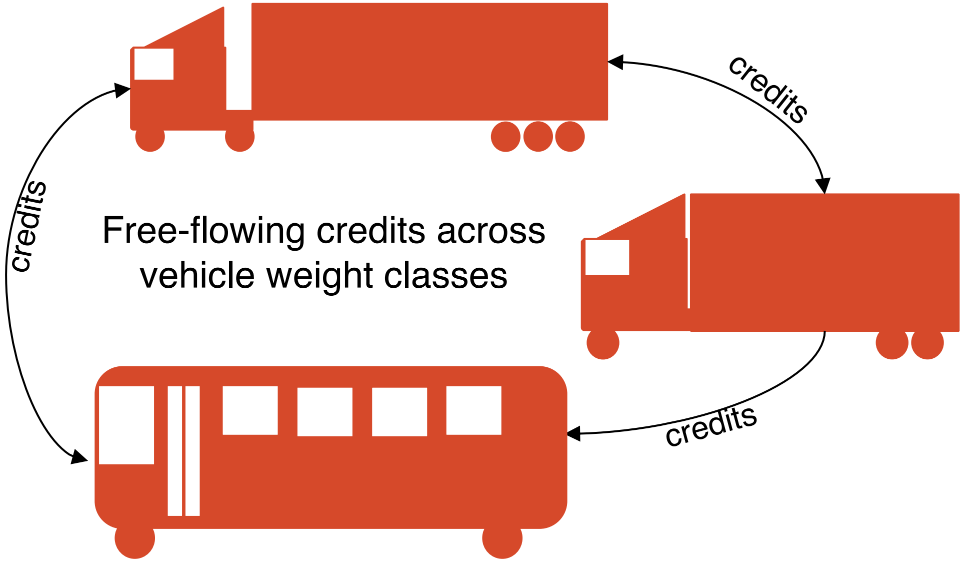
- Simple to understand and administer

Disadvantages

- Fails to incentivize technologies that currently are not cost competitive

Principle 2: Promote emerging fuel efficiency and zero emission technologies in all HDV types

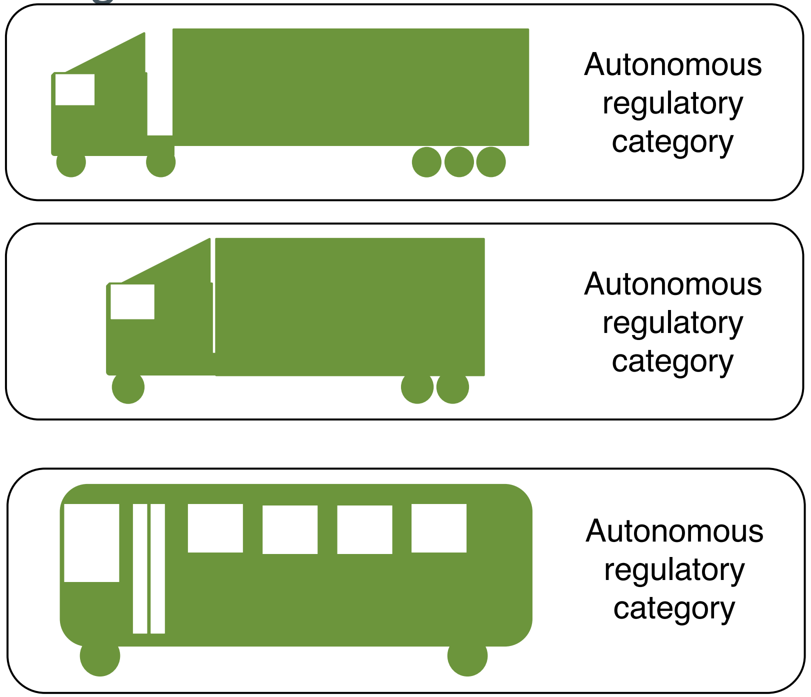
Scenario 1: credit trading allowed across various vehicle weight classes



