Advantages of Substituting Aluminum for Heavier Materials in Automotive Applications to Reduce CO_2 Emissions

LCA Research Committee, Japan Aluminium Association

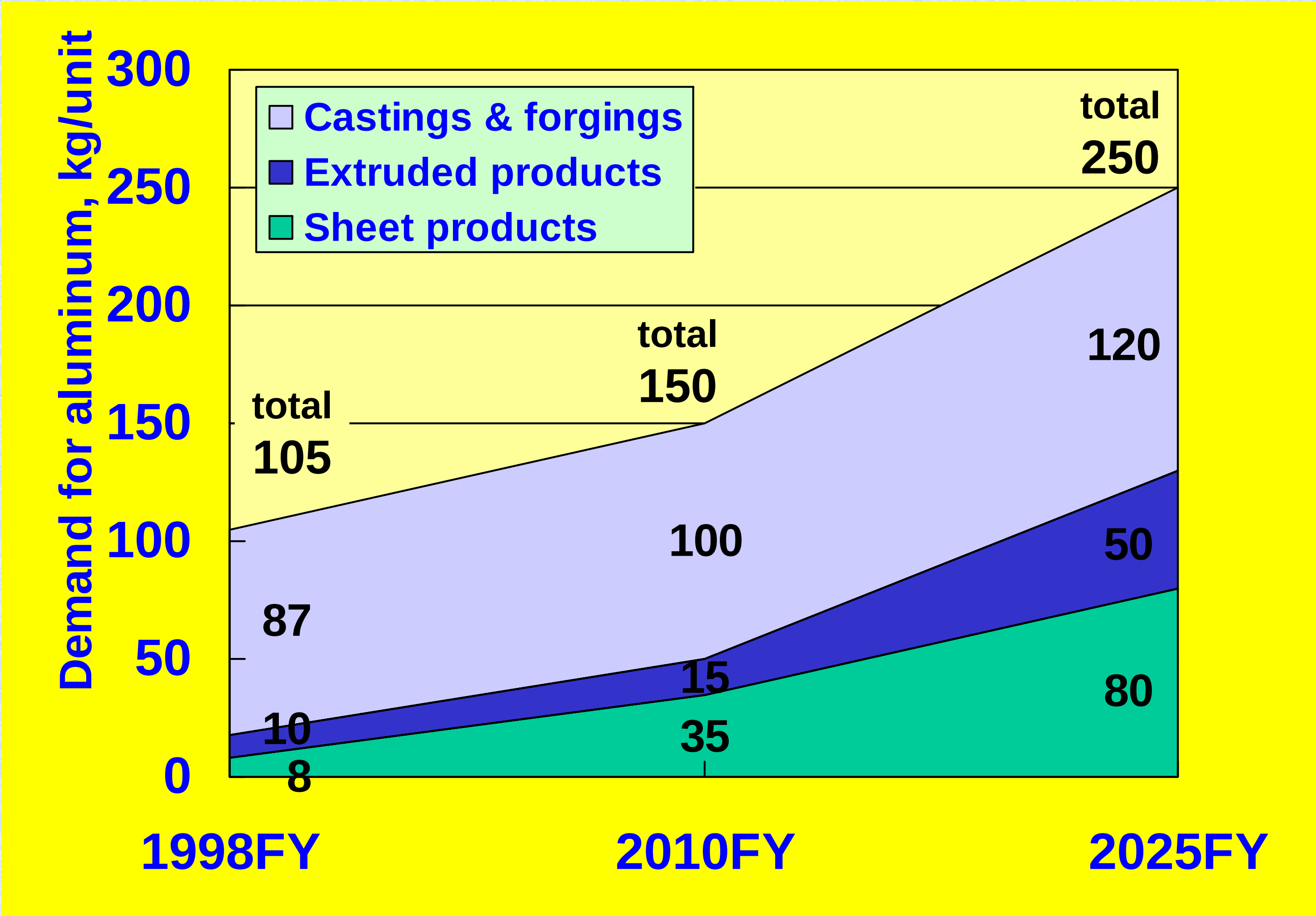
Masao Ookubo, Toshio Onoye

Introduction

- The Japan Aluminium Association worked out an initial trial calculation on the possible reduction of CO_2 emissions in Japan (for **Kyoto Protocol**) realized by extending the scope of the substitution of steel by aluminum as the material for car manufacturing.
- In this trial calculation, the use (driving) phase and the material production phase, which collectively account for more than 90 % of CO_2 emissions in the cars' life cycle, were considered.

Technological strategy in aluminum industry of Japan

~Demand of aluminum for automotive application ~



Technological strategy in aluminum industry
~ Approach (1) ~

- Reducing cost of aluminum materials
- Development of specific technology for the promotion of aluminum substitution

  <2002FY：700 million yen, a 100 % subsidized program (5 years' period)>

  – Development of high-formability automotive sheets
  – Development of technology for joining aluminum with other materials
  – Development of tailored process(porous aluminum)
- Utilization of recycled materials

  <Fiscal year 2002：350 million yen, a two-third subsidized program (3 years' period)>

  – Recommendation on recycling systems
  – Development of the technology for extending the range of allowable impurity through microstructure control
  – LCA studies related to aluminum substitution

Technological strategy in aluminum industry

~ Approach (2) ~

Advantages of aluminum substitution

~ verification and information disclosure ~

- Contribution in attaining Japan's objective for the reduction of green-house gas
  - Reduction of CO_2 emissions by private vehicles in the country
  - Trial calculation of CO_2 emissions on the material production phase and use (driving) phase
- Consideration of the compatibility in terms of cost
  - Changes in life cycle cost resulting from material substitution
  - Verification for compensation of the increase material costs with the fuel efficiency achieved by the weight saving and scrap recycling.
  - In addition, consideration of advantage gained by possible application of preferential taxation.
- Other Advantages
  - Improvement in operational performance, improved crashworthiness, increased corrosion resistance, high rigidity structure and other improvements due to weight saving.

