



中国一汽技术中心

轻型车节油与轻量化技术应用

Fuel saving of light-duty vehicle and application of light weight Tech

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时间：2014年5月

汽车节能减排-车企必为的工作

Reducing emissions-the work must be done by automobile enterprises



- 不论汽车对雾霾影响多大，但肯定是之一，因此汽车节能减排是车企的重点工作之一
- No mater how much it would be, auto emissions is one source of fog and haze

汽车节能减排途径

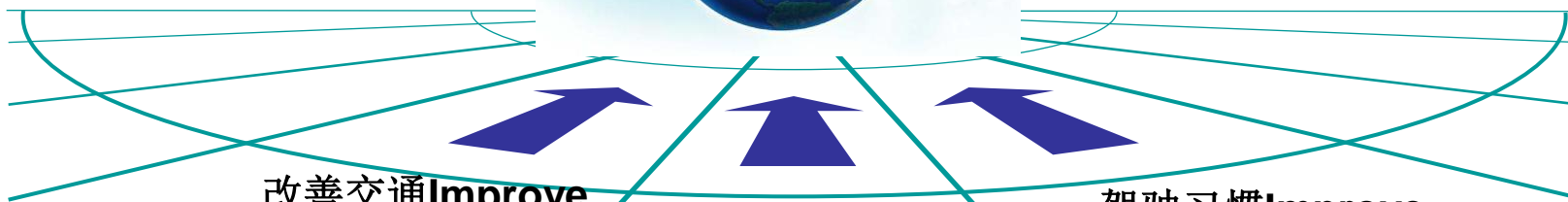
The critical way of reducing emissions and improving fuel efficiency of vehicle

节约能源，改善环境

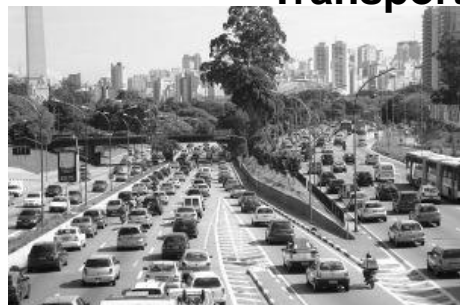
Save energy, improve environment



汽车vehicle



改善交通Improve Transportation



自身改进Improve Vehicle



驾驶习惯Improve Driving habits



各国汽车节能减排的法规与目标

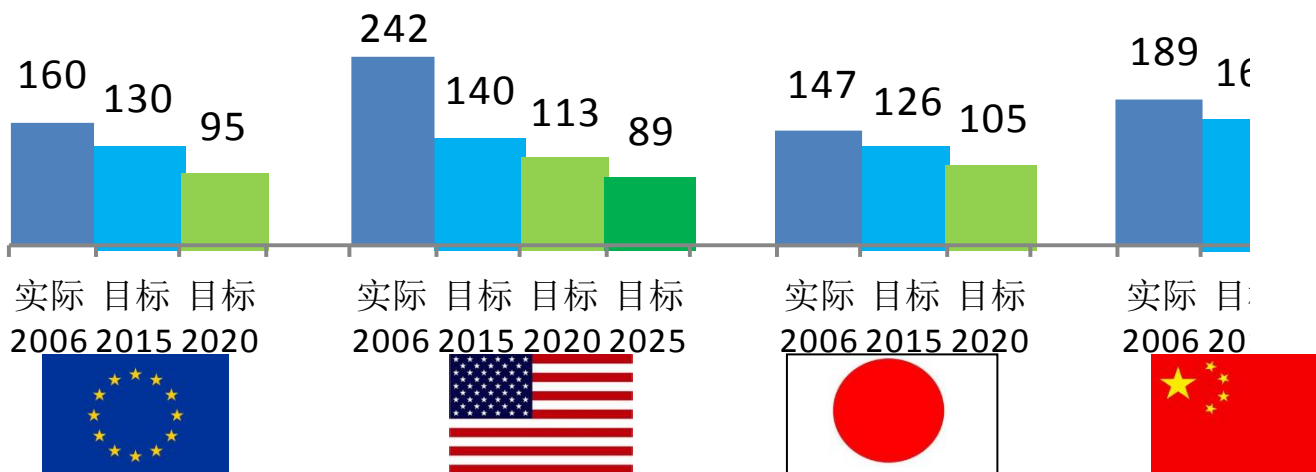
The targets of FC in the world



油耗目标对比

欧美日中乘用车碳排放限值 (g CO₂/km)

The CO₂ limits of passenger car in EURO USA JAPAN & CHINA

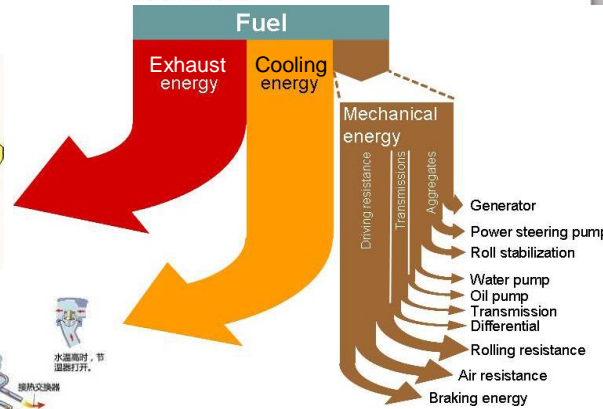
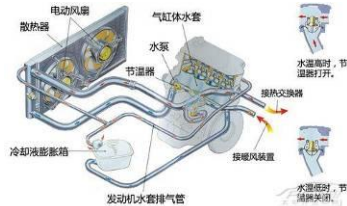
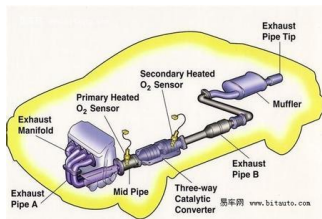
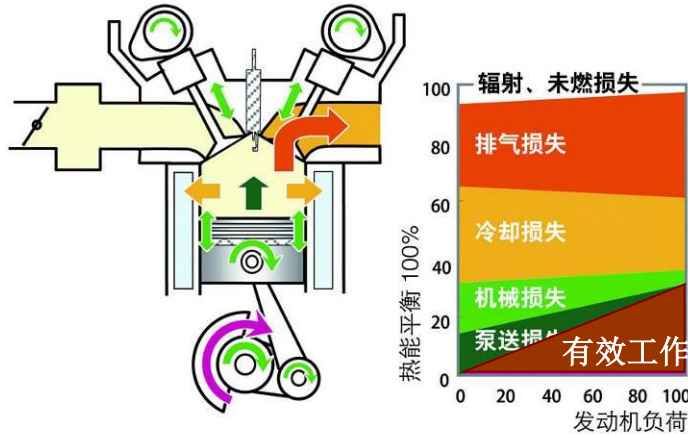


注：美国为轿车碳排放值，日本采用 10-15 工况数值。

燃油与 CO₂ 换算关系

汽油：1 L/100km=23.5 g CO₂/km 柴油：1 L/100km=26.9 g CO₂/km

燃料热能与行驶能耗 Fuel energy and driving performance



G 汽车重量 weight

f 滚动阻力

i 道路的坡度系数

δ 车旋转质量换算系数

Power consumption 功率消耗

- 1 滚动阻力
- 2 坡度阻力
- 3 加速阻力
- 4 空气阻力

$$P_f = G \cdot f \cdot V / 3600$$

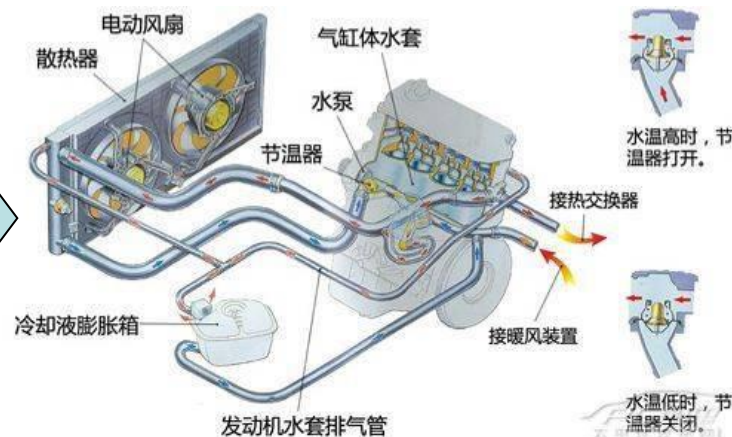
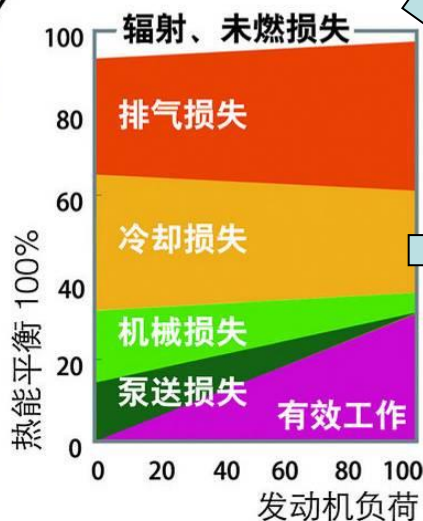
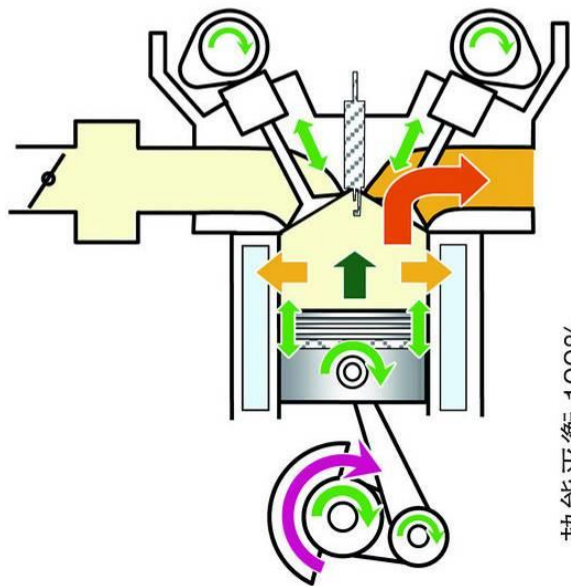
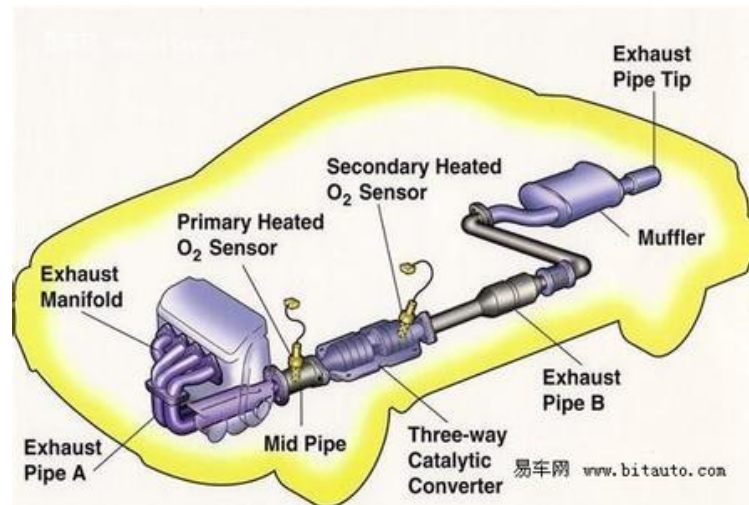
$$P_i = G \cdot i \cdot V / 3600$$

$$P_j = G \cdot \frac{\delta \cdot dV}{3600g \cdot dt} \cdot V$$

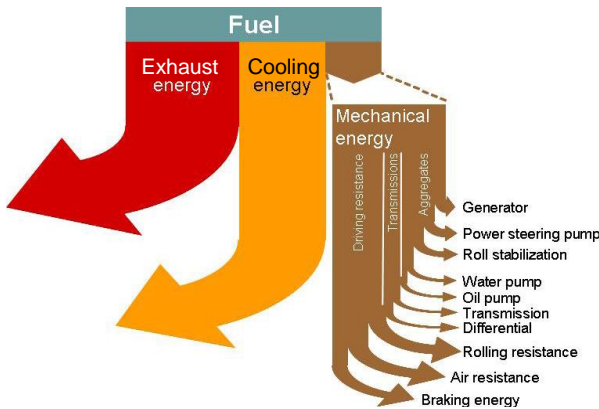
$$P_w = \frac{C_D \cdot A \cdot V_\alpha^3}{21.15 \times 3600}$$

- 1 rolling resistance
- 2 grade resistance
- 3 acceleration resistance
- 4 air friction

燃料热能与能量损失 the fuel energy and loss



燃料热能与行驶能耗 Fuel energy and driving performance



G 汽车重量 weight

f 滚动阻力

i 道路的坡度系数

δ 车旋转质量换算系数



功率消耗 Power consumption

1 滚动阻力 $P_f = G \cdot f \cdot V / 3600$

2 坡度阻力 $P_i = G \cdot i \cdot V / 3600$

3 加速阻力
制动减速 $P_j = G \cdot \frac{\delta \cdot dV}{3600g \cdot dt} \cdot V$

4 空气阻力 $P_w = \frac{C_D \cdot A \cdot V_\alpha^3}{21.15 \times 3600}$

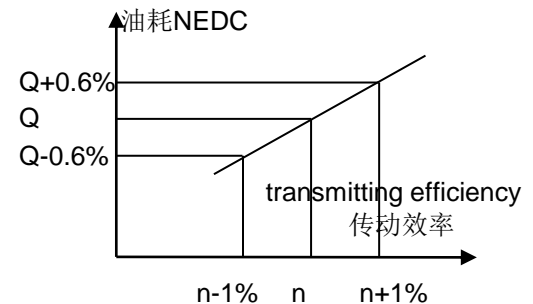
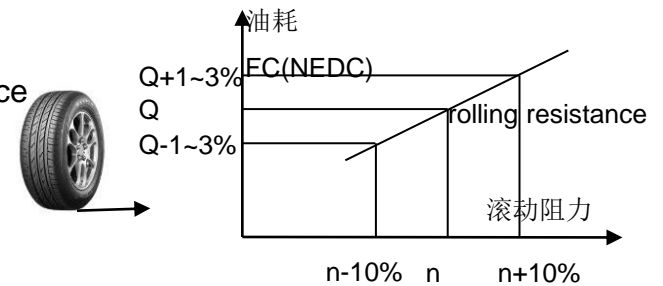
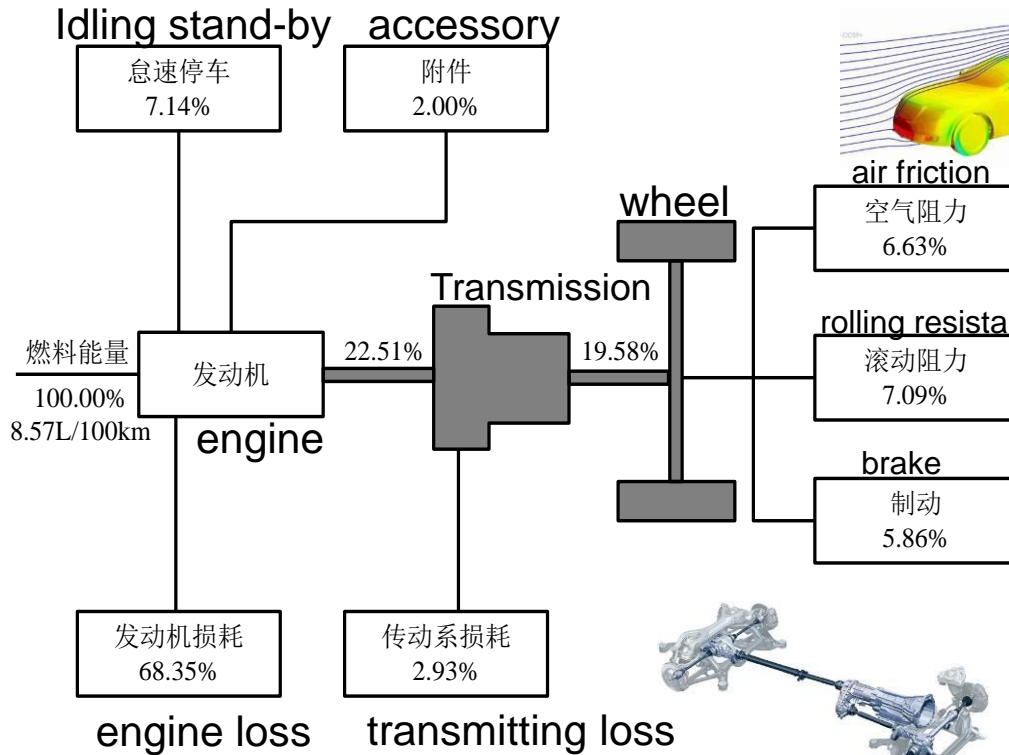
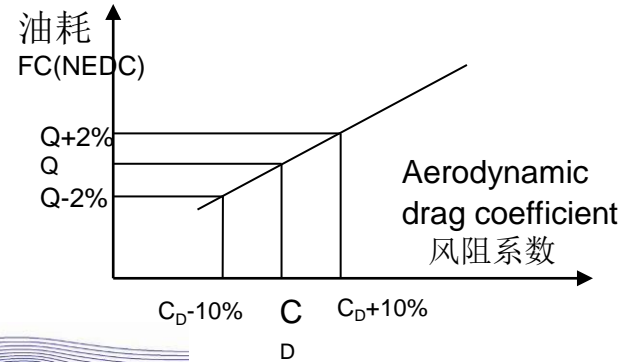
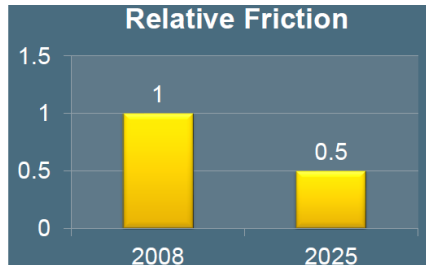
1 rolling resistance