Potential negative outcomes

- Manufacturer over-complies in one category and uses excess credits to delay technology deployment in another category
- Manufacturers that sell across multiple categories have advantage vs. manufacturer that focus on one (or two) categories

Scenario 2: no credit trading across various vehicle weight classes

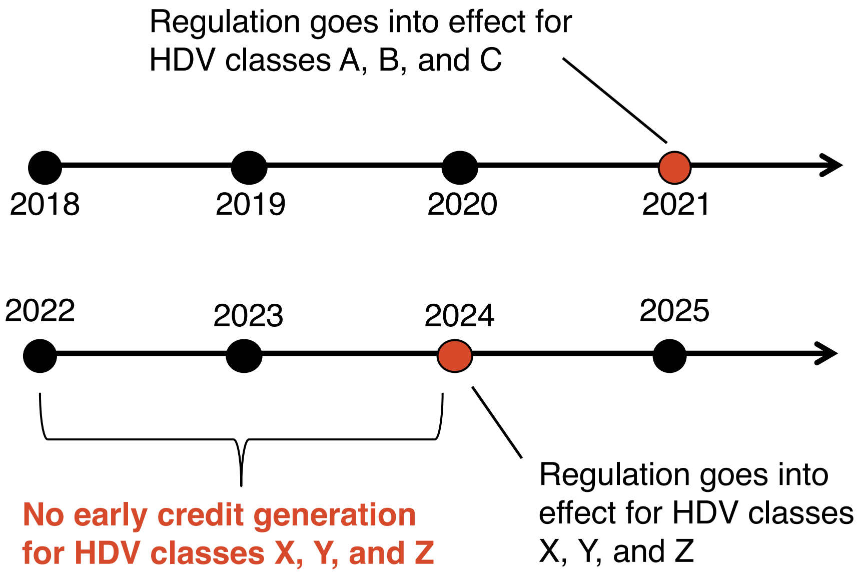


Positive outcomes

- Regulation encourages development and deployment of fuel-saving and zero emission technologies in all categories
- Creates more equitable conditions for all manufacturers, regardless of product mix

Principle 3: Incentivize non-regulated HDV categories to engage in early action

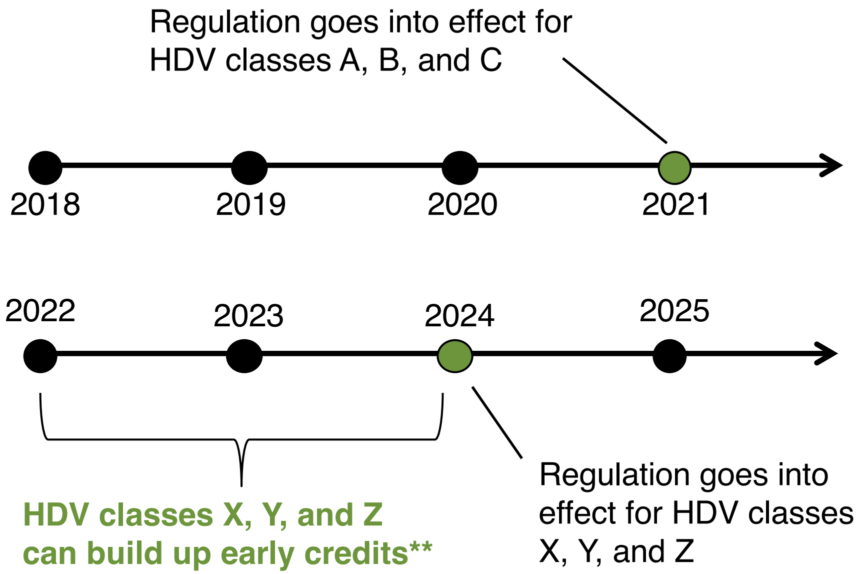
Scenario 1: no opportunity for non-regulated vehicle classes to generate early credits