Assumptions for trial calculation-1

Item		Description
Objects		Steel/aluminum parts of car produced and used in Japan
Period		From 1998 as the reference year, through 2010 (targeted year for GHG reduction) to 2025 (for a long term comparison)
Material production phase	Number of vehicles produced	Constant at 7.5 million units
	Weight of auto parts	Substitution ratio of steel parts with aluminum parts in weight: 0.5 for sheet products, 0.6 for extrusion products 0.8 for cast/forged products
	Material yield for parts	All process yields were assumed to be 0.5. This means that 50% of material is treated as process scrap
	Treatment of process scrap	Aluminum：90 % of scrap is recycled as raw materials. Steel：scrap is used as raw material for electric furnace.

Assumptions for trial calculation-2

Item		Description
Use (Driving) phase	Number of vehicles owned	Constant at 40 million units.
	Fuel consumption	Calculated based on the relation between the total weight of automobile (x: kg) and the fuel consumption (y：km/l) obtained by 10-15 mode measurement ($y=32.924e^{-0.0006x}$).
	CO_2 emission factor of gasoline	2.57kg-CO_2/l including refining and transportation.

Procedure of calculation and data sources

1.driving phase： Demand forecast of aluminum for auto parts

	Sheet products (kg)	Extruded products (kg)	Castings/ forgings (kg)	Total (kg)
1998FY	8	10	87	105
2010FY	35	15	100	150
2025FY	80	50	120	250

Substituting ratio of steel with aluminum in weight:

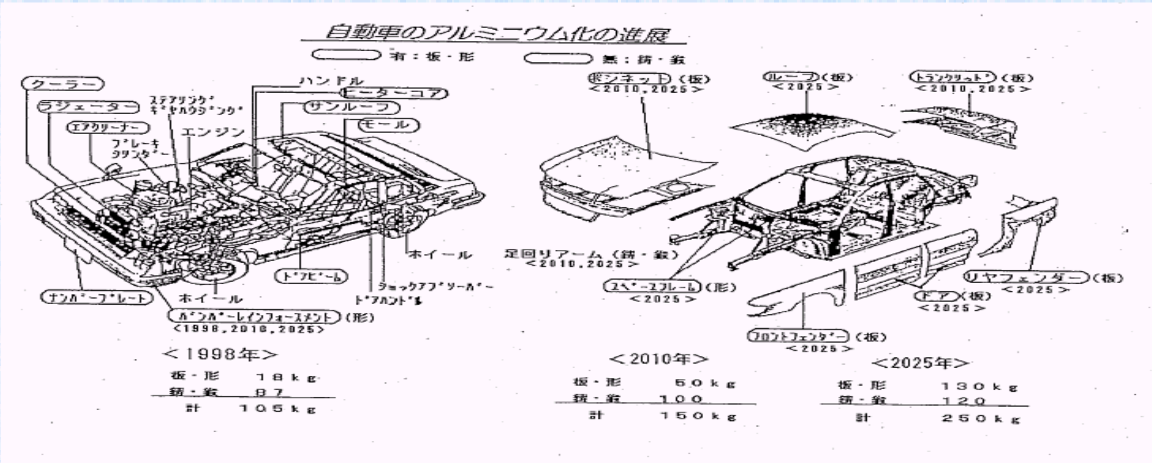
for sheet products Al/Fe = 0.5

for extruded products Al/Fe = 0.6

for castings/forgings Al/Fe = 0.8

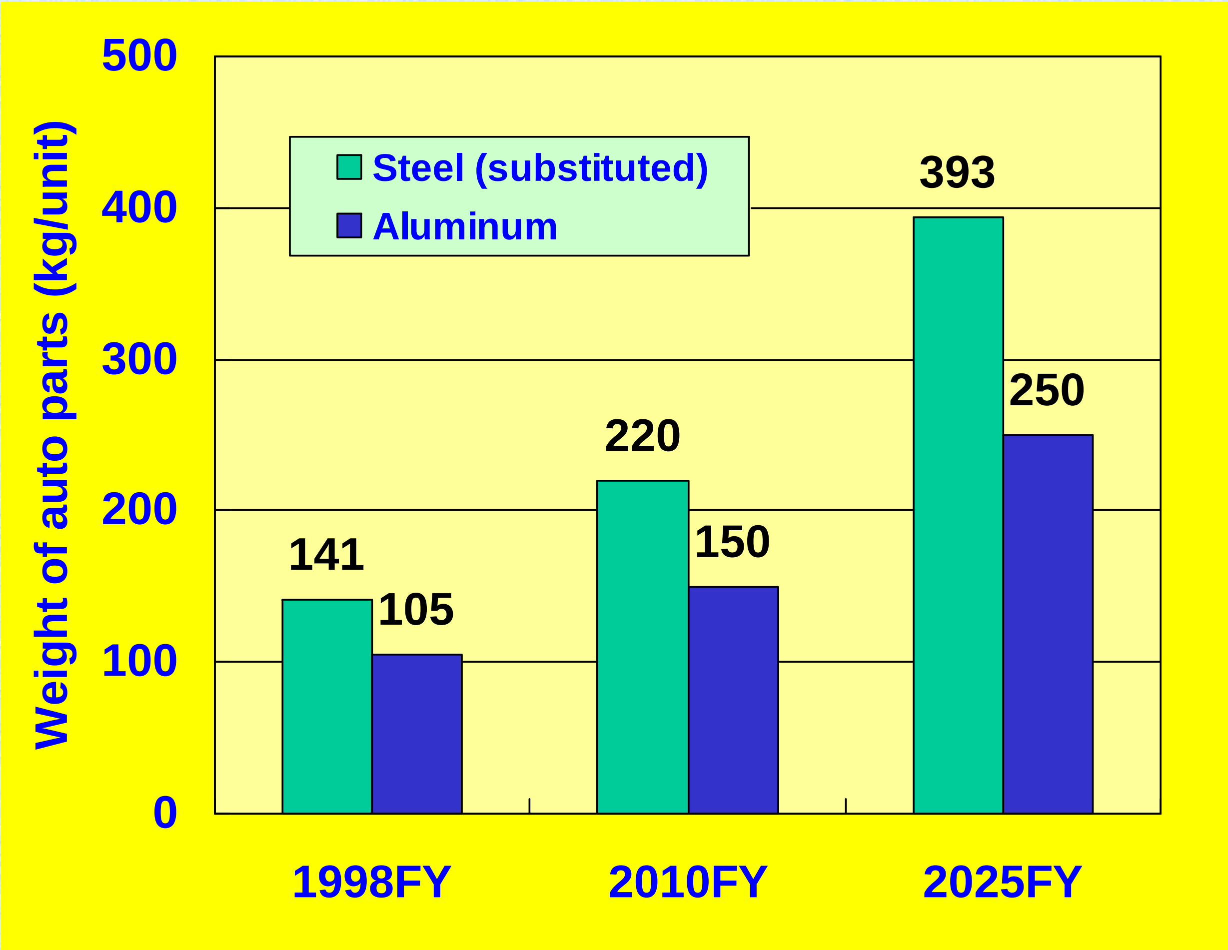
Substitution of auto parts with aluminum

	Main parts to be applied	Aluminum used (kg)	Steel substd. (kg)	Weight saving (kg)
1998FY	Heat exchanger, door beam, wheel, engine etc	105	141	Reference
2010FY	Ditto, plus hood, trunk lid, chassis etc.	150	220	34
2025FY	Ditto, plus roof, door, fender, space frame etc.	250	393	107