2 grade resistance

3 acceleration resistance

4 air friction

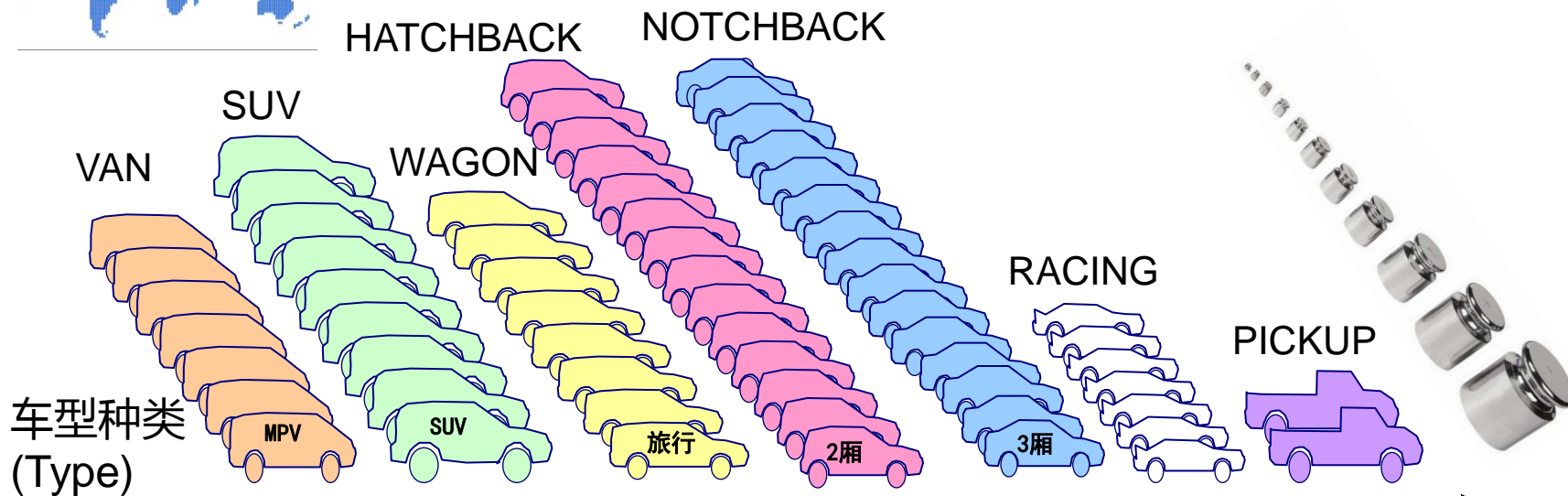
现代汽车的效率 modern vehicle efficiency



汽车节能减排(全球车辆特征)

REDUCING EMISSIONS AND IMPROVING FUEL EFFICIENCY (TOTAL VEHICLE IN THE WORLD)

全球车型数量 (the numbers of passenger car type and model in the world)



车型种类
(Type)

2010	345	389	449	737	714	367	103
2011	349	425	411	722	712	372	105
2012	381	439	410	707	705	364	99
2013	374	448	409	725	737	379	84

汽车节能减排(全球车辆特征)

REDUCING EMISSIONS AND IMPROVING FUEL EFFICIENCY

分析维度说明

车辆级别
(segment)

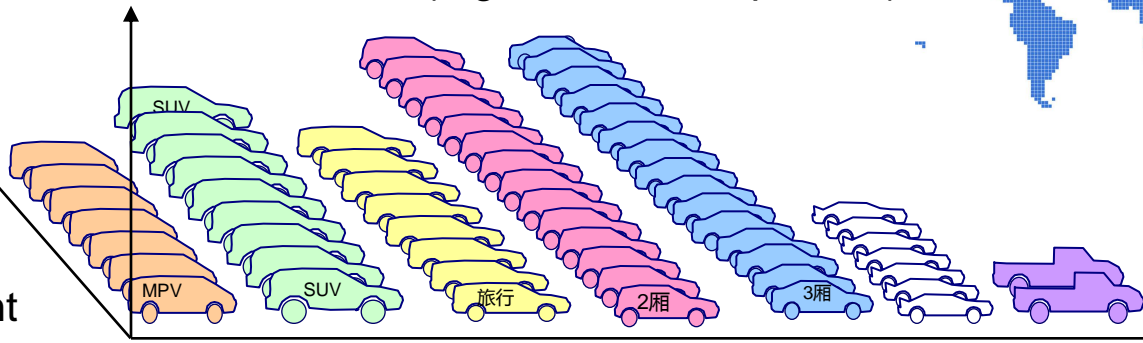
[大小]
dimensions

[轻重]
weight

产品性能特征 (重量/油耗.....)
Performance (e.g. fuel consumption...)

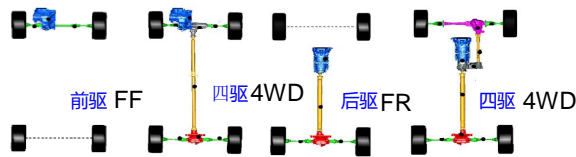


车型
种类
(Type)



车辆级别
(segment)

[大小]
[轻重]



横置 transversal 纵置 longitudinal 传动方式 driveline



发动机技术
Engine
tech/TYPE

乘用车发动机/车身技术特征

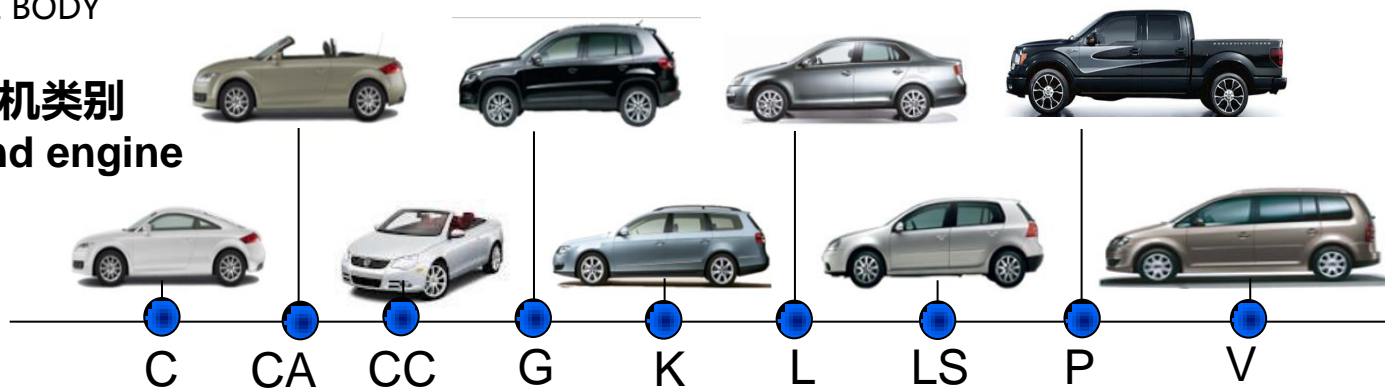
ENGINE & VEHICLE BODY



中国一汽技术中心
CHINA FAW R&D CENTER

车型种类与发动机类别

Vehicle type and engine



发动机类型	类型+气缸数	按类型合计		按车身型式合计	按车身型式									按燃料合计		按车型数
		按排量 (计)	按功率 (计)		C	CA	CC	G	K	L	LS	P	V	汽油车	柴油车	
		386	1020		195	139	33	389	449	715	737	103	345	2151	954	3105
水平对置	B4	4	7	按发动机类别合计					8	3	7			13	5	18
	B6	8	11		11	7		1	1					20		20
直列	R2	1	1								1			1		1
	R3	18	45		5	4		1	10	4	86		1	95	16	111
	R4	182	560		83	63	21	188	337	404	625	43	311	1298	777	2075
	R5	9	20		6	7		8	16	13	3	3	2	30	28	58
	R6	13	32		16	7	6	18	27	39	3	2		82	36	118
V型	V6	65	178		30	21	3	96	36	136	10	19	30	302	79	381
	V8	53	114		25	19	3	63	11	76	1	34		221	11	232
	V10	5	8		4	3		1	3	4				14	1	15
	V12	11	15	10	6		1		14				30	1	31	
W型	W12	1	6	3	2		1		6				12		12	
转子	WA2	2	2	2									2		2	
混合动力	R4+E	8	12				4		10	1		1	16		16	
	V6+E	2	4				2		2				4		4	
	V8+E	4	5				5		4		2		11		11	
合计		386	1020		195	139	33	389	449	715	737	103	345	2151	954	3105

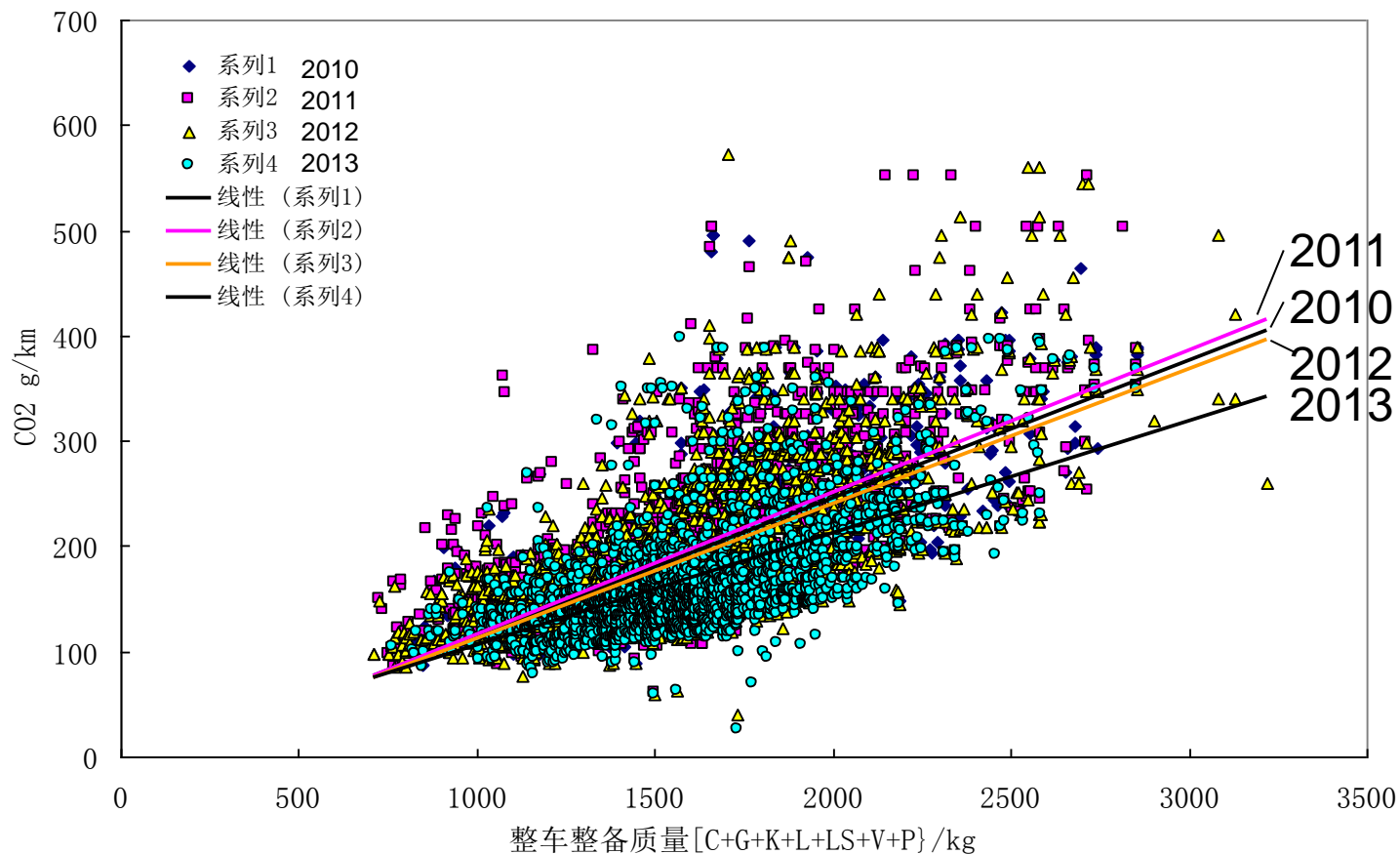
汽车节能减排(全球车辆特征)

Reducing emissions and Improving fuel efficiency



全球车辆 (车型) CO₂排放水平与年代的变化关系

CO₂ emissions vs model year in the world



全球车辆CO₂排放2013年整体效果显现，体现了产品换代？

Co₂ emissions of passenger car in 2013 much lower than last year

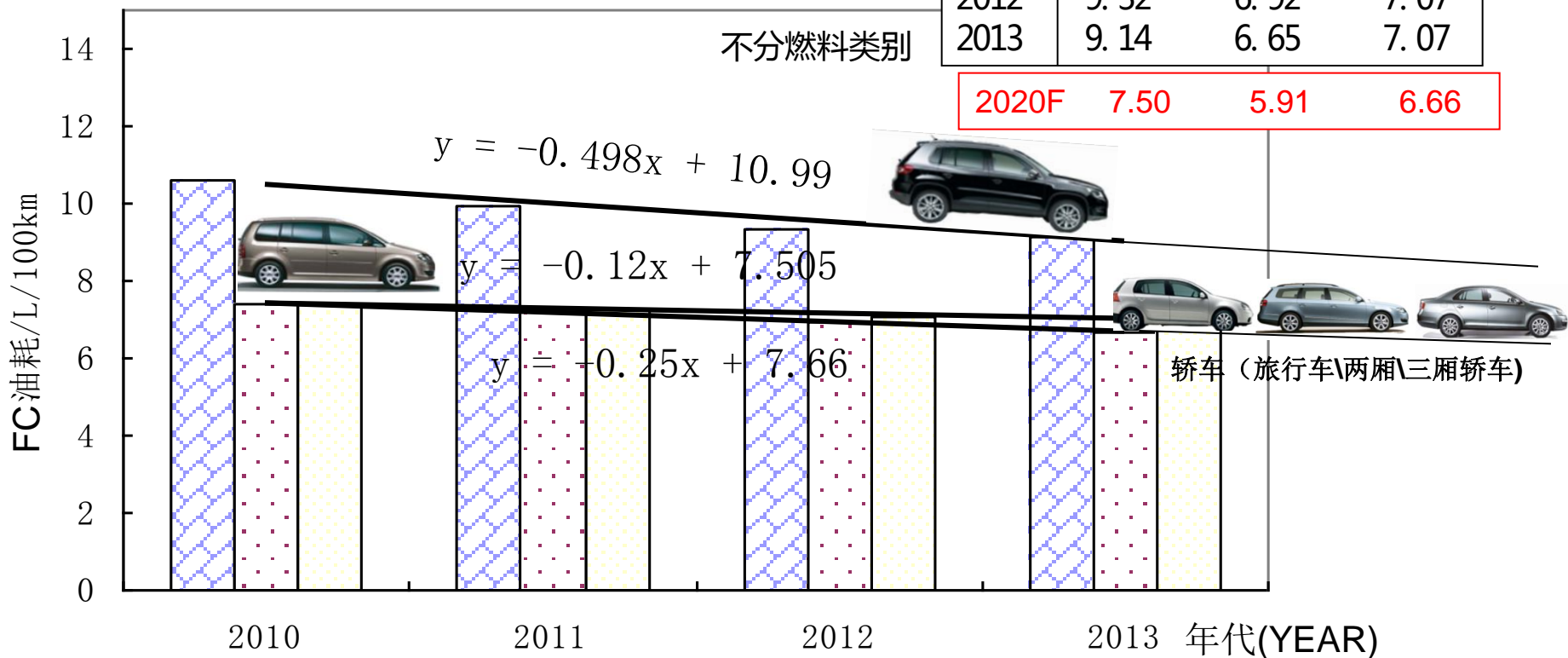
乘用车的油耗现状与趋势【全球市场】

FC STATES & TRENDS IN THE WORLD

	G	K/L/LS	V
2010	10.6	7.4	7.4
2011	9.92	7.17	7.28
2012	9.32	6.92	7.07
2013	9.14	6.65	7.07

油耗平均值随年代的变化

Fuel consumption vs model year in the world



【数据来源：全球名车录2010-2013 技术数据】

- ❑ SUV车型的油耗，每年平均以0.5 L/100km的速度在下降 SUV FC 0.5(L/100km)/per year ↓
- ❑ 轿车车型的的油耗，每年平均以0.25 L/100km的速度在下降 Sedan FC 0.25(L/100km)/per year ↓
- ❑ VAN车型的油耗，每年平均以0.12 L/100km的速度在下降 VAN FC 0.12(L/100km)/per year ↓