Potential negative outcome

- Manufacturer of HDV classes X, Y, and Z have no regulatory incentive to accelerate introduction of advanced technologies

Scenario 2: non-regulated vehicle classes have opportunity to build up early credits with sales of advanced technologies



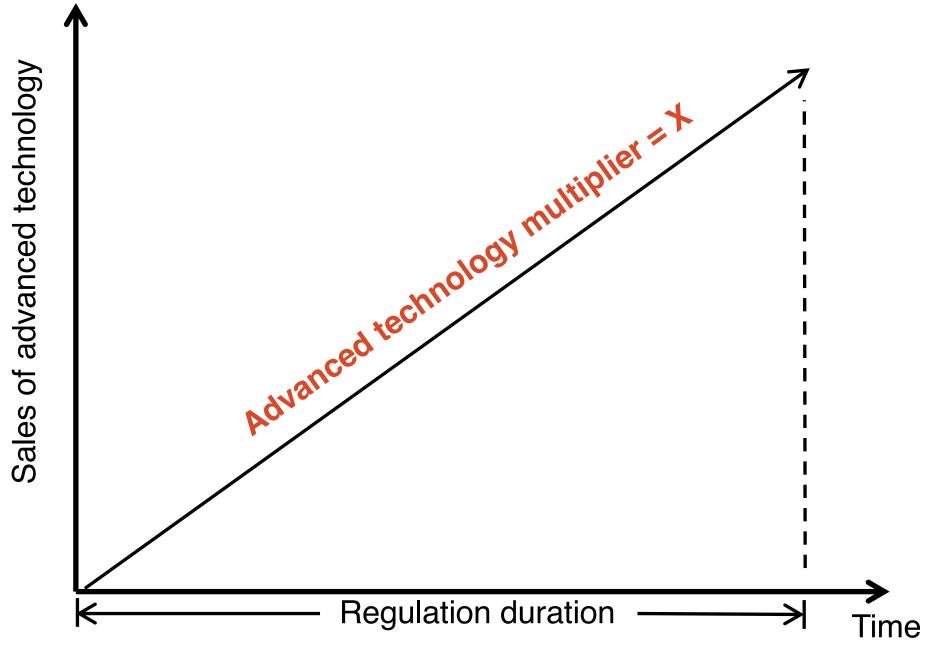
Positive outcomes

- Fuel use and GHG reductions can be achieved from non-regulated HDV classes
- Opportunity to bring manufacturers into the regulatory fold early

** Early credits for classes X, Y, and Z cannot be applied to classes A, B, and C

Principle 4: Link advanced technology multiplier values to sales targets

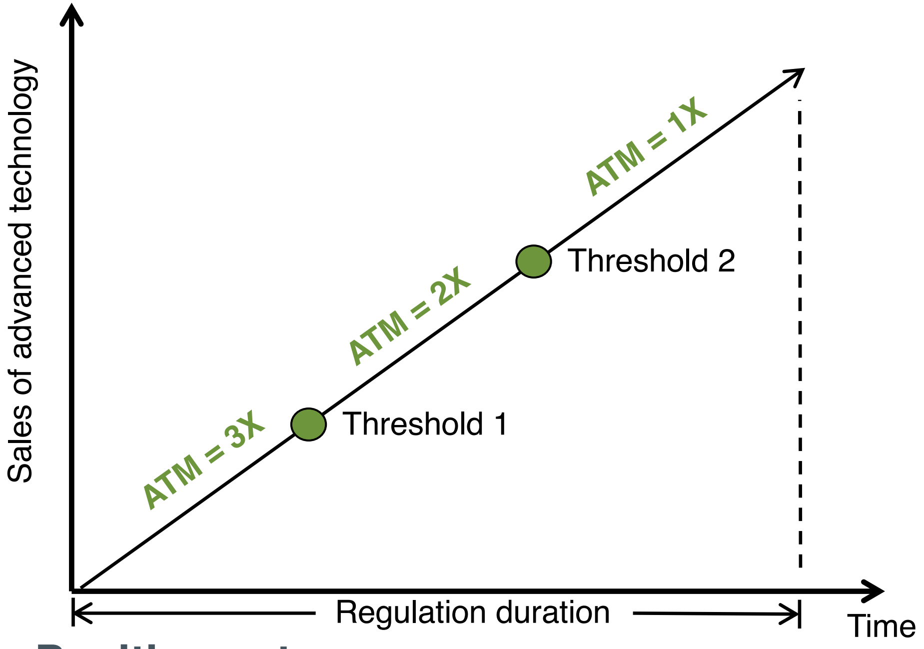
Scenario 1: advanced technology credits have constant value over life of the regulation



