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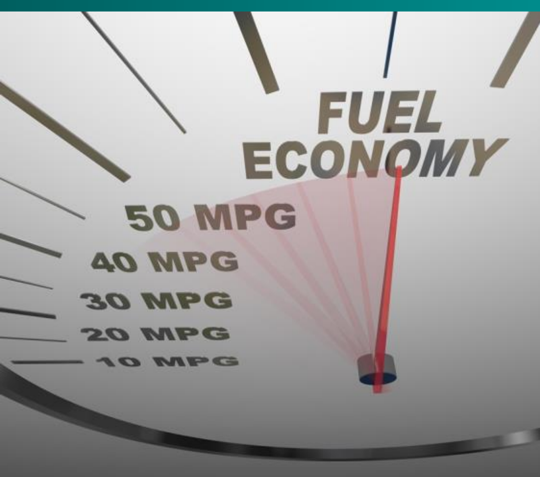
Performance of the Chinese New Vehicle Fleet Compared to Global Fuel Economy and Fuel Consumption Standards



Innovation Center for Energy and Transportation
iCET
能源与交通创新中心

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Table of Contents

Table of Figures

Acronyms

ACEA	European Car Manufacturers Association
CAAM	China Association of Automobile Manufacturers
CAFC	Corporate Average Fuel Consumption
CAFE	Corporate Average Fuel Economy
CATARC	China Automotive Technology and Research Center
EPA	Environmental Protection Agency
EU	European Union
JAMA	Japan Automobile Manufacturers Association
JV	Joint Venture
KAMA	Korean Automobile Manufacturers Association
MIIT	Ministry of Industry and Information Technology
MPG	Miles per Gallon
MPV	Multipurpose Vehicle
NDRC	National Development and Reform Commission
NEDC	New European Driving Cycle
NEV	New Energy Vehicle
NHTSA	National Highway Transport Safety Administration
SAC	Standardization Administration of China
SUV	Sports Utility Vehicle
UNFCCC	United Nations Framework Convention on Climate Change

1. Executive Summary

Context

- Fuel economy standards for passenger vehicles are important for countries that either manufacture these vehicles or import them, as they address a sector that is held responsible for 51% of global road transportation CO_2 emissions. Moreover, Standards have been proven to enable the reduction in corporate fuel consumption and result in substantial emissions reduction and related savings (ICCT & ClimateWorks, 2013).
- As national standards are being shaped and differ by their underpinning vehicle characteristics, vehicle attributes, and local market conditions, the ability to "evaluate or even mimic" different standards from one market to the other and compare with the existing ones – is an exciting research opportunity.
- As Chinese policy makers are considering options for standards design towards the Phase IV confirmed target (5L/100km), and drafting targets and paths beyond 2020, such research results have the potential of significantly contributing to China's new regulatory framework.

Purpose & method

- This study attempts to provide policy-makers with the tools to consider the adoption of footprint-based standards (recently adopted in the US), and evaluate the relative stringency of national standards against the EU and Japan's standards. First, this paper introduces selected global standards (namely US, EU, Japan, and China), outlines their historic development and evaluates their implementation success, and then the methodology and results are outlined.
- The study's analyses are based on officially available data of China's new vehicle fleet for the year 2011 (37 manufacturers and 426 vehicle models), and normalize global standards to relevant test methods and fuel consumption measurement methods (namely l/100km and CO_2/km).

China's fuel consumption standards stringency

- In terms of standards stringency, the study concludes that, if Chinese automakers only strive to meet the 2015 Chinese target as the maximum mandatory requirement, then none of the Chinese automakers would be able to meet either EU or Japanese 2015 standards. Most Chinese automakers could meet the 2012 US standards while few would be able to meet the US 2015 standards.
- However, since the Chinese fleet is much smaller than the US fleet in terms of vehicle size and power, the Chinese fleet average fuel consumption figure is still lower.
- Future outlook of standards stringency suggests that China's fuel economy standards would start to fall behind the US standards by 2015 on the equal footprint-basis as well as on the equal weight basis. While China's 2011 fleet GHG emission data was found to be quite close to the US 2012 standard line, China's 2015 GHG emission target was found far worse than that of the US 2015 target line.
- Given that many of the top 10 selling passenger vehicles in China are in fact joint-venture produced vehicles, it is clear that China can continue to demand better fuel consumption performance from its auto industry. The foreign partners of joint venture companies are the same companies that need to meet stringent Japanese and European weight-based standards.

Footprint-based standards evaluation for the case of China

- Our footprint-based analysis indicates that China's vehicle fleet has a very large range of fuel consumption for each footprint category – much larger than the range observed against weight-based standards. The range of fuel consumption is narrower at small footprints, and broader at larger footprints. This wide range of fuel consumption values could indicate several things regarding China vehicle fleet: First, there is a wide range of curb weights for each value of footprint; Second, there is possibly a wide variety of fuel economy technologies that are available for diverse types of models for each footprint category. Furthermore, the narrower range for some weights indicates that China's fuel consumption standard may have motived auto companies to produce vehicles conforming to a weight standard through the use of weight adjustment.
- Some key questions related to the above hypothesis are: would curb weights continue to be adjusted in order to meet weight-based fuel consumption targets while maintain the diversity of utility in the Chinese fleet? Would Chinese automakers be able to meet a standard scheme that is footprint based within a reasonable timeframe without compromising the diversity of utilities in the Chinese fleet? Insofar, it seems that due to the wide range of fuel consumption levels per each footprint unit, a footprint based standards would reshuffle vehicle manufacturing in China in the near term, and may therefore result in less diverse vehicle fleet and compromise consumer choices.
- The Chinese government needs to continue to force companies to improve the technology implemented in their vehicles and use more light-weighted materials, without merely shifting vehicles into other weight classes. It might be instructive to design a transitional footprint-based fuel economy reporting system alongside the current weigh-based standard that will certainly start to enforce light-weight technology to be incorporated into every weight class of vehicle.
- More careful and in-depth analyses are needed to make holistic recommendations regarding footprint vs. weight based standards. The design of footprint-based regulatory framework should rely on further studies tailored to China's vehicle fleet characteristics and trends, incorporating both quantitative and qualitative research approaches. Not less important is the process of standards design: stakeholders' involvement, appropriate testing that will reflect real-world China-specific driving conditions, and sound implementation plan that will include sufficient fiscal framework.

2. Introduction

Fuel economy standards for passenger vehicles are becoming a global trend, not only in major vehicle-producing countries, but even in vehicle importing countries. However, at this time, each fuel economy standard has different characteristics, is based on different vehicle attributes, validated by different testing method, and has different assumptions about the development of the automotive market. Studies have demonstrated that through the conversion and correlation of units and test cycles, different standards can be compared internationally at the fleet average level (An & Sauer, 2004),yet so far, very limited comparison have been performed at the detailed structure-level where the impacts of different standards on individual vehicle models are examined (ICCT, 2013).

While the average, aggregate level comparison can provide useful insight regarding the general developmental trend, it cannot demonstrate how national standards would impact individual vehicle models differently. Naturally, as global fuel economy standards move toward attribute-based approaches, such as using curb weight or footprint as surrogate variables, individual vehicle models will be influenced differently under different schemes.

Since standards are, among other reasons, meant to guide industrial development, they should not neglect industrial motivation. As a consequence to the variations in fuel consumption requirements between different markets, the international auto industry has room for gaming in vehicle models production by market requirements for minimizing costs implications. National standards' effectiveness is therefore not only important on the local level but also increasingly influential on the global level.

This study aims to compare the Chinese vehicle fleet average fuel consumption to the fuel economy and GHG/CO_2 emission standards of the US, European Union and Japan in order to gain an understanding of how the outcome of China's current fuel consumption standards compares to other standards on individual vehicle model bases. Furthermore, this study also seeks to exemplify how future fuel consumption standards could be improved to ensure efficient energy consumption and GHG/CO_2 emission savings while maintaining a healthy automotive market. In fulfillment of this study's goals, the Chinese new vehicle fleet of model year 2011, on which detailed official data is available, is being used.

3. An Overview of Global Fuel Economy and GHG Emission Standards

In this section, the details of four major approaches to the regulation of fuel economy, namely the US CAFE fuel economy standard, the EU GHG emission standards, the Japan "Top-Runner" fuel economy standard, and the Chinese mix of Minimum Energy Performance Standards and Corporate Average Fuel Consumption targets will be reviewed. This suction will therefore assist the reader in understanding the differences and similarities between standards prior to the detailed comparison analysis of Chinese new vehicle fleet data with these standards.

3.1 An introduction to the US CAFE Standards and GHG Emissions Limits

3.1.1 Importance

The US is home to the world's largest vehicle market, and third largest vehicle manufacture with vehicle output of over 12 million per year. Light-duty vehicles are responsible for 60% of US transportation-related petroleum use and GHG emissions (EPA, 2012).

The US is the first country to construct a standard framework for capping fuel consumption of vehicles. It is thus the most experienced country in the development, implementation, assessment and adjustments of fuel economy standards. The US is also pioneering the size-based corporate fuel economy standards, which success and relevancy is currently closely scrutinized by global experts.

3.1.2 Governance

The CAFE standard is governed by the National Highway Traffic and Safety Administration (NHTSA), while the US Environmental Protection Agency (EPA) has responsibility for administering and reporting fuel economy test procedures and setting GHG emissions standards.

The US CAFE and GHG Emissions Limits Governing Framework

	Vehicle Fuel Economy		Vehicle GHG Emissions
Authoritative Act/Ruling	National Energy Conservation Policy Act of 1975	the Clean Air Act (CAA) of 1975	US Supreme Court ruling, Energy Independence and Security Act of 2007
Agency	The Department of Transportation's National Highway Traffic and Safety Administration (NHTSA)	US Environmental Protection Agency (EPA)	
Responsibilities	Set CAFE standards for passenger vehicles and light trucks	Administrate and report fuel economy test procedures	Set, administrate and report GHG emission standards

3.1.3 History

In the wake of the 1973 oil crisis, the U.S. Congress passed the Energy Policy and Conservation Act of 1975 with the goal of reducing the country's dependence on foreign oil. Among other contributions, the act has established the world's first fuel economy standard, namely the Corporate Average Fuel Economy (CAFE). Later on in 2009, GHG Emissions Limits were added.

Both definitions of vehicle groups as well as their fuel consumption requirements have evolved. The CAFE scheme to this date maintains an important distinction between passenger cars and light trucks - each has its own standard. Under the initial regulation and in light of the limited role work-purpose vehicles played as oppose to private cars, passenger cars were classified as any four-wheeled vehicle not designed for off-road use that transports 10 people or fewer. Light trucks included four-wheeled vehicles that are designed for off-road operation or vehicles that weigh between 6,000 and 8,500 pounds (2,721.5-3,855.5kg) and have had physical features consistent with those of a truck.

The distinction between cars and light trucks have evolved and became increasingly fuzzy, in part because automakers have introduced crossover vehicles that combine mixed features of both cars and light trucks. Furthermore, light duty vehicles originally classified as trucks, such as minivans and sport utility vehicles (SUVs), have become extremely popular by private vehicle owners (Lipscy & Schipper, 2012).

Not only the definition of vehicle groups have evolved but also light trucks fuel economy requirement has gradually increased from the 2004 standard of 20.7 mpg to 21.0 mpg in 2005, 21.6 mpg in 2006, and 22.2 mpg by 2007 (Federal Register, 2003). Passenger cars CAFE standards averaged at 27.5 mile per gallon (mpg) however, remained unchanged between 1985 and 2007(DieselNet, 2013).

In the wake of increasing road safety issues[1] that are believed to partially result from increasing vehicle size differences, in April 2006 the National Highway Traffic and Safety Administration (NHTSA) adopted a reformed CAFE scheme for both passenger cars and light trucks that is based on vehicle size defined by vehicle's footprint (wheelbase length times track width[2]). A complicated formula correlating fuel economy targets based on vehicle size was applied (Federal Register, 2006). For the first three years (2008 through 2010) however, manufacturers could choose between vehicle size-based average fleet targets and the former method of average fleet targets of 22.5, 23.1, and 23.5 mpg, respectively for each consecutive year.

[1] The NHTSA recognized that the original CAFE method has resulted in down-weighting passenger vehicles and lighter-light trucks by manufacturers struggling to meet the requirements while still increasing the popular heavy car sales, was linked to the increase in road fatalities (NHTSA Final Regulatory Impact Analysis, March 2009).

[2] The wheelbase length is the distance between the center of the front axle and the center of the rear axle; Track width is the lateral distance between the centerline of the tires.

3.1.4 The standards and recent developments

In September 2009, the US Environmental Protection Administration (EPA) and Department of Transport (DoT) jointly proposed a regulation for GHG emission and corresponsive fuel economy for light duty vehicles. The proposal evolved into a light duty vehicle GHG Emission Standard falling from the 2009 level of 336 gCO_2e/mile to 250gCO_2e/mile for model year 2016, or equivalently, 26.4 mpg to 34.1 mpg.

Finally, in August of 2012, a GHG Emissions and Fuel Economy Standards for light duty vehicles was introduced. This regulation was aimed at reducing GHG emissions from 250 gCO_2e/mile in 2016 to 163 gCO_2e/mile in 2025, and increased fuel economy from 34.1 mpg in 2016 to 49.6 mpg in 2025, with vehicle footprint continuing to be the key regulatory attribute. 163 gCO_2e/mile should equate to 54.5 mpg, but it is expected that a portion of GHG emission reduction will be made through the elimination of air conditioner coolant leakage and use of alternative refrigerants, which are currently still not linked to fuel economy (NHTSA, 2010). Fuel improvements are considered exogenic factors to fuel economy standards.

Box 1: US CAFE Standards Emissions Standards Formulas

Under the reformed CAFE, corporate fuel economy target values are determined by the following equation: T = [1/a + (1/b - 1/a) e(x-c)/d/(1 + e(x-c)/d)]-1. Apart for a vehicle footprint value, the equation is also based on four parameters (a, b, c, d) adopted for each model year: T - fuel economy target (mpg), a - maximum fuel economy target (mpg), b - minimum fuel economy target (mpg), c - footprint value at which the fuel economy target is midway between a and b (ft2d), d - parameter defining the rate at which the value of targets decline from the largest to smallest values (ft2), e = 2.718, and x - footprint of the vehicle model (ft2). The resulting CAFE target curve was an elongated S-shape, with fuel economy targets decreasing from a to b as the footprint increases (NHTSA, 2012).

Under the emissions standards, light duty vehicles (passenger vehicles) corporate emissions target values are determined by the following equation: T=MIN(b ,MAX(a, c*footprint+d)). Apart for a vehicle footprint value, the equation is also based on four parameters (a, b, c, d) adopted for each model year: T - fuel economy target (mpg), a - maximum fuel economy target (mpg), b - minimum fuel economy target (mpg), c - footprint value at which the fuel economy target is midway between a and b (ft2d), d - parameter defining the rate at which the value of targets decline from the largest to smallest values (ft2). For *light trucks*, the formula is extended to include ceiling figures: T=MIN (MIN(b ,MAX(a, c*footprint+d), MIN(f, MAX(e, g*footprint+h)), where: e = Min CO_2Target for CO_2Ceiling Curve, f = Min CO_2Target for CO_2Ceiling Curve, g = Slope for CO_2Ceiling Curve, h = intercept for CO_2Ceiling Curve (NHTSA, 2012).