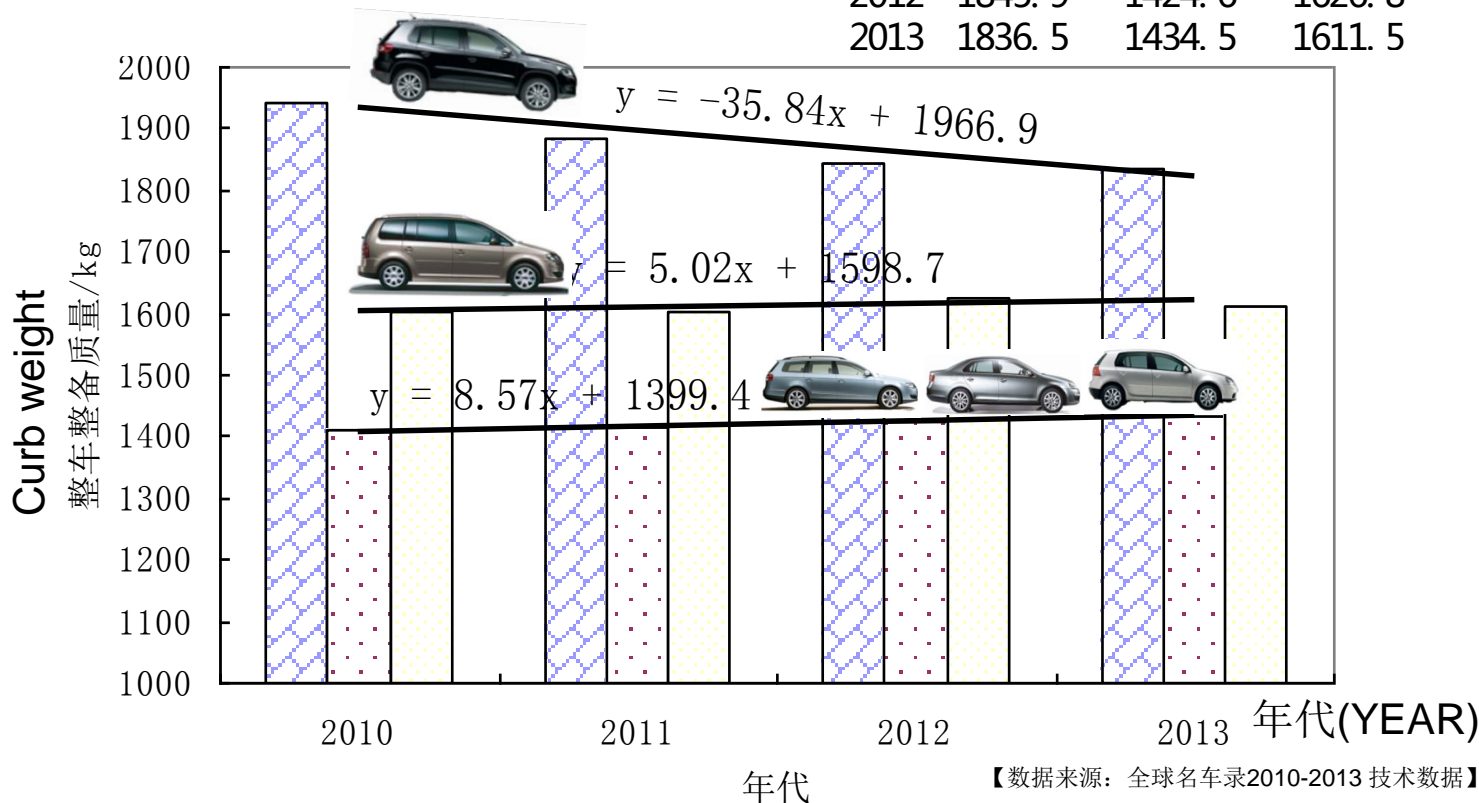
乘用车的整备质量现状与趋势【全球市场】

CURB WEIGHT STATES & TRENDS IN THE WORLD

整备质量平均值与年代

average curb weight with time in order

	G	K/L/LS	V
2010	1943.5	1409.1	1602.3
2011	1883.3	1415.1	1604.2
2012	1845.9	1424.6	1626.8
2013	1836.5	1434.5	1611.5



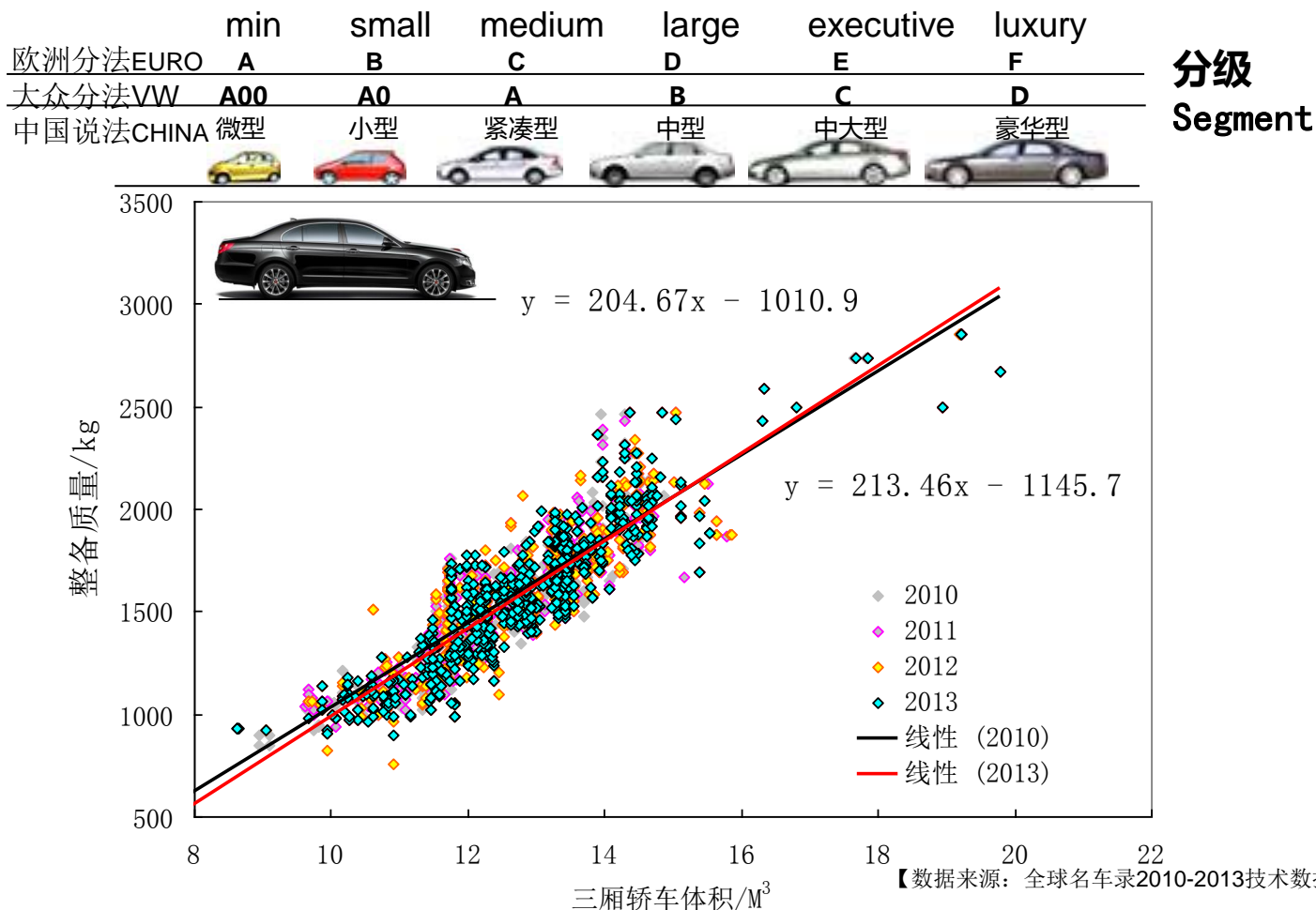
【数据来源：全球名车录2010-2013 技术数据】

- ▣ SUV车型的整备质量，每年平均以36kg的速度在下降 SUV CW 36kg/per year ↓
- ▣ VAN(MPV)车型的整备质量，每年平均以5kg的速度在上升 VAN CW 5 kg/per year ↑
- ▣ 轿车车型的整备质量，每年平均以8.5kg的速度在上升 SEDAN CW 8.5kg/per year ↑

整备质量随年代的变化【全球市场】

CURB WEIGHT WITH TIME IN ORDER IN THE WORLD

整备质量与车体大小 Sedan curb weight with the volume



- 小型车车重略有降低，大型车略有升高，整体变化不明显
- The sedan curb weight changed little during four years (from 2010 to 2013)

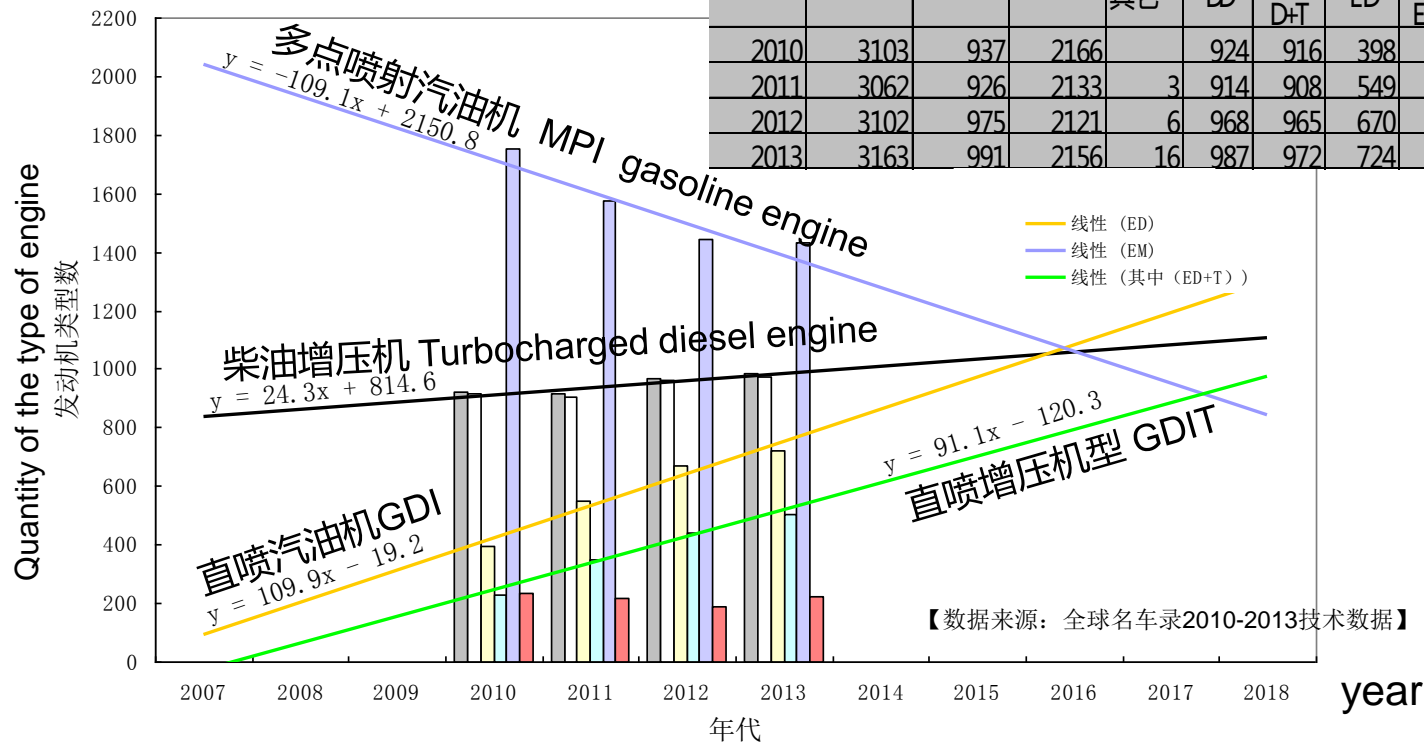
发动机技术现状与趋势【全球市场】

ENGINE TECH STATES & TRENDS IN THE WORLD

发动机技术应用与年代

Engine tech application with time

年代	车型总数	D柴油机		G汽油机	OTHER 其它	D柴油机		G汽油机			
		DD	其中 D+T			ED	其中 ED+T	EM	其中 EMT		
2010	3103	937		2166		924	916	398	229	1752	234
2011	3062	926		2133	3	914	908	549	350	1574	215
2012	3102	975		2121	6	968	965	670	442	1446	191
2013	3163	991		2156	16	987	972	724	502	1431	226



- 装有多点喷射汽油机车辆平均每年减少109个型车
Vehicles with MPI 109 decrease/per year
- 装有直喷汽油机的车辆平均每年增加110个型车, 其中91种为直喷增压机型
Vehicles with GDI 110 decrease/per year
- 装有柴油增压的车辆平均每年增加24个型车
Vehicles with Turbocharged diesel engine 24 decrease/per year

燃油消耗与整备质量 Fuel consumption versus Curb weight

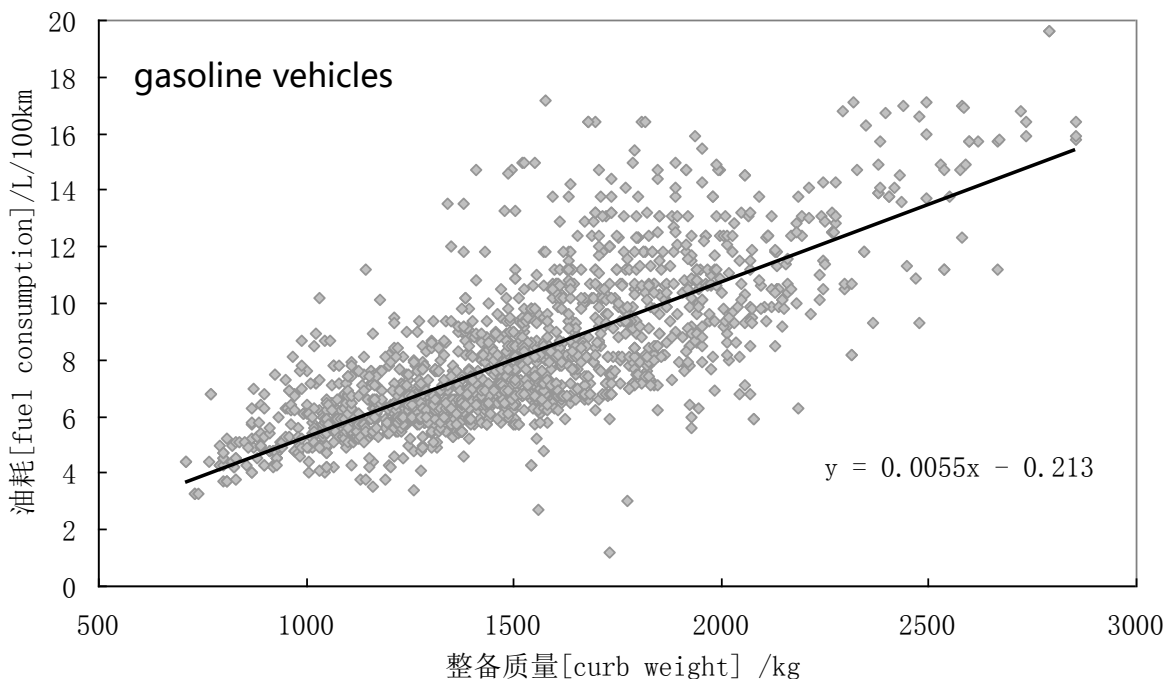
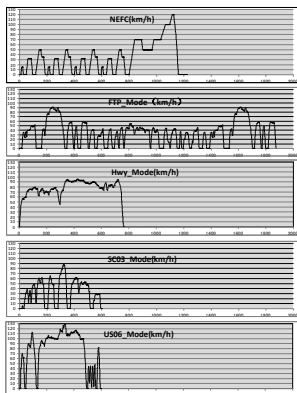
	min	small	medium	large	executive	luxury
欧洲分法EURO	A	B	C	D	E	F
大众分法VW	A00	A0	A	B	C	D
中国说法CHINA	微型	小型	紧凑型	中型	中大型	豪华型



分级
Segment

不同国家用的测试
工况不同，油耗结
果有差异

Different test method
different results



车种
VEHICLE TYPE



【数据来源：全球名车录2013技术数据】

汽油乘用车每降低100kg 节油0.55L/100km[不包含pickup车]

Fuel consumption will be reduced by 0.55L/100km with every 100kg mass drop in gasoline vehicles

汽油车燃油消耗与整备质量 FC of gasoline vehicles versus Curb weight

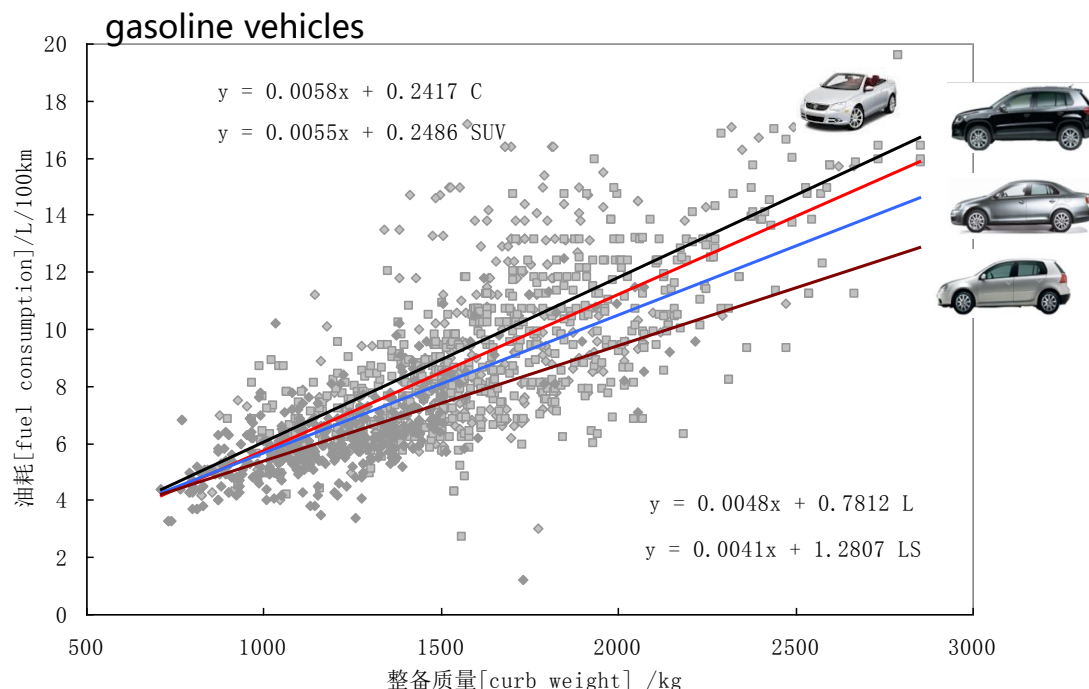
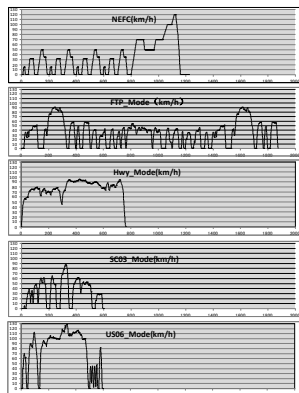
	min	small	medium	large	executive	luxury
欧洲分法EURO	A	B	C	D	E	F
大众分法VW	A00	A0	A	B	C	D
中国说法CHINA	微型	小型	紧凑型	中型	中大型	豪华型

分级
Segment



不同国家用的测试
工况不同，油耗结
果有差异

Different test method
different results



【数据来源：全球名车录2013技术数据】

控制轿跑车\SUV也是节油的有效途径

Controlling the SUV & Racing car is also good way for reducing fuel consumption

柴油车燃油消耗与整备质量 FC of diesel vehicles versus curb weight

	min	small	medium	large	executive	luxury
欧洲分法EURO	A	B	C	D	E	F
大众分法VW	A00	A0	A	B	C	D
中国说法CHINA	微型	小型	紧凑型	中型	中大型	豪华型