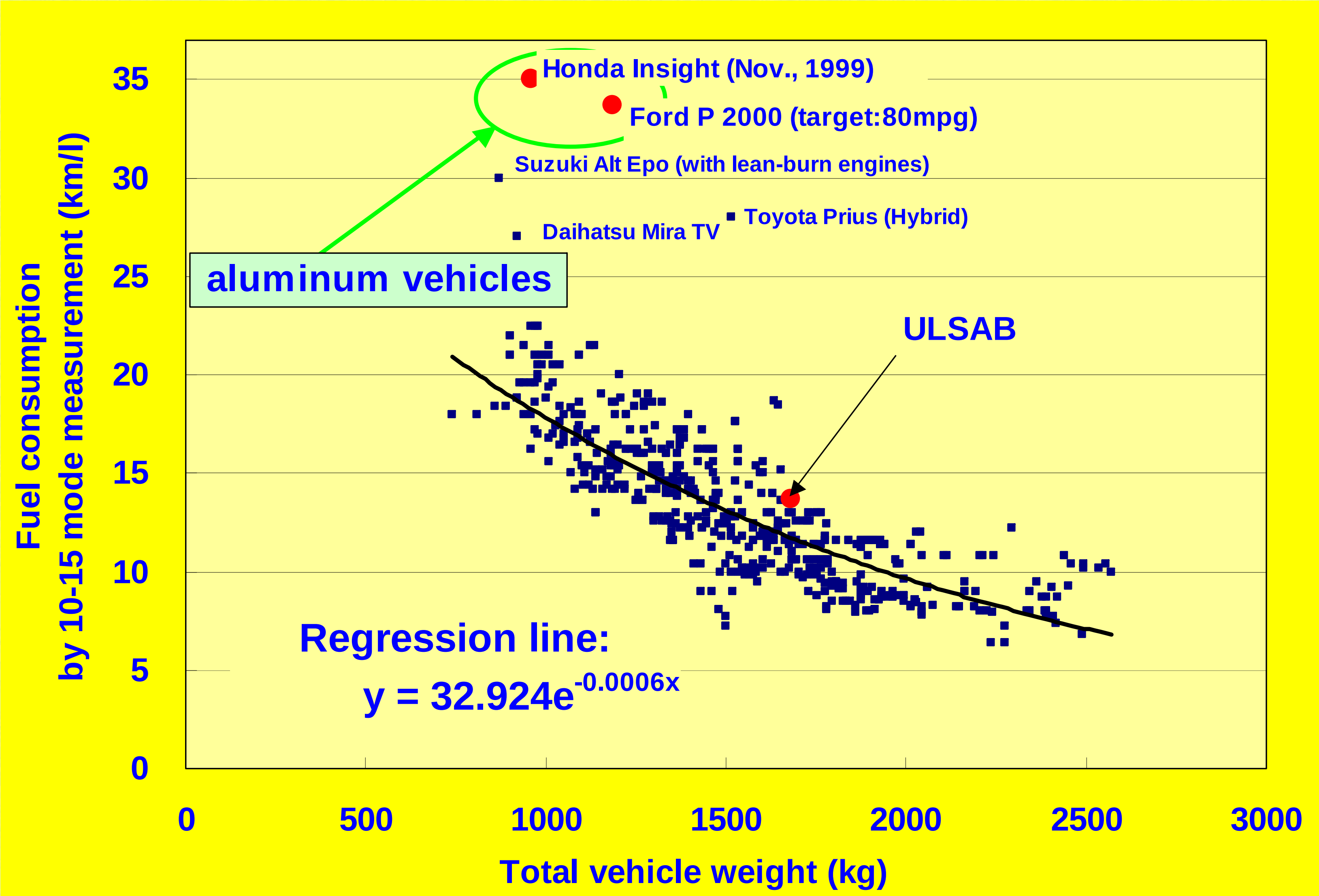


Substitution of auto parts with aluminum

For average weight of passenger car of 1,543 kg



Vehicle weight and fuel consumption



Estimation of Average Fuel Consumption

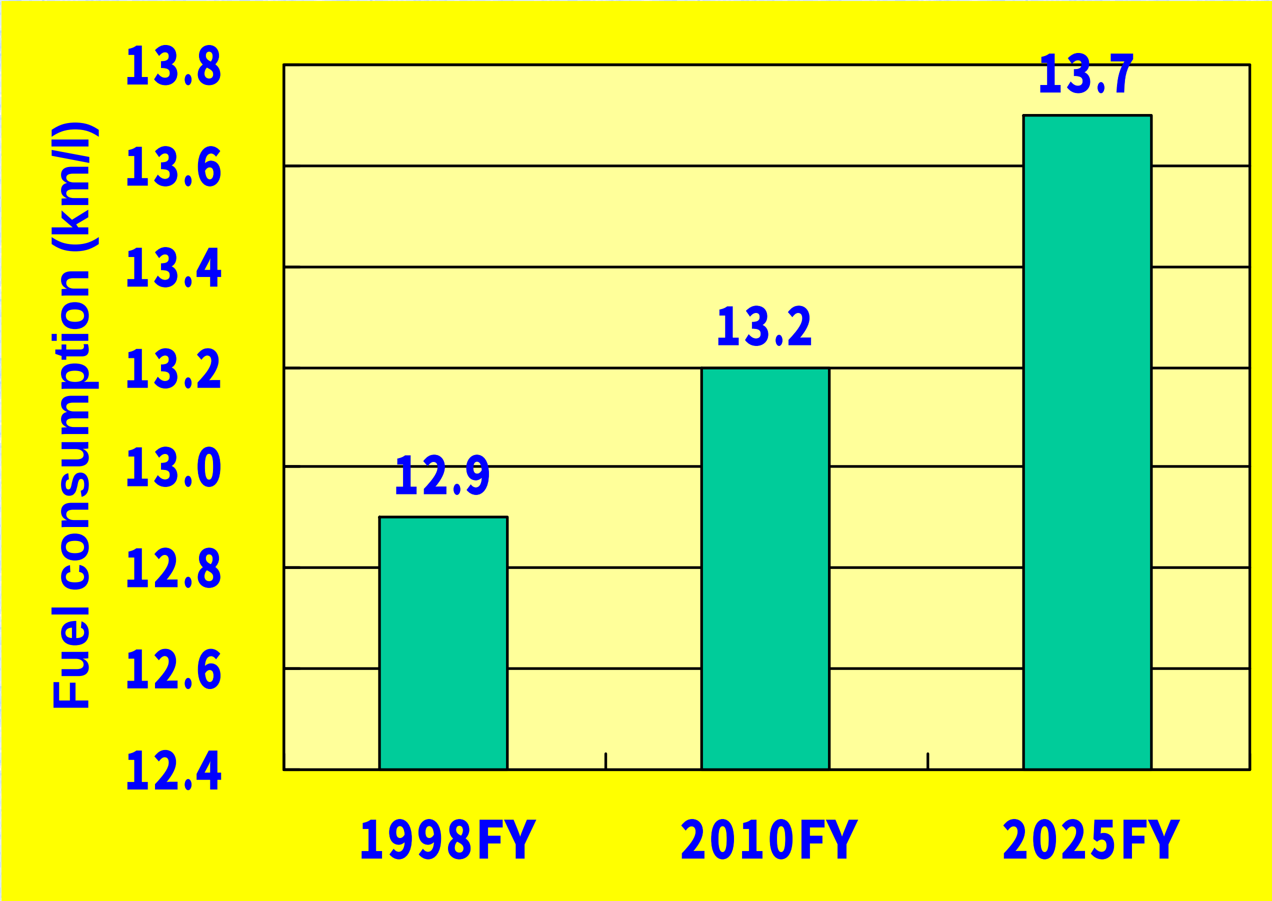
Year of first registration	Distribution ratio (%)	Fuel consumption of vehicles used in FY1998		Fuel consumption of vehicles used in FY 2010		Fuel consumption of vehicles used in FY2025	
current year	2.29	FY1998	13.045	FY2010	13.311	FY2025	13.910
1 year ago	8.26	FY1997	13.028	FY2009	13.288	FY2024	13.869
2 year ago	9.51	FY1996	13.011	FY2008	13.266	FY2023	13.828
3 year ago	9.85	FY1995	12.982	FY2007	13.244	FY2022	13.788
4 year ago	9.16	FY1994	12.953	FY2006	13.221	FY2021	13.748
5 year ago	8.66	FY1993	12.923	FY2005	13.199	FY2020	13.707
6 year ago	8.34	FY1992	12.907	FY2004	13.177	FY2019	13.667