Figure 1: GHG emission targets for US new passenger cars, 2012-2025

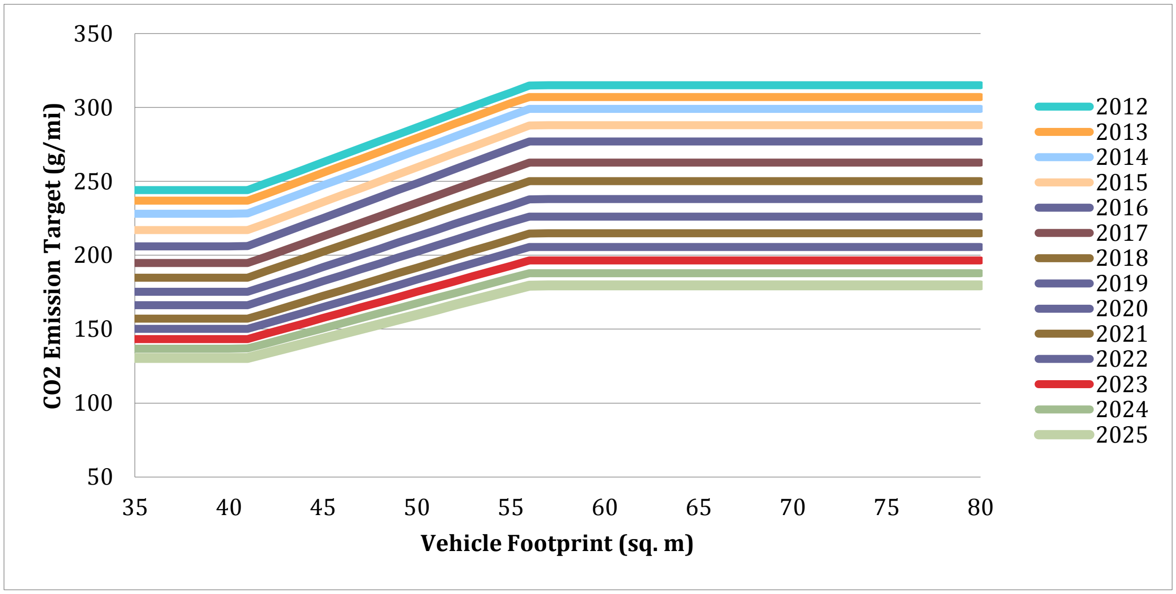


Figure 2: GHG emission targets for US new passenger cars, 2012-2025

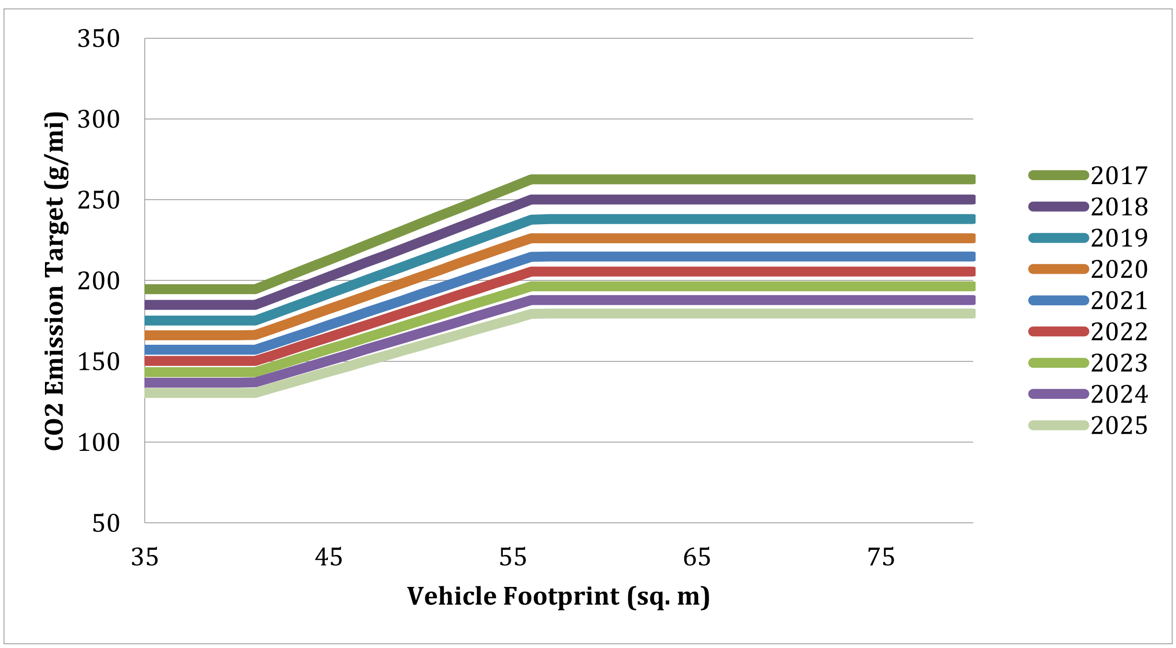


Figure 3: Fuel Economy targets for US new passenger cars, 2012-2025

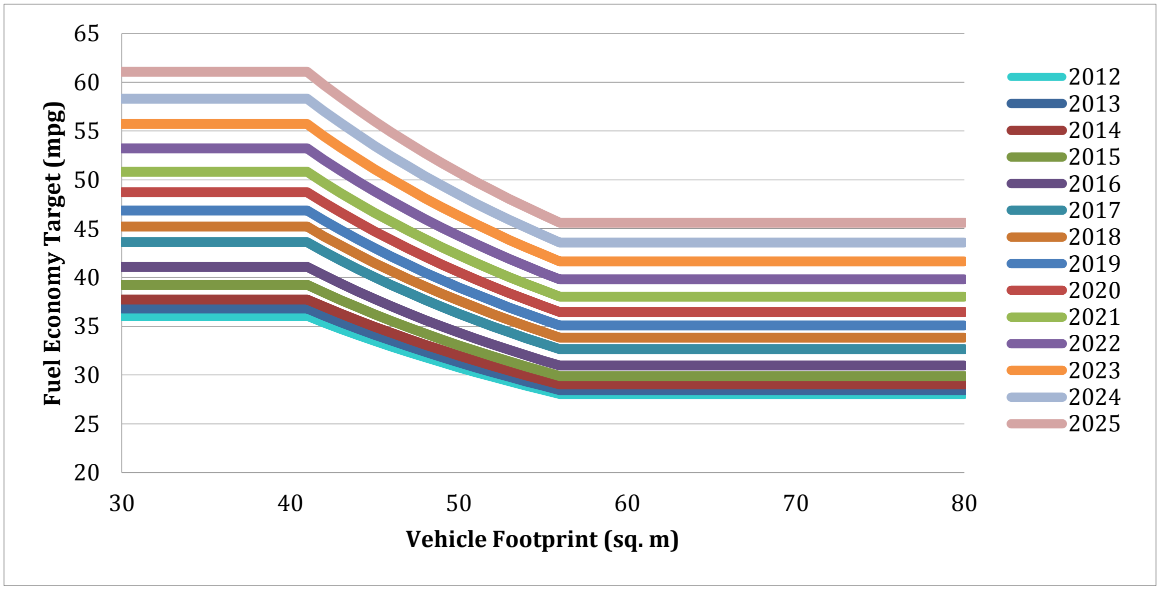
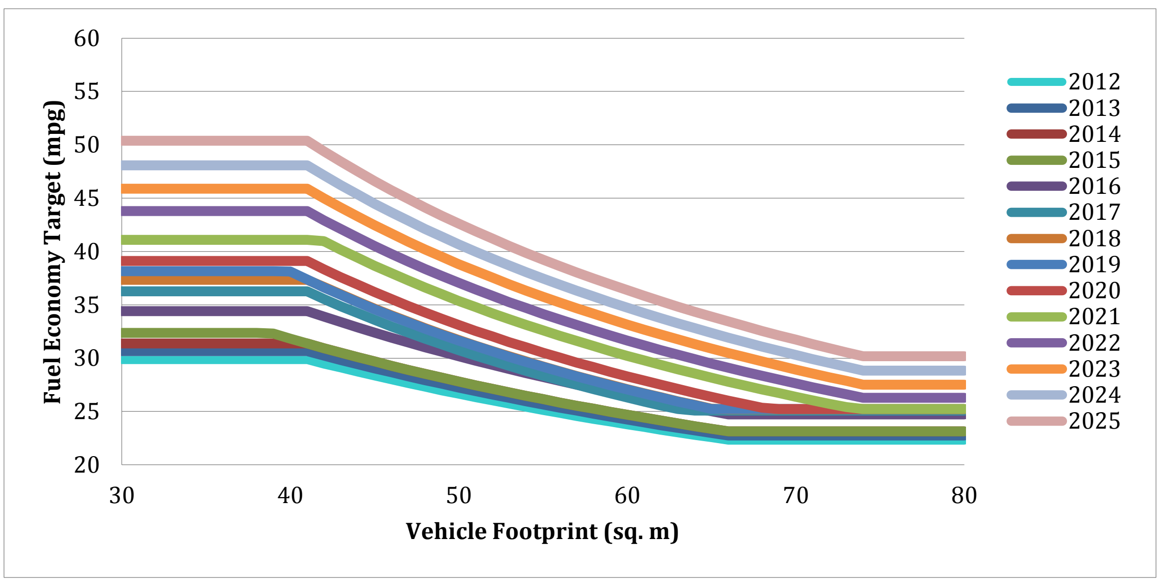


Figure 4: Fuel Economy targets for US new light trucks[3], 2012-2025



[3] Light Trucks, as defined by the US authorities, are any motor vehicle rated at 8,500 pounds GVWR or less which has a vehicle curb weight of 6,000 pounds or less and which has a basic vehicle frontal area of 45 square feet or less, which is: (i) Designed primarily for purposes of transportation of property or is a derivation of such a vehicle, or (ii) Designed primarily for transportation of persons and has a capacity of more than 12 persons, or (iii) Available with special features enabling off-street or off-highway operation and use (40 CFR 86.1803-01).

California was granted a waiver allowing it to implement its GHG standard for MYs 2009-2011 vehicles. However in light of the stringency of the new regulations, California decided to abandon its own 2012-2016 program and comply with the new federal program for the relevant model years.

The NHTS is currently drafting its 2022-2025 standards in more detail. As part of its preparatory work, a multi-stakeholder workshop was held last May (2013). Fuel economy and possible pathways for safe, affordable and coordinated vehicle-mass reduction were discussed (NHTSA, 2013). The outcomes of the workshop and subsequent potential regulatory updates are beyond the scope of this work.

3.1.5 Implementation Issues

The US CAFE fuel economy standards' enforcement is considered to be very advanced in comparison to other markets. Manufacturers of fleets that fail to meet their CAFE standards are liable for a penalty of $5.50 per every 1/10 of a mpg under the target value times the total volume of vehicles manufactured for the specific model year. From 1983 to 2004, manufacturers paid over $618 million in penalties (the majority of fines were borne by European manufacturers).

The fuel economy of vehicles is determined according to the Federal Test Procedure 75 (FTP-75) governed by the EPA by multiplying using a carbon balance equation measured over the dynamometer test. This CAFE figure is referred to as an unadjusted value, and is used for assessing compliance with the CAFE standards provided by the NHTSA. The unadjusted figures are often significantly different from the adjusted on-road values derived from tests conducted by the EPA (Department of Energy) in its compliance verification process. The adjusted figures are based not only on real-road data but also on a more representative test cycles of real-world driving behavior[4].

The standard scheme incentivizes compliance through an emission reduction compliance credit scheme. Credits can be maintained by manufacturers that introduce breakthrough achievements in areas such as: air-conditioning system technologies, flexible fuel vehicle deployment, off-cycle technologies, and zero-emission vehicles introduction. However, only some of the credits obtained through this scheme reflect real-road emission reduction (e.g. the air-conditioning credits) because most technologies' contribution is already being rewarded during the test cycle as it improves the fuel economy result. Furthermore, as NRDC stated recently: "(credits would) undermine the emissions benefits of the program and will have the unintended consequence of slowing the development of conventional cleaner vehicle emission reduction technologies into the fleet" (Niedermeyer, 2013).

[4] e.g. US06 for high-speed driving and SC03 for using air conditioning while driving.

3.1.6 Conclusion: Standard Highlights

The new US CAFE standard is unique globally in that it focuses on the footprint of vehicles rather than on their curb weight. The US EPA, as well as other global experts, argues that the footprint attribute has the highest ability to affect fuel economy while maintaining customer choice and road safety in the automotive market. The standard is developed so as to ensure that auto makers will not change the sizes of their vehicles in order to fall into lower fuel economy bins, as footprint involves modifying the chassis of a vehicle for changing the vehicle size, incurring high design manufacturing costs. As a result, manufacturers are typically incented to invest in the vehicle technology (both hardware, e.g. materials for weight reduction, and software e.g. improved engine performance) to improve efficiency.

The US GHG emissions targets are unique in that they aim at capturing the six types of greenhouse gas emissions, rather than only the particular well-recognized CO_2 which is being promoted through the EU vehicle emission standard. Furthermore, emissions resulted from air-conditioning for examples are included in the new tests added to the Federal Test Procedure (e.g. SC03 and US06).

Government documents as well as consumer labeling system puts great emphasize of potential benefits to consumers, mainly in the shape of economic saving over the usage of an efficient vehicle with low fuel consumption. The consumer angle is adding to the economic pillar of the sustainability of CAFE standards and extending its declared multi-stakeholder engagement assurance sustainability of the CAFE, could be evaluated to the case of China. However this is beyond the scope of this work.

3.2 An Introduction to EU CO_2 Emissions Standards

3.2.1 Importance

The EU is the second largest producer of vehicles in the world, with an annual output of about 17 million vehicles, and its vehicle sales take up 25% of global demand. Road transport is said to generate 20% of the EU's totalCO_2emissions, and have increased by over 35% since 1990 (European Commissions Climate Action, 2014).

Following its UNFCCC commitments, the EU have agreed to independently reduce its greenhouse gas emissions by 20% by 2020, compared with 1990 levels. As the road transport sector was identified as a second largest greenhouse gas emitting sector in the EU, the EU has initiated a road map for its vehicle emissions, and has pioneered the integration of CO_2emissions reductions in vehicles' governing regulatory framework. It is for these reasons that the EU vehicle standards are being closely followed by various countries (Official Journal of the European Union, 2009).

3.2.2 Governance

The EU vehicle GHG emissions standards were voluntary when first introduced by the European Commission in 1995, part of its broader vehicle efficiency strategy. The voluntary CO_2tailpipe emission reduction agreements scheme was based on agreements signed with vehicle associations as of 1998, which were representing of about 90% of the EU's annual vehicle sales. These three big vehicle associations were: the European Car Manufacturers Association (ACEA)[5], Japan Automobile Manufacturers Association (JAMA)[6], and Korean Automobile Manufacturers Association (KAMA)[7].

Only in April 2009 a binding CO_2standard came into force, when the European Parliament and the Council have signed and published EC 443/2009 regulation, adopted under the EC Treaty/Euratom Treaty and "whose publication is obligatory setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO_2emissions from light-duty vehicles" (Official Journal of the European Union, 2009).

The EU CO2 Governing Framework

	Vehicle CO_2Emissions	
Authoritative Act/Ruling	EC 443/2009 regulation, EC Treaty/Euratom Treaty	Regulation (EC) No 715/2007 Directive 2007/46/EC
Agency	European Parliament and the Council	Member States and Vehicle manufacturers
Responsibilities	Set emissions standards for passenger vehicles and light-commercial vehicles	Administrate and report CO_2emissions test procedures and reporting

3.2.3 History

The European Union first considered fuel consumption from the perspective of fuel, but later on changed its strategy - in light of its commitments under the Kyoto Protocol of the UNFCCC - to regulate carbon dioxide emissions from vehicles. This regulation attribute was accepted by experts as it is based on the relatively consistent relationship between the combustion of fuels such as gasoline and diesel, and carbon dioxide emissions. When labeling vehicles on the market, individual member states still have varying reporting units, including gCO_2/km and L fuel/100 km.

A large part of the early success in increasing fleet-average vehicle fuel economy was due to vehicle dieselization. This trend occurred in Europe due to the inherent efficiencies of diesel engines and higher energy content of diesel. However, it has been argued that dieselization of the passenger vehicle fleet may not result insignificant overall decrease in vehicular GHG emissions. Schipper and Fulton (2008) noted that there have

[5]ACEA consists of: BMW, DaimlerChrysler, Fiat, Ford, GM, Porsche, PSA Peugeot Citroën, Renault, VW Group.
[6]JAMA consists of: Daihatsu, Honda, Isuzu, Mazda, Mitsubishi, Nissan, Subaru, Suzuki, Toyota.
[7]KAMA consists of: Daewoo, Hyundai, Kia, Ssangyong.

only been marginal energy and CO_2emission savings as a result of this large shift to diesel engines, particularly because the vehicles tend to be heavier, and they tend to be driven more than gasoline vehicles because of lower diesel prices and better fuel economy.

In 1995 the EU Commission has adopted a Community Strategy for reducing CO_2emissions from cars, targeting 120g CO_2/km by 2012. The strategy was based on three pillars: voluntary commitments for emissions reduction made by vehicle manufacturers, improvements in consumer information and the promotion of fuel-efficient cars through fiscal measurements. Each Auto association had sign a voluntary agreement in consistence with the EU strategy: in 1998 the ACEA agreed to an average vehicle emissions target of 140 gCO_2/km by 2008, while in 1999 JAM and KAMA have agreed to target the same emission factor by 2009.

The EU Commission have further created a well-established process of measuring and monitoring registered vehicles' CO_2 emissions since its June 2000 Decision No 1753/2000/EC when a scheme to monitor the average specific emissions of CO_2 from new passenger cars was established. However in Feb 2007 the EU Commission recognized that although progress had been made towards the target of 140gCO_2/km by 2008/2009, the Community objective of 120gCO_2/km would not be met by 2012 in the absence of additional measures.

To further strengthen its regulation on automakers, on 23 April 2009 the EU adopted Regulation [EC] No. 443/2009 of the European Parliament and of the Council stipulating that by 2012, the fleet average to be achieved by all cars registered in the EU would be 130 gCO_2/km (and a desired community target of 120 gCO_2/km). Furthermore, additional 10 gCO_2/km in savings were to be achieved on the basis of a community-integrated approach through the implementation of clean fuels and more efficient technologies[8].

Beyond the binding target, the EU Commission has also made some important notes in its 2009 declaration. For instance, it noted that funds for developing appropriate technologies and creating an adequate fiscal framework are in need. Incentives for car manufactures to develop appropriate technologies for achieving the target would also create jobs and assist in maintaining the European industry maintain its "long-term competitiveness"(Official Journal of the European Union, 2009). A specific technology type of importance was stated to be propulsion.

The EU standard declaration of 2009 also mentions that in order to maintain vehicle models diversity it is important to create a linear utility-based standard. Since mass data was stated to be readily available and to provide a correlation with present emissions - it

[8] E.g.: i) use of biofuels; ii) gear shifting reminders; iii) efficient air conditioners; iv) low rolling resistance tires; v) tire pressure monitoring; and vi) a limit curve for light commercial vehicles.

was chosen as the basis for the initial binding target. The EU Parliament and Council however stated in their standard declaration that the Commissions should gather and assess data on alternative utilities, such as footprint, by 2014.