分级
Segment

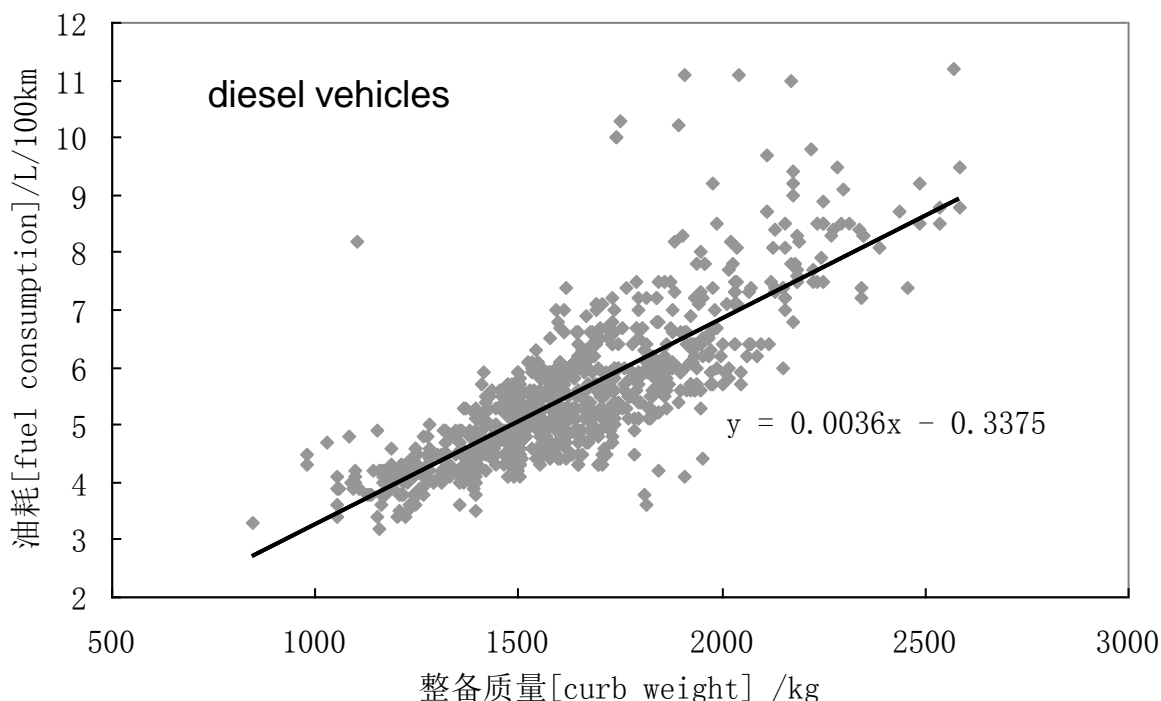
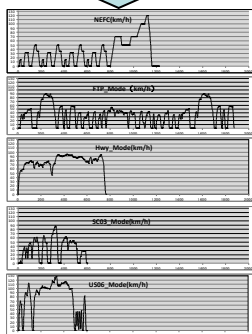
车种

VEHICLE TYPE



不同国家用的测试工况不同，油耗结果有差异

Different test method different results



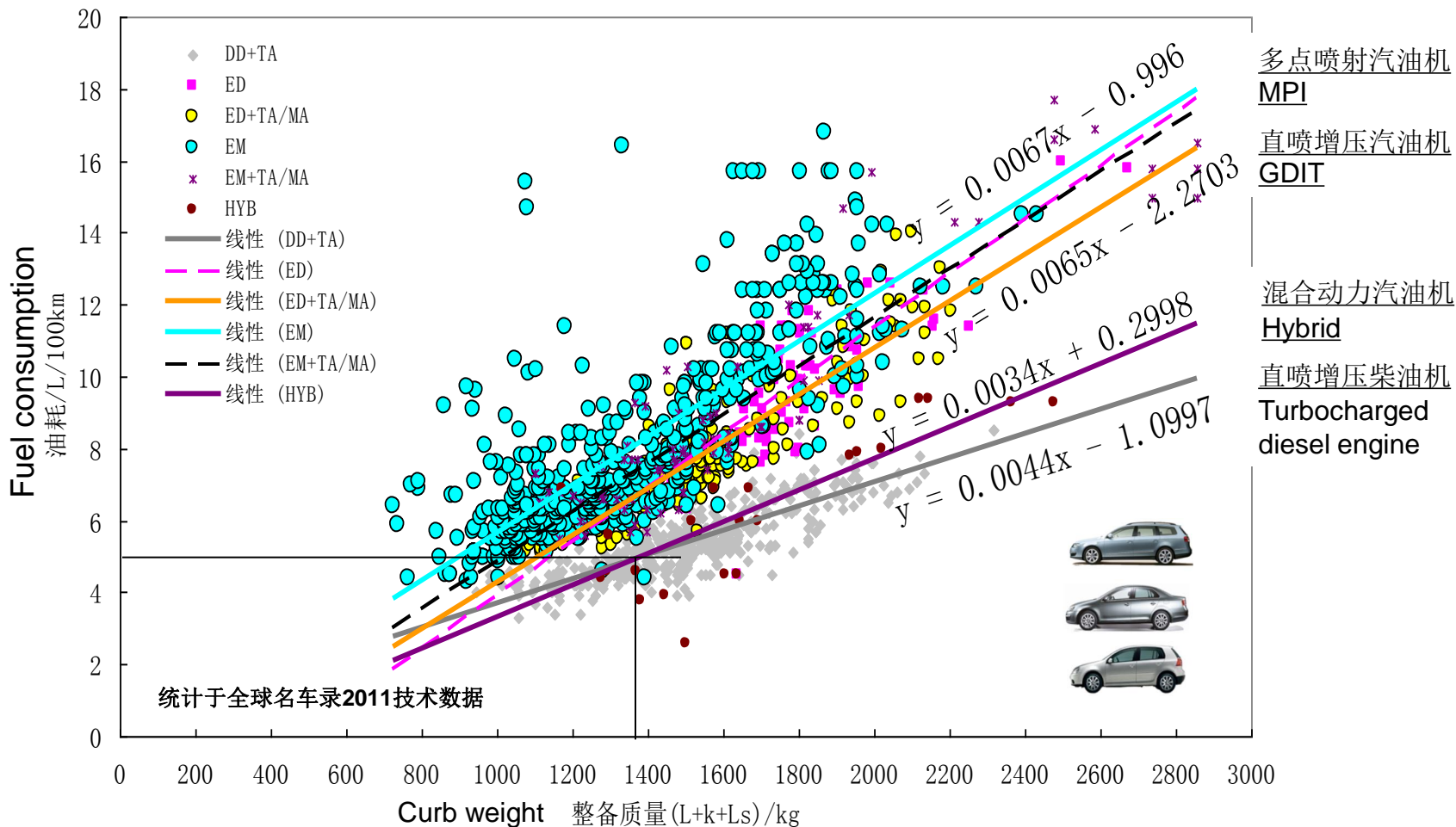
【数据来源：全球名车录2013技术数据】

柴油乘用车每降低100kg 节油0.36L/100km

Fuel consumption will be reduced 0.36L/100km per 100kg mass lighter in diesel vehicles

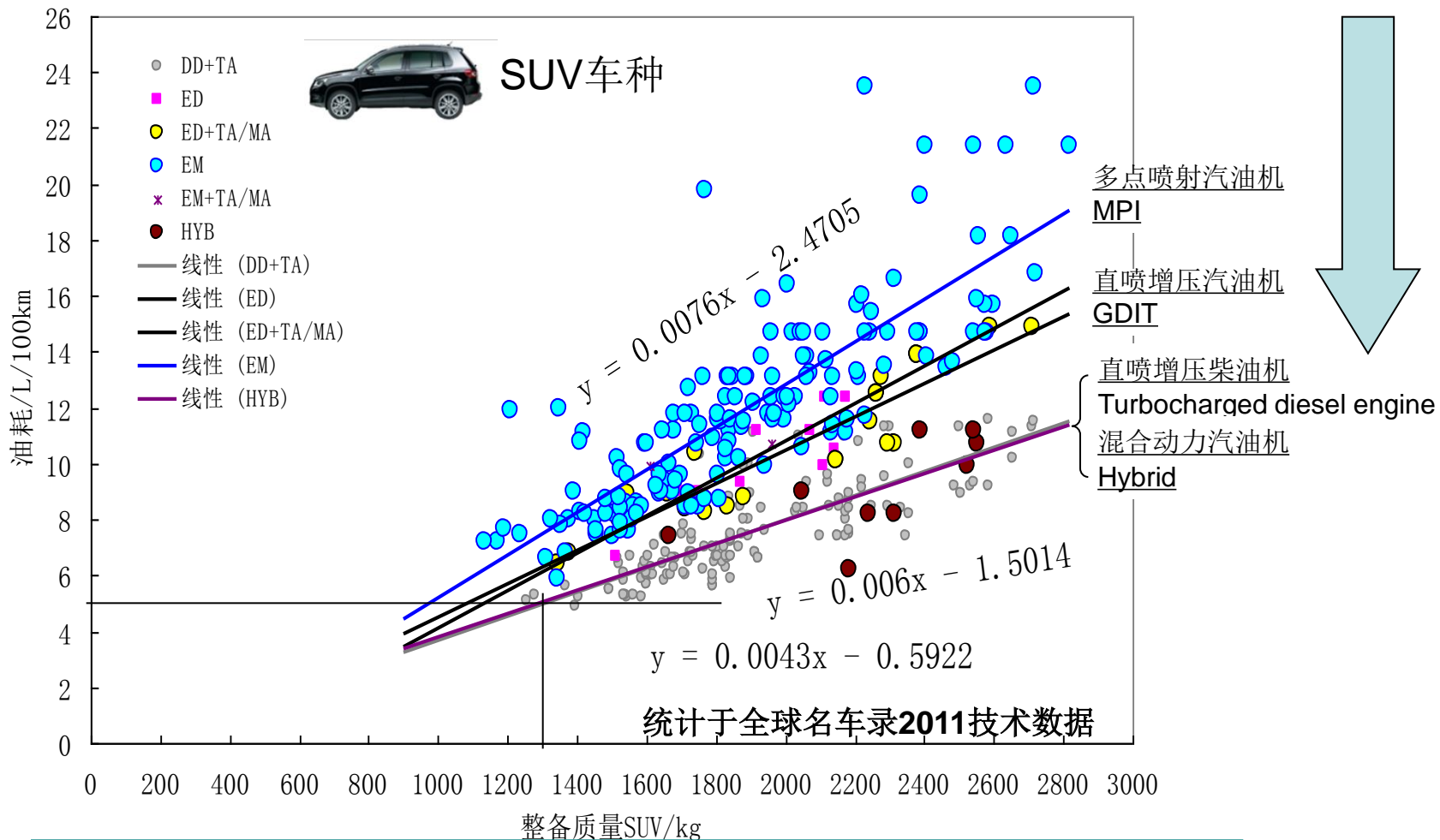
不同动力轿车油耗与整备质量[不同发动机燃料/混合气形成]

Fuel consumption versus Curb weight [different engine/fuel/mix]



■ 多点喷射、直喷增压汽油机、混合动力、柴油机依此次更节油
■ FC from high to low is GMPI GTDI HYB & Turbocharged diesel

不同动力SUV油耗与整备质量[不同发动机燃料/混合气形成] FC of SUVs versus Curb weight [different engine/fuel/mix]





多点喷射、直喷增压汽油机、柴油机、混合动力 依此次更节油

不同动力车型油耗与整备质量[不同发动机燃料/混合气形成]

FC of vehicles versus Curb weight [different engine/fuel/mix]

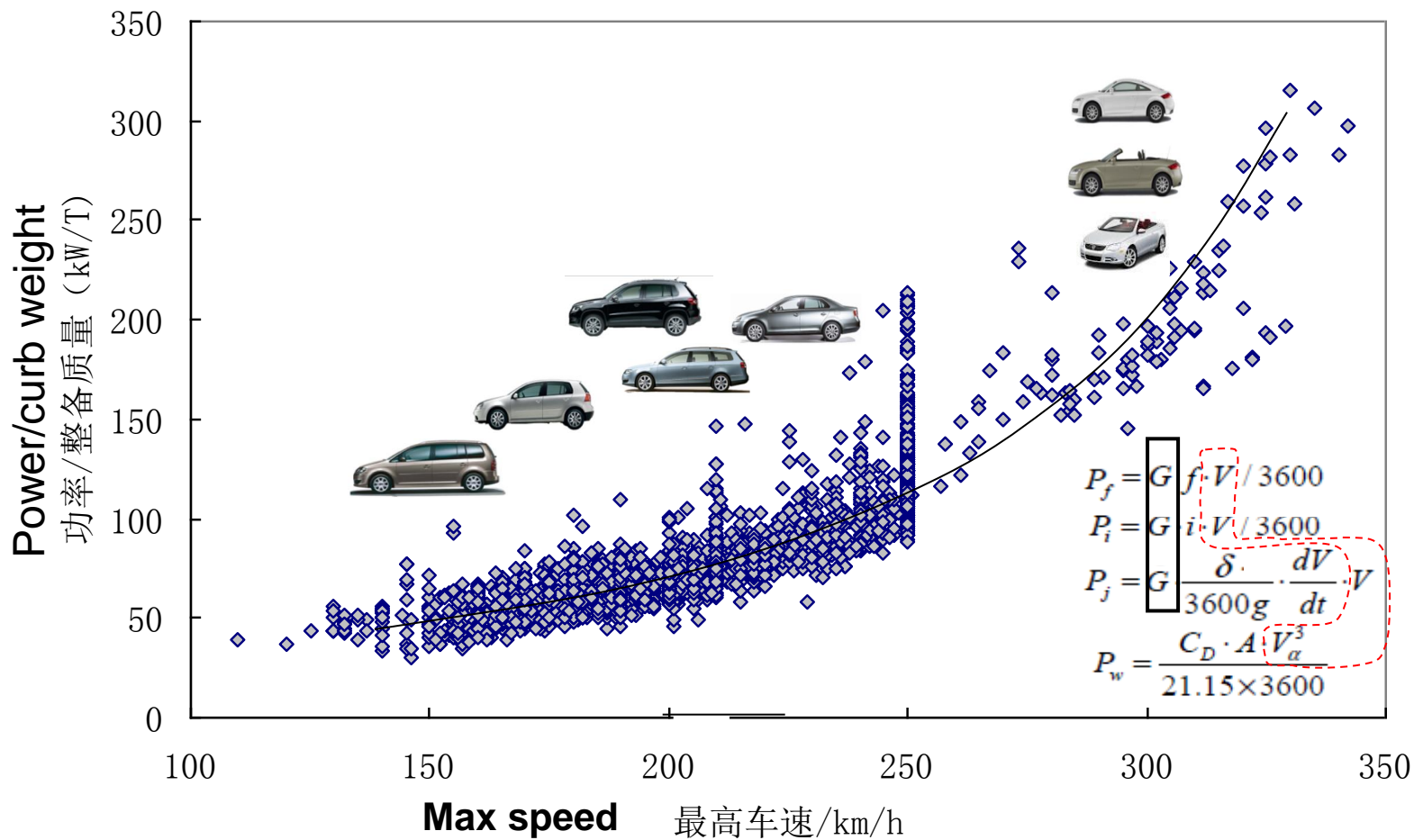
依据全球名车录2011技术数据，统计平均算出：各种动力的平均油耗量(L/100km)见下表
The table is estimated by 2011 models, the average FC in difference vehicles

简图	FC(L/100km)				FC(L/100km)		
							
整备质量(kg)	EM	ED+TA/MA	HYB	DD+TA	EM	ED+TA/MA	HYB
1000	5.704	4.2297	3.6998	3.3003	5.1295	4.4986	3.7078
1100	6.374	4.8797	4.0398	3.7403	5.8895	5.0986	4.1378
1200	7.044	5.5297	4.3798	4.1803	6.6495	5.6986	4.5678
1300	7.714	6.1797	4.7198	4.6203	7.4095	6.2986	4.9978
1375	8.2165	6.6672	4.9748	4.9503	7.9795	6.7486	5.3203
1400	8.384	6.8297	5.0598	5.0603	8.1695	6.8986	5.4278
1500	9.054	7.4797	5.3998	5.5003	8.9295	7.4986	5.8578
1600	9.724	8.1297	5.7398	5.9403	9.6895	8.0986	6.2878
1700	10.394	8.7797	6.0798	6.3803	10.4495	8.6986	6.7178
1800	11.064	9.4297	6.4198	6.8203	11.2095	9.2986	7.1478
1900	11.734	10.0797	6.7598	7.2603	11.9695	9.8986	7.5778
2000	12.404	10.7297	7.0998	7.7003	12.7295	10.4986	8.0078
2100	13.074	11.3797	7.4398	8.1403	13.4895	11.0986	8.4378
2200	13.744	12.0297	7.7798	8.5803	14.2495	11.6986	8.8678
2300	14.414	12.6797	8.1198	9.0203	15.0095	12.2986	9.2978
2400	15.084	13.3297	8.4598	9.4603	15.7695	12.8986	9.7278
2500	15.754	13.9797	8.7998	9.9003	16.5295	13.4986	10.1578

