Improving heavy-duty vehicle fuel efficiency in India

Market, technology potential, and test procedure considerations for designing a regulatory program

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icct
THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

Purpose of this webinar series is to have a dialogue around heavy-vehicle fuel efficiency standards in India

ICCT is studying various aspects of a possible heavy-vehicle fuel efficiency standard in India:

1. Market survey to understand the existing HDV engines and manufacturers
2. Testing methods for heavy-duty vehicle fuel efficiency
3. Survey of commercial vehicle industry stakeholders (industry, owners, operators)
4. Investigate how efficiency improvements in engines translates to fuel consumption reduction across vehicle platforms and duty cycles
5. Evaluate cost-effectiveness of efficiency technologies

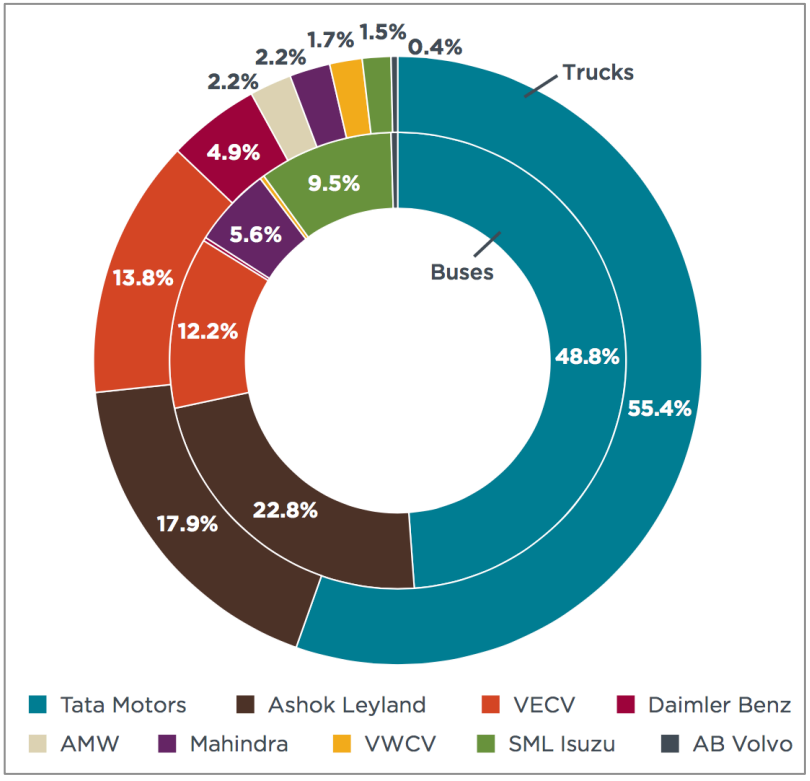
Today's webinar focuses on the heavy-duty vehicle market in India

- Overview of the HDV sales market in India
- Unique aspects of the Indian HDV market the case for engine-based efficiency standards
- Development of an engine categorization scheme for India
- Future webinar(s) will focus on results of engine and vehicle simulations, stakeholder survey, cost-effectiveness analysis

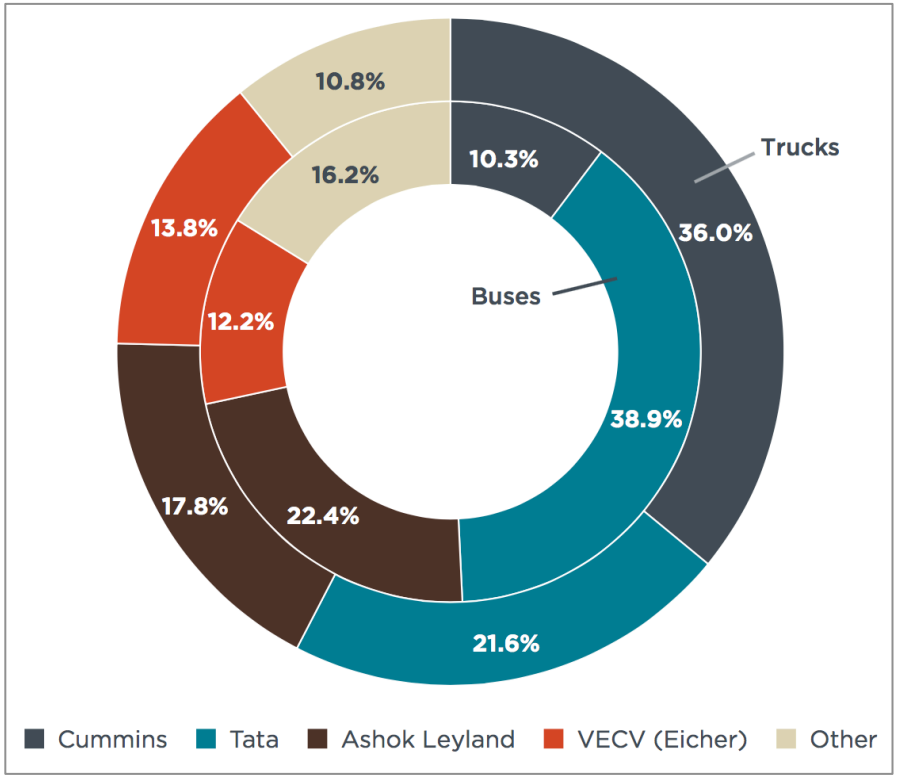
Manufacturer market shares

- Tata (53%), Ashok Leyland (19%), and VECV (14%) are the market leaders
- Cummins (30%) has largest share of HDV engine market