The EU also emphasized the importance of manufacturers' flexibility to meet the target, based on their fleet characteristics and size. Therefore, an average fleet emission requirement was meant to be phased in between 2012 and 2015. Furthermore, manufacturers were allowed to form a pool for jointly meeting a pool-based target (with some limitations e.g. agreement should not exceed 5 years). Niche manufacturers faced a 25% lower target from their specific 2007-based average emissions, in recognition of their limited resources.

3.2.4 The Standards and Its Recent Developments

Vehicles in the EU are tested according to the New European Driving Cycle (NEDC), and emissions are reported in gCO_2/km. The national sales-weighted average CO_2emission targets for new vehicles in 2015 and 2020 are 130 gCO_2/km and 95 gCO_2/km, respectively. These averages are meant to be achieved by forcing manufacturers to sell fleets that meet a weight-based limit along a linear curve standard.

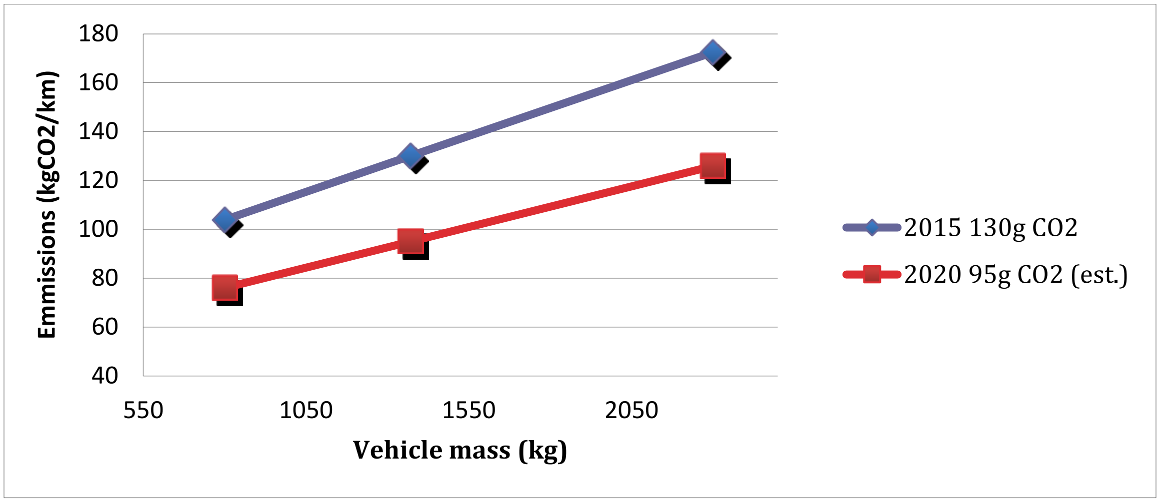
Box 2: EU CO_2Standards Formula

The emission targets for vehicles between 2012 and 2015 are determined according to the formula: $CO_2 = 130 + a \text{ x } (M\text{-}M_0)$, where M is the mass of the vehicle in kilograms, M_0 is 1372 kg (for calendar year 2012-2015), and a is 0.0457. The target for 2016 will be set where M_0 represent the average weight of the new vehicle fleet registered between January 2013 and December 2015, while a remains the same. Finally, the formula of the targets for 2020 will be estimated where M_0 is the average weight of the new vehicle fleet registered between January 2017 and December 2019, and a equals 0.0333.

During the regulation's phase-in period, between 2012 and 2015, only a percentage of a new passenger vehicle fleet is required to meet the annual target: in 2012 only 65%, in 2013 only 75%, in 2014 85% and in 2015 onward 100% corporate compliance with the target is required(Official Journal of the European Union, 2009).

On 24 April 2013, the Environment Committee of the European Parliament voted on a regulatory proposal to define CO_2 emission targets for new passenger cars beginning in 2020. The 95 g/km target for 2020 was confirmed by the Parliament. However, instead of just using mass as the underlying index parameter—heavier a car, the higher the CO_2 emission level allowed—the Parliament added vehicle size as an alternative parameter. Beginning in 2020, manufacturers can choose to comply by making use of mass or size (measured as 'footprint' of a vehicle) as the index parameter. In terms of fuel consumption, the 2020 target equates to approximately 4.1 l/100 km of petrol or 3.6 l/100 km of diesel. For the 2025 target, the European Parliament defined an indicative range of 68–78 g/km (TransportPolicy, 2014).

Figure 5: Weight-based GHG 2015 & 2025 targets curves for EU registered vehicles



3.2.5 Implementation Issues

To date, the voluntary phase of the EU vehicle emissions standards has demonstrated significant CO_2 emission reductions, and culminated in a 5% drop in average emissions in 2009. However, despite the considerable success derived from the auto associations' engagement, none of the three associations was able to reach the 140 g/km target by its target year. In 2008 ACEA reached an average of 152.3 CO_2/km, and in 2009 JAMA and KAMA reached 142.6 and 141.8 respectively.

During the more stringent binding targets phase, it is recognized that actual averages achieved by manufacturers will be affected by the inclusion of incentives for manufacturers. For that reason, incentives for producing alternative fuel vehicles, such as electric vehicles, were introduced through the use of a super-credit system (Article 5 of the Regulation). The credit scheme stipulates that each new passenger car with specific emissions of CO_2 less than 50g CO_2/km should be counted as 3.5 cars in 2012; 3.5 cars in 2013; 2.5 cars in 2014; 1.5 cars in 2015 and 1 car in 2016 and beyond in the average emissions of the company that manufactures them. The European Commission has proposed to reintroduce the system after 2015, where vehicles with emissions below 35 g CO_2/km would be counted as 1.3 cars from 2020 until 2023 (Official Journal of the European Union, 2009).

Other regulatory tools for incentivizing compliance are mainly: Pooling, where manufacturers sign an agreement of up to five years for jointly submitting their emissions scores and have joint compliance targets; Manufacturers of limited fleet size may apply for targets reduction benefits; Manufacturers may apply for eco-innovation credits (limited to 7

gCO_2/km equivalent) for technologies that are not yet accounted for in the EU test cycle, e.g. efficient lights (Official Journal of the European Union, 2009).

Further to the above incentives, the EU has also introduced penalties. Manufacturers that have introduced a fleet that excessed the allowed average are forced to pay an excess emissions premium that is growing over time. Between 2012 and 2018 corporate penalties are €5 per vehicle for the first g/km of CO_2, €15 for the second gram, €25 for the third gram, and €95 from the fourth gram onward; as of 2019, manufacturers will pay €95 for each g/km exceeding the target. Further to the above penalties, the EU Commissions has suggested that the implementing countries will take further measurements in order to ensure compliance and effective promotion of the long-term targets of this emissions regulation(Official Journal of the European Union, 2009).

3.2.6 Conclusion: Standards highlight

The EU standards is unique in three main areas: first, it is the only binding standards that is based on actual and specific emission criteria (namely, CO_2emission reduction) which is closely linked to the region's obligations for global climate action and its subsequent independent targets; it is the only binding standard on a regional (or multi-national) level and as such it has a potential to greatly influence and be influenced by car manufacturers (demonstrated by manufacturers associations' active engagement at the voluntary stage and the range of incentives provided to them during the binding phase); and in its consumer involvement approach which involves straight-forward indication of the subsequences of driving inefficiently by providing emission related information which is consistent with national and regional targets.

Another worthy element of the EU system is its particular statements on issues to be further explored for ensuring an effective standard mechanism, in particular its declared required process for alternative vehicle utilities assessment (e.g. footprint-based mechanism).

3.3 An Introduction to Japan's Fuel Economy Standard

3.3.1 Importance

Japan is historically known for its light and highly efficient vehicle fleet: already in 2008 the average passenger vehicle CO2 emissions amounted only 141 gCO2/km, some 7%below the European Union average (TransportPolicy, 2013). However, as Japan's road transportation still accounts for over 15% of the country's total CO2emissions (Boden & Blasing, 2012), its fuel economy standards and innovative technology promotion program are of global value (Lipscy & Schipper, 2012).

Japan's auto industry of significant national importance not only for its emissions but also as it is accountable for 37% of Japan's total machinery value, 17% of its total manufacturing value and 9% of its workforce[9]. Japan has been among world' top three vehicles manufactures for nearly a decade, making it an influential global leader in terms of vehicle emissions and vehicle industry development.

In Japan's 2006 "Outline of Economic Growth Strategy" (Council for Fiscal and Economic Reforms) and the "New National Energy Strategy" (Ministry of Economy, Trade and Industry) two transportation related targets were set: improving energy consumption efficiency by 30% and reducing the transport sector's oil dependency to about 80% by 2030. These announcements have increased the importance, stringency and range of fuel economy standards to include heavy duty vehicles for example (The Automobile Evaluation Standard Subcommittee, 2007).

3.3.2 Governance

Japan's Law Concerning the Rational Use of Energy (Energy Conservation Law) set the foundation for Japan's fuel economy regulations already in 1979. It has authorized the Ministry of International Trade and Industry (MITI) to establish fuel economy standards for passenger vehicles. The first fuel economy for gasoline passenger vehicle was approved later that year.

In 1999, revisions to Section 6 of the law established the Top Runner Program, an energy efficiency system applicable to automobiles and certain types of machinery, under the authority of the Ministry of Economy, Trade and Industry (METI). The Top Runner has become the basis for Japan's new benchmark for annual fuel economy standards.

Japan's Fuel Economy Governing Framework

	Vehicle Fuel Economy		
Authoritative Act/Ruling	Energy Conservation Law	Top Runner	
Agency	Ministry of International Trade and Industry (MITI)	Ministry of Economy, Trade and Industry (METI)	Ministry of Land, Infrastructure and Transport (MLIT)
Responsibilities	Set fuel economy standards for passenger vehicles and light-commercial vehicles	Set the standards benchmark	Administrate and report fuel economy test procedures and reporting

[9] http://www.jama-english.jp/about/intro.html

3.3.3 History

Japan's first fuel economy standard was introduced in 1979, targeting 1985model year gasoline vehicles. In 1993 new targets were set for vehicles of model year 2000. In 1999 the Top Runner concept was introduced to the fuel economy regulatory scheme, setting a benchmark for vehicles standards according to the best-of-class (weight class) fuel consumption achievements.

The resulted average target of the first Top Runner round was of about 15.1 L/km by 2010. In 2007, a target of 16.8 L/km was set for 2015. In 2011a target of 20.3 km/L was set for 2020.

3.3.4 The standards and recent developments

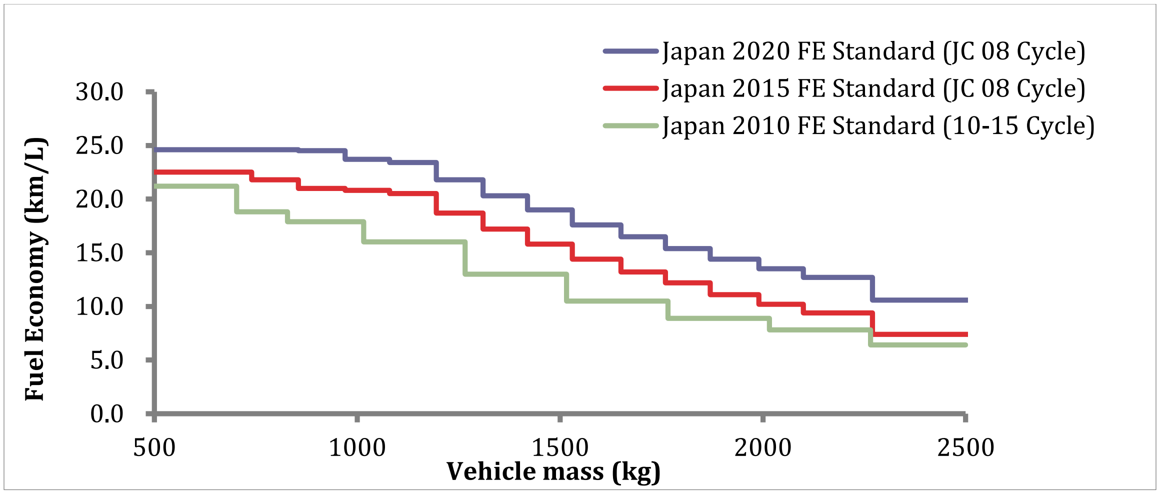
The Japanese fuel economy standard is a weight-based standard that breaks the range of passenger vehicles up into weight bins and is defined by the range enabled for each unit of fuel (km per liter) as oppose to the US fuel economy standard.

The standard requires that the harmonic average fuel efficiency of vehicles sold by each manufacturer in the target year is not lower than the fuel economy values set for that manufacturer. Each manufacturer's target is set according to the average standards of its models, where each model has a target set according to its weight category and the weight of each model standards is set according to the number of vehicles actually shipped.

The weight-bins standards are updated according to the "Top Runner" system, where the most efficient vehicles of the previous term, for each weight group, become the standard of the next term, thus ensuring that vehicles become increasingly efficient over time.

Japan's 2015 targets apply to most type-approved vehicles below 3.5 ton (excluding LPG vehicles and none-gasoline/diesel/LPG fueled vehicles), and targets an average fuel economy of 16.8 km/L. The 2015 standards target represents a 23.5% increase over 2004 levels (13.6 km/L). The 2020 target sets the average fuel economy of Japan's vehicles at 20.3 km/L, with an increase of about 24% over 2009 levels.

Figure 6: Weight bin-based targets for Japanese new passenger vehicles



Japan's 2015 and 2020 fuel consumption testing is performed over the JC08 cycle, which fully replaces the 10-15 mode test as of 2010. A weighted harmonic average, which is the reciprocal of the weighted average of reciprocals of the measured data, is based on a combination of cold start and warm start test runs, which are weighted 0.25 and 0.75 respectively. The JC08 is allowing for an increase of about 9% in standard stringency, since it includes a higher average speed, quicker acceleration, and a cold start phase.

3.3.5 Implementation issues

Japan's fuel economy standards were traditionally achievable by manufacturers – they were set long enough in advance and have been at levels and slopes that suited the market (ICCT, June 2013). For instance, vehicle of model year 2005 have been in line with the 2010 standards, and model year 2010 vehicles were well around the coming 2015 target.

Nevertheless, Japan's standards are accompanied by financial incentives: purchase vehicle tax relieves on vehicles that go beyond the required standard and progressive tax levies on vehicles that do not comply with the standard. Penalties for not meeting the targets, on the other hand, are considered very low.

The 2020 standards announced in 2011 were also criticized for being too loose, easily achievable by recent years' models fuel consumption performance improvements.

3.3.6 Conclusion: Standards highlights

Japan's fuel economy offers several unique angles for designing, testing and enforcing standards: first, the measurement of range rather than liters is an illustration of a different consumer-facing regulation than that of the US and EU, which represents the travel distance as the value of money invested on the pump. A study of the implications such a standards and representative labeling to have on Chinese consumers are beyond the scope of this work.

Second, the Top Runner concept which shifts the powers to set the fuel economy target to the market, is an innovative way for engaging and incentivizing the proactive participation of automakers and technology providers in the fuel economy regulatory framework. This method seems to have been working well for the case of Japan, however the readiness of Chinese automaker for participating in such a framework is beyond the scope of this work.

Third, Japan's recent test cycle changes demonstrate well the importance of testing in increasing the effectiveness of the fuel economy standards. Again, tests amylases are beyond the scope of this work.

Last, Japans incentive scheme seems to work well in promoting fuel economy uptake. A more thorough study of the relative impacts of each factor on the standards uptake is however in order for better supporting this contention.

3.4 An Introduction to China's Fuel Consumption Standards

3.4.1 Importance

Road transport is estimated to be responsible for as much as 22% of city CO2 emissions, and 50% of city center air pollution. Private vehicle ownership increased by over 9% annually in the past decade, already making the world's most rapidly developing vehicle market. Furthermore, the vehicle market is a major driver of national fuel consumption, which has already reached export dependency and of which the transport sector account for about 60%. Vehicle fuel consumption standards therefore have the potential of greatly mitigating China's GHG emissions, improving air quality and reducing fuel dependency. Since 2004 the Chinese government has been designing, updating and assessing its CAFC Standards and automakers are planning their implementation strategies.

In the midst of China's rapid economic development, China's automotive industry has undergone phenomenal growth. In 2009, China manufactured and sold more than 10 million cars, making it the top automotive manufacturer in the world. In 2013, China manufactured and sold almost 18 million cars (Qiu, 2014), maintaining its position as the world leader. As world largest and fastest growing auto market, China's shift towards more efficient fuel consumption standards, these standards in turn have the potential of shaping global future mobility.

3.4.2 Governance

China's fuel consumption standards for passenger vehicles were adopted in 2004 (National Standard GB 19578-2004). The standard initially established two phase that were to be phased in between 2005-2006 and 2008-2009 respectively. The new phase of fuel economy for passenger vehicle standard (GB27999-2011) was issued in December 2011, which introduces "Corporate Average Fuel Consumption" (CAFC) instead of the single car fuel consumption limitation

The China Automotive Technology and Research Center (CATARC), a semi-governmental organization, drafted the regulations during a two-year process involving multiple agencies of the Chinese government. The National Technical Committee of Auto Standardization was responsible for standards assessment and approval, while Standardization Administration of China (SAC) have authorized the standard.

The standards' implementation is under the responsibility of different government organs, as illustrated in the below table.