Curb weight

比功率与最高车速

POWER RATIO VERSUS MAX SPEED OF VEHICLE



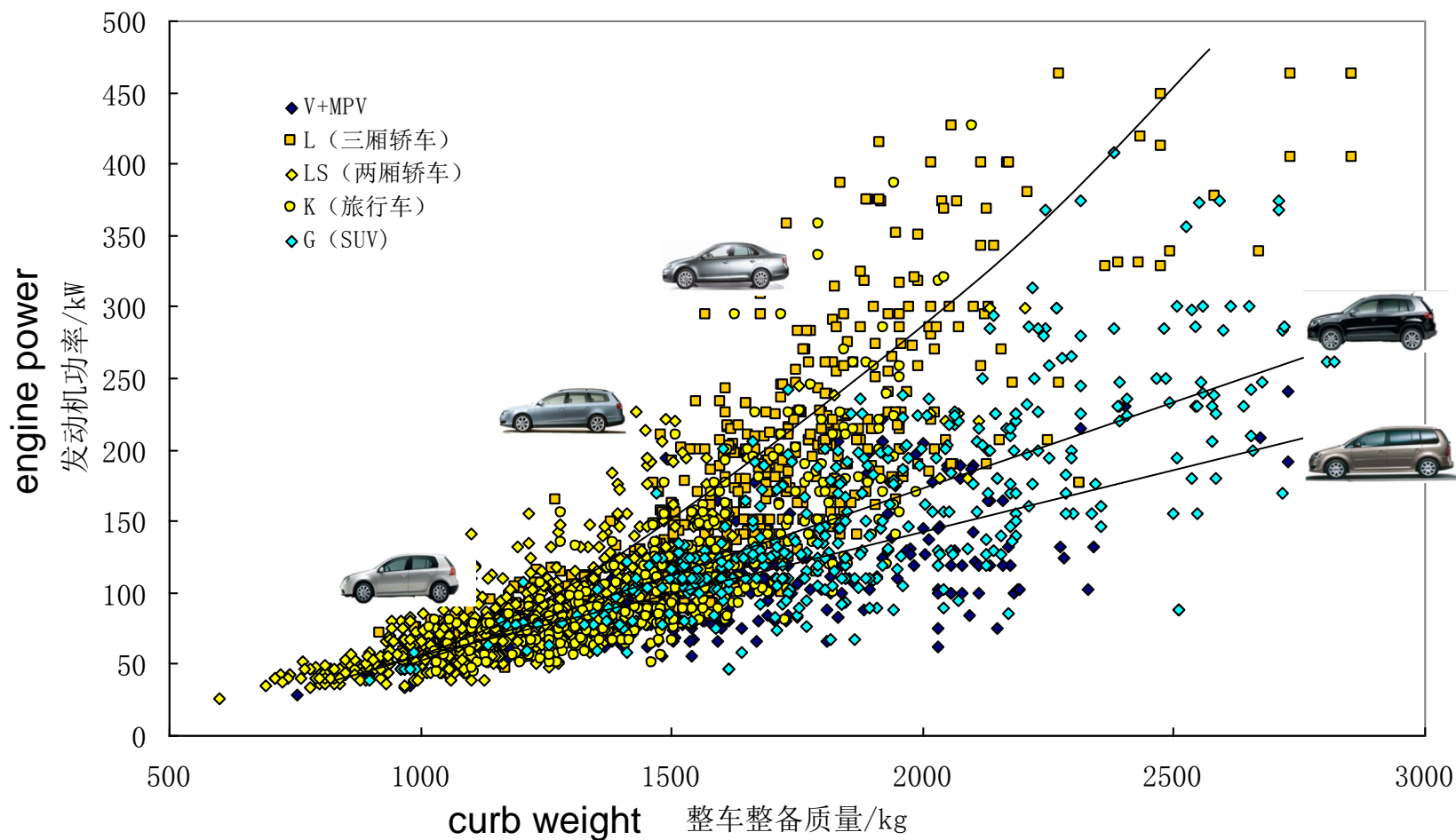
【数据来源：全球名车录2011技术数据】

发动机功率与整备质量

ENGINE POWER VERSUS CURB WEIGHT



中国一汽技术中心
CHINA FAW R&D CENTER

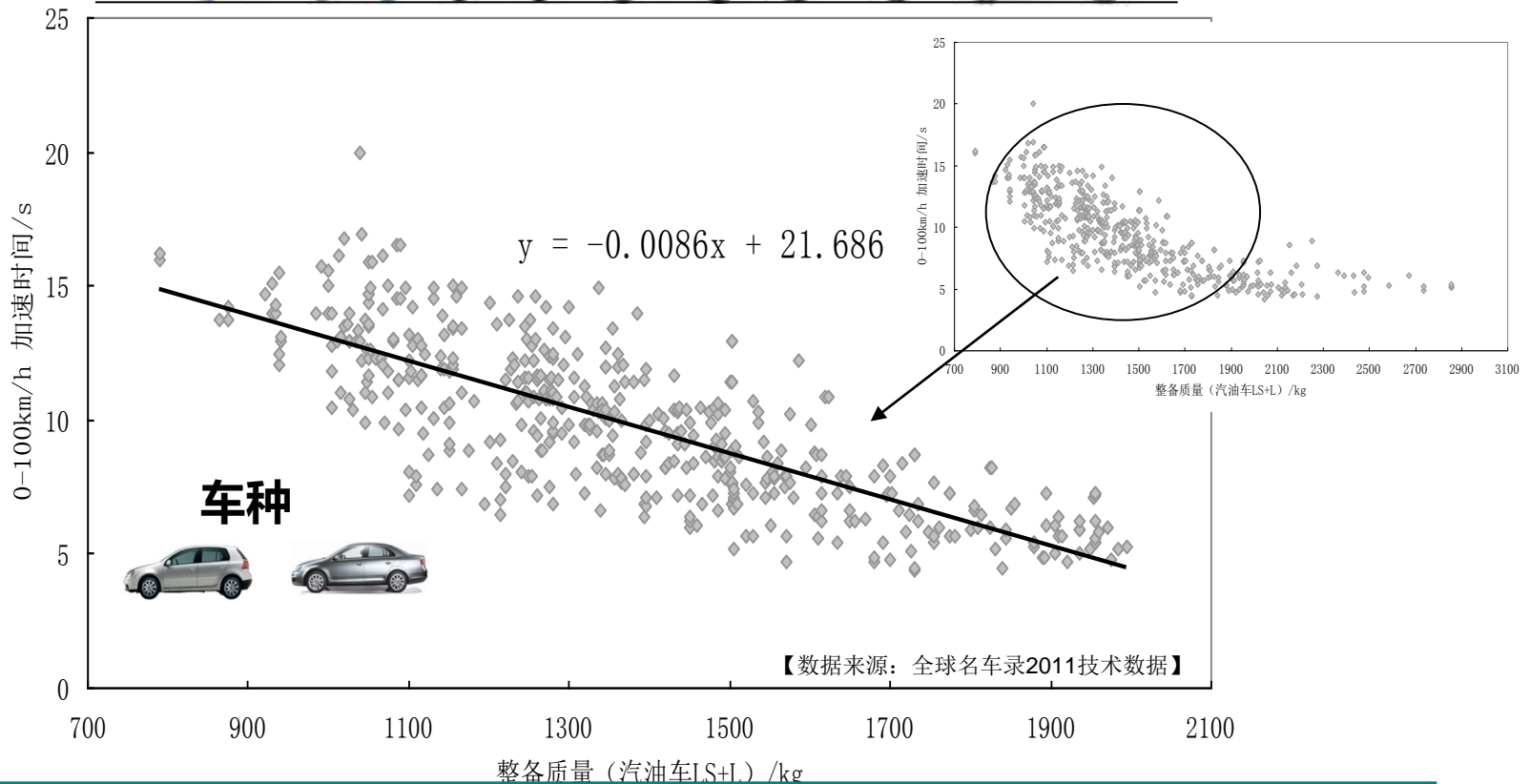


【数据来源：全球名车录2011技术数据】

动力性能与整备质量

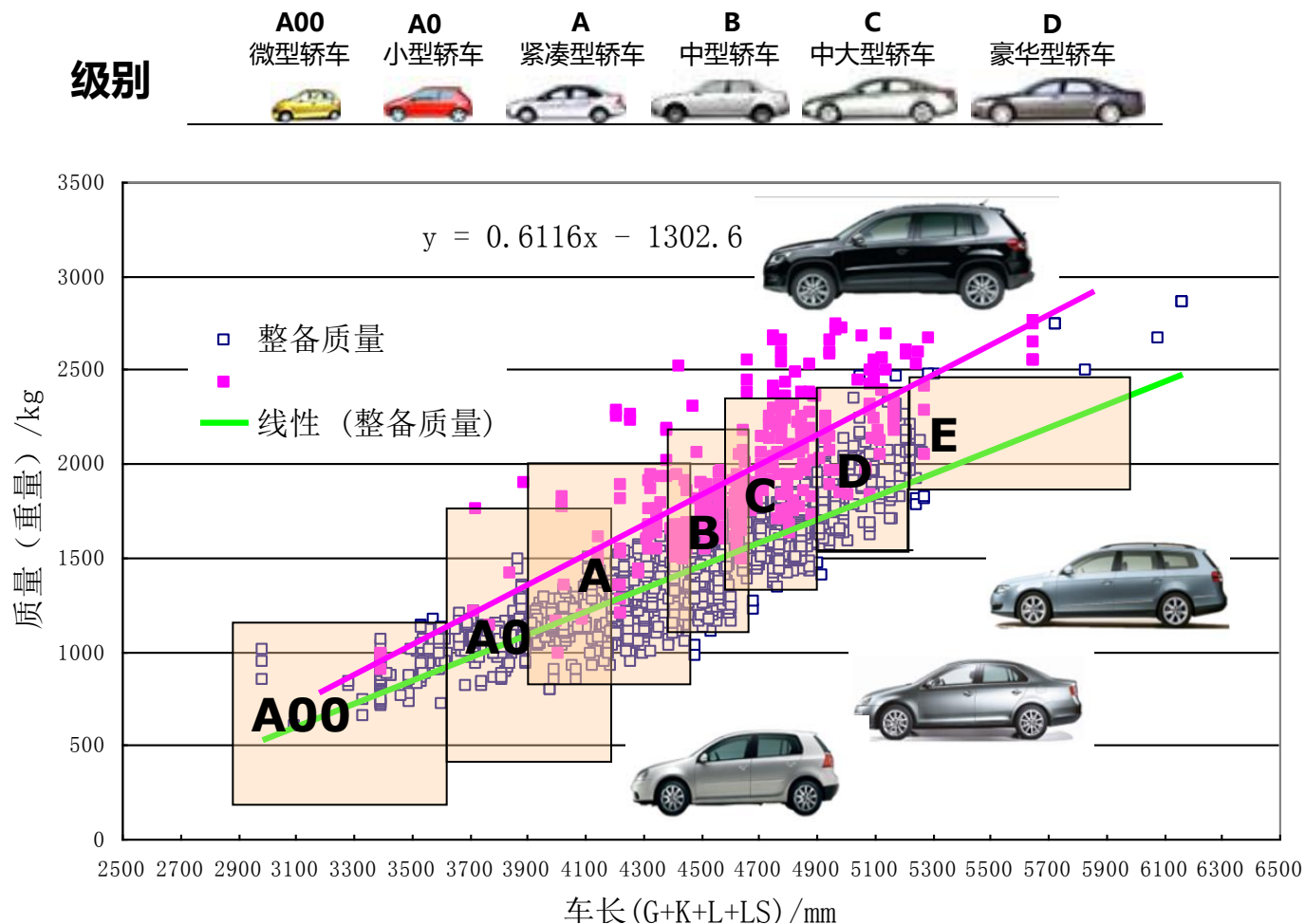
POWER PERFORMANCE VERSUS CURB WEIGHT

	min	small	medium	large	executive	luxury	
欧洲分法EURO	A	B	C	D	E	F	分级 Segment
大众分法VW	A00	A0	A	B	C	D	
中国说法CHINA	微型	小型	紧凑型	中型	中大型	豪华型	



- 每降低100kg 加速性能 (0-100km/h) 加速时间减少0.86s
- The acceleration time (0-100km/h) be reduced 0.86s per 100kg mass lighter

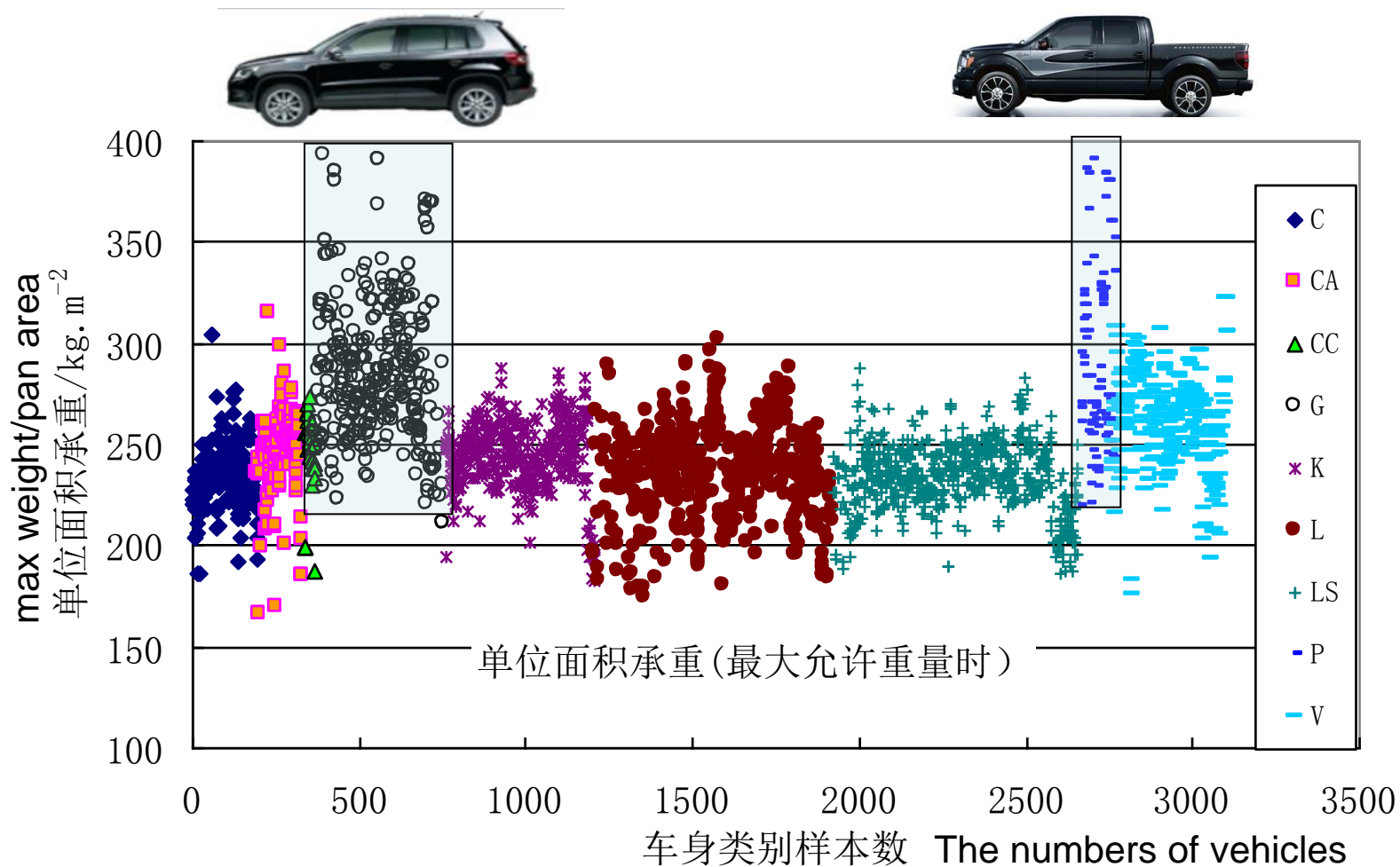
SUV级别分布与整备质量 comparing the weights of SUV & Sedan



- 同样车长的轿车和SUV, SUV 比轿车重很多
- The mass of Sedan is lighter than SUV in same lengths

整备质量与车底面积

THE CURB WEIGHTS VS PAN AREA



以2011-2013工信部的公告油耗为基础，统计出的燃油消耗量、重量等

The average curb weight/FC/Displacement be calculated from 2011-2013

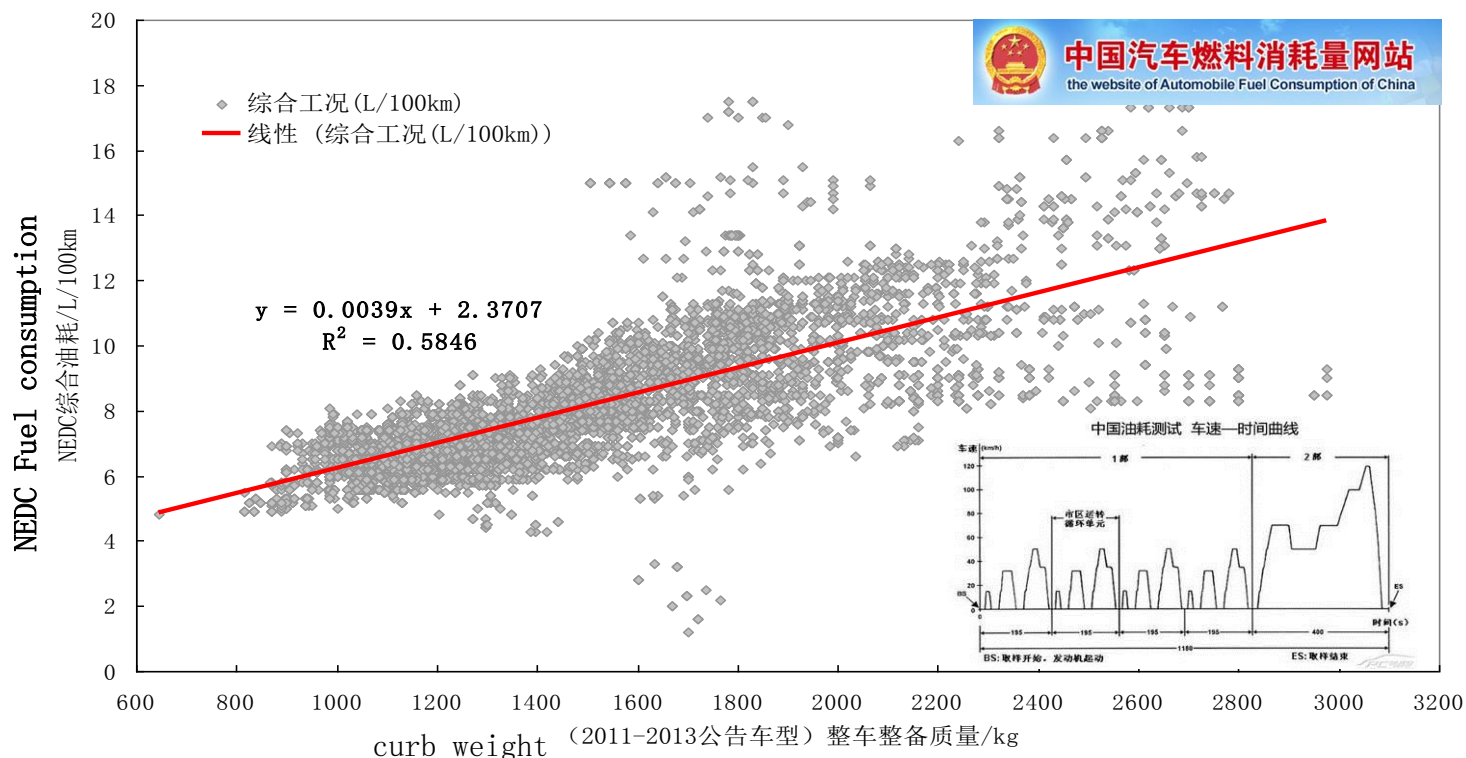


项目	2011	2012	2013
排量 (L) Displacement (average)	1.866	1.792	2.053
整备质量(kg) Curb weight	1433.02	1401.65	1519.38
功率 (kW) power	100.32	99.84	122.87
综合油耗NEDC (L/100km) FC	8.16	7.777	8.06
车型数 (公告) Quantity of registration	1924	2917	3016