Vehicle market shares

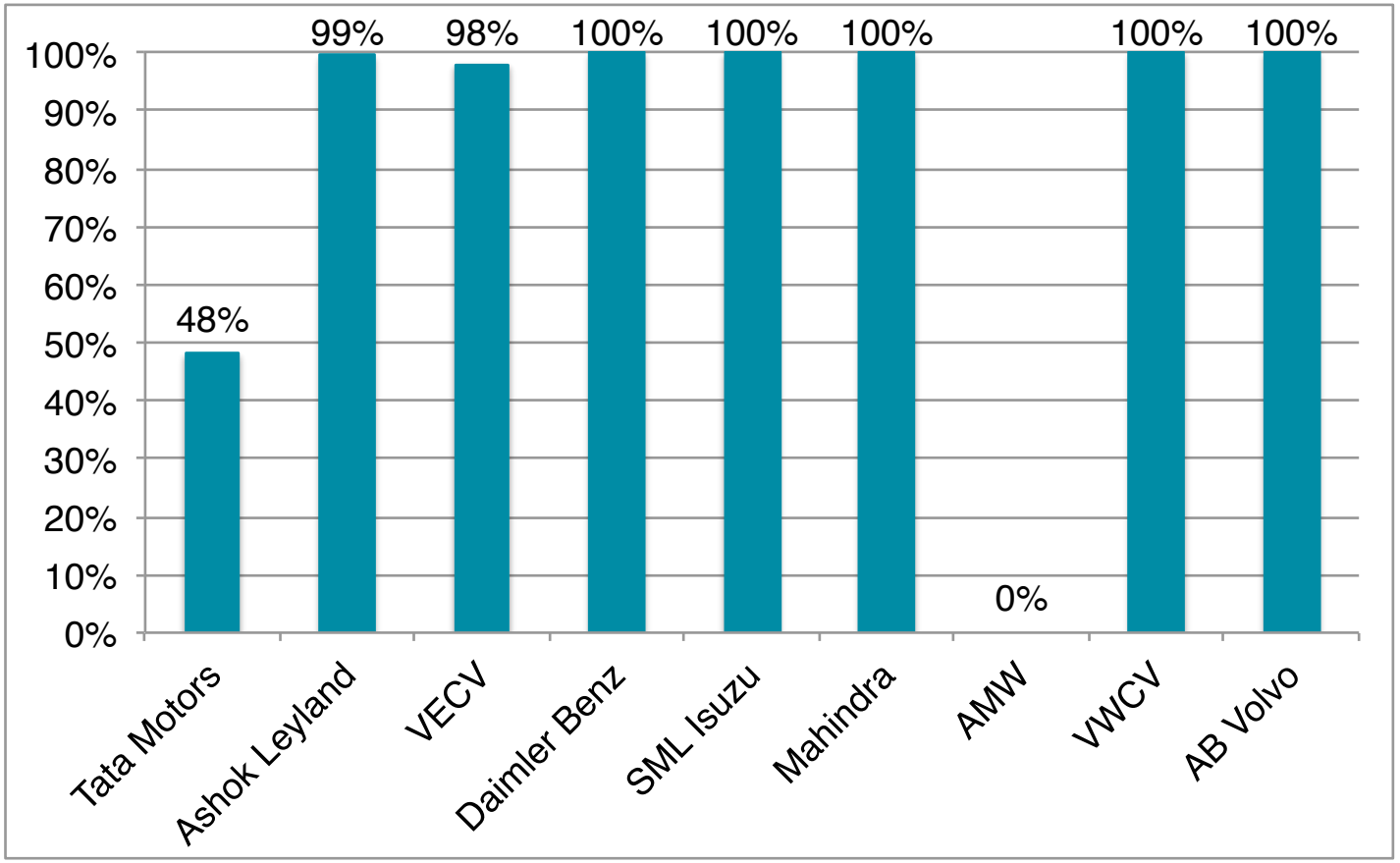


Engine market shares



Most manufacturers sell their own self-made engines

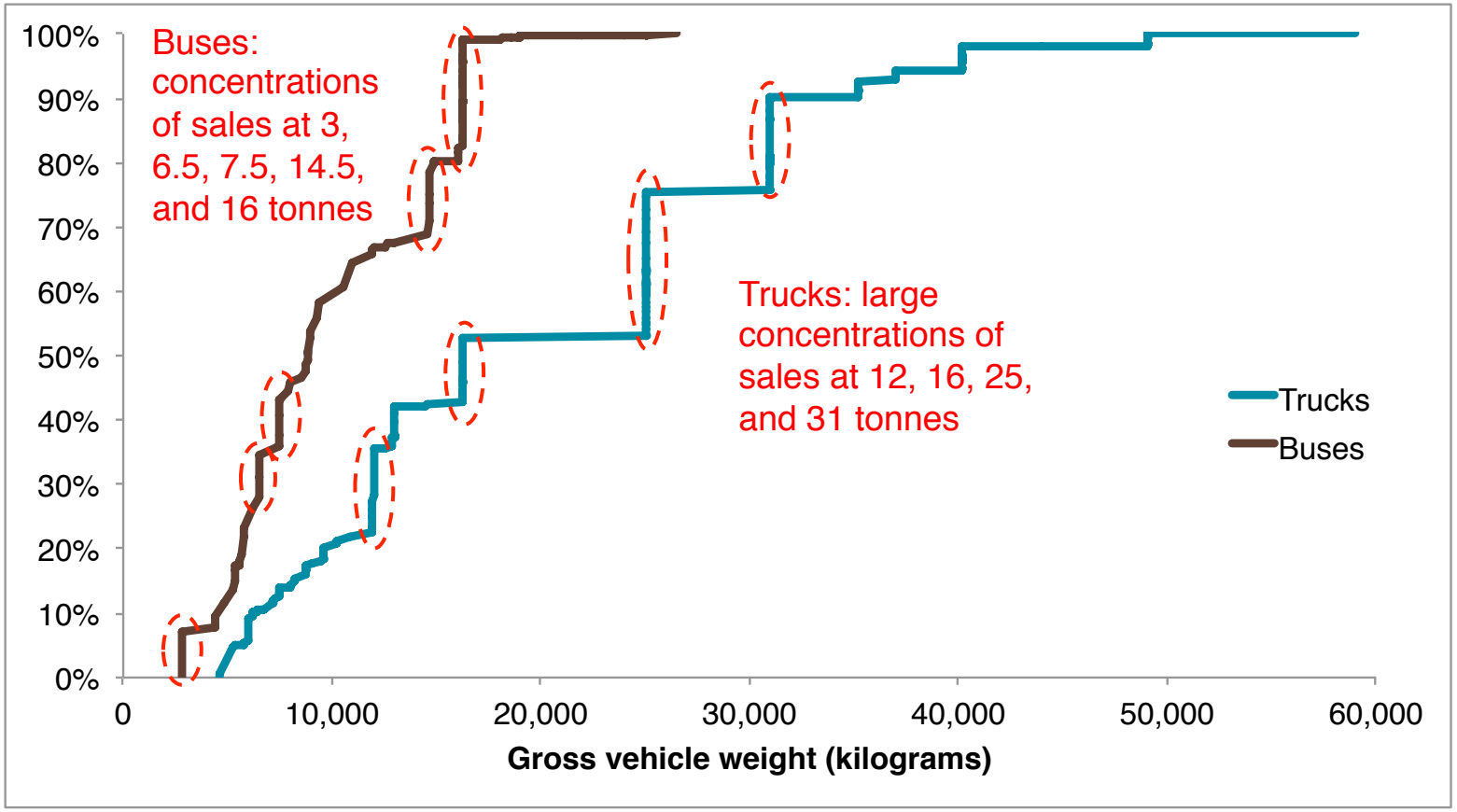
- Most OEMs producing and selling their own engines
- Exceptions: Tata (~ 50-50 split with Cummins) and AMW (exclusively using Cummins engines)



Shares of self-made engines

Cumulative truck and bus sales by gross vehicle weight

- Trucks > 25 tonnes: nearly half of truck sales
- Buses < 12 tonnes: almost two-thirds of bus sales



Tata and Ashok Leyland have most popular vehicle models

- Tata has best selling model in all of the truck weight classes and for the smallest bus category
- Ashok Leyland models biggest sellers for large buses
- Most consolidated segment: trucks < 7.5 tonnes
- Least consolidated segment: buses > 12 tonnes

Segment	Model	Fiscal year 2013-14 sales	% of segment sales	Top 5 models: % of sales	Top 10 models: % of sales
Trucks < 7.5 tonnes	Tata LPT 407	9,078	32.0%	72.6%	87.3%
Trucks 7.5 – 12 tonnes	Tata LPT 1109	14,609	33.1%	56.6%	72.8%
Trucks 12 – 16 tonnes	Tata LPT 1613	8,262	23.1%	60.7%	80.1%
Trucks 16 – 25 tonnes	Tata LPT 2518	12,284	26.0%	41.7%	66.4%
Trucks > 25 tonnes	Tata LPT 3118	11,419	36.2%	71.3%	88.4%
Tractor trucks > 25 tonnes	Tata LPS 3518	2,811	16.2%	61.3%	79.1%
Buses < 7.5 tonnes	Tata Winger	4,685	17.7%	48.3%	74.0%
Buses 7.5 – 12 tonnes	Ashok Leyland Lynx	2,284	13.1%	51.0%	78.9%
Buses > 12 tonnes	Ashok Leyland Viking	5,424	24.9%	38.0%	60.2%