7 year ago	8.72	FY1991	12.890	FY2003	13.155	FY2018	13.627
8 year ago	8.74	FY1990	12.874	FY2002	13.133	FY2017	13.587
9 year ago	8.41	FY1989	12.845	FY2001	13.111	FY2016	13.547
10 year ago	6.60	FY1988	12.816	FY2000	13.089	FY2015	13.507
11 year ago	4.35	FY1987	12.788	FY1999	13.067	FY2014	13.468
12 year ago	2.79	FY1986	12.759	FY1998	13.045	FY2013	13.428
13 year ago	1.69	FY1985	12.731	FY1997	13.028	FY2012	13.389
14 year ago	1.13	FY1984	12.703	FY1996	13.011	FY2011	13.350
15 year ago	0.64	FY1983	12.674	FY1995	12.982	FY2010	13.311
16 year ago	0.39	FY1982	12.646	FY1994	12.953	FY2009	13.288
17 year ago	0.20	FY1981	12.618	FY1993	12.923	FY2008	13.266
18 year ago	0.15	FY1980	12.590	FY1992	12.907	FY2007	13.244
19 year ago	0.11	FY1979	12.562	FY1991	12.980	FY2006	13.221
Total	100	Average	**12.909**	Average	**13.177**	Average	**13.667**