China's Fuel Economy Governing Framework

	Vehicle Fuel Economy			
Agency	MIIT	MOT	SAC	CATARC
Responsibilities	Fuel consumption management for passenger and commercial vehicle	Fuel consumption management for operating vehicle (meant for commercial use)	Fuel economy standards authorization.	Fuel economy standards development

3.4.3 History

In 2004, China released the "Passenger Vehicle Fuel Consumption Limit" (GB19578-2004). This national standard aimed to promote the development and application of energy efficient technologies for motor vehicles, increase the fuel economy level of passenger vehicles, control the amount of fuel burned by passenger vehicles, and mitigate the energy and environmental problems associated with fuel consumption. The law marked China's first compulsory national fuel consumption standard.

In 2005 and 2008 China enacted two phases of the "Passenger Vehicle Fuel Consumption Limit" standard. Beginning on January 1, 2008 and January 1, 2009, newly approved vehicles and vehicles in production must have met their respective fuel consumption limits for the second phase.

The 2011 "Passenger Vehicle Fuel Consumption Assessment Methods and Targets," developed by CATARC (following multi-stakeholder engagement drafting process) which serves as the third phase of the "Passenger Vehicle Fuel Consumption Limit" and formally enacted in 2011 and went into effect in 2012, allowing manufacturers until 2015 to fully meet the CAFC Target.

The third phase of the fuel consumption limits continues to use the fuel consumption assessment methods of the second phase and incorporate concepts including "Corporate Average Fuel Consumption" (CAFC) and the "Corporate Average Fuel Consumption Targets." Based on the fuel consumption of each passenger vehicle model and the model's corresponding number of vehicles produced, the fuel consumption limits will require manufacturers to CAFC Targets while still allowing the industry to maintain product diversity.

By 2015, China's vehicle standards are aimed at bringing the Chinese average vehicle to 6.9L/km, and by 2020 to 5L/km (however the path for achieving the goals of the fourth phase is still under design).

3.4.4 The standard and recent developments

The Chinese fuel consumption standard is a minimum energy performance standard which separates the entire market of new vehicle into 16 weight classes (or bins). The standard makes a differentiation between two types of vehicles; each has its own by-class targets: manual transmissions vehicles and automated transmissions vehicles (or vehicles with 3 seats rows and above).

Currently, the smallest weight class of manual vehicles is defined as below 750kg with 5.2L/100km requirement (for 2015), further 8 classes are below 1660kg with up to 8.1L/100km, and additional 7 classes are placed above these weights with a maximum consumption of 11.5L/100km. For automated and three seat-rows vehicles the classes are similar yet fuel consumption requirements are generally less stringent (5.6L/100km for lowest class, 8.4L/100km for 1660kg, and up to 11.9L/100km).

After the Phase II fuel consumption standard expired at the end of 2011, China began to phase in its Phase III fuel consumption standard, which is not only a mandatory standard for specific vehicles (based on the Phase II standard), but also a target-based corporate average fuel consumption standard based on weight bins. The standard aims for China's new passenger vehicle fleet in 2015 to achieve a fleet average fuel consumption of 6.9 l/100km.

The third phase of standards will continue to employ an assessment method based on vehicle curb weight, but certain areas have been adjusted for more flexible implementation. Using the second phase requirements as a baseline, passenger vehicles must also adhere to a new assessment criterion where fuel consumption targets are based on vehicle model. The third phase will also introduce the concepts of "Corporate Average Fuel Consumption" (CAFC) and "Corporate Average Fuel Consumption Targets", and set CAFC targets for automotive manufacturers based on their vehicle model fuel consumption targets and corresponding quantities of vehicles produced and sold. Automotive manufacturers can then flexibly adjust their mix of products while still maintaining product diversity.

The CAFC uses vehicle model, year, and annual sales to calculate a weighted average for fuel consumption based on the New European Driving Cycle (NEDC), as shown in the formula below:

$$\text{CAFC} = \frac{\sum_{i}^{N} FC_i \times V_i}{\sum_{i}^{N} V_i}$$

N: the vehicle model code number
FC: fuel consumption of the "i"th model
V: annual sales of the "i"th model

The CAFC Target is based on individual vehicle fuel consumption targets, using the quantity of annual sales of each model to calculate a weighted average. See the formula below:

$$T_{CAFC} = \frac{\sum_{i}^{N} T_i \times V_i}{\sum_{i}^{N} V_i}$$

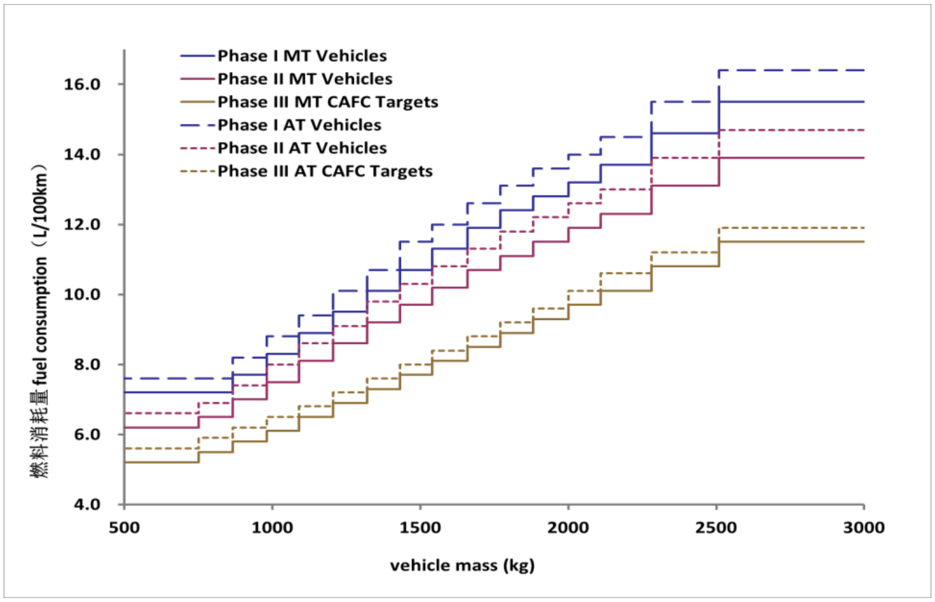
N: the vehicle model code number
FC: fuel consumption of the "i"th model
V: annual sales of the "i"th model

These fuel consumption targets also account for the time that vehicle manufacturers need for product planning, technology upgrades, and developing new vehicle models. The CAFC requirement was enacted in 2012 and allows automotive manufacturers until 2015 to gradually reduce their fuel consumption levels and meet the target.

The third phase of standards also sets forth a production consistency requirement, requiring manufacturers to prove that the vehicles they produce are consistent with the approved models. If a manufacturer fails to meet the consistency requirement, the approval for that particular model will be repealed. This requirement aims to increase the effectiveness of the fuel economy standard.

As announced in March 2013, auto manufacturers are required to publish their final entire annual fleet fuel consumptions scores and sales as well as the average values by the 1st of February each following year, and publish their half-annual figures by the 1st of August each year. MIIT then publically announces the annual CAFC results figures, after confirming their credibility, by June 1st each following year.

Figure 7: China weight-based new vehicle fuel consumption standards (Phases I and II) and Phase III targets for automatic and manual transmission vehicles



3.4.5 Implementation Issues

By the time this second binding target was drafted, the implementation of the first two phases showed successful reduction of some 11.5% in average fuel consumption. Between the first standard and its subsequent third phase release, three "Limits and Measurement Methods" standards were instructed (all of which during 2005). During the 1st FYP (by 2010) JVs were making remarkable fuel consumption reductions while in the last couple of years domestic brands have been contributing much to the successful implementation of the standard by making substantial FC reductions.

In 2009, the national level stood at 7.78L/100km, but by 2010 it had risen 0.6% to 7.83L/100km. From the distribution of car models sold in 2009 and 2010, it is evident that the proportion of new cars sold with fuel efficiencies below 8.0L/100km stood at roughly 70%, but by 2010 this proportion had dropped down to roughly 60%. This slight change occurred because in 2010 fewer small engine displacements, low fuel consuming cars were produced, while larger engine displacement, high fuel consuming cars were produced.

This trend of both demand and supply of high fuel consumption vehicles may impede the overall success in creating a diverse vehicle market with low average fuel consumption; instead, a market of limited models that comprise two fuel consumption extremes vehicle types may be introduced, creating road safety risks and enable the continues production of high consuming heavy-weight vehicles.

Therefore, even should manufacturers would continue to meet their corporate average target, the availability of diverse low fuel consumption vehicles may be relatively low. Standards should thus take into account potential gaming is vehicle weight by auto manufacturers and adequate standards curves should be considered, including standards with other vehicle attributes.

China's third phase of the "Passenger Vehicle Fuel Consumption Limit", in comparison to the first two phases and although binding, is said to better encourage an increase in the fuel economy levels of all vehicle models: corporations can flexibly adjust their product mixes to meet the standard, giving them incentive to increase their overall fuel economy.

Government ministries control the average fuel consumption level of each corporation and the average fuel consumption level of the entire country, thereby strengthening energy conservation management of the automotive industry. This new standard slowly brings the system of automotive energy conservation standards one step closer to completion by promoting low energy-consuming vehicles, reducing the average size and weight of Chinese-produce vehicles, and raising the Chinese automotive industry's overall fuel economy level.

There are however concerns over the credibility of data provided to the authorities: the test cycle (NEDC) reflectiveness of China's real-world driving conditions is challenged, tests results based on specific vehicles selected by manufacturers (with the clear aim of passing the test) may not be reflective of actual on-market models, and tests' quality and independency necessary for providing reliable figures has been questioned. These factors, however, are beyond the scope of this work. In this study, both 2011 official data and NEDC cycle are taken as a given.

3.4.6 Conclusion: Standard highlights

China's fuel economy standards are rapidly evolving, showcasing close governmental attention and adequate framework development. Implementation, however, is challenged by both methodologies' and participation sufficiency. Figures' credibility is therefore challenged – making standards stringency and efficiency assessment of limited real-world value.

China has the potential of shaping global standards, as it is home to the world fastest growing vehicle market. It also has the advantage of a late-participant, in that it can evaluate and adopt standards that have been tested elsewhere. As China's driving, preferences and manufacturing are still being shaped, it is important that any such potential standards are properly evaluated and tested for the case of China.

4. Study Methods

After outlining the purpose of this study, this chapter will review the method employed and the characteristics of the subject of this study – the Chinese car fleet.

4.1 Study Goals

This study is aimed at providing decision makers with insights and recommendations that will enable informed design of Phase IV standards and develop further standards tailored to the Chinese market.

The study is therefore primarily focused on the comparison of fuel consumption performance of Chinese vehicles under the US, European and Japanese standards, which are all functioning market-proven standards. These comparisons will provide insights on the estimated effect of different types of standards on the Chinese fleet over time.

4.2 Study Method

This study is making use of fuel economy standard formulas and targets under normalized test data which is based on the NEDC cycle for enabling fuel economy standards comparison. Vehicle fleet influence is based on estimations that include steady market growth by segment and model from the base year of 2011.

For each of the comparisons, several charts were developed. These comparisons included a direct overlay of Chinese models compared to the foreign standard, an overlay of the CAFC of 37 Chinese manufacturers compared to the foreign standard, an overlay of the 2015 weight-based targets for each of the 426 models compared to the foreign standards, and finally the performance of the top selling passenger vehicles in the Chinese 2011 passenger vehicle fleet.

Qualitative analysis for evaluating the considerations behind each fuel economy scheme, its implementation success and potential development are beyond the scope of this work.

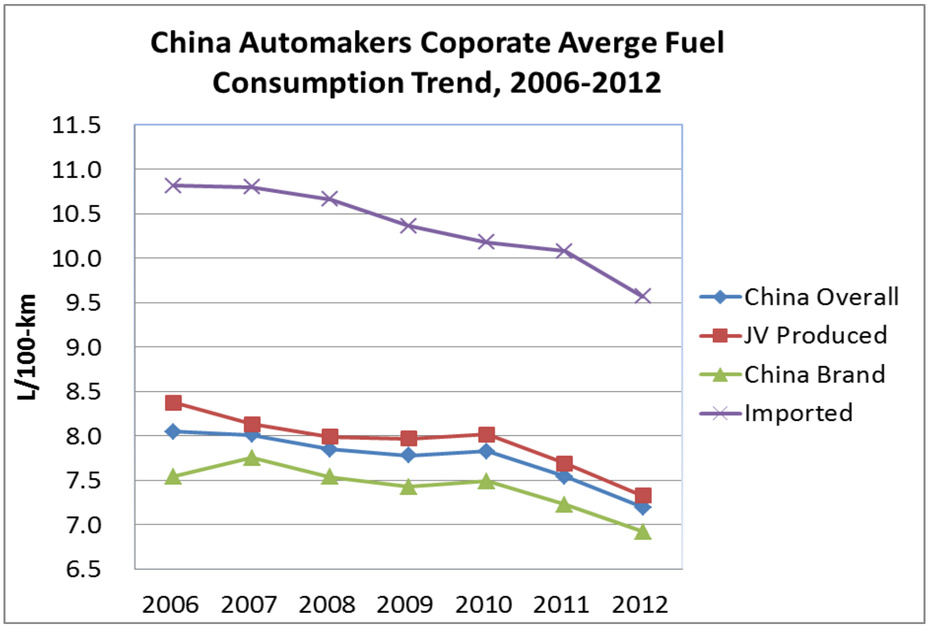
4.3 An Introduction to China's Automotive Fleet Data

In this report, 2011 new domestic passenger vehicle fleet officially available data[10] of426 vehicle models from 37 joint ventures and fully Chinese-owned manufacturers was analyzed(excluding imported vehicles).

[10] 427 models according to sales figures supplied by the China Association of Automotive Manufacturers (2012) Automotive Industry Yearbook. This is in comparison to up to 6782 discreet models that were registered with the Ministry of Industry and Information Technology (MIIT) Automobile Fuel Consumption of China website (2009 – 2011 models). Many models are never actually sold, and CAAM does not discreetly report on sales of all models.

National sales-weighted average fuel consumption of domestically-produced vehicles had fallen steadily between 2006 and 2012, except in 2010 when the national average saw a slight increase (see Figure 8). The sales-weighted average curb weight of the 2011 new vehicle fleet was 1274 kg, with a sales-weighted fuel consumption of 7.5 L/100km, engine displacement of 1.6 liters, and power output of 86 kW(iCET, 2012).

Figure 8: National sales-weighted fuel consumption of the Chinese new vehicle fleet, 2006-2012(iCET, 2013)



We have examined the fuel economy performance of these 426 vehicle models under the three phases of Chinese standards. Chinese domestic new vehicles nearly all met the Phase II national standards in 2011, and generally gathered around the weight bin targets for the Phase III national fuel consumption targets which are to be met by 2015 (see Figures 8 and 9). We will use these same data sets to compare with the other fuel economy, fuel consumption and GHG emission standards presented in this report.

Figure 9: 2011 new manual transmission models compared to the three phases of the Chinese fuel consumption limits and targets for manual transmission vehicles

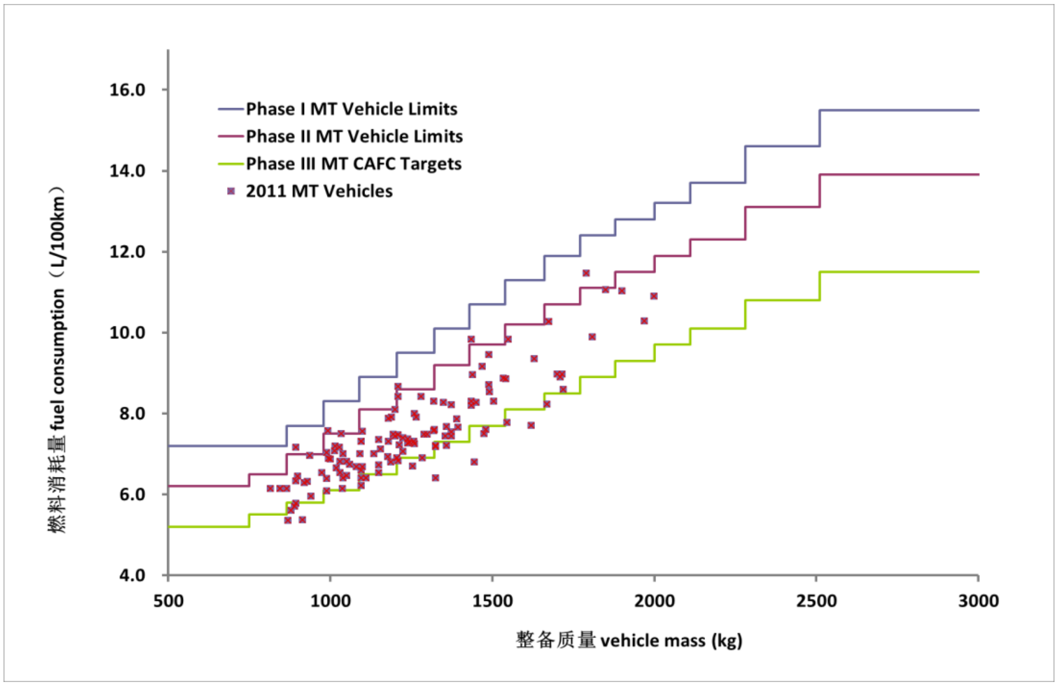
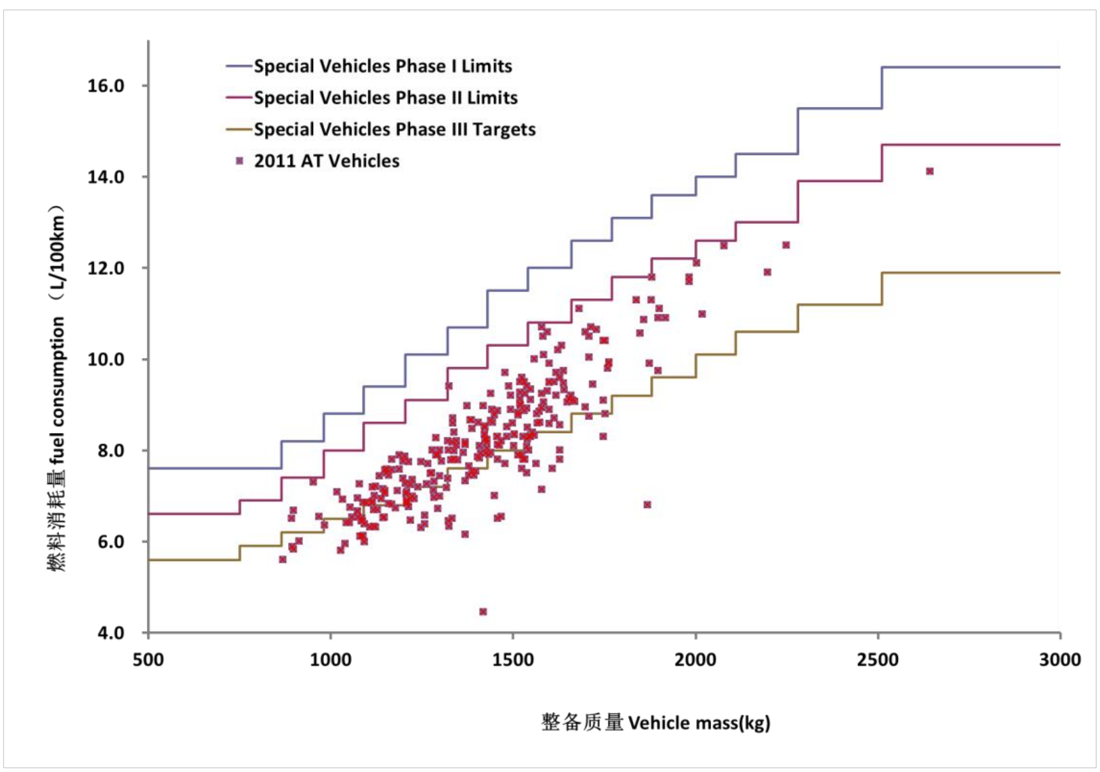