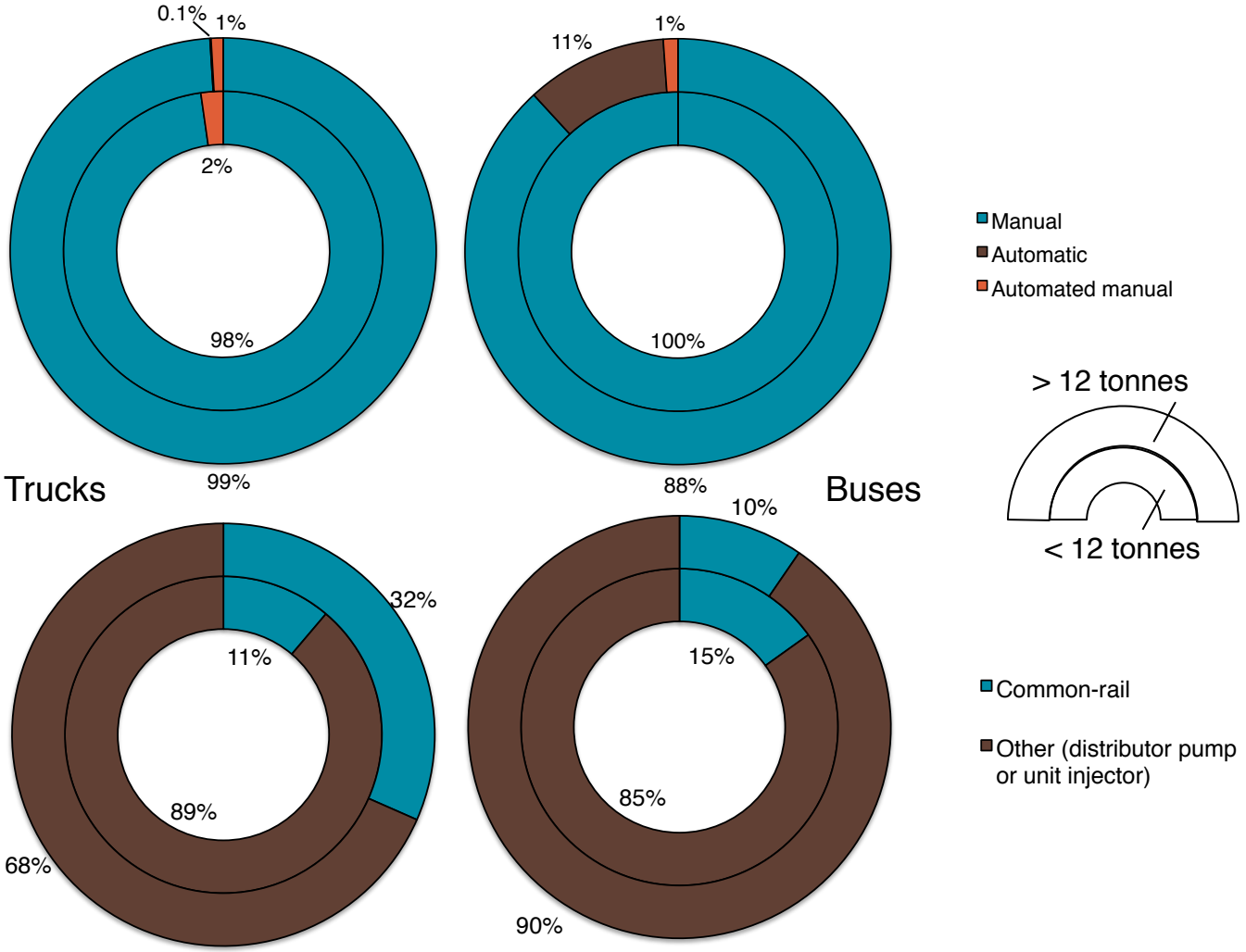
HDVs in India have much room for modernization

Transmission type

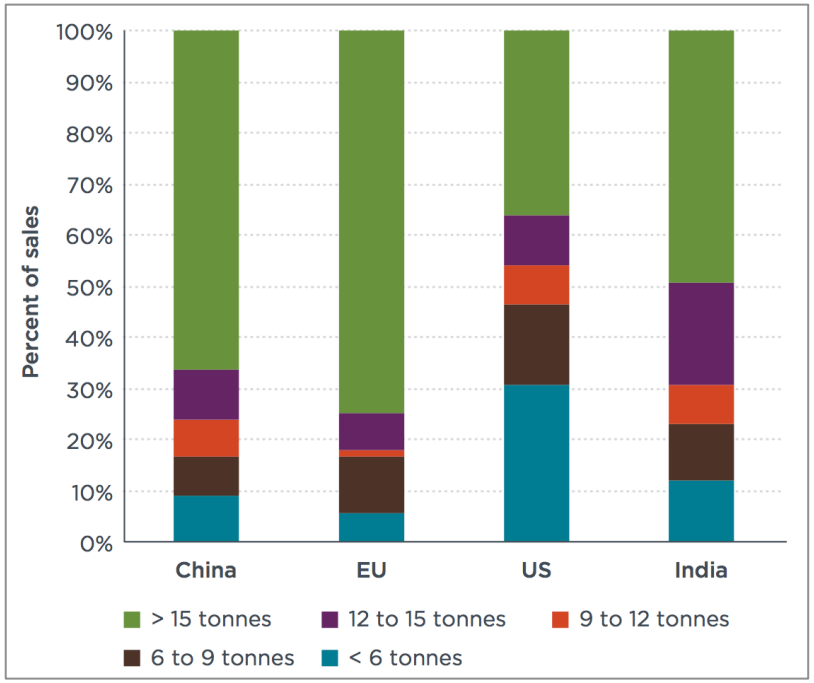
- Trend towards automation in the more advanced markets such as the EU and US
- Automation typically increases efficiency and mitigates effects of poor drivers

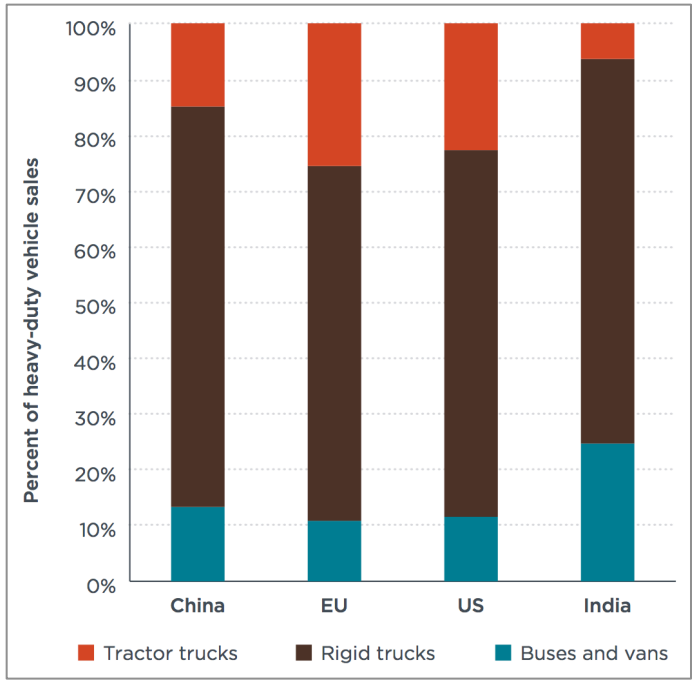
Fuel injection type

- Common-rail fuel injection enabled by transition to electronic controls
- Common-rail injection allows for more sophisticated injection timing and increases efficiency