CO_2 emission factor used is 2.57kg-CO_2/L, which contains emission in refinery and distribution stages of gasoline

	FY1998	FY 2010	FY2025
Average CO_2 emission (g-CO_2/km)	199.1	195.0	188.0
Annual CO_2 emission (t-CO_2/year/unit	1.991	1.950	1.880
Number of vehicles owned (million units)	40	40	40
Estimated annual CO_2 emission (million t/y)	**79.6**	**78.0**	**75.2**
Effect of reduction in CO_2 emission (million t-CO_2/y)		**1.62**	**4.42**
The amount of fuel saving (thousand kL-oil/y)		630	1,720

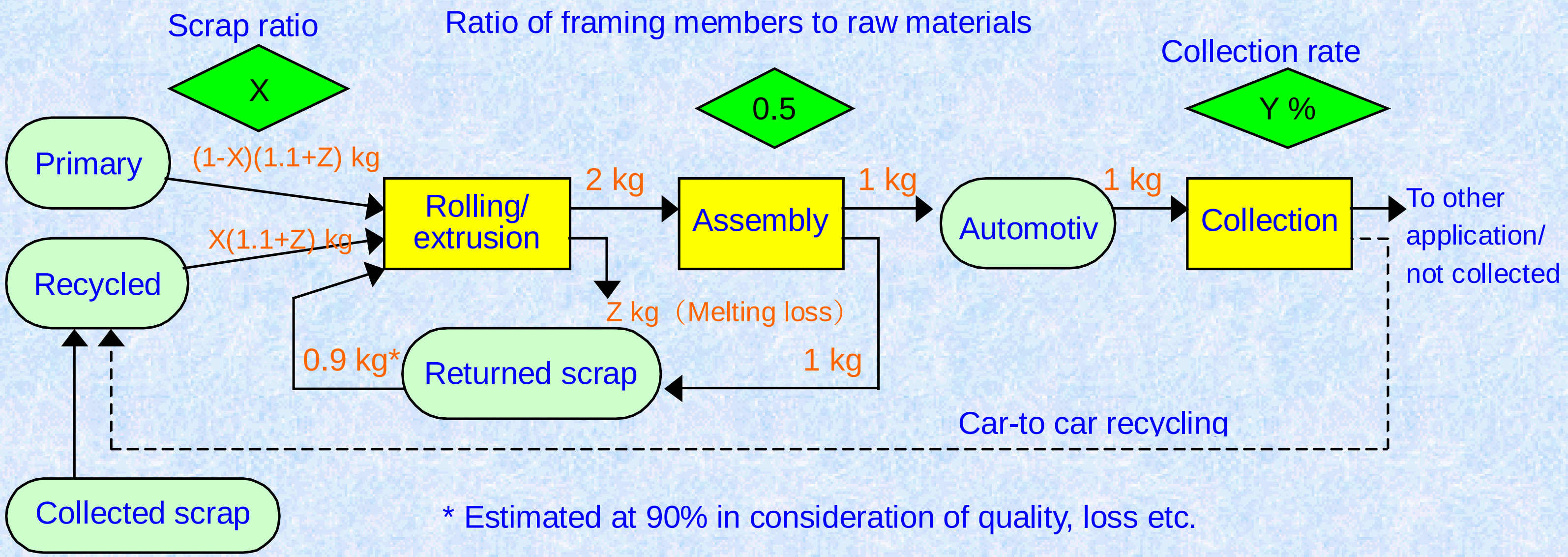
Average fuel consumption of each year

- Estimated for each year considering the distribution of the vehicles used in the year according to the year of first registration.