燃油消耗与整备质量[公告] Fuel consumption versus the curb weight

以2011-2013工信部的公告油耗为基础，统计出的燃油消耗量与重量的关系

The statistical relationship between fuel consumption and curb weight



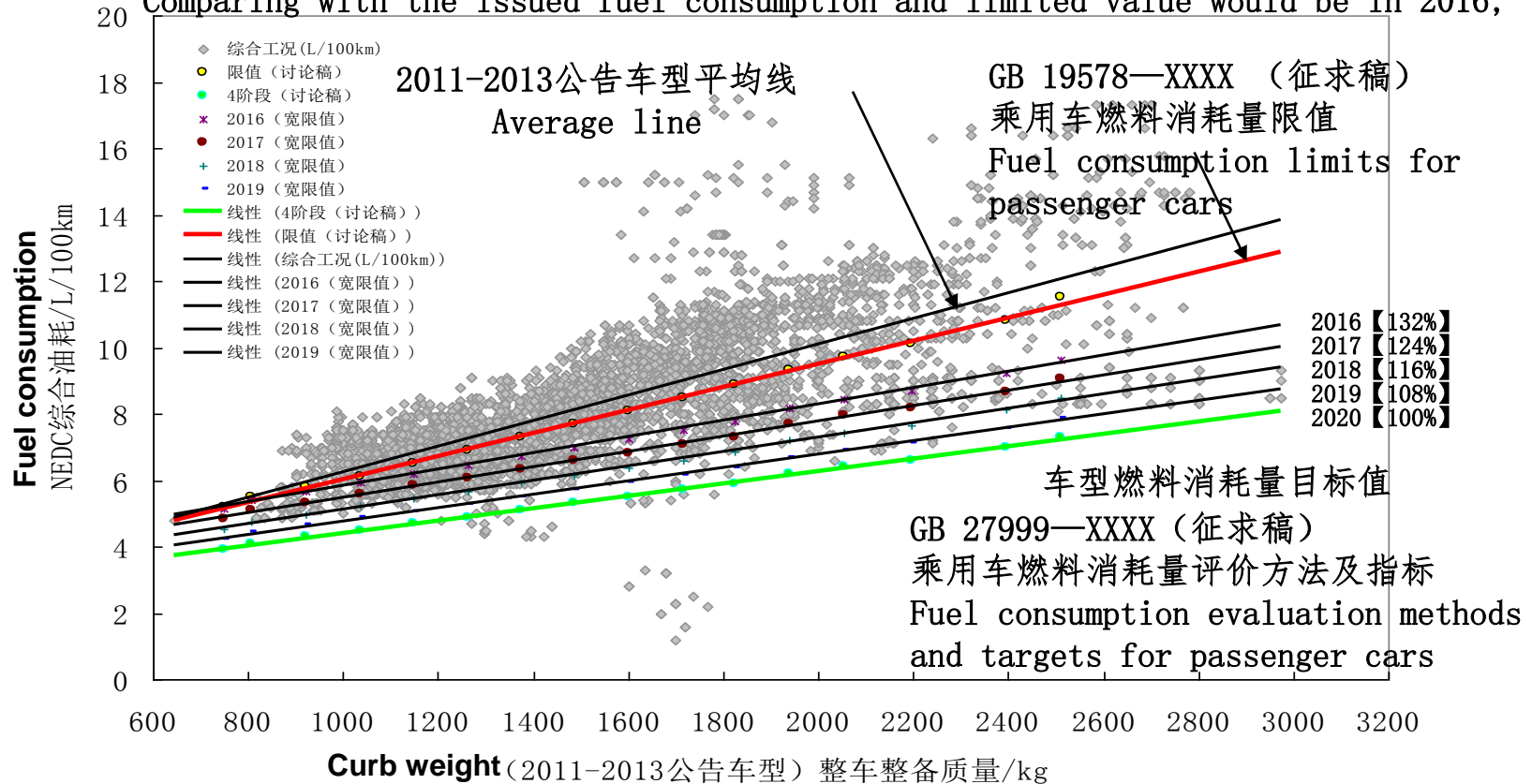
- 整车整备质量每减少100kg 综合油耗(NEDC)减少0.39L/100km
- NEDC Fuel consumption will be reduced 0.39L/100km per 100kg mass lighter

燃油消耗与整备质量[目标与现状]

Fuel consumption versus curb weight (targets and present)

以2011-13工信部的公告油耗为基础，与2016年油耗限值及四阶段放宽线

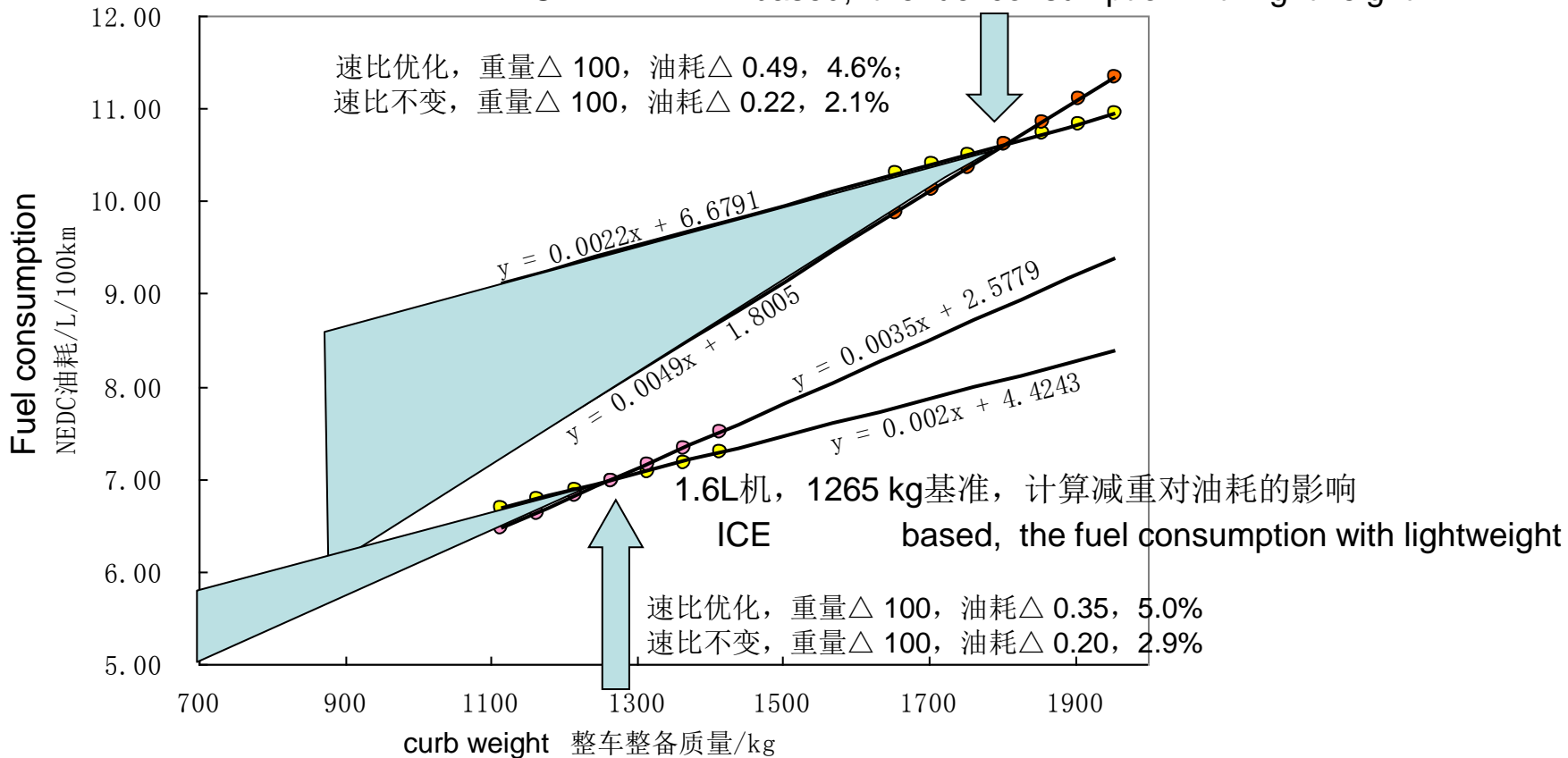
Comparing with the issued fuel consumption and limited value would be in 2016,



□ 用2016年的限值考评2013车型：在售车型达标率41.1%，公告车型达标率53.4%
According to the stricter regulation will be issued in 2016, only 41.1 % of the passenger vehicles on sale are met, only 53.4% of the new issued vehicles in 2013, are met .

燃油消耗与整备质量[计算模拟] Fuel consumption versus the curb weight (CAE)

3L 发动机, 1800kg基准, 计算减重对油耗的影响
ICE based, the fuel consumption with lightweight



燃油消耗与降低车重[计算模拟] Fuel consumption and the curb weight (CAE)

车辆级别	德A/欧C		德C/欧E	
整车整备质量(kg)	1265		1800	
	速比不变	速比调整	速比不变	速比调整
G-25	0.04	~ 0.087	0.055	~ 0.12
G-50	0.08	~ 0.174	0.11	~ 0.24
G-75	0.12	~ 0.261	0.165	~ 0.36
G-100	0.16	~ 0.348	0.22	~ 0.48
G-125	0.2	~ 0.435	0.275	~ 0.6
G-150	0.24	~ 0.522	0.33	~ 0.72
G-175	0.28	~ 0.609	0.385	~ 0.84
G-200	0.32	~ 0.696	0.44	~ 0.96

One important customer demand is improved driving dynamics. The ideal balance for driving dynamics is a minimal vehicle mass, a center of gravity below the axle line located perfectly between the two axles in the center of the vehicle, and a structure with high static stiffness.

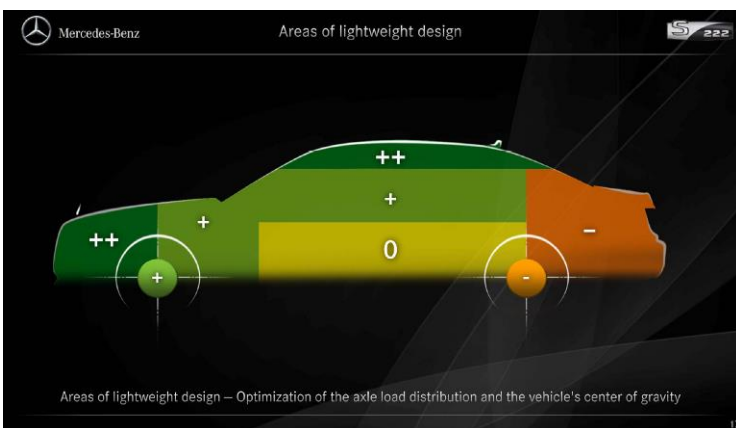
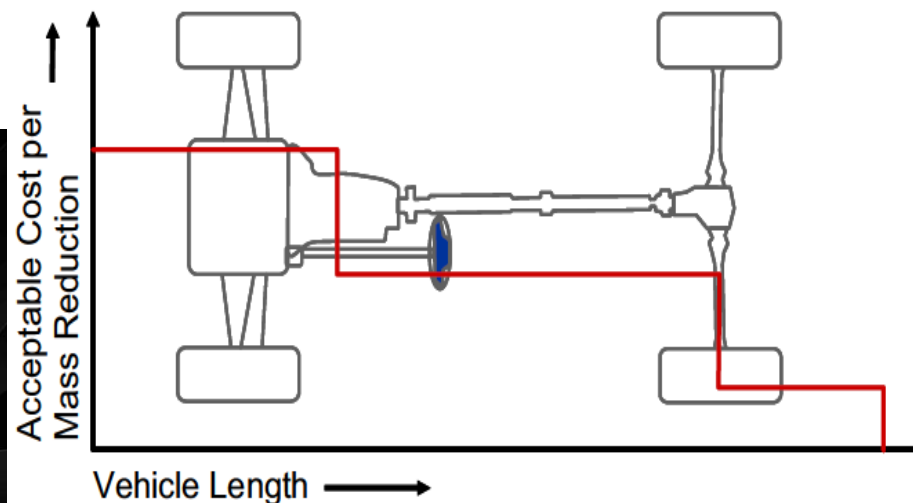
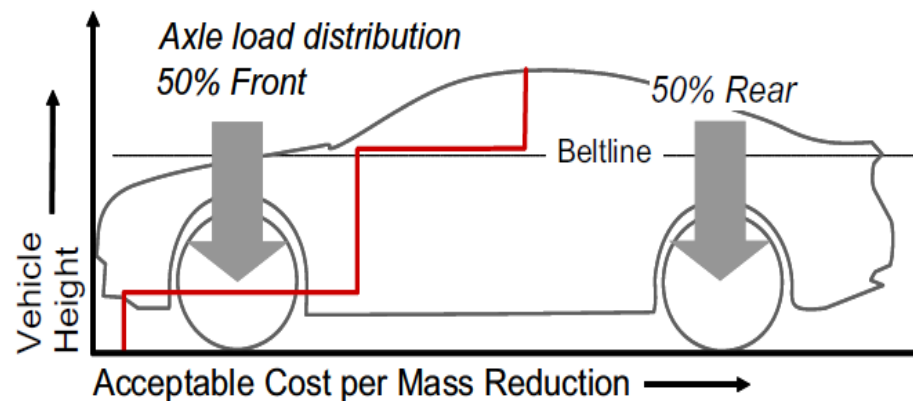
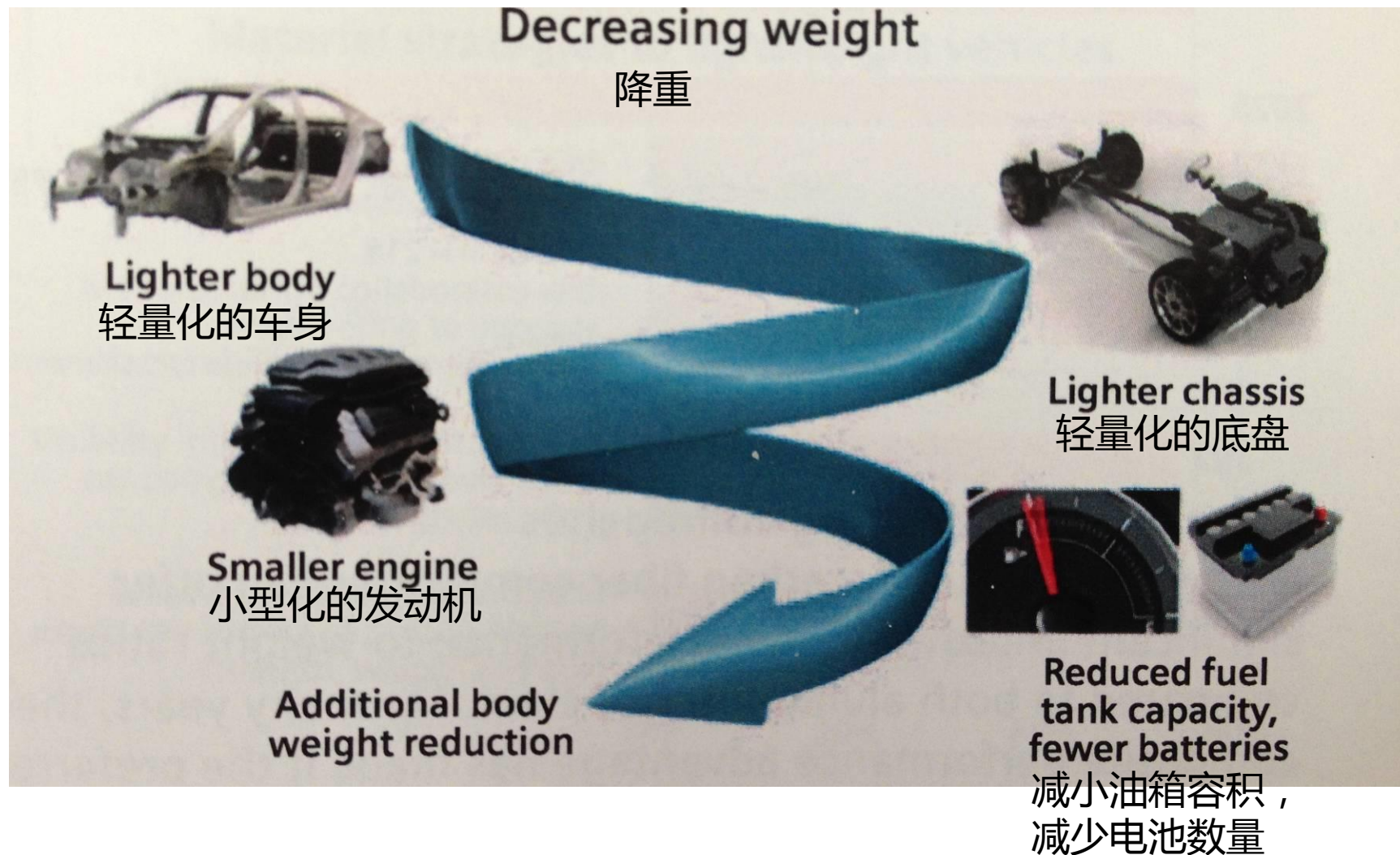


Figure 3: Value proposition for the implementation of lightweight solutions

整车重量与各总成的占比

大总成或系统	占比%	部件	占比%	英文
车身+4门+2盖	27.19	车身	22.686	body structure
		闭合件	4.504	closures
内饰	20.43	内饰	20.434	body non-structure
外饰	2.17	保险杠	2.168	bumpers
动力与传动	22.52	动力总成	18.515	drivetrain
		附件	4.003	fuel, battery, exhaust
底盘	20.43	前悬架	4.921	front suspension
		后悬架	4.420	rear suspension
		转向	1.418	steering
		车轮	6.505	wheels tires
		制动	3.169	brakes
空调	2.67	空调	2.669	air conditioning
电气	4.59	电气	4.587	electrical