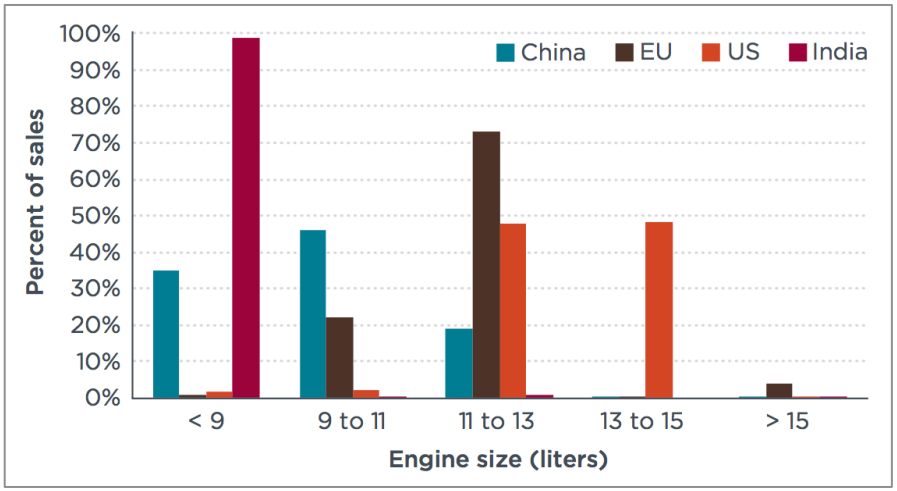


India is unique compared to other markets



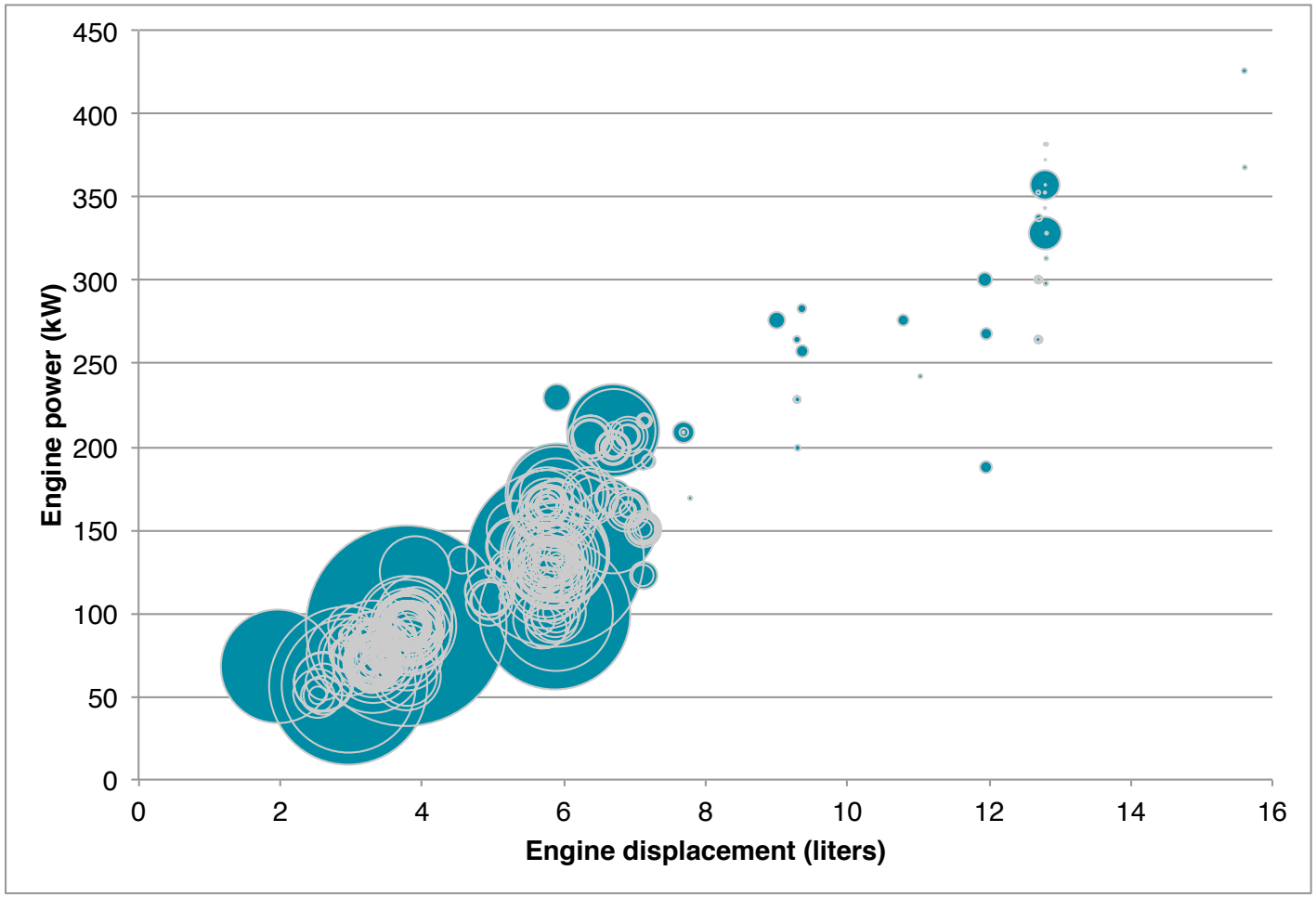


Most unique feature of Indian market: smaller engine size and power ratings



HDV engines in India are relatively small

- Nearly 99% of HDVs sold have engines 7 liters or less

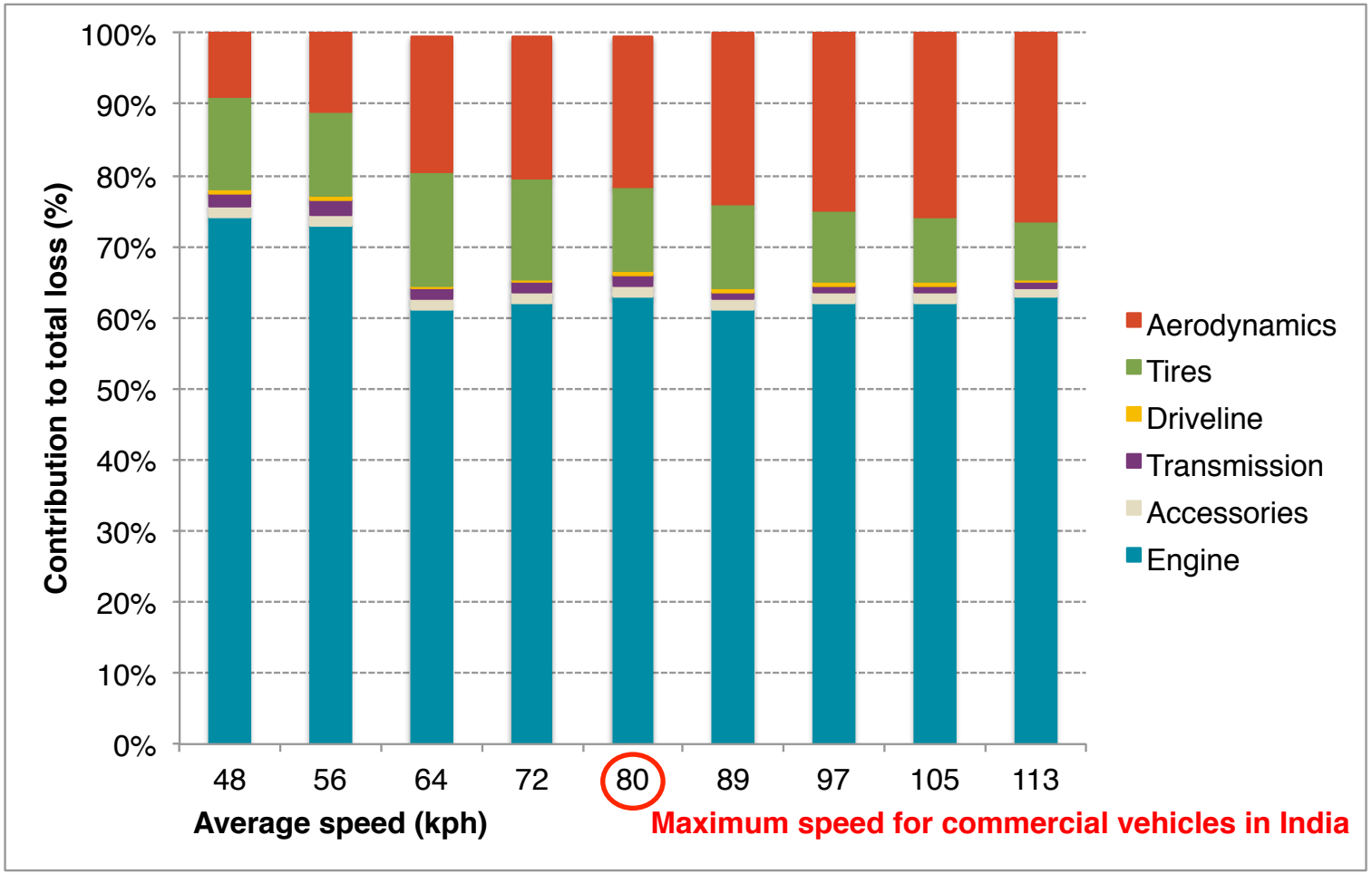


Size of bubble corresponds to sales at that engine displacement/power point

Small engines and frequent overloading lead to low average speeds in India

- Typical characteristics of HDVs in India
  - Trucks have lower power-to-weight ratios compared to other major markets
  - Overloading quite common
  - Therefore: lower speeds than trucks in the EU or North America
- Impacts for fuel efficiency
  - Lower speeds, high percentage of heavily-loaded trucks → **engine** and **tire** improvements much more important than aerodynamics

Engines make up the majority of energy losses



Source: Delorme et al. (2009). Evaluation of Fuel Consumption Potential of Medium and Heavy Duty Vehicles through Modeling and Simulation.