Figure 10: 2011 new automatic transmission models compared to the three phases of the Chinese fuel consumption limits and targets for automatic transmission vehicles



5. Analyses Results

5.1 Comparison to the US Footprint Based GHG Emission Standards

In order to properly compare China's 2011 new vehicle fleet to current US standards, the fleet was separated into cars and light trucks. Since China does not have separate categorizations for cars and light trucks as the US, the following method for categorizing Chinese vehicles according to Chinese regulations was used: (i) first, a search was done in the US market for all the vehicles available in the Chinese market, and where there was an equivalent US vehicle, the Chinese vehicle was sorted according to the US categorization; (ii) if there was no equivalent vehicle in the US, then the Chinese definition of SUV or light truck was used to sort the vehicles; (iii) and if no Chinese classification was available, a judgment was made by the investigators based on weight and design of the model.

The footprint of each of these vehicles was calculated based on the wheelbase and front and rear average track width of the vehicles. The track width and wheelbase data is not reported by official government sources, so where available, the data was taken from the official manufacturer websites. If manufacturer websites did not make wheelbase data available, or if data for the 2011 models was no longer available, data was taken from online databases such as sycyx.com or auto.sina.com.cn which allow for model lookup and claim to report official MIIT, government and verified industry data in their databases (Commercial Vehicle Sales Service Network, 2012).

5.1.1 Footprint vs. Vehicle Weight Correlation

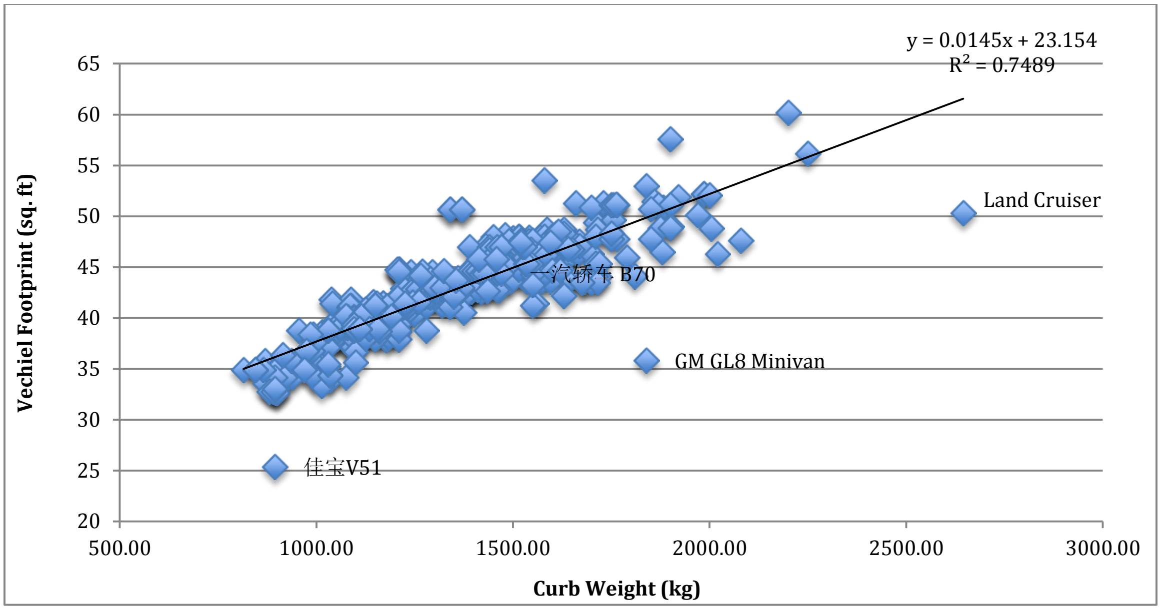
As part of the data verification work, a correlation was conducted on the footprint versus curb weight of the 426 vehicle models from the Chinese market (Figure 11), which demonstrated some outliers of particularly heavy vehicles including minivans and SUVs. After light trucks were removed from the same, the correlation improved significantly (Figure 12). This high correlation generally indicates that the footprint-seeking exercise was likely representative of reality. Figure13 displays the correlation between footprint and curb weight for light trucks which is considerably weaker than that for the car fleet, may be due to the diversity of the light truck market in China. China's existence of low-cost microvans, as well as a wide range of mixed passenger-commercial-use vehicles, actually fit in this category.

These correlation analyses are also very meaningful in terms of the "Footprint vs. Weight Debate" for regulation purpose. While vehicle footprint can be more directly linked to the vehicle size, thus can be viewed as a useful utility factor of the vehicle, vehicle weight is not directly connected with any customer experience, thus is an attribute that can be subjected to cost-effective reduction without sacrificing the demand for a specific vehicle size or interplaying with consumers' preferences.

The rather strong correlation between weight and footprint may imply that the both regulatory frameworks can be exchangeable. However, more careful examination of the below figures implies some strong variations of weight vs. size. It can be argued that the footprint based approach would encourage automakers to make lighter vehicles while maintaining the same vehicle size.

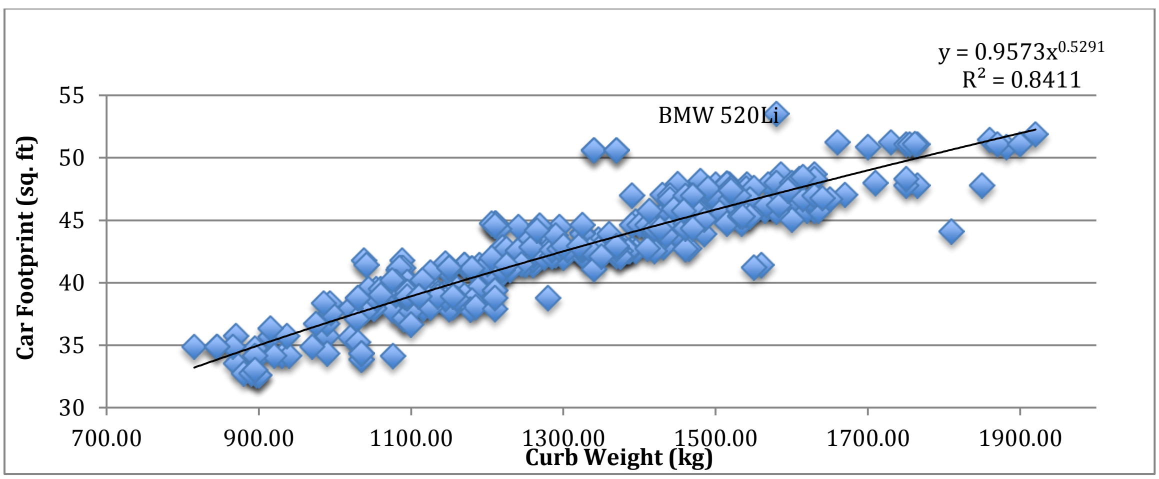
It is valuable to capture the potential contribution of footprint-based linear standards as oppose to bin-based standards, and compare these with the current Chinese weight-based standards and actual (reported) vehicle fuel economy. This analysis is beyond the scope of this work.

Figure 11: Chinese 2011 new fleet car and light truck footprint and weight correlation



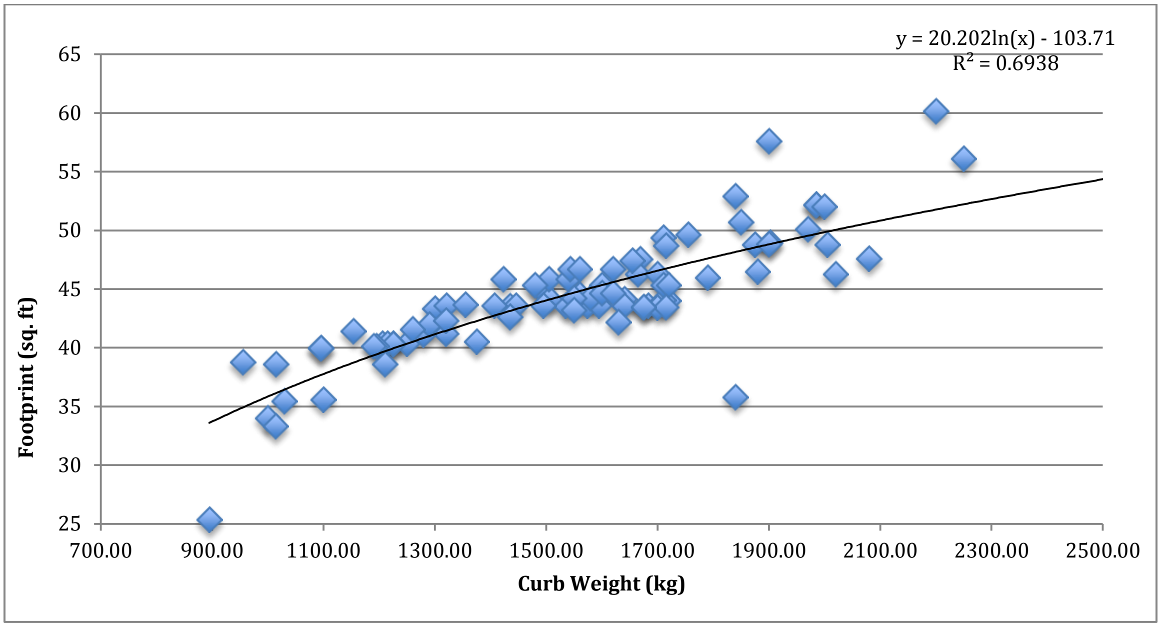
Assumptions: Chinese models footprint was decided either by its US equivalent, it official Chinese definition or on the basis of its available weight and design data (by priorities).

Figure 12: China 2011 new car fleet footprint and weight correlation



Assumptions: Chinese models footprint was decided either by its US equivalent, it official Chinese definition or on the basis of its available weight and design data (by priorities).

Figure 13: China 2011 new light truck fleet footprint and weight correlation



Assumptions: Chinese models footprint was decided either by its US equivalent, it official Chinese definition or on the basis of its available weight and design data (by priorities).

5.1.2 Comparison to the US GHG Standards

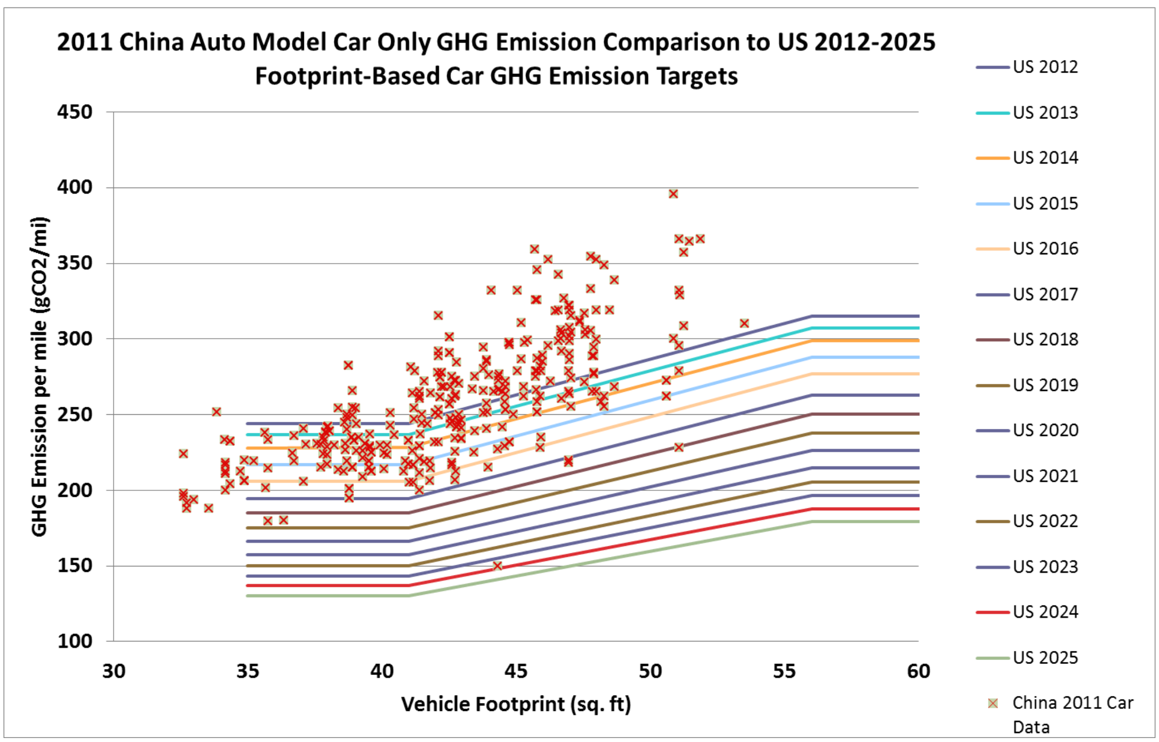
This section is aimed at analyzing the influence of recent US GHG standards on china's 2011 available car models and auto-makers. It attempts to answer the following challenging question: how would Chinese vehicle perform in terms of GHG emissions if they were placed in the US market?

Figure 14 gives an overall perspective on how the Chinese 2011 new car fleet is performing compared to the 2012-2025 car GHG emission targets of the US standard. In the figure, all China's fuel consumption (l/100km) ratings were converted to CAFE-equivalent gCO_2/mi according to the methodology developed in An and Sauer (2004). The figure shows that, approximately speaking, most of the small sized Chinese models (less than 42 sq. ft) would have met or exceeded the 2012 US targets (below the target line), and most of the large size models (above 42 sq. ft) would have failed the 2012 US standards (above the target line), thus greater compliance achieved with smaller footprint vehicles than with larger footprint vehicles. It becomes obvious that for each footprint value, there is a wide range of GHG emissions.

Figure 14 indicates a low correlation between GHG emission and vehicle size, meaning that for every size class of vehicle on the Chinese market, there are possibly vast opportunities to decrease fuel consumption or GHG emission. As more vehicles come closer to the lower value, it would indicate that vehicles of equal utility are producing less GHG emissions per unit of distance.