Material production phase：

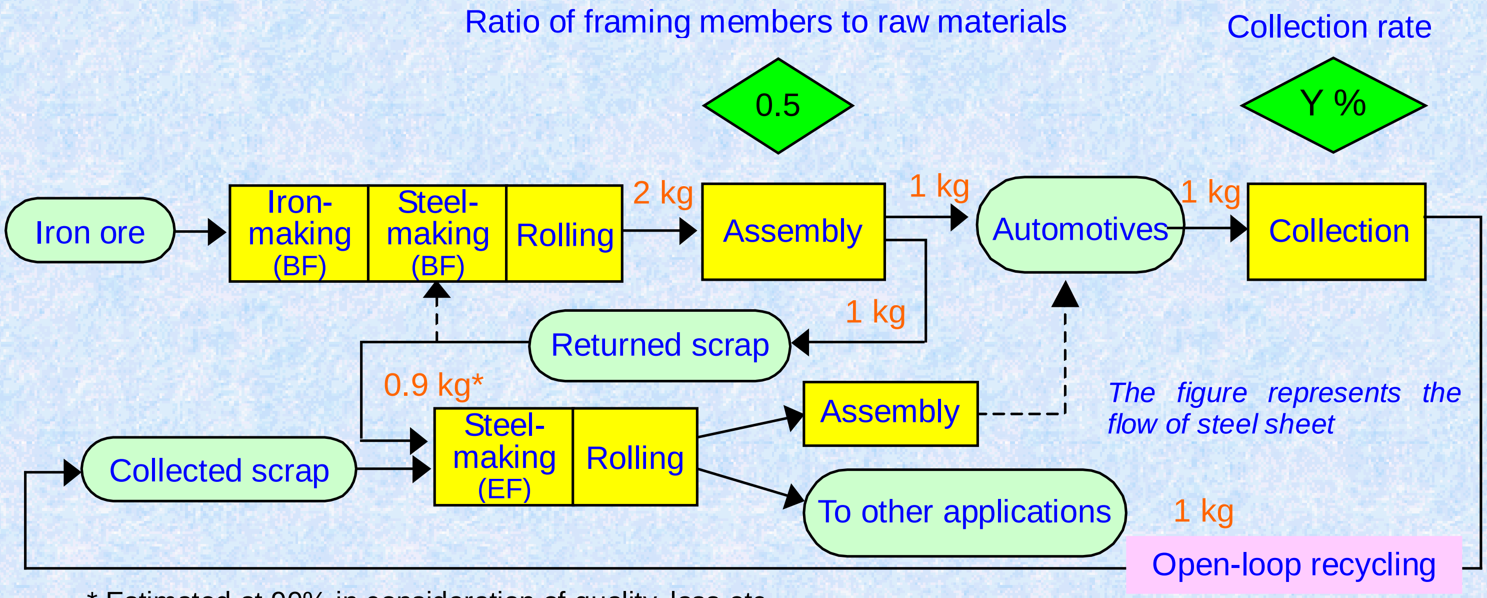
Material flow & inventory of aluminum



* Estimated at 90% in consideration of quality, loss etc.

Phase			Energy (MJ)		COx (g)	
			Off-shore	Domestic	Off-shore	Domestic
Primary aluminum			153.7	0	9,601	0
Secondary aluminum			0	5.69	0	308
Process	Rolled Product		0	21.9	0	1,507
	Extruded Product		0	23.5	0	1,707
	Cast/Forged Product (incl. raw materials)	Prim.Al		-	13,081	
		Sec.Al				1,352

Material flow & inventory of steel



* Estimated at 90% in consideration of quality, loss etc.

Phase		Energy (MJ)		COx (g)	
Site		Off-shore	Domestic	Off-shore	Domestic
Iron-making		2.04	22.80	165	1,560
Steel-making		0.05	0.50	7	154
Process	Hot rolling	0.06	2.87	4	286
	Cold rolling	0.06	3.10	4	365
	Surface treatment	0.05	2.28	3	274

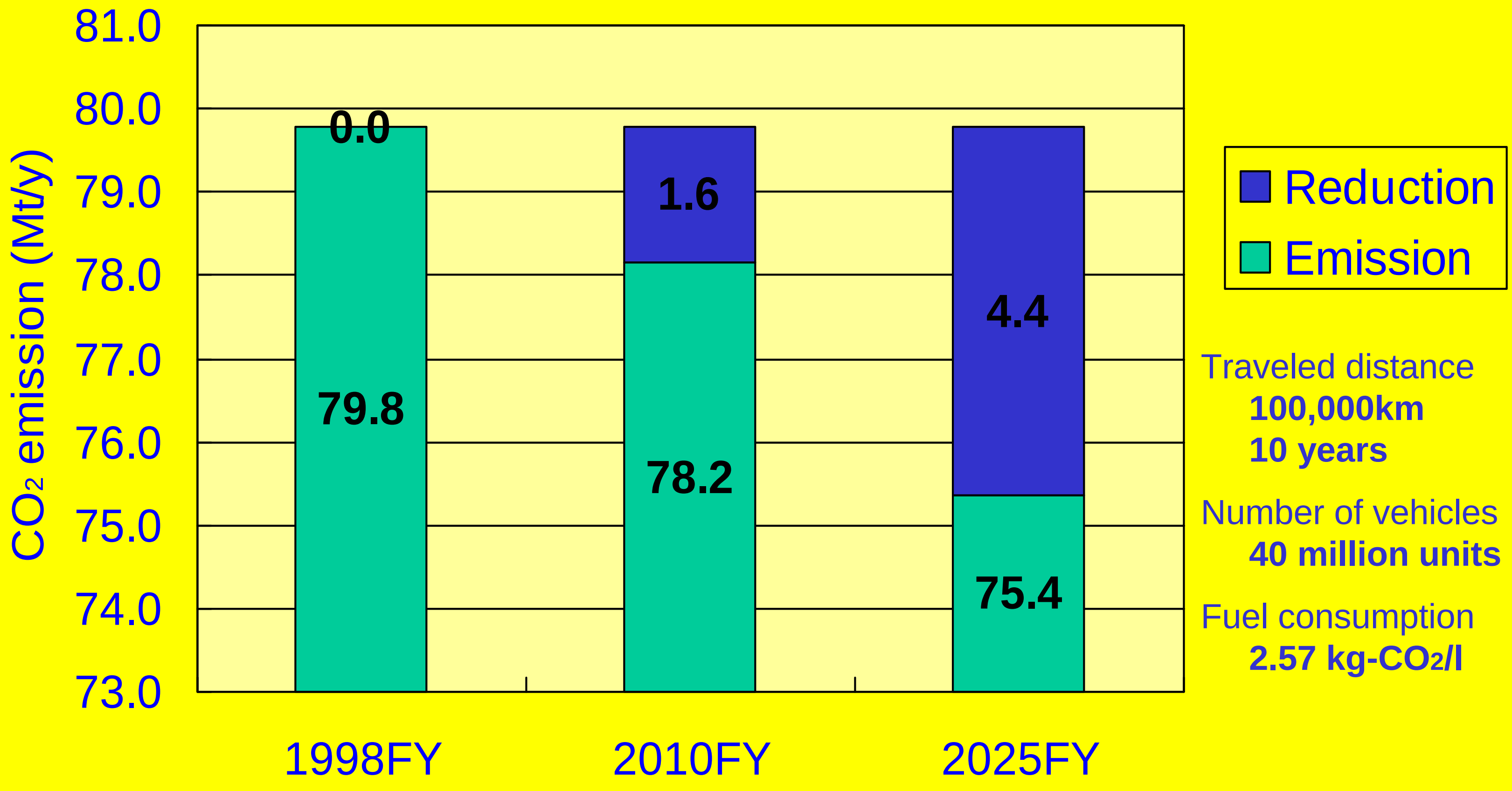
(by Funazaki et al.)