Engines and tires are the biggest areas for HDV efficiency improvement in India

Smaller engine sizes + high degree of overloading → slower average driving speeds

Engines and **tires** make up majority of losses

Energy balance example: urban delivery drive cycle (15 kph avg.), half loaded, level road

Aerodynamic losses: 3%

Engine losses: 70%

Tires and braking: 21%

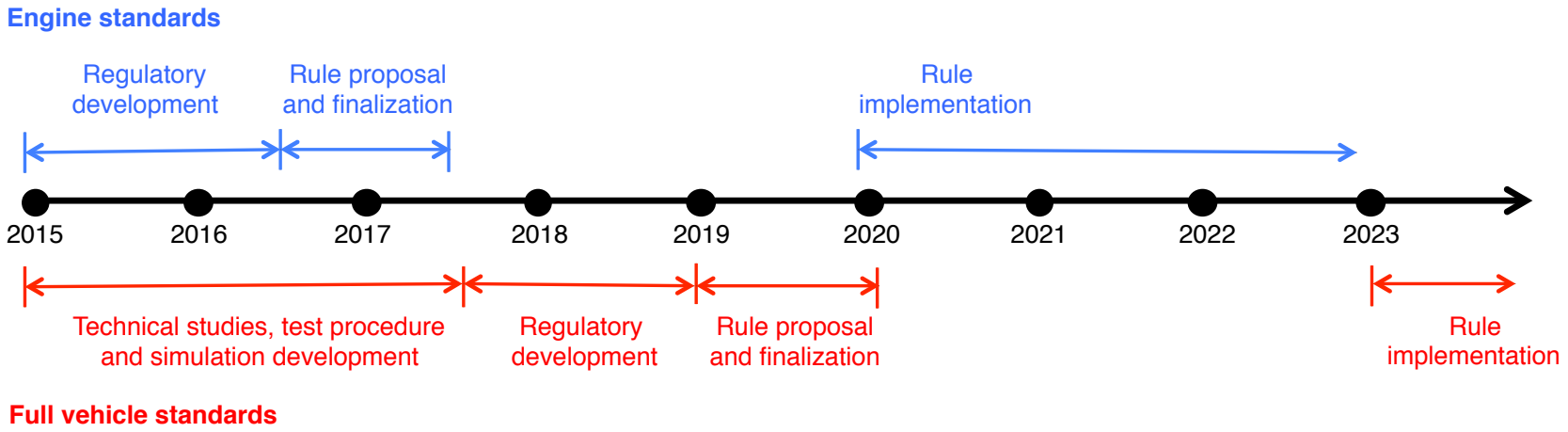
Drivetrain: 5%

Auxiliary loads: 1%

Source: ICCT simulation analysis

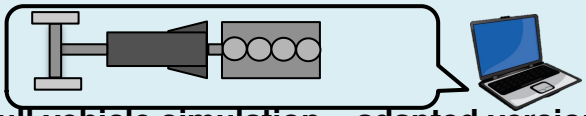
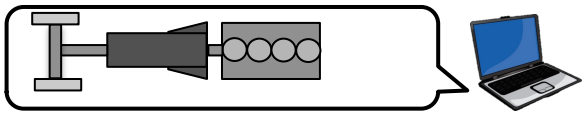
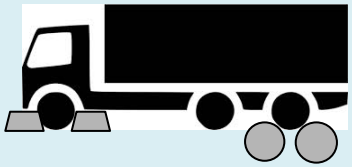
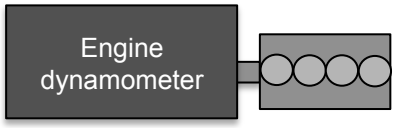
Establish engine-based standards as a first phase regulation

- ICCT recommendation: establish engine-based standards as a first phase regulation
  - Leverage existing testing facilities and expertise
  - Limit complexity
  - Maximize fuel savings as soon as possible
- Policy action on tires is also a significant low-hanging fruit
- Work to develop a more comprehensive full vehicle approach should start in parallel. Our vision for the regulatory timeline:



http://www.theicct.org/hdv-efficiency-test-procedures-trends-implications-india

Engine standards offer the most benefits compared to other regulatory approaches

Certification option	Ability to leverage existing testing facilities	Complexity of certification process	Timeframe for regulatory implementation
 Full vehicle simulation – adapted version of VECTO, GEM, Japan or China model			5-7 years
 Full vehicle simulation – new India model		?	5-7 years
 Chassis dynamometer			5-7 years
 Engine dynamometer			3-5 years