轻量化路径



整备质量与车辆特征 curb weight & vehicle feature

分级

Segment

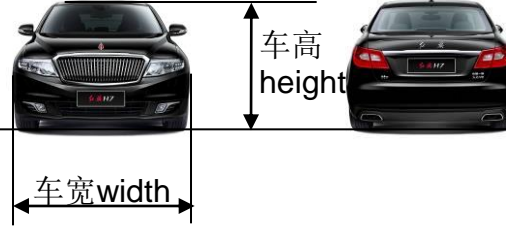
	min	small	medium	large	executive	luxury
欧洲分法EURO	A	B	C	D	E	F
大众分法VW	A00	A0	A	B	C	D
中国说法CHINA	微型	小型	紧凑型	中型	中大型	豪华型



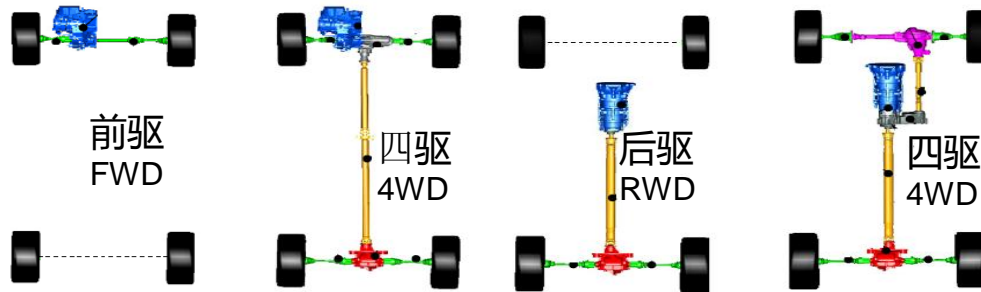
车型种类
Type



L_l 长度Length
 V_v 体积Volume
 S_f 表面Surface



D {
F 前驱 FWD
H 后驱 RWD
A 四驱 4WD



横置transversal







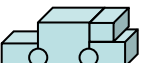
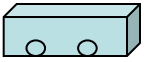
纵置longitudinal

建立以车型大小和传动方式为主特征的整备质量统计关系

Try to find: the curb weight Versus vehicle sizes and driveline

车型种类与形体简化 Vehicle type & Shape factor

$$W(T,D)=f(V_v, S_f, L_l)$$

形体简化 shape simplify	车型种类 vehicle type					
阶型体 Notch/Hatch		●				
			●	●		
长方体Cuboid		●	●	●	●	●

阶型体notch/hatch :

3厢式 [体积]=[轴距X车高+(车长-轴距)X车高/2]X车宽

Sedans volume=[wheelbase*height+ (length-wheelbase)*height*.5]*width

2厢式/SUV [体积]=[轴距X车高+(车长-轴距)X车高X2/3]]X车宽

SUVs & Hatchbacks volume =[wheelbase*Height+ (Length-wheelbase)*height*2/3]*width

长方体cuboid: [体积]=长X宽X高 Volume=Length* width*Height

[表面积/2]=长X宽+长X高+宽X高

Surface/2=Length* Width+ Length *Height+ Width*Height

线性相关系数 R²

型体分类 Shape Type		L	LS	G	K	V
车长度length	线长length	0.809	0.785	0.63	0.635	0.85
阶型体	体积Volume	0.818	0.806	0.792	0.475	
notch/hatch	表面积Surface	0.831	0.831	0.786	0.624	
长方体	体积Volume	0.798	0.813	0.786	0.503	0.899
cuboid	表面积Surface	0.816	0.828	0.783	0.613	0.912

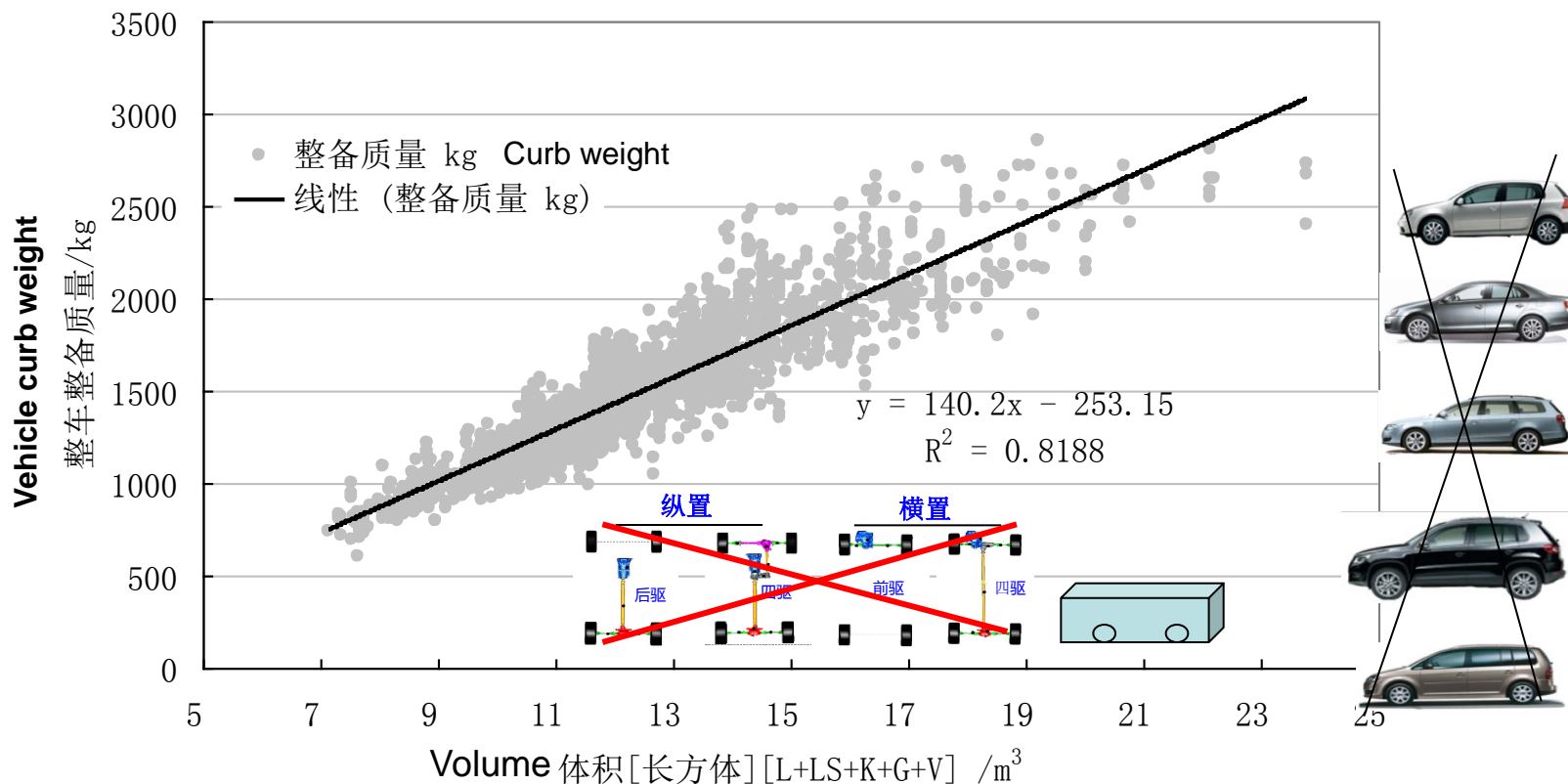
通常当R的绝对值大于0.75时，认为两个变量有很强的线性相关关系

Two variables have strong linear connection while R² is more than 0.75

整备质量与车辆级别[车体]特征

Vehicle curb weight versus Segment feature

[不分车种 不分驱动型式] [w/o Distinguished vehicle type and drive mode]

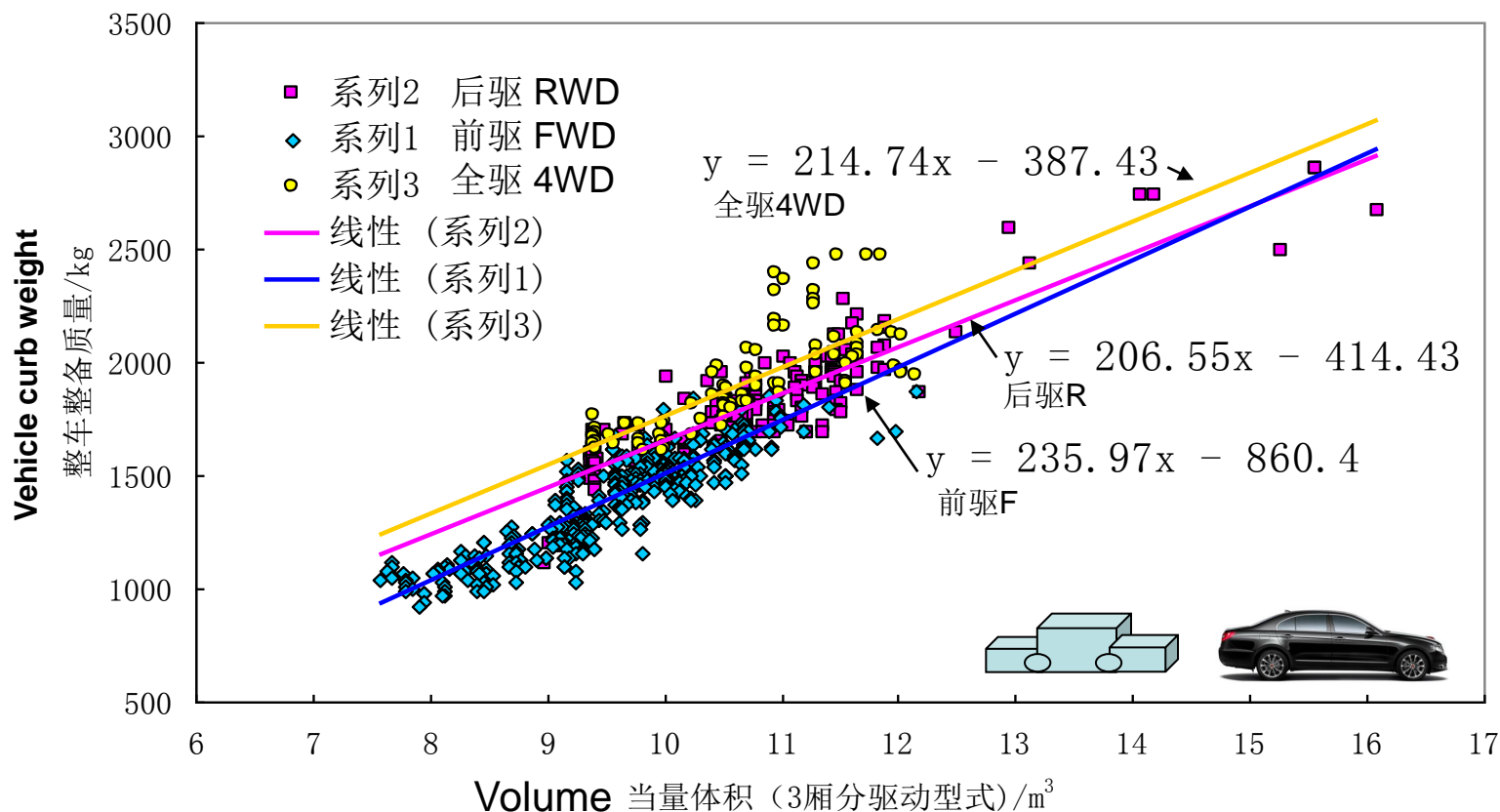
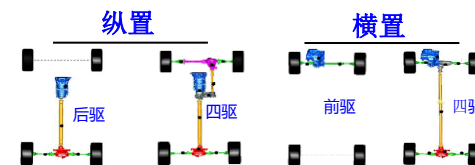


【数据来源：全球名车录2011技术数据】

乘用车的轻量化评价-【阶型车体】评价标杆线

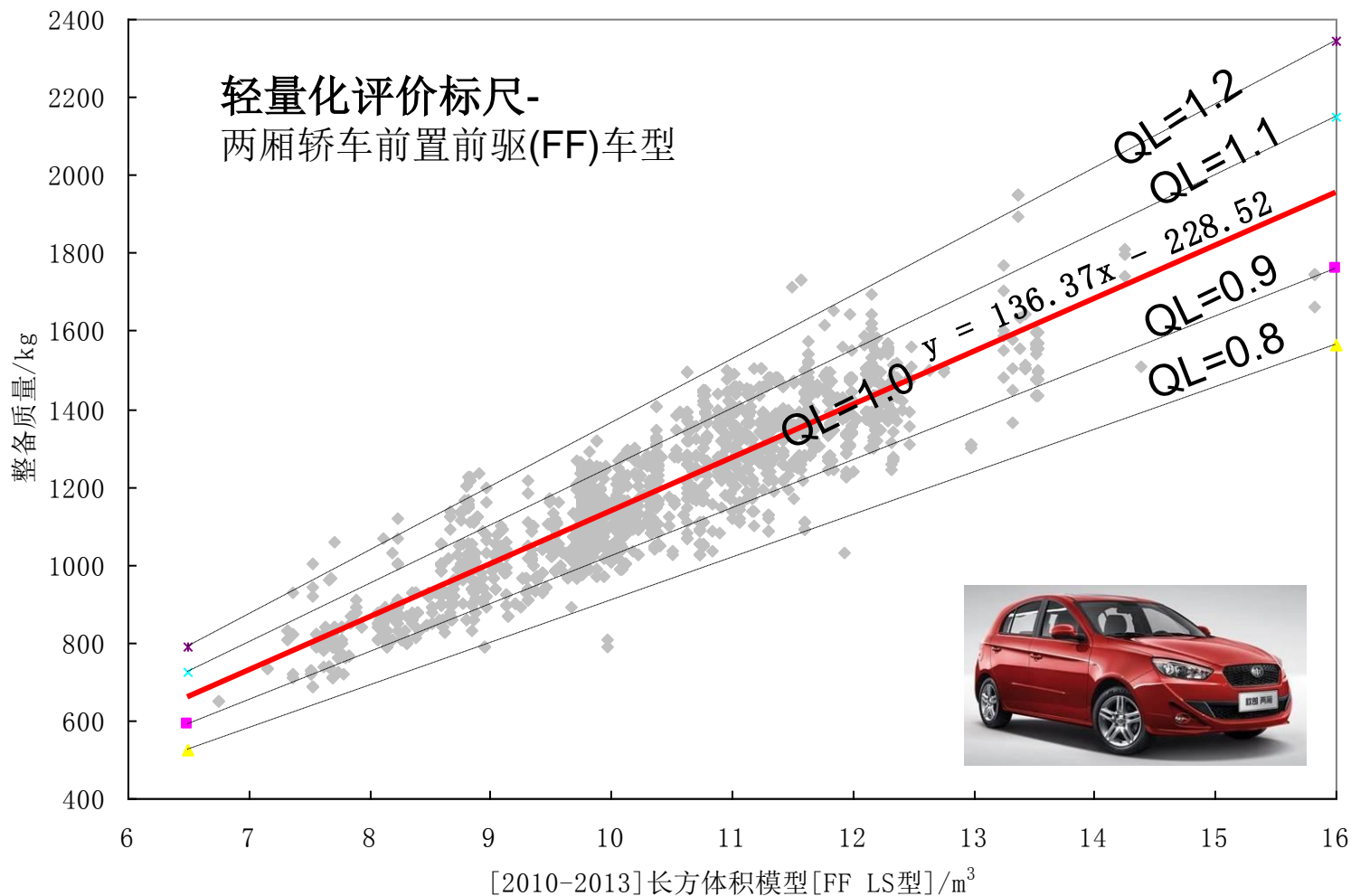
Lightweight Assessment –Notchback- benchmark line

三厢车型（分驱动型式）Notchback(Distinguished driving mode)