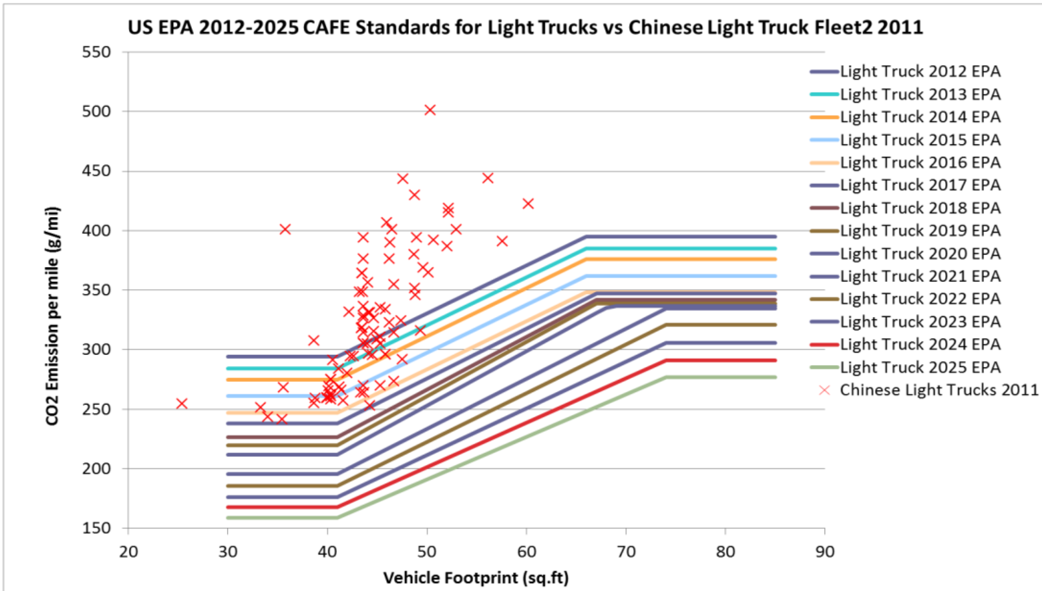
Figure 14 shows an even more scattered relationship between light trucks and footprint than cars. At the small end of the light truck fleet, it seems that Chinese trucks produce considerably fewer emissions than what the US standard expects. This is likely due to the production of microvans that are very tall, giving them cargo utility, but havevery small footprints. Additional or alternative reason could be limited powertrain platform varieties by domestic manufacturers, resulting in various models (with various usage purposes) that have the same platform. Additionally, Chinese trucks have very small 1.0L to 1.6L engines that cannot compare to the typical engine in a US light truck. However, as Chinese light trucks become slightly larger, their GHG emissions vastly outpace the US standards indicating that technology is not being effectively utilized to reduce fuel consumption and GHG emissions from light trucks.

Figure 14: 2011 China Auto Model Car Only GHG Emission Comparison to US 2012-2025 GHG Emission Targets



Assumptions: China's fuel consumption (l/100km) ratings were converted to CAFE-equivalent gCO_2/mi according to the methodology developed in An and Sauer (2004).

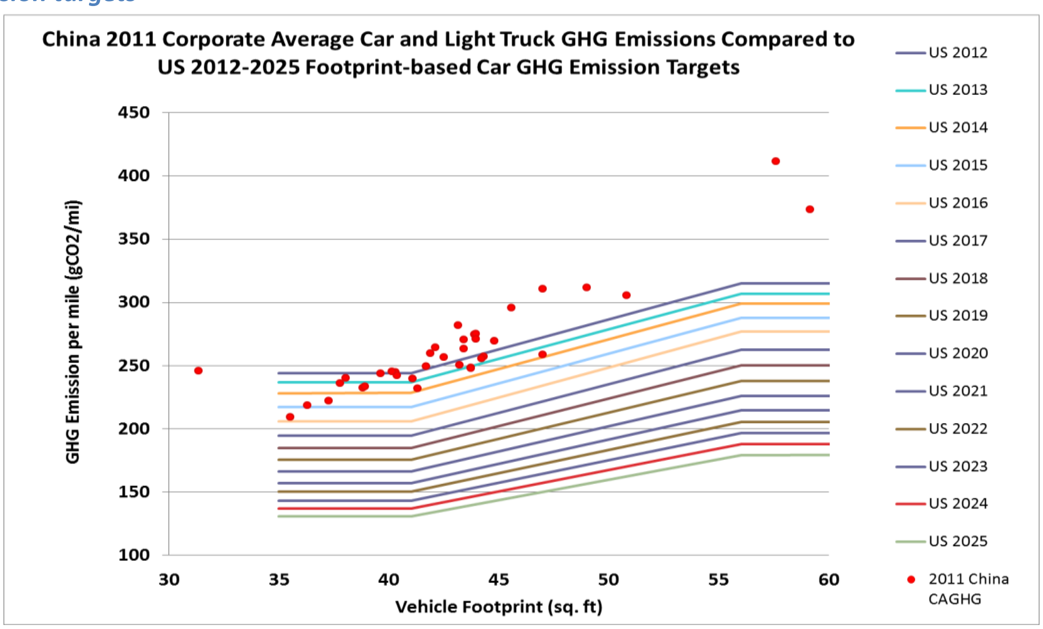
Figure 15: China 2011 Light Truck GHG emissions compared to US 2012-2025 GHG emission targets for Light Trucks



Assumptions: China's fuel consumption (l/100km) ratings were converted to CAFE-equivalent gCO_2/mi according to the methodology developed in An and Sauer (2004).

Figure 16 compares the China 2011 corporate average GHG emissions to the US 2012-2025 car emission targets. Again, on the 37 corporate average fuel consumption bases, all small car makers (vehicles under 42 sq. ft) meet the 2012 US standards, while most large car makers fail to meet the standards. It's also interesting to notice that, the bigger the vehicles, the larger the gaps.

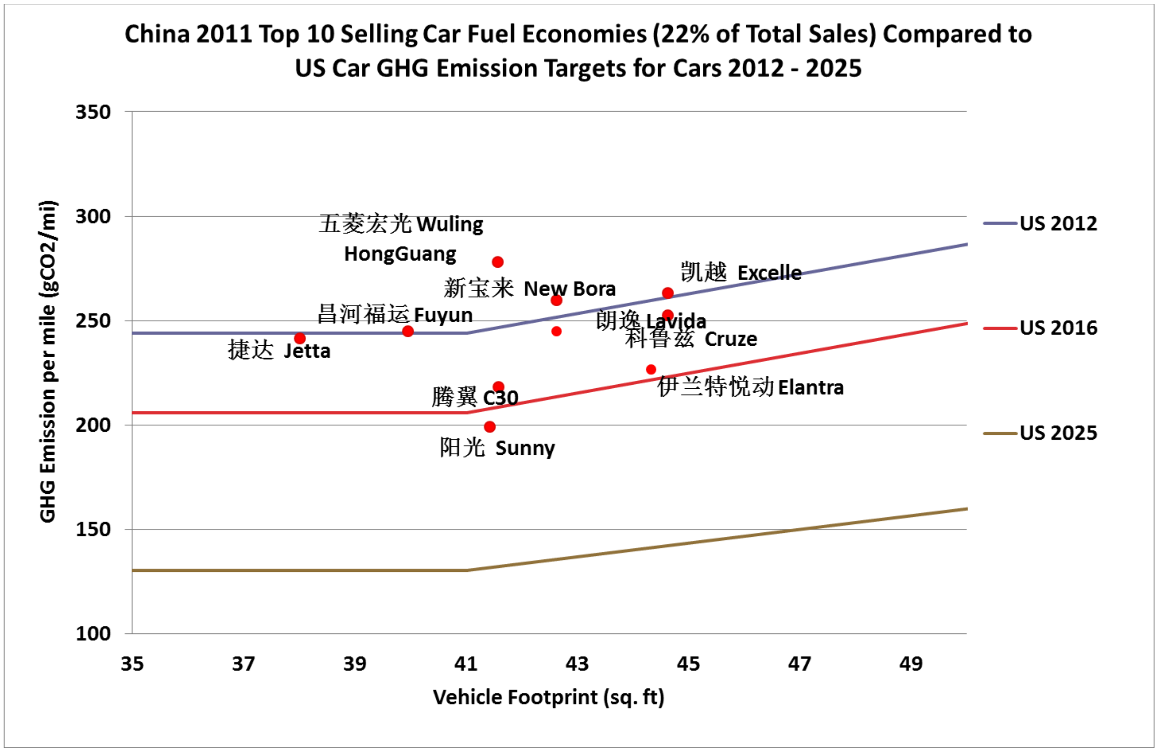
Figure 16: China 2011 CAFC for Car and Light Truck GHG emissions compared to US 2012-2025 car emission targets



Assumptions: China's fuel consumption (l/100km) ratings were converted to CAFE-equivalent gCO_2/mi according to the methodology developed in An and Sauer (2004).

Figure 17 demonstrates China's Top 10 best-selling vehicle GHG emissions to US car GHG emission targets, 2012-2025. It shows that all vehicle models except the Wuling and Bora have met the 2012 US standards. The Nissan Sunny even met US 2016 standards.

Figure 17: China Top 10 best-selling light duty vehicle GHG emissions compared to US car GHG emission targets, 2012-2025



Assumptions: China's fuel consumption (l/100km) ratings were converted to CAFE-equivalent gCO_2/mi according to the methodology developed in An and Sauer (2004).

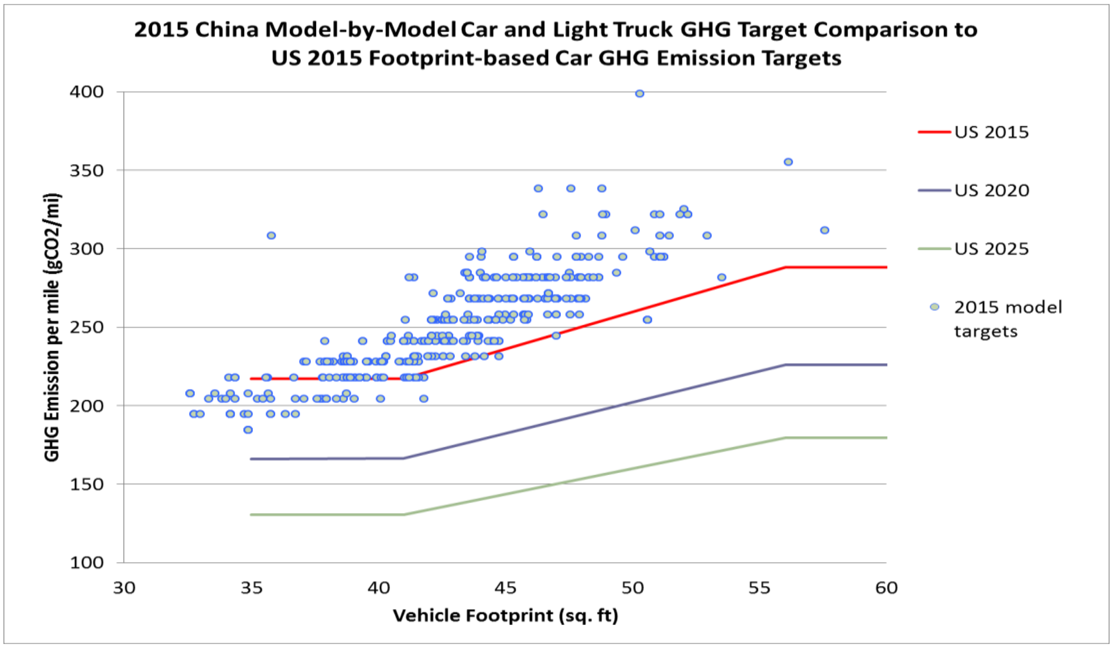
5.1.3 Compare with the 2015 Chinese Standard

This section is aimed at examining how Chinese car models (available on the market in 2011) and automakers would be influenced by the US standards should they reach the Chinese 2015 targets. In other words, this section is an attempt to answer the following questions: if all the Chinese vehicle models would meet the 2015 Chinese standards, how would they compare with the US 2015 standards?

Figure 18 demonstrates the Chinese car and light truck models that would meet the 2015 Chinese standards compared to the US 2015-2025 emission targets. It shows that almost all the vehicle models, except the very small ones would fail to meet the US 2015 standards. This means that, contrary to widely belief, the Chinese fuel economy standards will actually greatly fall behind to the US standards by 2015.

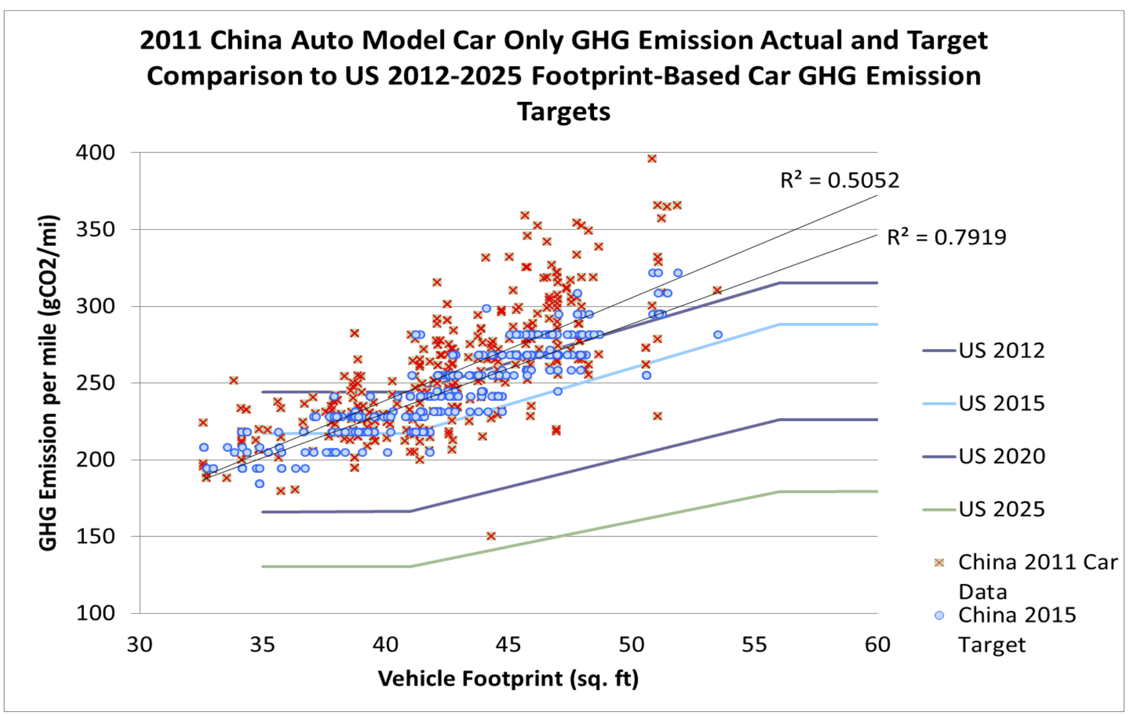
Figure 19 compares the actual Chinese 2011 car GHG emissions vs. the 2015Chinese targets, and compares both of them to the US 2012-2025 footprint-based GHG emission targets. It shows that while China's 2012 trend line is closer to the US 2012 standard, China's 2015 trend line (with R2 = 0.7919) is far worse than the US 2015 target line.

Figure 18: 2015 Car and Light Truck model target GHG emissions compared to US 2012-2025 emission targets



Assumptions: China's fuel consumption (l/100km) ratings were converted to CAFE-equivalent gCO_2/mi according to the methodology developed in An and Sauer (2004).

Figure 19: 2011 China Auto Model Car Only GHG Emission Actual and Target Comparison to US 2012-2025 Footprint-Based Car GHG Emission Targets

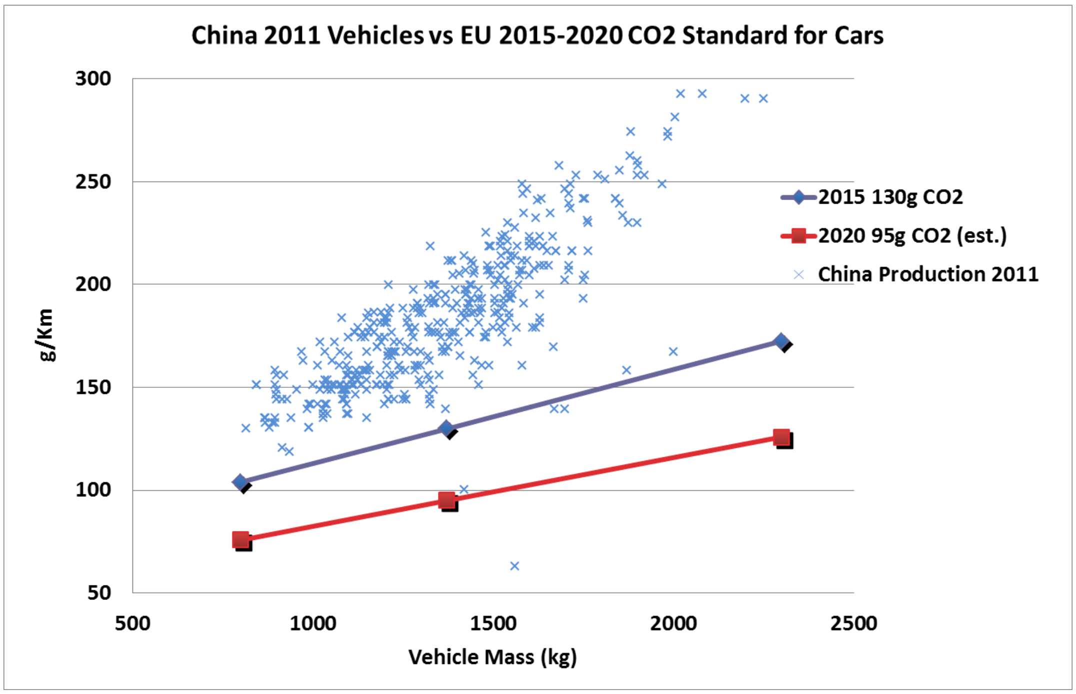


Assumptions: China's fuel consumption (l/100km) ratings were converted to CAFE-equivalent gCO_2/mi according to the methodology developed in An and Sauer (2004).

5.2 Comparison to EU Weight-Curve Based GHG Emission Standards

As described in chapter 3.2, the European CO_2 emission standard currently makes use of curb weight as the attribute for setting its vehicle emission standards and of the NEDC as a test cycle. Since 2011 Chinese fleet data utilized the same attribute and test cycle, no conversion for comparison attribute was required. Chinese fuel consumption was simply converted to gCO_2eq/km according to a standard conversion factor (1 L/100km = 23.2 gCO_2eq/km).