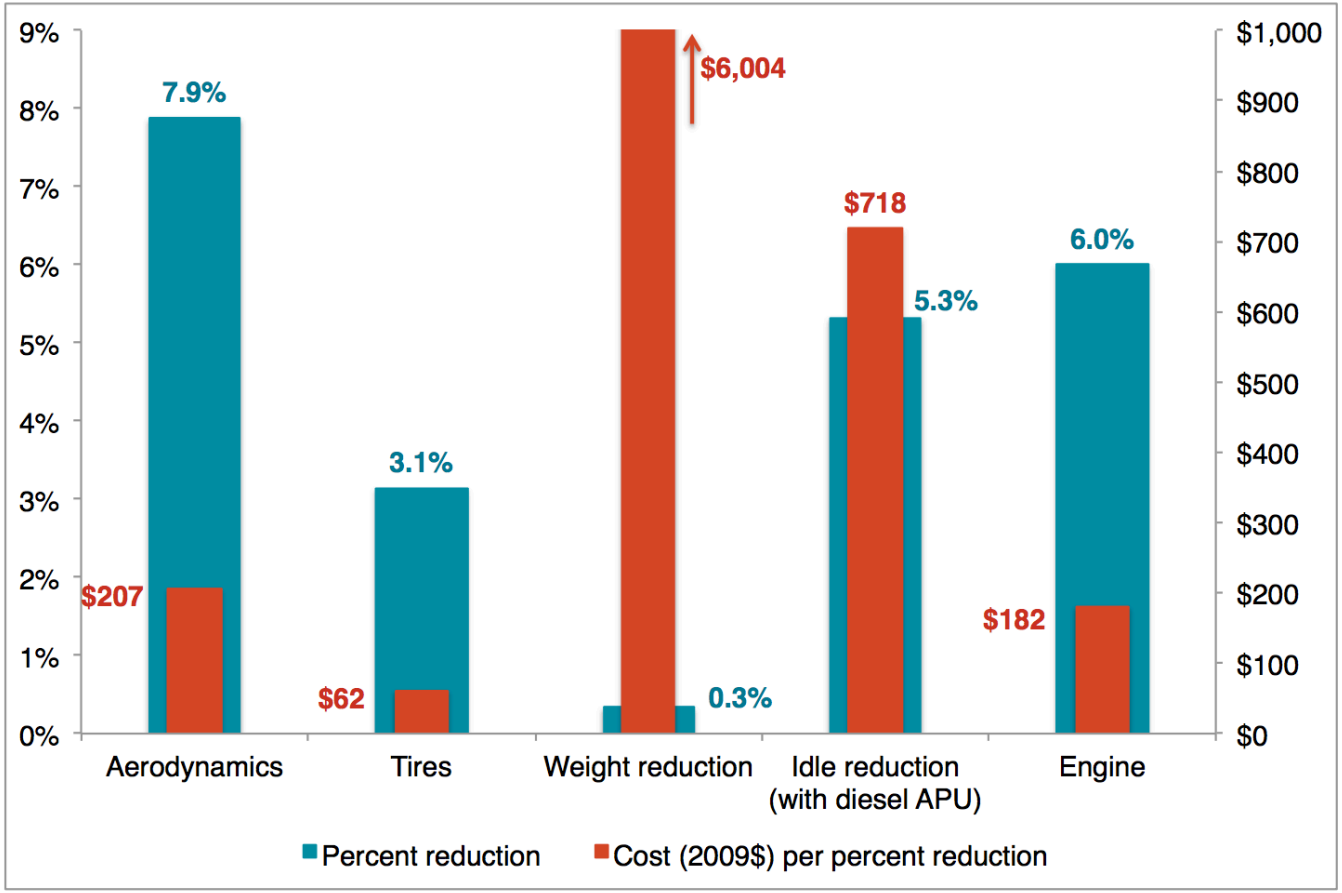
ICCT recommendation

Favorable Moderate Unfavorable

http://www.theicct.org/hdv-efficiency-test-procedures-trends-implications-india

Engine technologies have been very cost-effective in the regulatory programs in the US and Canada

Our initial research suggests that engine cost-effectiveness will be as good or better in India



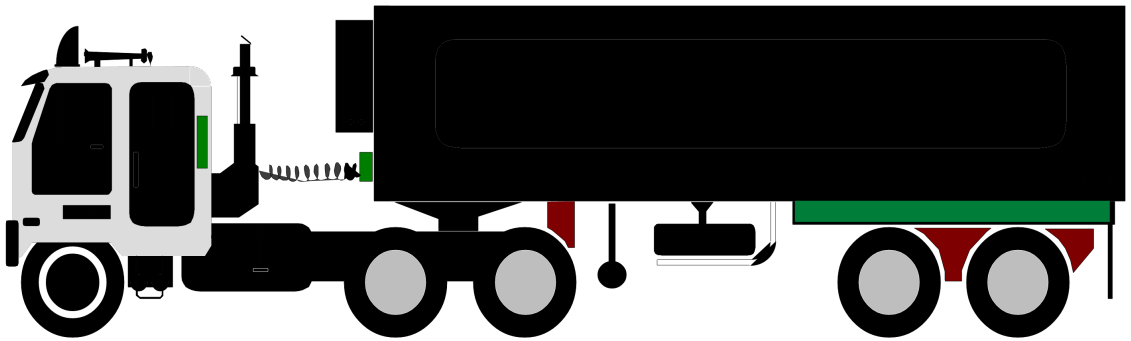
ICCT analysis of the US Phase 1 regulation

http://www.theicct.org/cost-effectiveness-engine-technologies-hdv-efficiency-regulation-india

ICCT's proposed regulatory framework for engine-based standards

- Engine manufacturer is the regulated entity
  - Engine manufacturer is responsible for fulfilling all testing and reporting requirements of the regulation
- Each engine must be certified before it is ultimately installed in an actual vehicle
- Leverage existing criteria pollutant type approval process
  - Perform testing for criteria pollutants and fuel consumption/CO_2 at the same time
  - Identical metric: (grams/kW-hr)

1. Engine certification



2. Certified engine is installed in vehicle. Full vehicle is type approved following existing protocols.

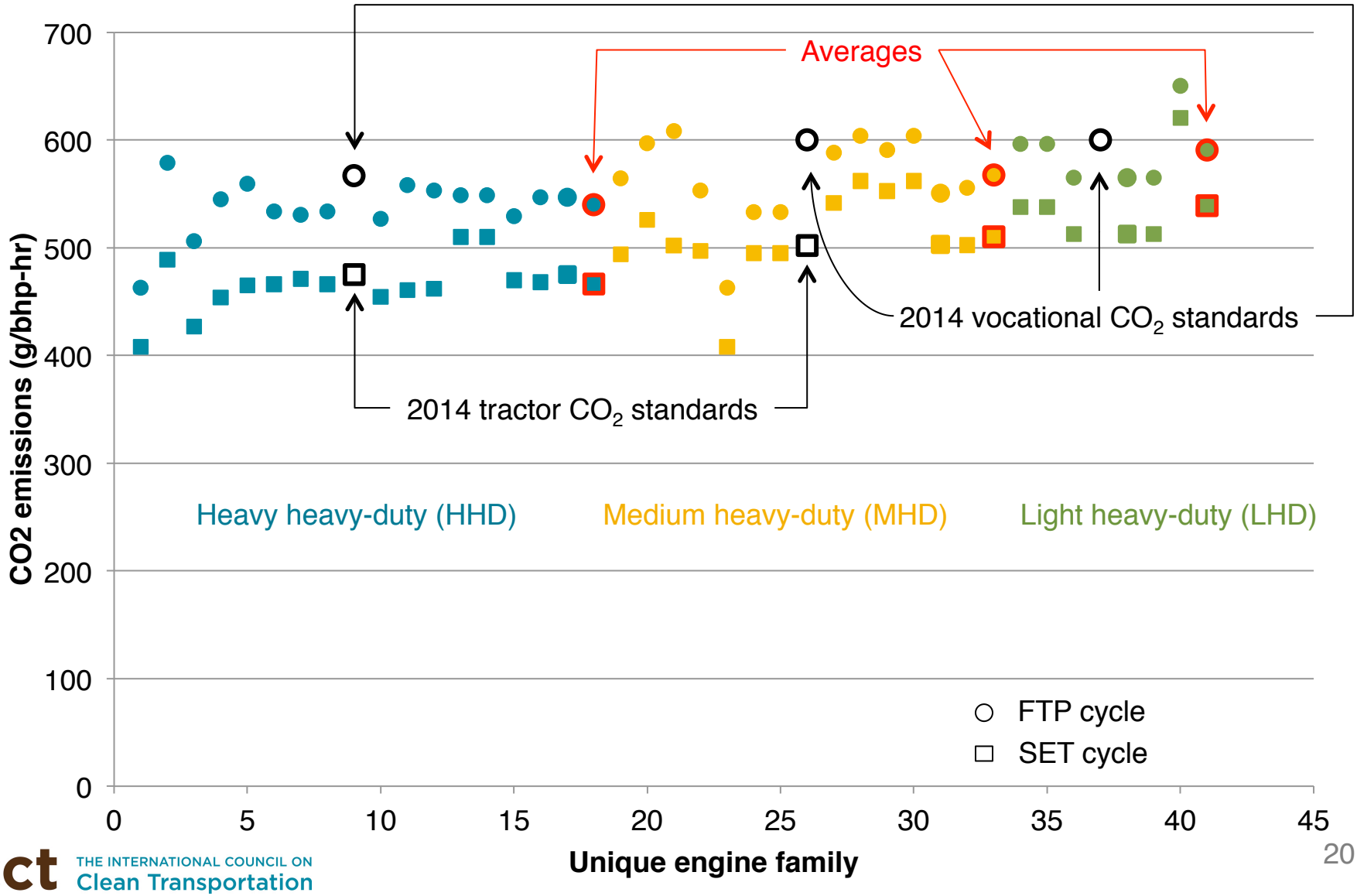
Constant speed fuel consumption (CSFC) testing is not ideal for regulatory purposes

- Advantages:
  - Ability to test vehicle in its 'near-final' state
  - Measurement of fuel consumption in km/l
- Disadvantages:
  - High testing costs and low repeatability compared to other methods
  - Potentially large number of vehicle variants that would need to be tested
  - Vehicles are not tested as they would be operated in the real-world
    - Test weights are very different: vehicle is often tested without the final body assembly and no payload → test weight is much lower than in real-world conditions
    - Constant speed testing is not representative of actual driving: evaluating at one set speed (40 or 60 kph) and at zero grade only exercises the engine at limited portions of the map → much more cost-effective to do steady-state engine testing