Potential negative outcome

- As sales of advanced technology increase, the stringency of the overall regulation can be compromised

Scenario 2: value of advanced technology credits is linked to sales thresholds**

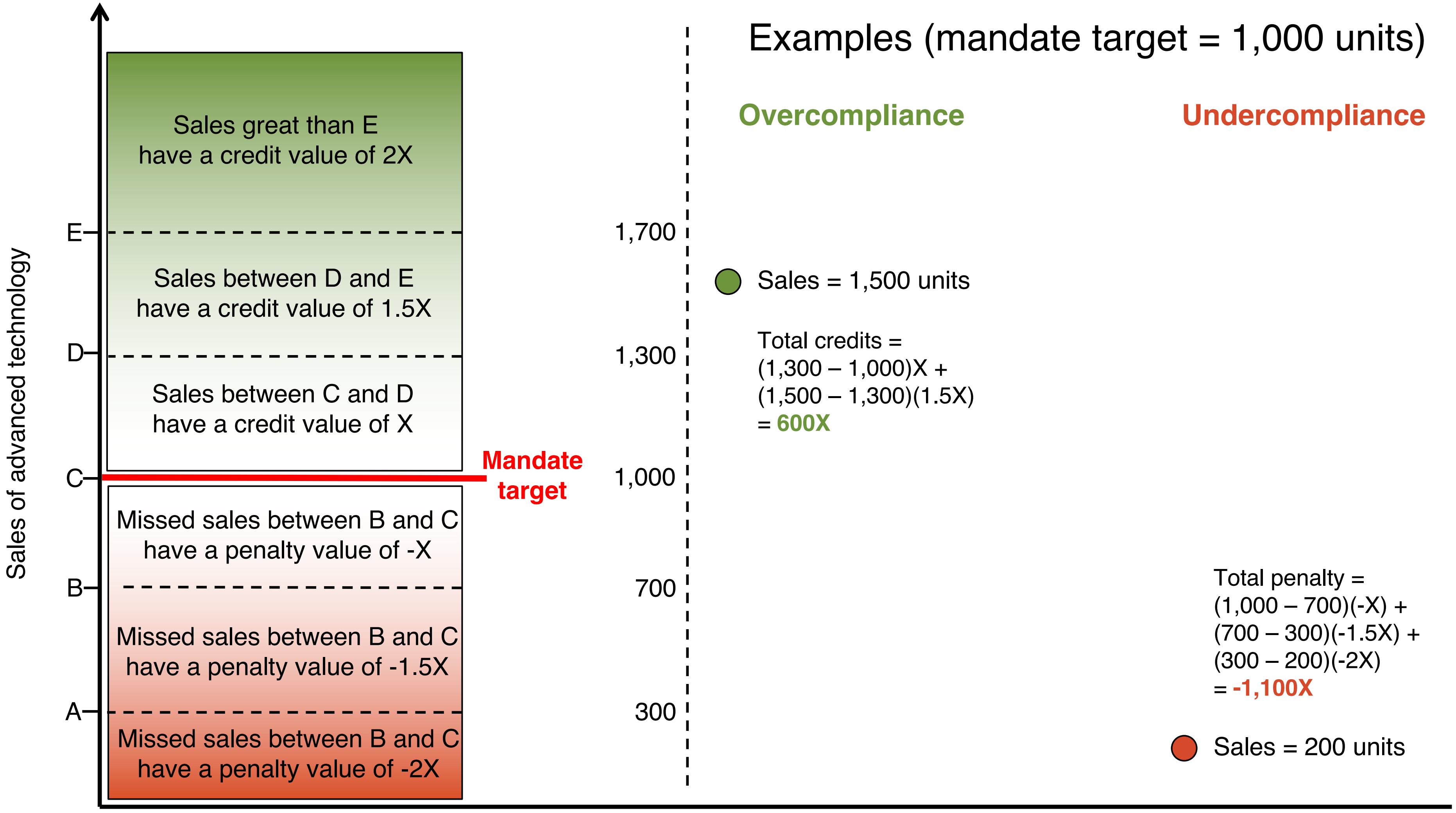


Positive outcomes

- Sends clear signal to industry about decreasing value of credits over time
- Lowers risk that a surge in advanced technology sales will erode stringency of overall regulation

** Thresholds can be percentages of total sales or absolute values

Concept for a flexible advanced technology (or “ZEV”) mandate: progressive incentives and penalties



** Thresholds can be percentages of total sales or absolute values

Regulatory design

Trailer and engine standards

Example of successful implementation of engine standards: US Phase 1 and Phase 2 GHG HDV regulation.

Summary of U.S. Phase 1 heavy-duty diesel engine standard CO_2 limits

Vehicle Type	GVW (tons)	Base (2010) g/kWh	Step 1 (2014) g/kWh	Step 2 (2017) g/kWh	Phase 1 reduction (%)	Test Cycle	Full Vehicle Reduction (%)	Engine share of full vehicle reduction (%)
Tractor	11.8 to 15	695	673	653	6.0	SET (Phase 1)	10.2-13	46-59
	15+	657	637	617	6.1	SET (Phase 1)	9.1-23.4	26-67
Non-tractor	3.9 to 8.8	845	805	772	8.6	Composite FTP[a]	8.6	100
	8.8 to 15	845	805	772	8.6	Composite FTP	8.9	97
	15+	783	760	744	5.0	Composite FTP	5.9	85

a. The cycle is run as both a cold- and a hot-start test. The composite FTP results are obtained by using a weighting factor of 1/7 for the cold-start results and 6/7 for the hot.

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Muncrief, R., & Rodríguez, F. (2017). *A roadmap for heavy-duty engine CO2 standards within the European Union framework*. The International Council on Clean Transportation. Retrieved from http://www.theicct.org/publications/roadmap-heavy-duty-engine-co2-standards-within-european-union-framework

Engine standards accelerate the development and deployment of engine technologies.