Figure 20: China 2011 light duty vehicle GHG emissions compared to EU 2015 and 2020 CO_2emission targets

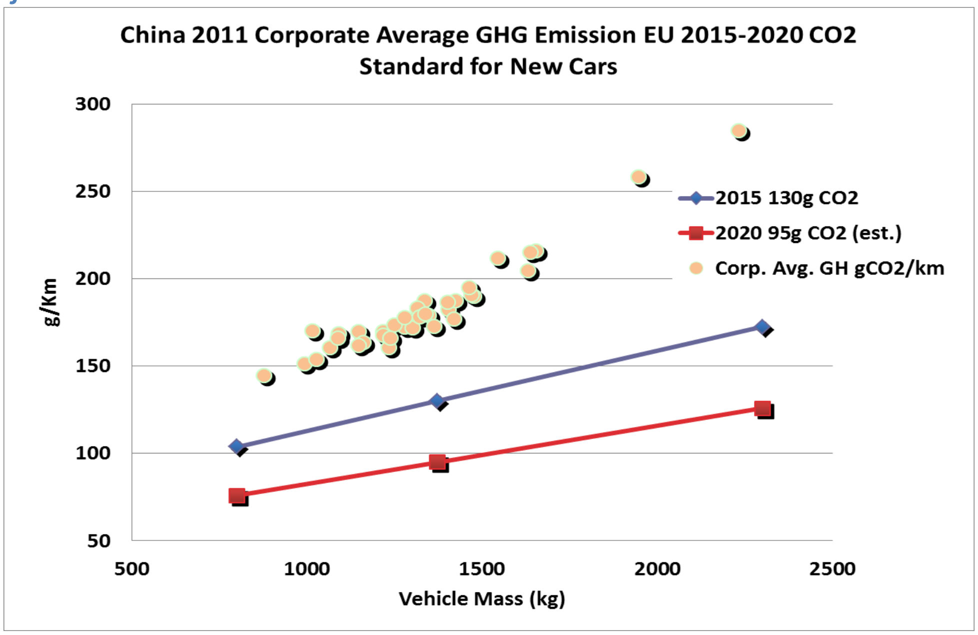


Assumptions: Chinese fuel consumption was converted to gCO_2eq/km according to the standard conversion factor of: 1 L/100km = 23.2 gCO_2eq/km.

What becomes immediately obvious about the 2011 Chinese fleet is that it is not nearly as competitive in terms of current or future CO_2 emissions when compared to the 2015 EU GHG emission standard (Figure 20). Unlike the footprint-based US standard, where some Chinese vehicles were already meeting the 2015 or 2016 GHG emission standards (e.g. Nissan Sunny and Hyundai Elantra), no top-selling vehicles (Figure 21) and no conventional drivetrain vehicles (Figure 22) meet or exceed the 2015 EU standard. Indeed, vehicles meeting the 2015 standard are hybrid or plug-in hybrid vehicles.

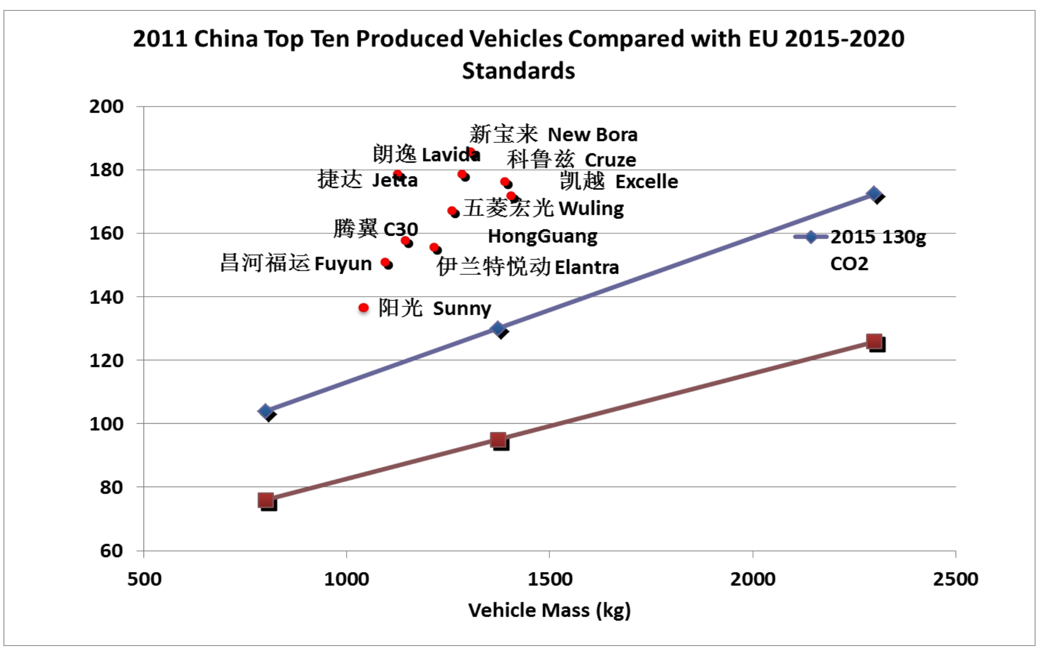
In the case of the single outlier that has vastly smaller emissions than even the 2020 EU standard, the plug-in hybrid BYD F3DM, the low fuel consumption rating is due to the fact that China's methodology for evaluating plug-in hybrid vehicles does not account for the electric portion of the drive cycle in the fuel consumption drive test. The 2015 targets for the Chinese 2011 fleet remain considerably higher than the targets suggested by the EU standard (Figure 23).

Figure 21: China 2011 Corporate Average GHG Emissions vs. EU 2015-2020 CO2 Emission Targets for New Cars



Assumptions: Chinese fuel consumption was converted to gCO_2eq/km according to the standard conversion factor of: 1 L/100km = 23.2 gCO_2eq/km.

Figure 22: China 2011 Top Ten Produced Vehicles CO2 Emissions vs. EU 2015-2020 CO2 Emission Standards

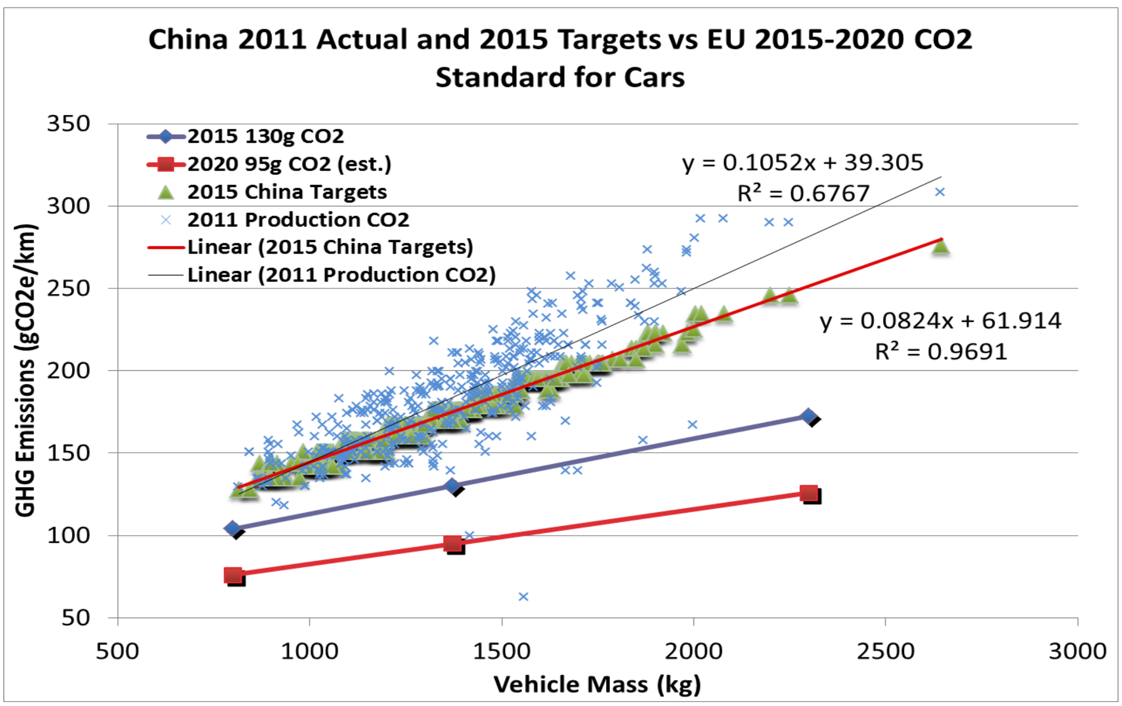


Assumptions: Chinese fuel consumption was converted to gCO_2eq/km according to the standard conversion factor of: 1 L/100km = 23.2 gCO_2eq/km.

Finally, Figure 23 indicates that while the 2015 target emissions for China's 2011 new vehicle fleet are lower, the decrease in emissions is observed in heavier vehicles in the shallower slope of the trend line from 2011 to 2015. However, the slope of the Chinese trend line is still steeper than the EU 2015 and 2020 standards, indicating that the Chinese standards do not force efficiencies in heavier vehicles as strictly as the European standards. Meanwhile, lighter vehicles need to make few changes between 2011 and 2015 to meet the Chinese standard, and make little progress towards the EU standard.

Generally, these observations indicate that Europe is forcing significantly greater efficiency improvements in heavier vehicles, which will see greater GHG emission reductions over the relevant period (2015-2020).

Figure 23: China 2011 Actual and 2015 Target CO2 Emissions vs. EU 2015-2020 CO2 Emission Standards for New Cars



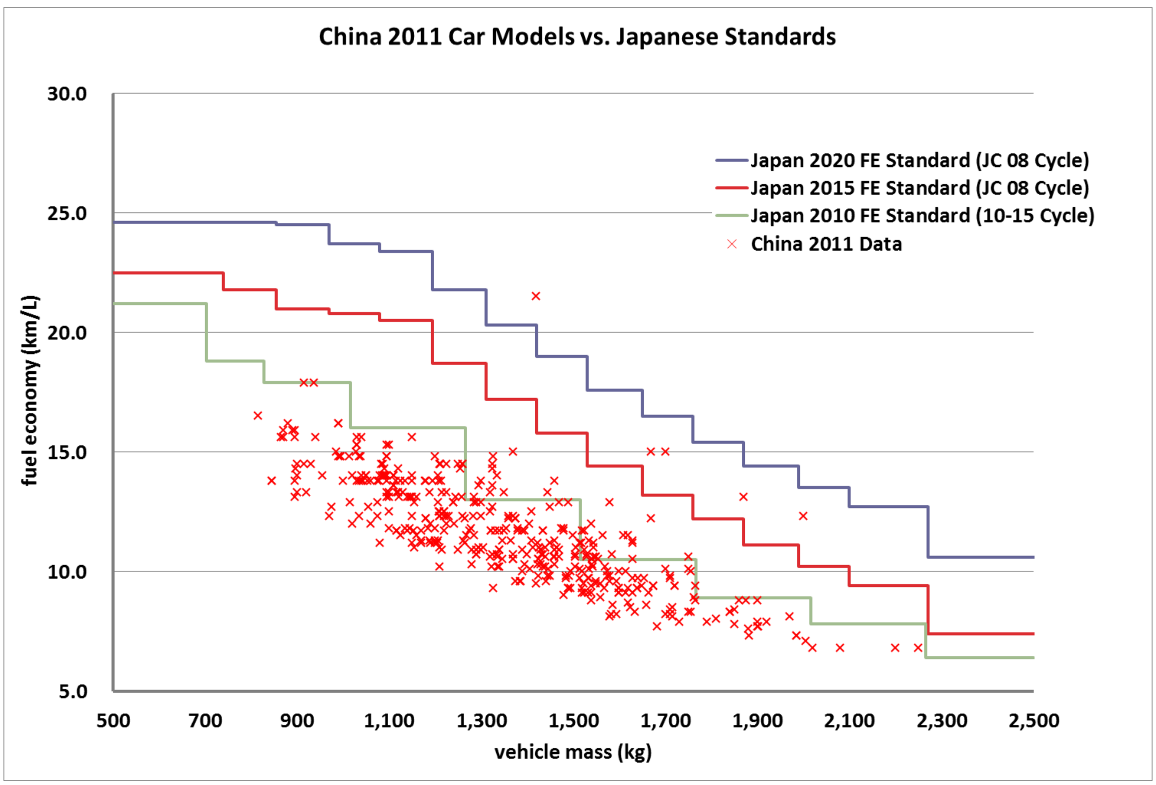
Assumptions: Chinese fuel consumption was converted to gCO_2eq/km according to the standard conversion factor of: 1 L/100km = 23.2 gCO_2eq/km.

5.3 Comparison to Japan Weight-bin Based Fuel Economy Standards

As described in chapter 3.3, the Japanese fuel economy standard is weight-bin based standard displayed as distance travelled per liter of fuel consumed. In terms of fuel consumption testing, Japan utilized the 10-15 Cycle for the 2010 standard and has been replaced by the JC 08 cycle in 2011 to serve 2015, 2020 standards and beyond. This study therefore uses a conversion factor (developed by iCET) for NEDC L/100 km fuel consumption to km/l on the JC 08 drive cycle for all three standard targets recently set by Japan.

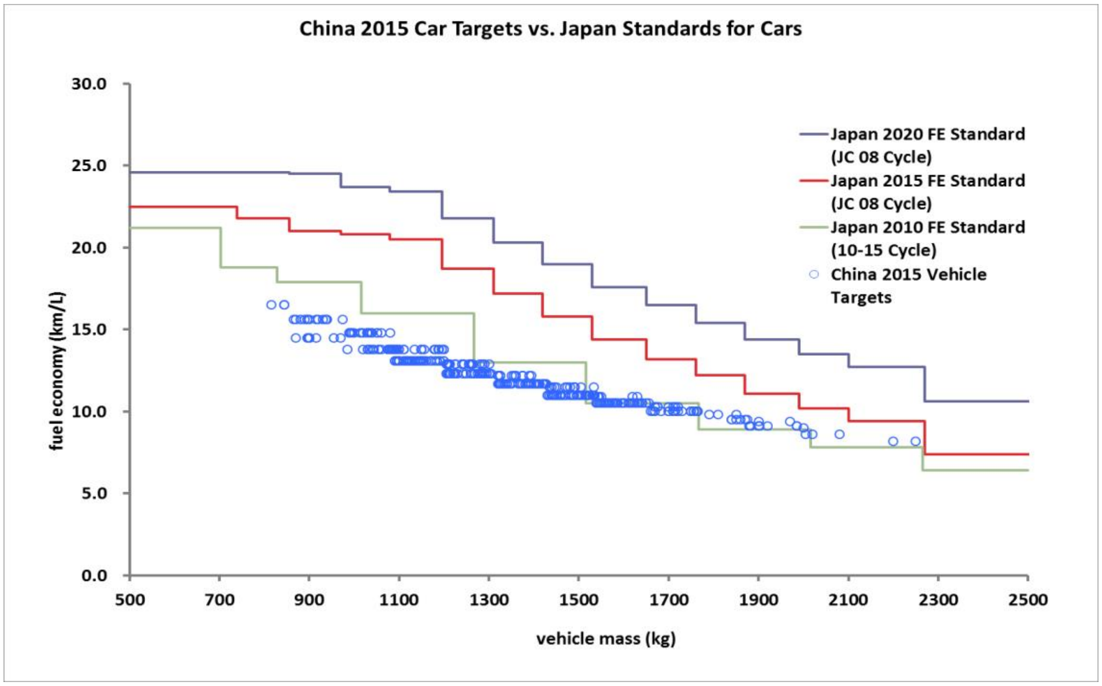
Figure 24, much like previous comparisons, indicate that Chinese data for the 2011 fleet is less efficient than even the 2010 fleet in Japan, with very few models coming exceeding the 2010 Japan standard. The 2011 Chinese model fuel economies generally decrease with curb weight as the Japanese standard, and the one outlying vehicle that outperforms the Japanese 2020 standard is the plug-in hybrid BYD F3DM, which has a fuel economy rating that does not include the part of the test cycle that is drive on battery power.

Figure 24: China 2011 Model Fuel Economy vs. Japan 2010-2020 Fuel Economy Standards



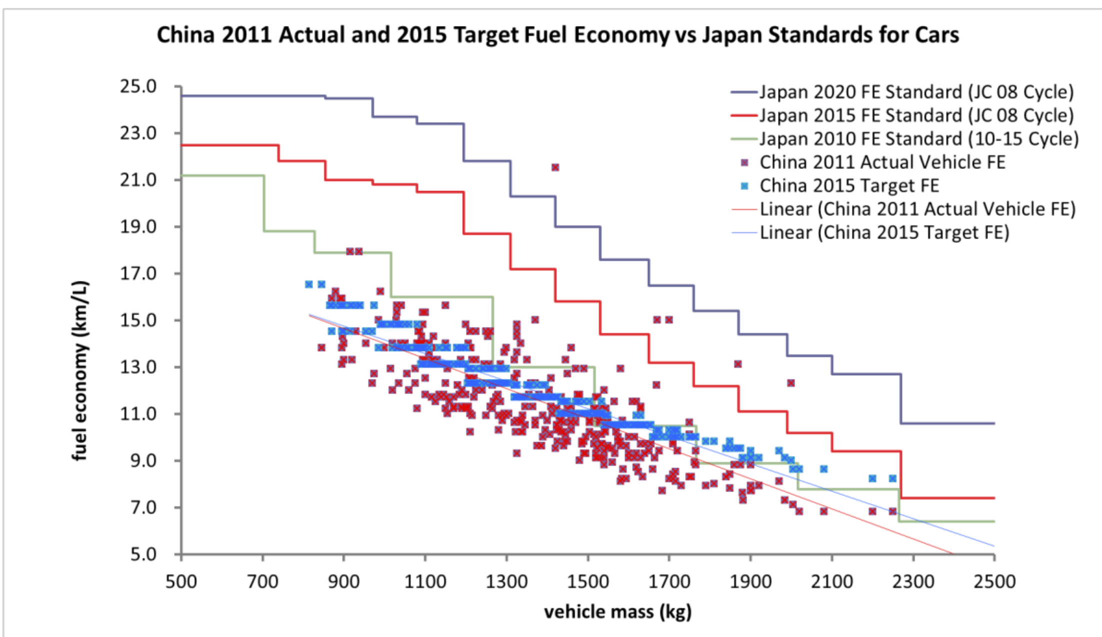
Assumptions: a conversion factor developed by *i*CET for NEDC L/100 km fuel consumption to km/l on the JC 08 drive cycle was used for all three standard targets – 2010, 2015 and 2020.