Create regulatory categories for engines to minimize unwanted market impacts

- Likely not prudent to regulate all sizes of engines together in one regulatory category
  - Smaller engines are inherently less efficient than larger engines per unit of power produced: heat transfer losses are proportional to the surface area-to-volume ratio of the cylinders, which is lower for larger engines
  - Regulating all engines together would incentivize sale of larger engines and could unintentionally distort the market
- International precedent for categorizing engines in efficiency regulation
  - Both the US and Canada have 5 engines categories based on the gross vehicle weight and type of the intended vehicle

Engine categories have worked well in the US and Canadian Phase 1 regulations

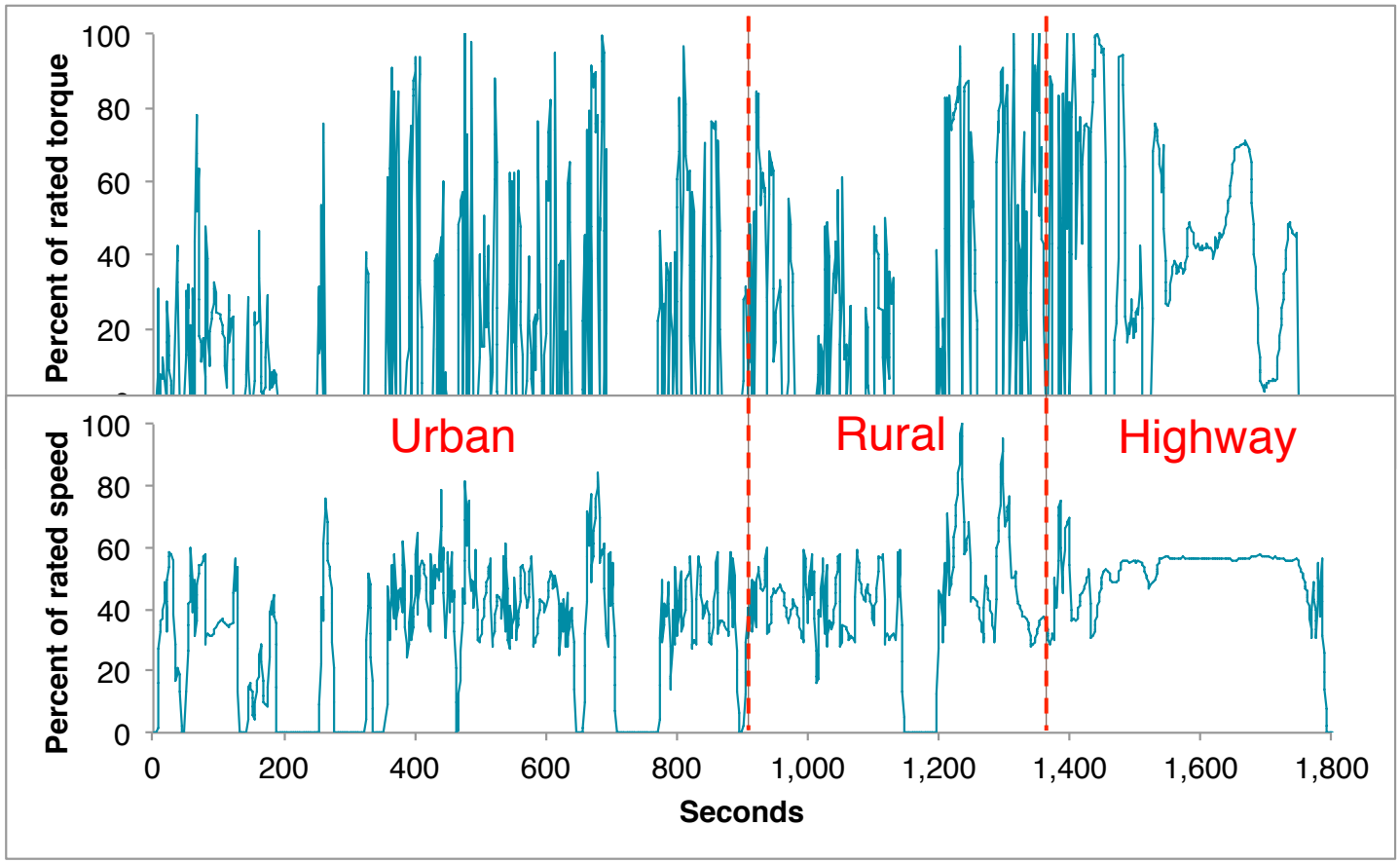


Grouping engines by vehicle size and type seems to be the most attractive option

Grouping by	Advantages	Disadvantages
Vehicle GVWR and type	• Most attractive method for ensuring engines installed in similar types of vehicles are grouped in the same category • Unique engine cycles can be utilized to better reflect real-world operations	Could lead to wide ranges of engine size and power ratings in the same regulatory category → inherent efficiency advantage of large engines could incentivize trend towards bigger engines
Engine size	Parameter is very difficult to change without major hardware overalls → virtual eliminates opportunities for gaming	Very little opportunity to choose different test cycles to more closely match in-use operations
Engine power	Parameter directly corresponds to the grams per brake horsepower metric for evaluating engines.	Same as above.

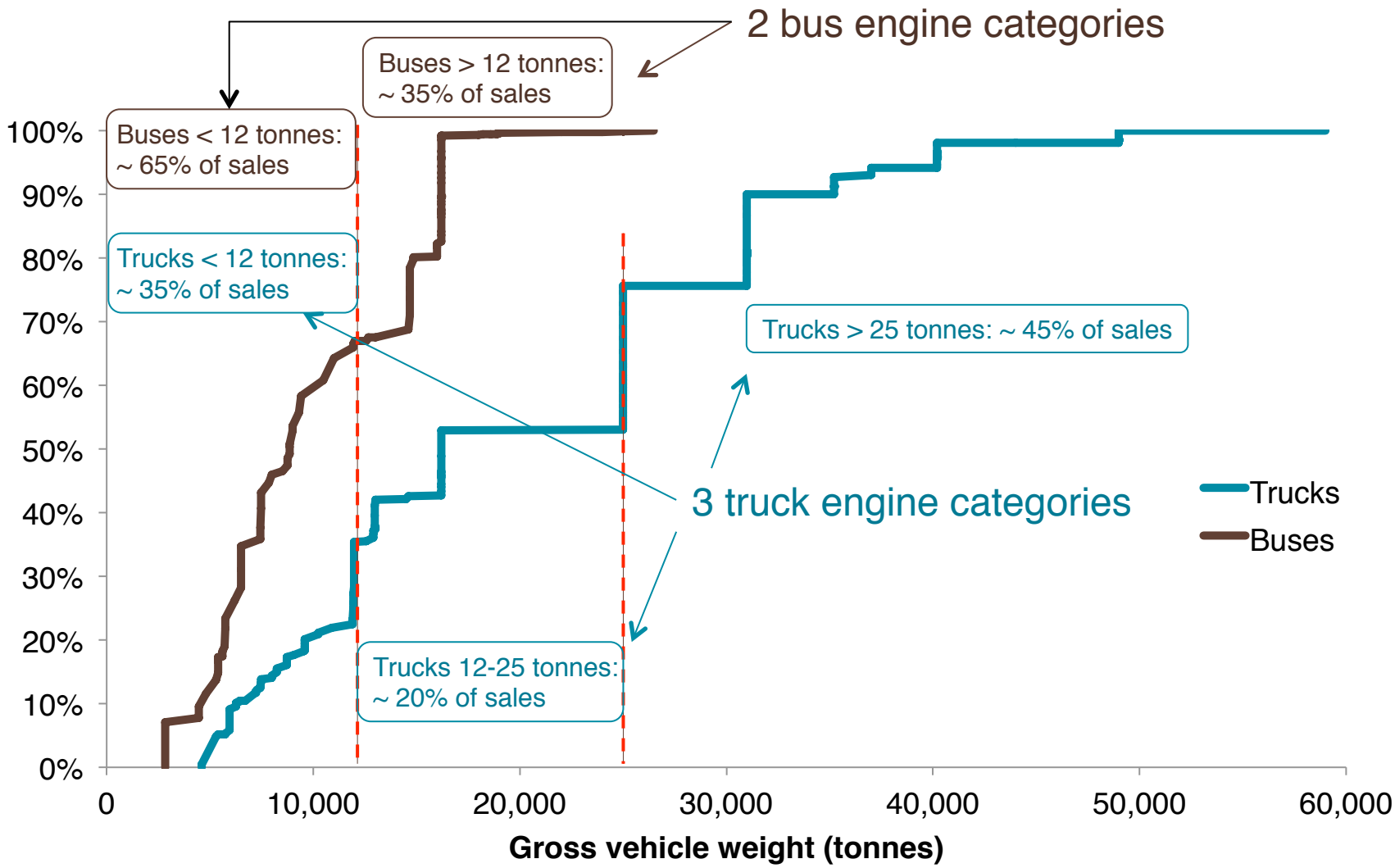
We are seeking feedback on this issue!