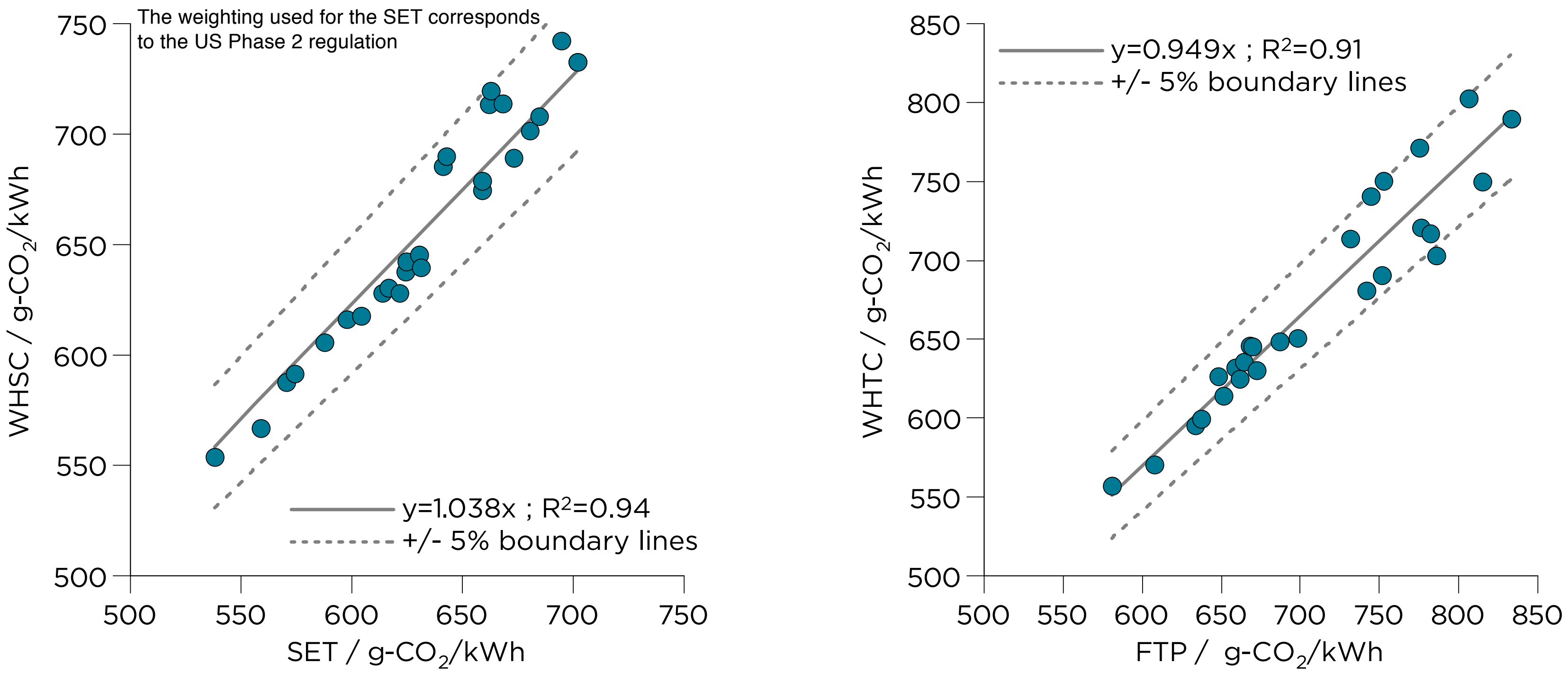
Phase 2 assumed engine technologies, reductions, and market penetrations for tractor engines

Technology	SET weighted reduction (%)	Market penetration (2021) (%)	Market penetration (2024) (%)	Market penetration (2027) (%)
Turbocompound with clutch	1.9	5	10	10
Waste heat recovery	3.6	1	15	25
Parasitic/Friction reduction	1.5	45	95	100
Improved aftertreatment	0.6	30	95	100
Air handling	1.1	45	95	100
Improved combustion	1.1	45	95	100
Downsizing	0.3	10	20	30
		Reductions (2021) (%)	**Reductions (2024) (%)**	**Reductions (2027) (%)**
Weighted reduction (%)		1.7	4	4.8
Downspeeding optimization (%)		0.1	0.2	0.3
Total reduction (%)		**1.8**	**4.2**	**5.1**

Estimated technology adoption necessary to meet the Phase 2 engine standards in the United States

Muncrief, R., & Rodríguez, F. (2017). *A roadmap for heavy-duty engine CO2 standards within the European Union framework*. The International Council on Clean Transportation. Retrieved from http://www.theicct.org/publications/roadmap-heavy-duty-engine-co2-standards-within-european-union-framework

The Phase 1/2 standards can be used as a blueprint for other regions. EU and US duty cycles can be correlated for CO_2 emissions.



Comparison of 26 different engine maps over a simulated environment were used to estimate the correlation coefficients between the stationary WHSC and SET cycles, as well as between the transient cycles WHTC and FTP.