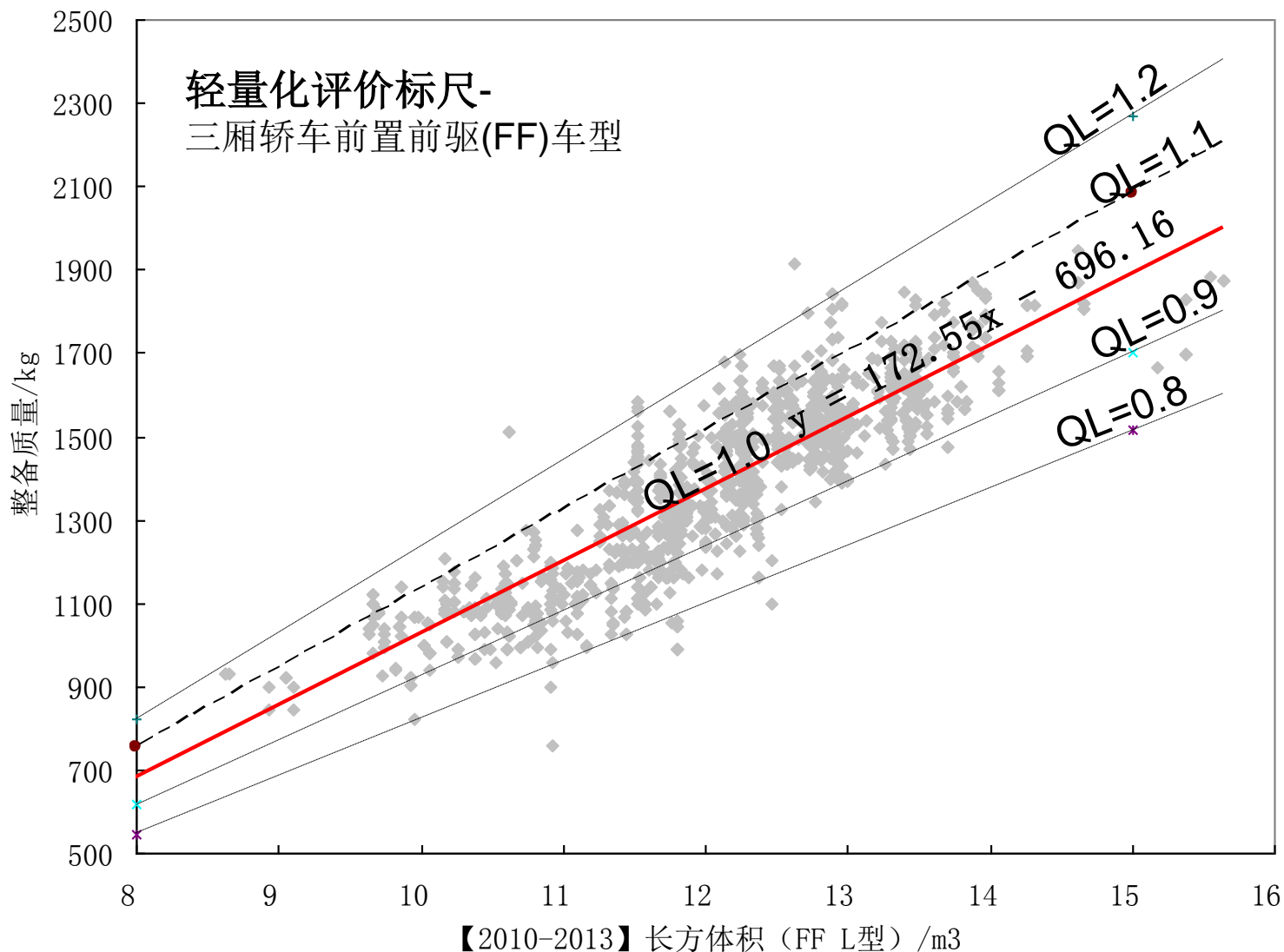


【数据来源：全球名车录2011技术数据】

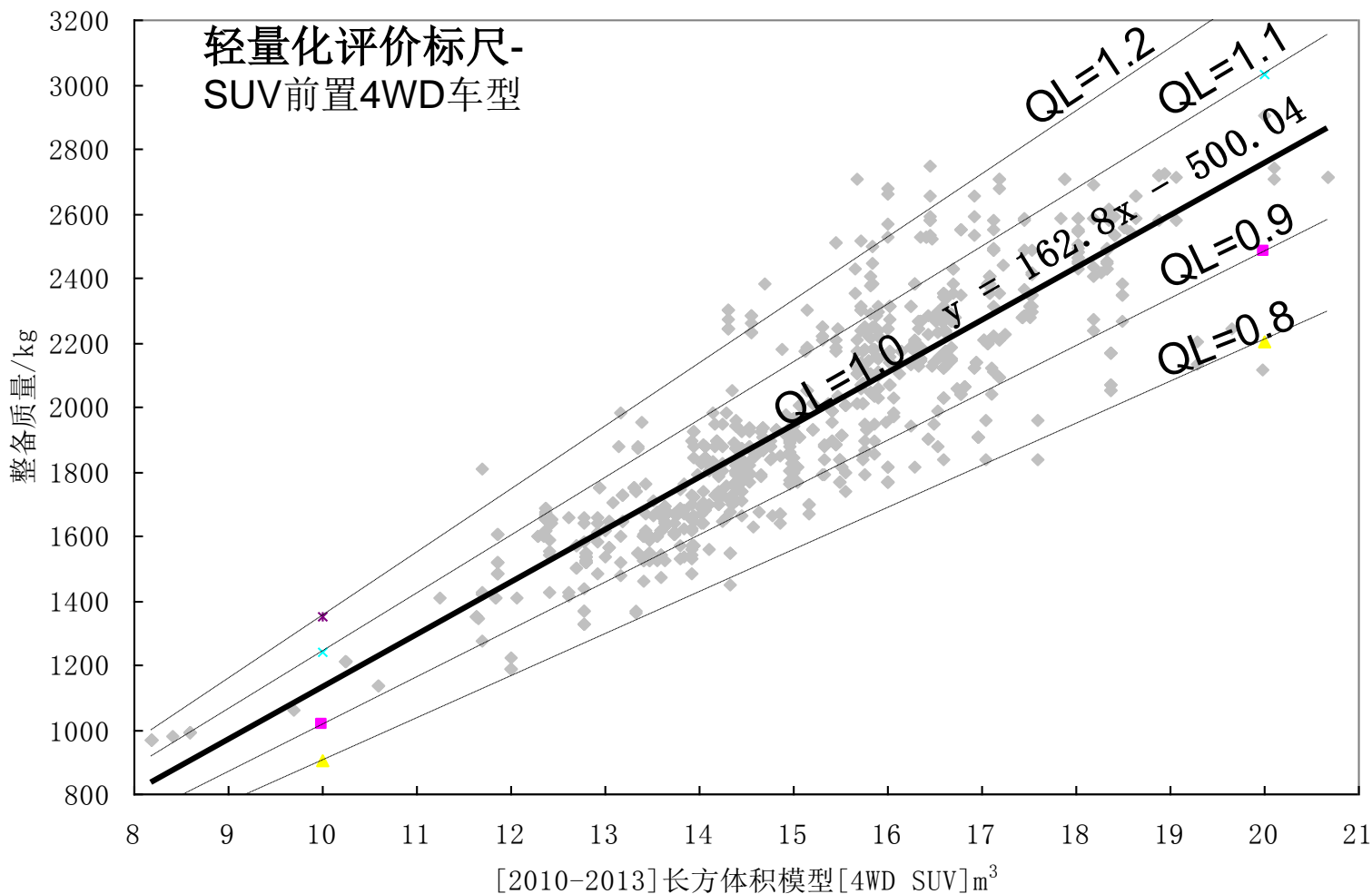
两厢轿车（前置前驱产品）-评价标尺 Hatchback Vehicle (FF)- benchmark line



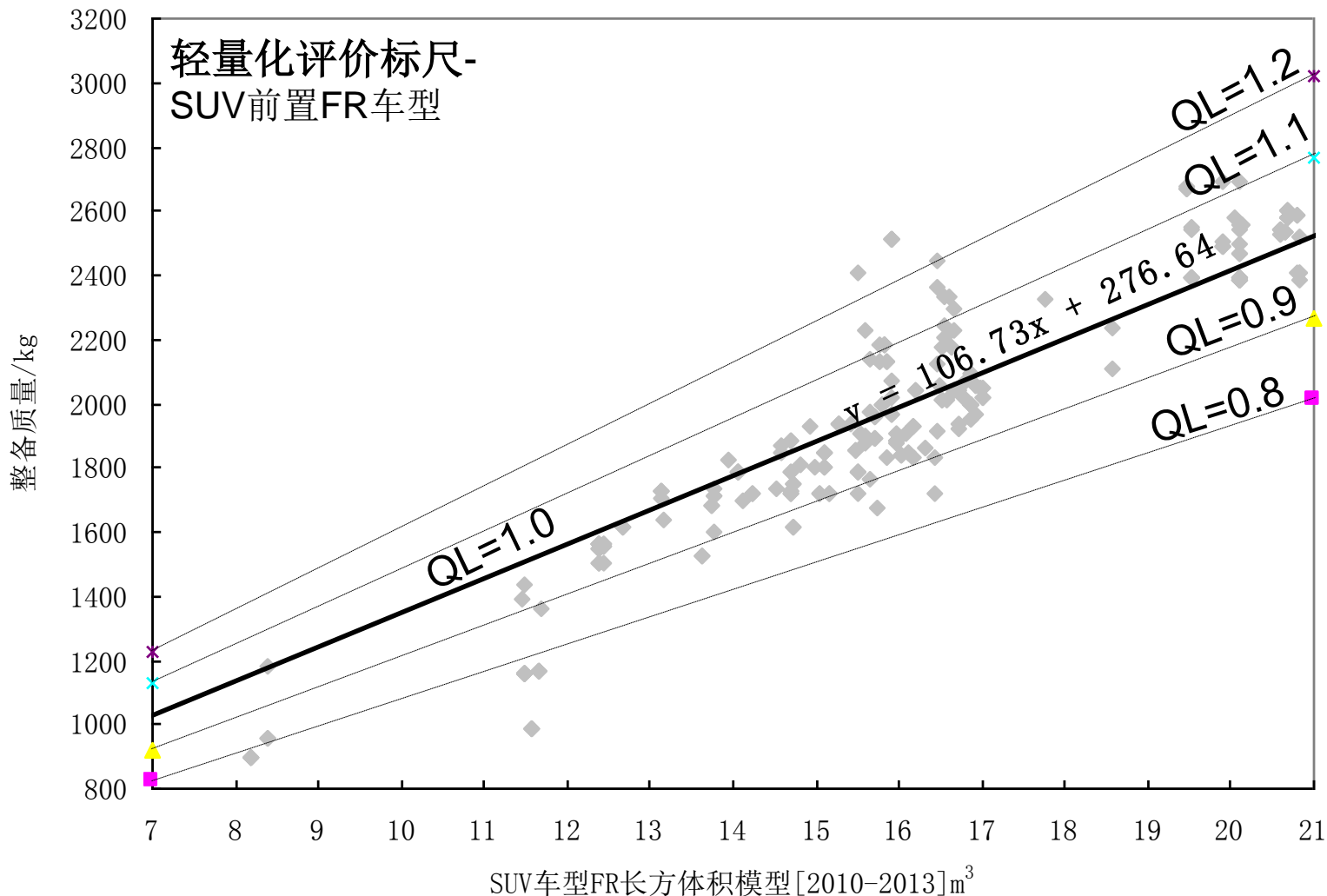
三厢轿车（前置前驱产品）-评价标尺 Notchback Vehicle (FF)- benchmark line



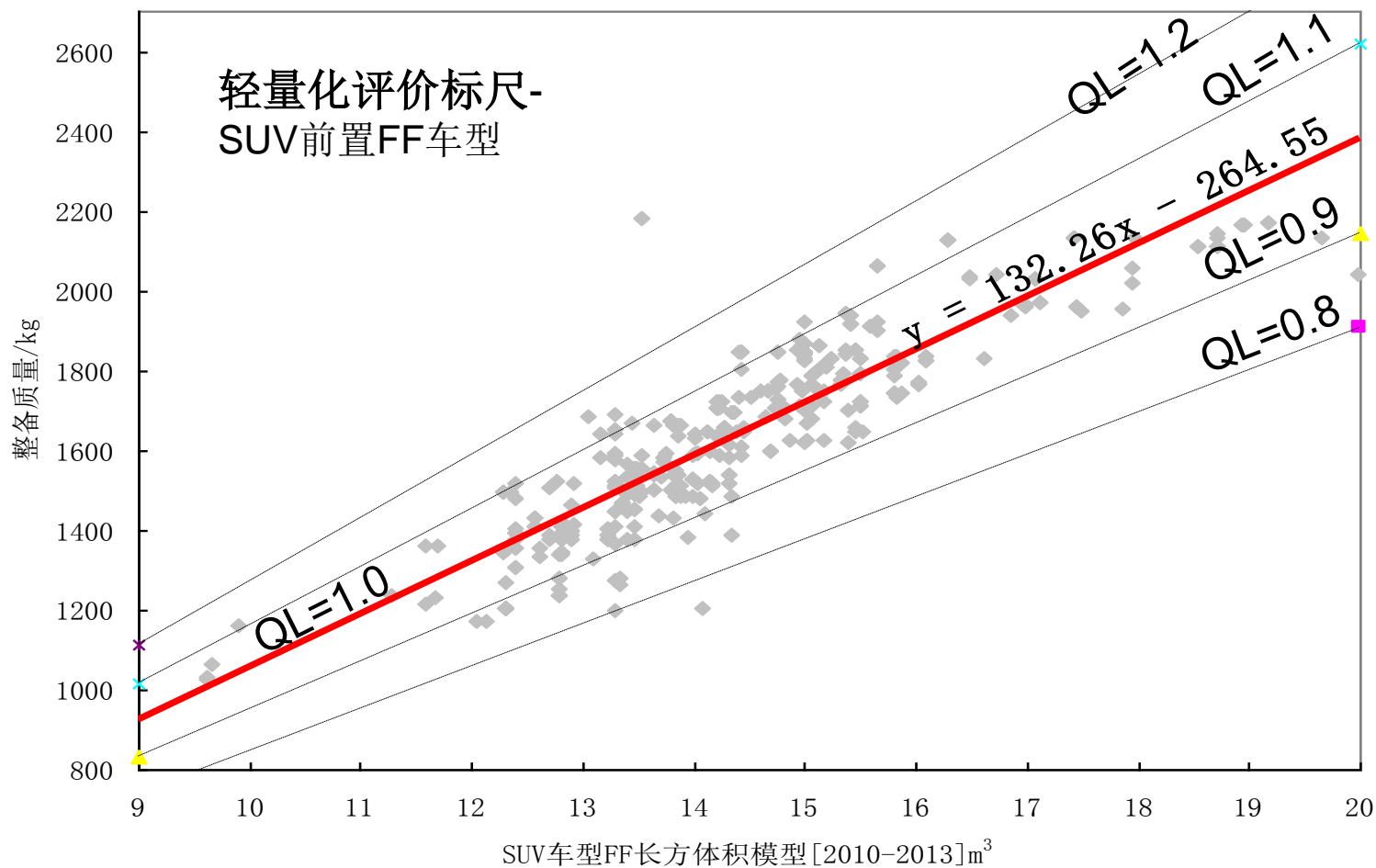
SUV (前置全驱4WD产品) -评价标尺 SUV (4WD)- benchmark line



SUV (前置后驱FR产品) -评价标尺 SUV (FR)- benchmark line



SUV (前置前驱FF产品) -评价标尺 SUV (FF)- benchmark line



轻量化与承载综合评价 lightweight and loading index

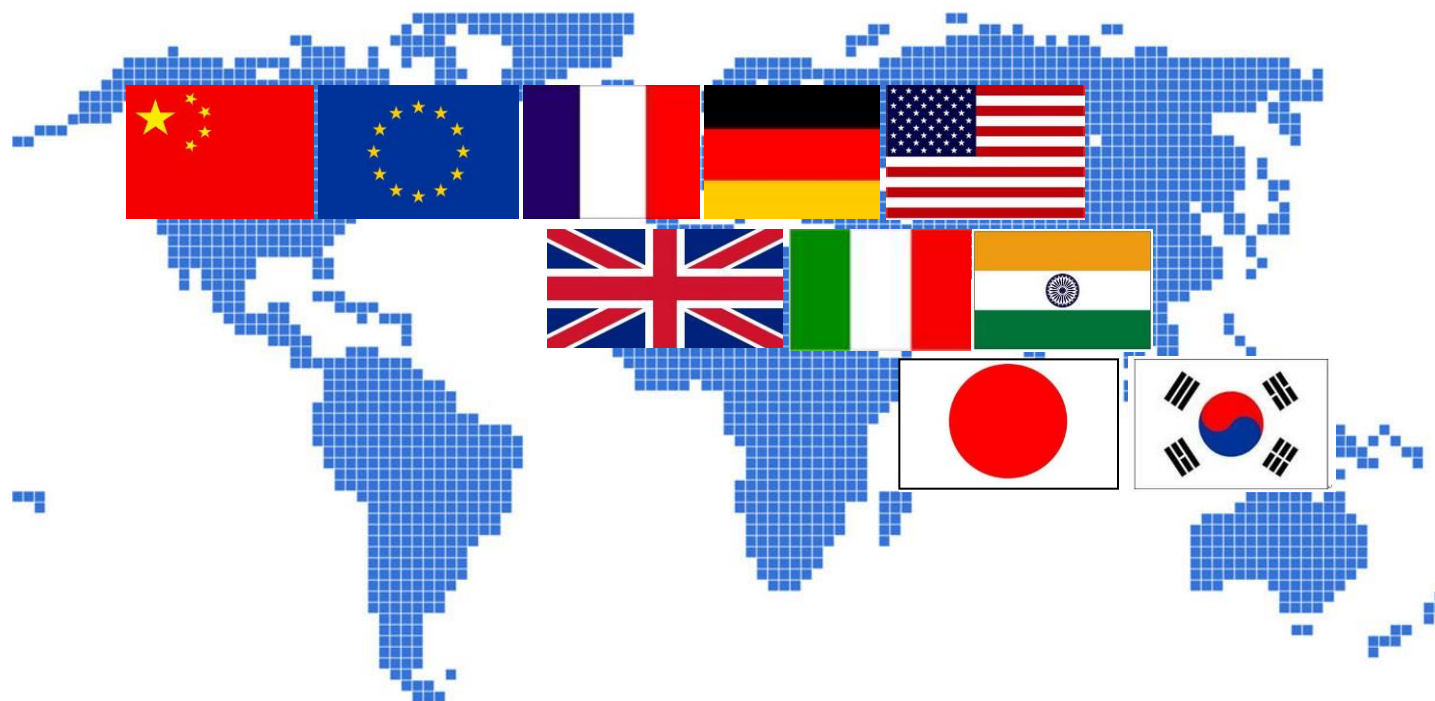
车长 mm	车宽 mm	车高 mm	整备 质量kg	最大允许 重量kg	载重量 (kg)	整备质 量标值L 法	轻量化 系数L	当量体 积(m ³)	整备质量 标值V法	轻量化 系数V
4965	1795	1477	1772	2157	385	1772.48	1.000	13.163	1676.639	1.057
4899	1860	1464	1760	2295	535	1709.26	1.030	13.340	1713.7	1.027
4865	1854	1465	1825	2350	525	1676.7	1.088	13.214	1687.239	1.082
5035	1855	1485	1780	2225	445	1839.52	0.968	13.870	1824.659	0.976
5015	1874	1455	1740	2270	530	1820.37	0.956	13.674	1783.692	0.976
5015	1874	1455	1800	2310	510	1820.37	0.989	13.674	1783.692	1.009
5015	1874	1455	1820	2320	500	1820.37	1.000	13.674	1783.692	1.020
5095	1875	1485	1800	2200	400	1896.99	0.949	14.186	1890.991	0.952
5095	1875	1485	1805	2255	450	1896.99	0.952	14.186	1890.991	0.955



最大允许重 量标值kg	载重量标值 kg	承载系数 q	强化系 数1	强化系 数2	轻量化 值 Lkg	轻量化 值 Vkg	超载值	综合
2240.173	468.173	0.822	0.963	-0.216	0.477	-95.36	-83.17	-178.53
2226.854	466.854	1.146	1.031	0.1274	-50.74	-46.3	68.15	21.85
2298.998	473.998	1.108	1.022	0.0971	-148.3	-137.8	51.00	-86.76
2249.052	469.052	0.949	0.989	-0.054	59.523	44.659	-24.05	20.61
2204.656	464.656	1.141	1.030	0.1233	80.367	43.692	65.34	109.04
2271.250	471.250	1.082	1.017	0.076	20.367	-16.31	38.75	22.44
2293.448	473.448	1.056	1.012	0.0531	0.367	-36.31	26.55	-9.76
2271.250	471.250	0.966	0.993	-0.036	96.991	90.991	-16.25	74.74
2276.800	471.800	0.954	0.990	-0.048	91.991	85.991	-21.80	64.19



过错是一时的遗憾
错过是一代车的遗憾



成功必须努力
但正确的方法也不可或缺！