Advantage of grouping engines by intended vehicle class is the ability to use tailored engine test cycles



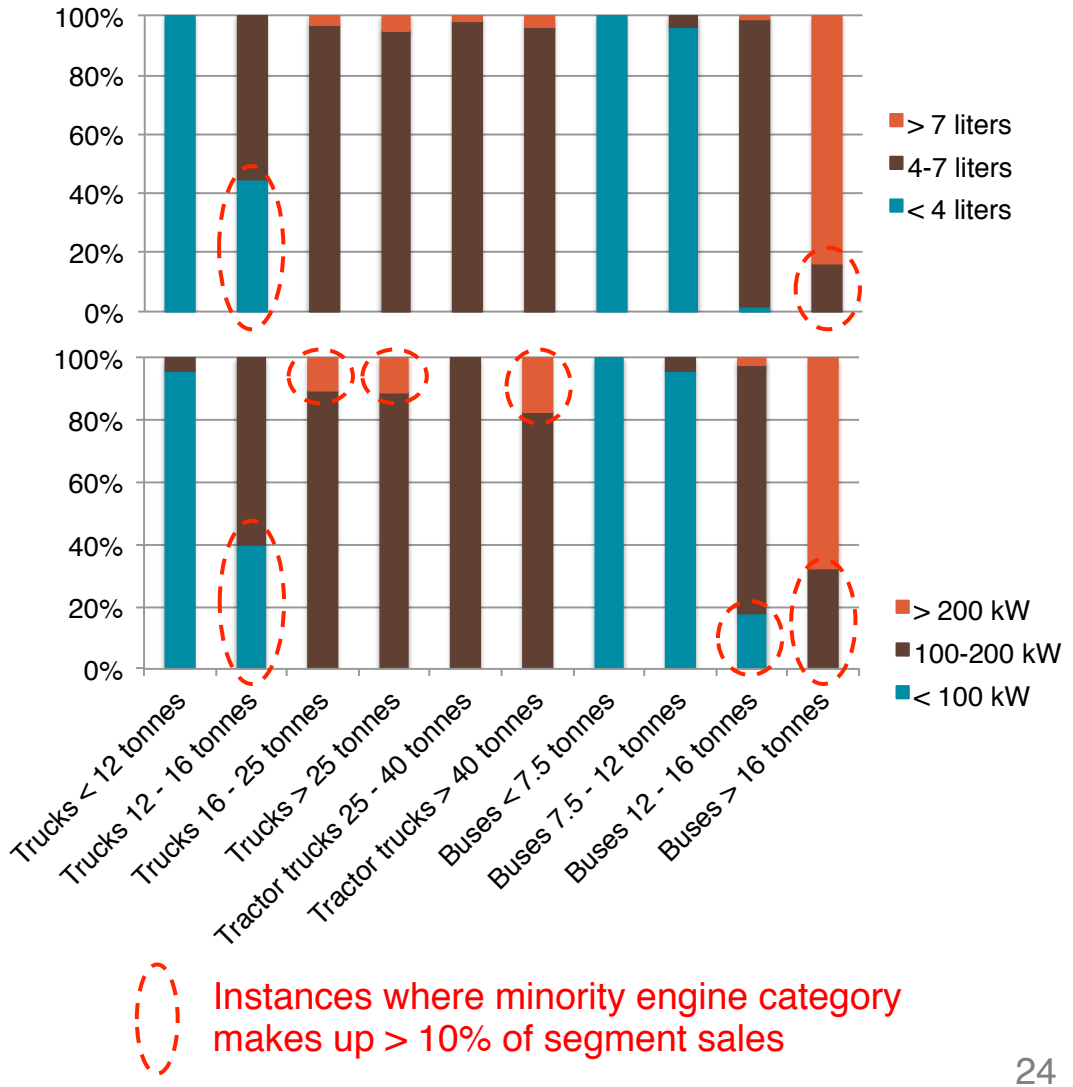
- BS6 requires transition to WHTC
- WHTC has 3 mini-cycles to represent range of HDV driving profiles: urban, rural, highway
- Opportunity to potentially weight these mini cycles based on the different sizes and types of HDVs (e.g., tractor trucks, urban delivery trucks, etc.) → **better representing real-world operations**

We propose 5 engine classes: 3 for truck engines and 2 for bus engines



Using engine parameters as a categorization method

- Figures show the breakdown of sales using the two engine parameter grouping approaches: by engine size (top) and power (bottom)
- Goal: have as homogeneous distributions of engine categories as possible (i.e., columns as close to fully solid as possible)
- Both result in similar distributions for the various vehicle classes, though, grouping by size yields more homogeneity in the columns
  - Grouping by size: 2 instances where the minority category has > 10% of segment sales
  - Grouping by power: 6 instances where the minority category has > 10% of segment sales
- Grouping engines by size is slightly preferable than grouping by power in this example
- However, this is likely more of a function of the choice of size and power bins in this particular example



Summary (1 of 2)

- HDVs make up the majority of fuel consumption and emissions from the on-road transportation sector
  - Without policy intervention, HDVs' percent contribution is projected to increase over time
- Development of HDV fuel efficiency and GHG regulations is happening in a number of countries and regions around the world
- Regulators in India are currently in the regulatory development process for HDV efficiency
- ICCT is doing research in a number of areas to support this rulemaking process

Summary (2 of 2)

- Indian HDV market is fairly consolidated, with the top 3 OEMs accounting for over 85% of total sales
- Distinguishing feature of Indian HDVs: smaller engines compared to other major markets (China, the EU, US)
- Smaller engines coupled with high degree of overloading → lower average speeds → engines and tires are biggest technology improvement areas in the near-term
- ICCT recommends engine-based standards as a first phase regulation along with policy action on tires
- Grouping engines into regulatory categories is prudent to mitigate the intrinsic efficiency advantage of larger engines
  - Categorizing according to intended vehicle class seems advantageous to doing so based on engine parameters (size or power) → ability to use engine test cycles that better match real-world operations

Thank you!

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- Working paper on test procedure options and recommendation that India pursue engine-based standards as a first-phase regulation: http://www.theicct.org/hdv-efficiency-test-procedures-trends-implications-india
- Position piece on engine technology cost-effectiveness: http://www.theicct.org/cost-effectiveness-engine-technologies-hdv-efficiency-regulation-india
- Working paper on the HDV sales market in India and options for an engine categorization scheme : http://theicct.org/market-analysis-heavy-duty-vehicles-india

Next webinar in the series

Auto Fuel Policy Roadmap for India – What Next?

- Date: September 16, 2015
- Time: 10 – 11 am
- Timezone: Asia/Kolkata (+ 5:30 GMT)
- Registration: https://attendee.gotowebinar.com/register/3669230099455729409