Muncrief, R., & Rodríguez, F. (2017). *A roadmap for heavy-duty engine CO2 standards within the European Union framework*. The International Council on Clean Transportation. Retrieved from http://www.theicct.org/publications/roadmap-heavy-duty-engine-co2-standards-within-european-union-framework

Engine standards bring along a number of benefits

a) Link between CO_2 and NOx

b) Benefits over the complete life of the vehicle

c) Incentivize new engine technologies

d) Cover segments not included in a 1st phase of a whole vehicle CO_2 standard

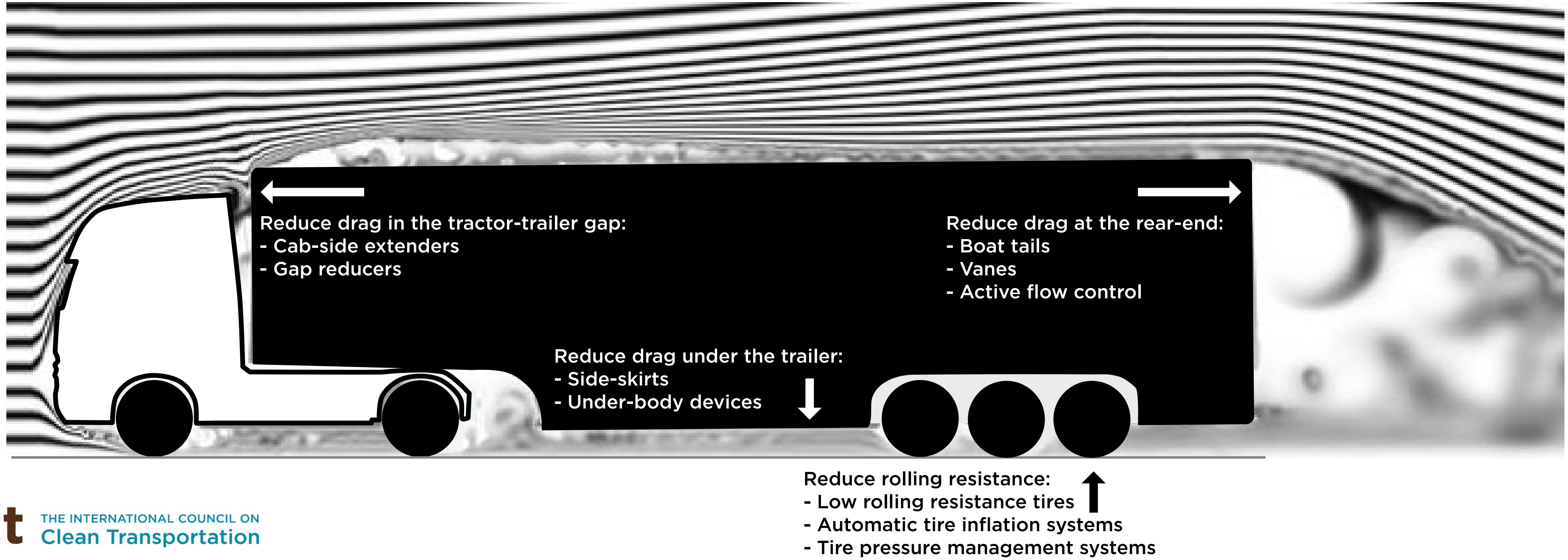
e) Easy to implement with the existing regulatory framework