Figure 25: China 2015 Fuel Economy Targets vs. Japan 2010-2020 Fuel Economy Targets



Assumptions: a conversion factor developed by iCET for NEDC L/100 km fuel consumption to km/l on the JC 08 drive cycle was used for all three standard targets – 2010, 2015 and 2020.

Figure 26: China 2011 Actual and 2015 Target Fuel Economy vs. Japan Standards for Cars

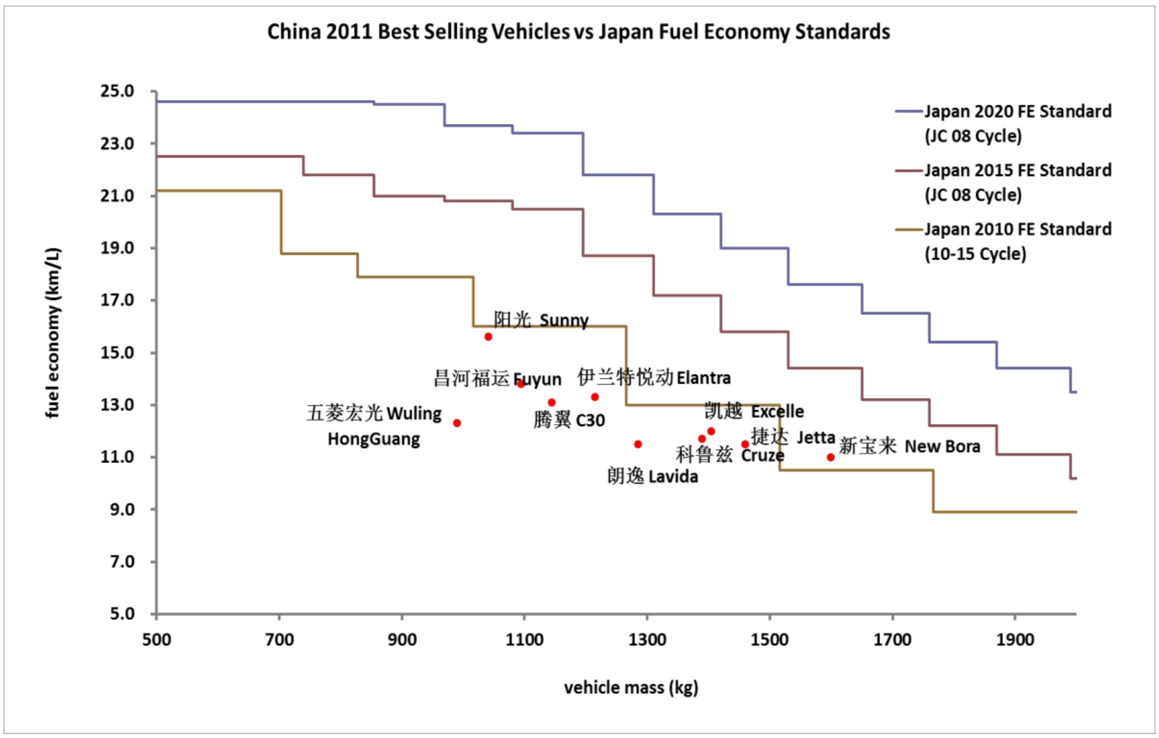


Assumptions: a conversion factor developed by iCET for NEDC L/100 km fuel consumption to km/l on the JC 08 drive cycle was used for all three standard targets – 2010, 2015 and 2020.

China's 2015 targets for the 2011 Chinese models do manage to approach the Japanese 2010 standard, particularly at lighter curb weights, and at the boundaries of weight bins in heavier weight classes. However, the 2015 Chinese targets do not approach the Japanese 2015 standards, as indicated in Figure 25.

Figure 26 demonstrates well how the 2011 Chinese fleet improves slightly on the JC08 cycle by 2015, but the trend line does not approach the 2015 standard, and only partially satisfies the 2010 standard.

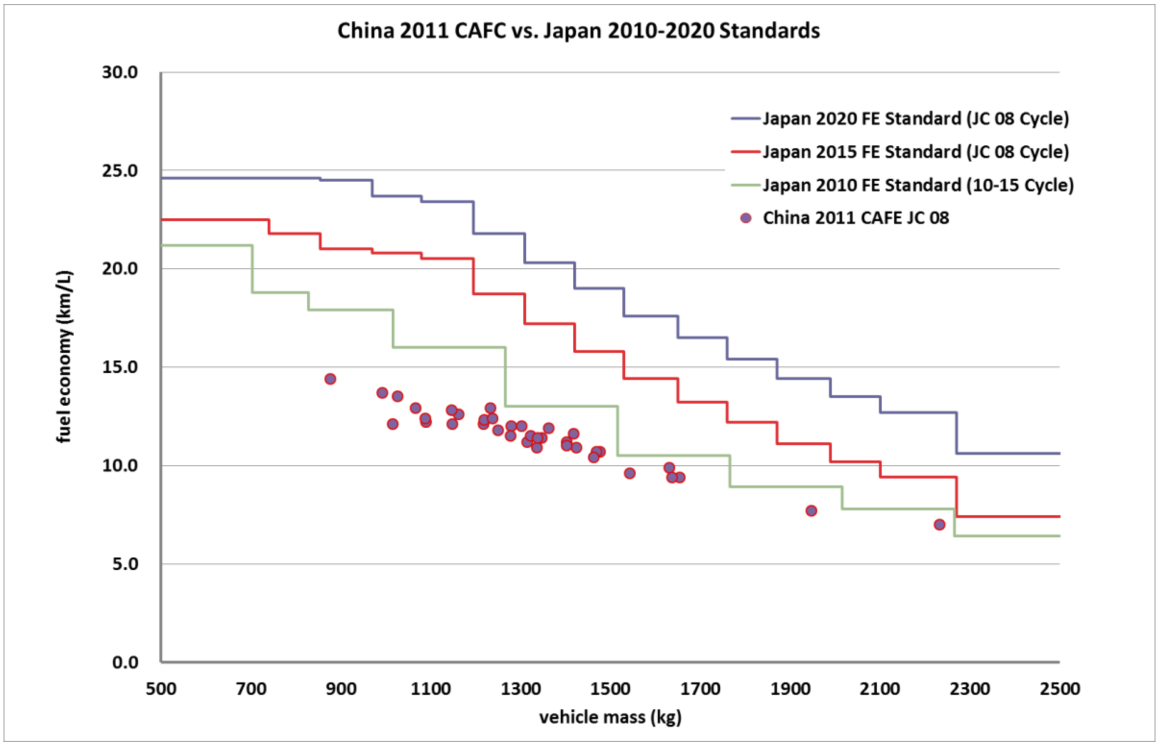
Figure 27: China 2011 Actual Top 10 Best Selling Cars vs. Japan 2010-2020 Fuel Economy Targets



Assumptions: a conversion factor developed by iCET for NEDC L/100 km fuel consumption to km/l on the JC 08 drive cycle was used for all three standard targets – 2010, 2015 and 2020.

For better examining the relative fuel economy of models that are leading the Chinese market growth, we've assessed China's Top 10 selling vehicles for the year 2011 against the Japanese standards. Figure 27 indicates that, among the top 10 selling cars in China, only the Volkswagen Bora has met even the 2010 Japanese standards. Therefore, national fleet assessment aside, the crucial role of standards commercialization which is tested at vehicles selling points seems to have delivered poor results in 2011 from Japan's perspective. Moreover, Figure 28 indicates that on corporate average basis, none of the current 37 vehicle manufacturers in China has met the 2010 Japanese standards.

Figure 28: China 2011 CAFE vs. Japan 2010-2020 Fuel Economy Standards



Assumptions: a conversion factor developed by iCET for NEDC L/100 km fuel consumption to km/l on the JC 08 drive cycle was used for all three standard targets – 2010, 2015 and 2020.

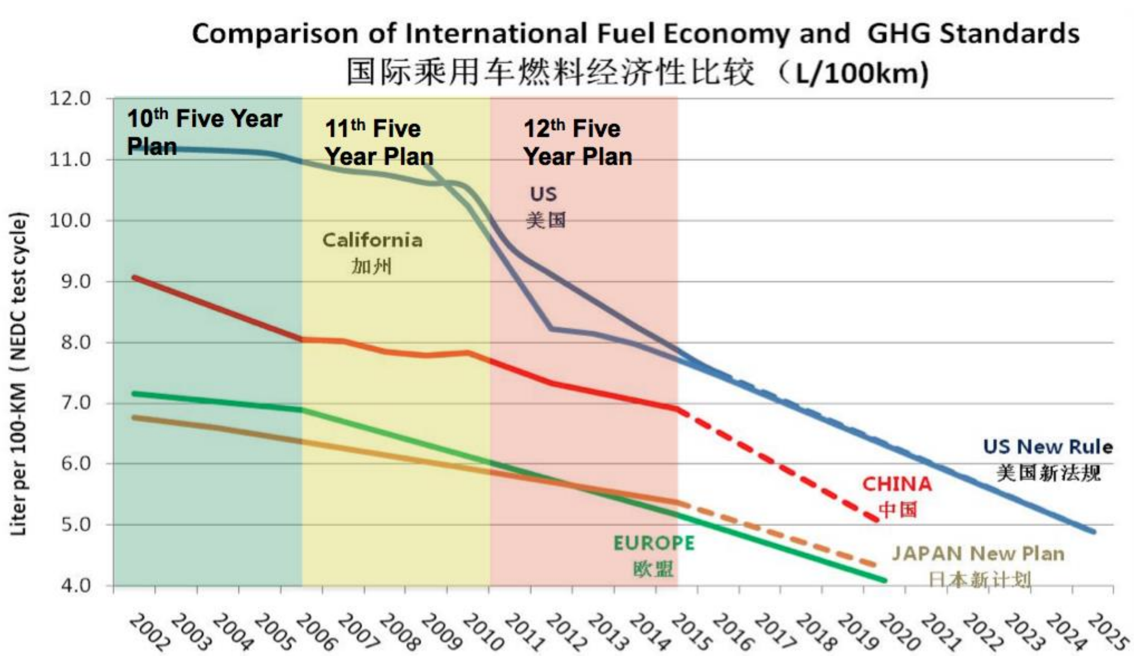
6. Conclusions

At the time this study has commenced, it offered a direct comparison of Chinese models available in China's vehicle fleet to the standards of other countries and regions for the first time. This study has managed to make these comparisons by converting the Chinese fleet data into units and drive cycles of these countries and regions. Chinese data was comprised of primarily on-market vehicle for year 2011 to which comprehensive official figures are available, major automakers average fuel consumption data, as well as the future 2015 fuel consumption targets of all those models, based on the 2015 Fuel Consumption Targets for Chinese Passenger Vehicles.

As expected, according to the analysis performed originally in Feng An, et al in 2004, and continued by iCET and others, Chinese fuel economy standards have remained consistently around ten years behind European and Japanese fuel economy or GHG emission standards, as demonstrated in Figure 29.

However this study, as well as the below Figure 28, also shows that many of China's top-selling vehicles were meeting or exceeding the 2012-2016 US footprint-based targets for fuel economy. It may be implied that the US average fuel consumption standards areseveral years behind that of the Chinese average at this time. Nevertheless, this storyline would change somewhat if we closely examine the fleet data against the detailed structure of US standards.

Figure 29: International Comparison of Fuel Economy Standards



Assumptions: Standardsare normalized according to the NEDC test cycle.

Examination of the Chinese fleet data with the US footprint-based and EU/Japan weight-based standards achieve three general conclusions and four specific conclusions:

General conclusions:

1. Based on the current trend and 2015 Chinese target, none of the Chinese automakers would meet either EU or Japanese 2015 standards.

2. Most Chinese automakers can meet the 2012 US standards; only few Chinese automakers would meet the US 2015 standards. However, since the Chinese fleet is much smaller than the US fleet in terms of vehicle size and power, the Chinese fleet average fuel consumption figure is still lower.

3. China's fuel economy standards would start to fall behind the US standards by 2015 on the equal footprint-basis as well as on the equal weight basis. While China's 2011fleet emission data is quite close to the US 2012 standard line, China's 2015 emission target is far worse than that of the US 2015 target line.

Specific Conclusion regarding the footprint-based approach:

4. The range of fuel consumption for each footprint category in China's 2011 fleet was quite large – much larger than the range observed against weight-based standards. The range of fuel consumption is narrower at small footprints, and broader at larger footprints. This wide range of fuel consumption values could indicate several things regarding China vehicle fleet: First, that there is a wide variety of curb weights for each value of footprint; Second, that there is possibly a wide implementation of fuel consumption influencing technologies for each value of footprint catering for diverse types of models per single footprint (and powertrain).

5. A complementary observation to the above point is that when compared to weight-based fuel consumption standards, ranges for fuel consumption are much narrower in each weight category (compared to footprint). Specifically, ranges are narrow for light and heavy vehicles, but slightly wider in the mid-weight vehicles classes. The narrower range for weight indicates that China's fuel consumption standard may be driving companies to produce vehicles conforming to a weight standard through the use of weight adjustment.

   While many Chinese companies are attempting to incorporate technologies into their vehicles, it also seems that some vehicles are achieving their fuel consumption targets through increasing curb weights to enter a higher fuel consumption limit area, and not through fuel efficiency technological developments as hoped (and necessary). As a result, footprint fuel economies are spread wider than expected.
   It is interesting to understand the whether fuel consumption standards are major driver for vehicle weight sifts per footprint, or possible other factors (e.g. saving on production costs while introducing more divers vehicle utilities).

6. One of the key questions for the hypothesis that weight is being adjusted upwards in the Chinese fleet in order to meet fuel consumption targets is: would curb weights continue to be adjusted in order to meet fuel consumption targets *and* maintain the diversity of utility in the Chinese fleet? It will be important to continue this analysis over a period of a number of years to better understand and benchmark the annual performance of the Chinese passenger vehicle fleet in terms of weight as well as footprint, and to determine a better mathematical relationship between range of fuel consumption in each category of weight and footprint. Another useful method that could be employed for better understanding corporate response to china's weight-based standards is to conduct a qualitative study that will incorporate a systematical coverage of Chinese auto manufacturers across their operations.

7. Another key question is whether Chinese automakers would be able to meet a standard scheme that is footprint based within a reasonable timeframe *without* compromising the diversity of utilities in the Chinese fleet? Insofar, it seems that due to the wide range of fuel consumption levels per each footprint unit, a footprint based standards would reshuffle vehicle manufacturing in China in the near term, and may therefore result in less diverse vehicle fleet and will possible create safety compromises – both of which are not sustainable and collide with other national goals (e.g. social unrest).

8. Recommendations and Future Work

Given that many of the top 10 selling passenger vehicles in China are in fact joint-venture produced vehicles, it is clear that China can continue to demand better fuel consumption performance from its auto industry. The foreign partners of joint venture companies are the same companies that need to meet stringent Japanese and European weight-based standards.

The Chinese government needs to continue to force companies to improve the technology implemented in their vehicles and use more light-weighted materials, without merely shifting vehicles into other weight classes, as is suggested by the wide range of fuel economies under footprint-based rating.

It might be instructive to begin a voluntary footprint-based reporting system alongside the current weigh-based standard, and eventually transfer to a pure footprint-based system in order to narrow the range of fuel consumption values for each footprint range, or to a mixed weight-based and footprint-based standard that will certainly force technology to be incorporated into every weight class of vehicle.

The design of such voluntary regulatory framework should rely on further studies tailored to China's vehicle fleet characteristics and trends, which will examine and compare various relevant footprint-based structures (e.g. bin-based vs. linear, various slopes, various milestones). Not less important is the process of standards design: stakeholders' involvement, appropriate testing that will reflect real-world China-specific driving conditions, and sound implementation plan that will include sufficient fiscal framework.

More careful and in-depth analyses are needed to make holistic recommendations regarding footprint vs. weight based standards. A multiple-year comparison will be required in order to understand the change in the Chinese footprint versus weight-based standard changes, and mathematical relationships should be determined to understand the behavior of the range of fuel consumptions for each weight bin and for each range of footprint in the Chinese new vehicle fleet. An important complementary research approach would be an independent qualitative study covering a wide range of auto-industry stakeholders, which will shed light on the reasons for trends identified and the potential results of different regulatory approaches.

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