f) Ensure R&D in engine technologies

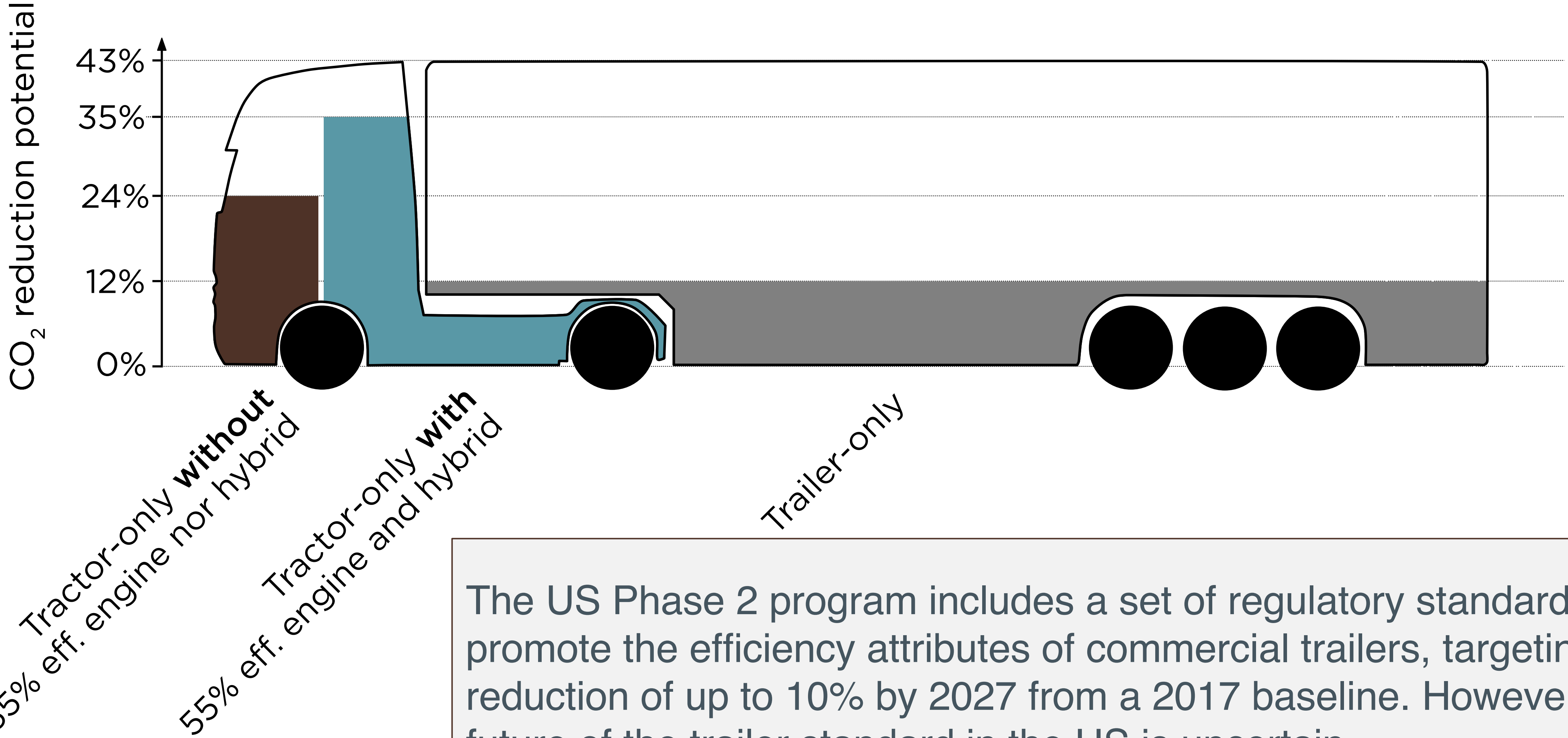
g) Are easy to harmonize across regions

Trailers are responsible for a significant share of the energy losses in tractor-trailers

Improvements in **trailer** road-load losses are a key lever to reduce long-haul CO_2 emissions. A trailer certification procedures, and trailer CO_2 standards are important regulatory measures. Key trailer technologies are illustrated below.



In the EU, ICCT estimates that trailer-only technologies can bring about 12% fuel consumption reduction.



The US Phase 2 program includes a set of regulatory standards to promote the efficiency attributes of commercial trailers, targeting a reduction of up to 10% by 2027 from a 2017 baseline. However, the future of the trailer standard in the US is uncertain.

Questions? Contact the HDV team at the ICCT

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