Domestic CO_2 emission

- For use (driving) phase : improvement of fuel efficiency by weight saving
  - Life cycle traveled distance : 100,000 km for 10 years
  - Number of vehicles : 40 million
  - CO_2 emission factor : 2.57 kg-CO_2/l (incl. refining & transportation of fuel)
- For material production phase : difference between CO_2 emission of steel and that of aluminum
  - Annual production of vehicle : 7.5 million units
  - Only CO_2 emission of primary aluminum is omitted as offshore one

Result：Domestic CO_2 emission

~ Use (driving) phase ~



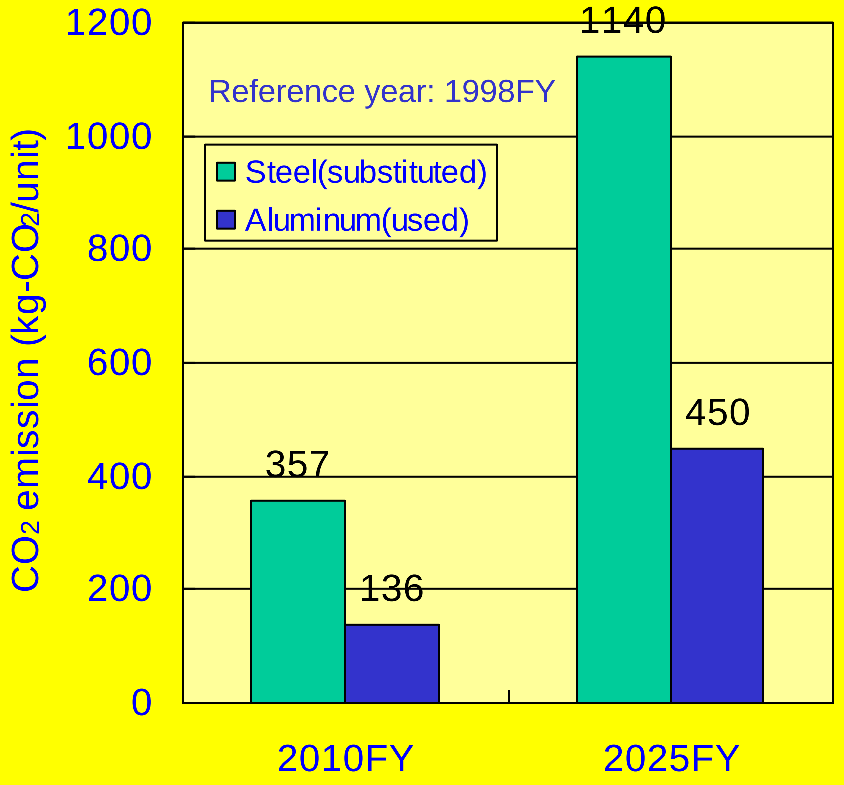
Traveled distance
100,000km
10 years

Number of vehicles
40 million units

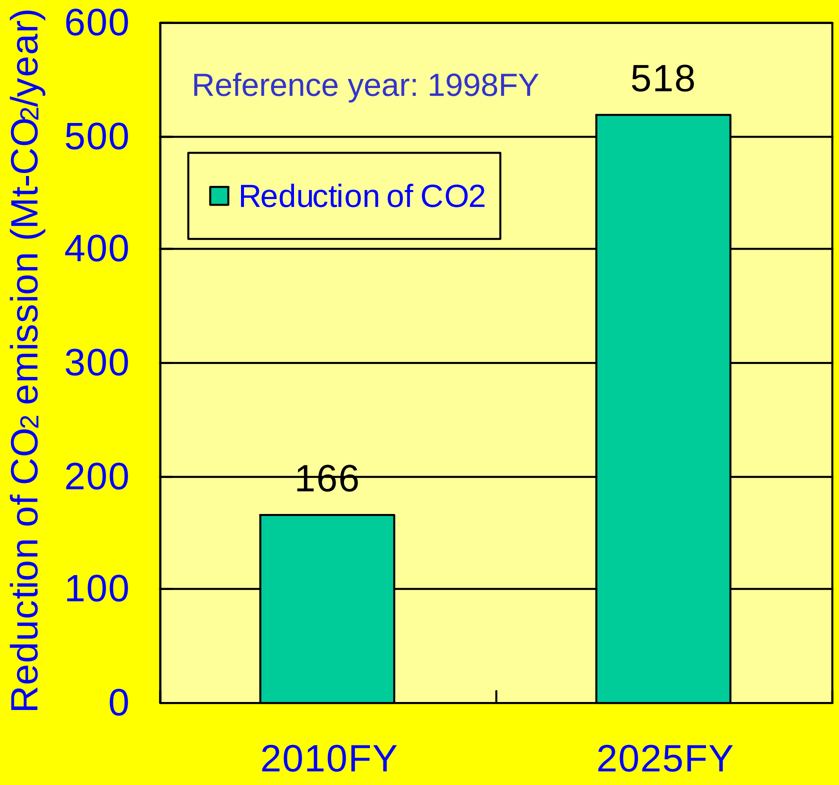
Fuel consumption
2.57 kg-CO_2/l

Domestic CO_2 emission

~ Material production phase~

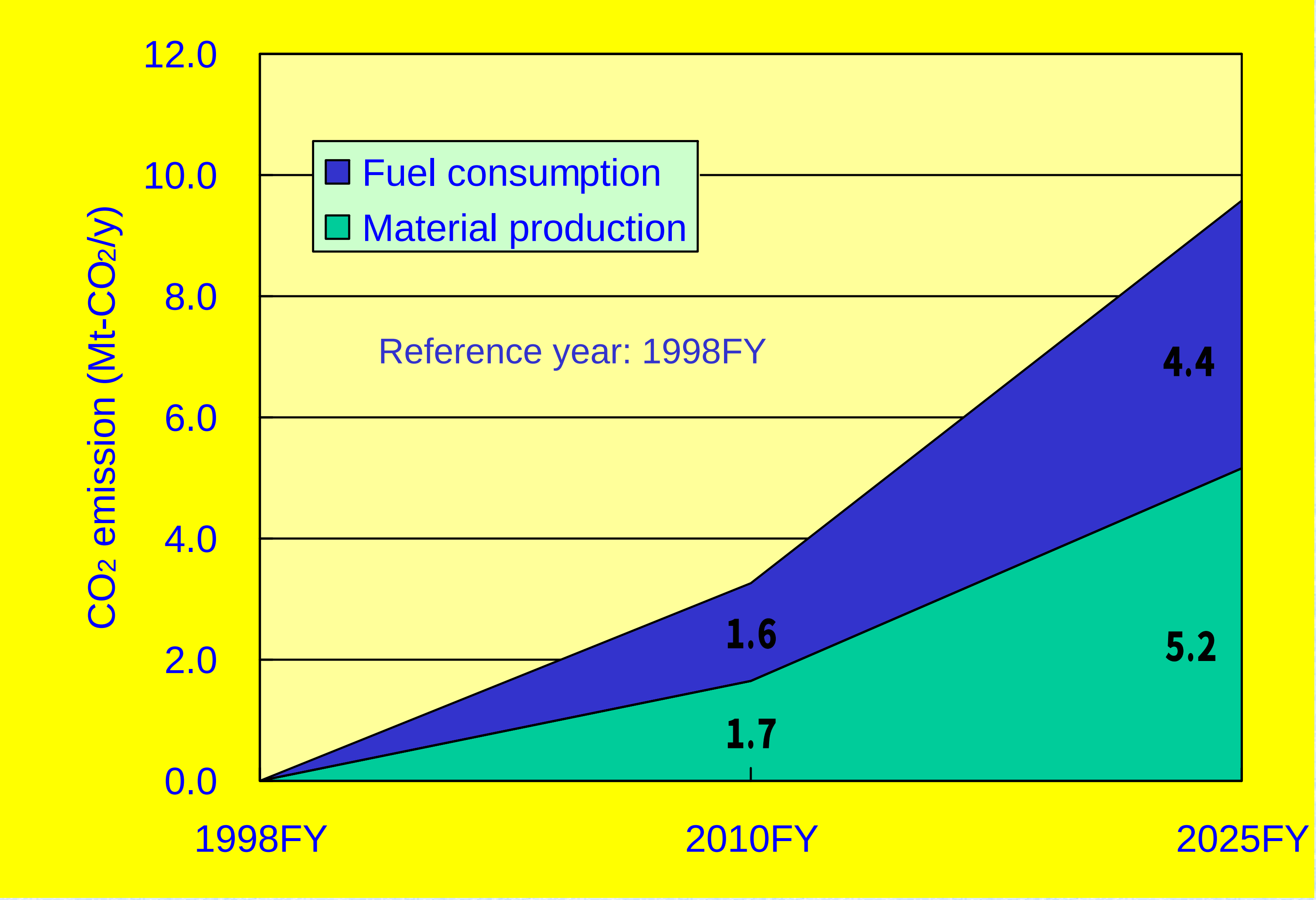


CO_2 emission of producing aluminum parts and steel being substituted

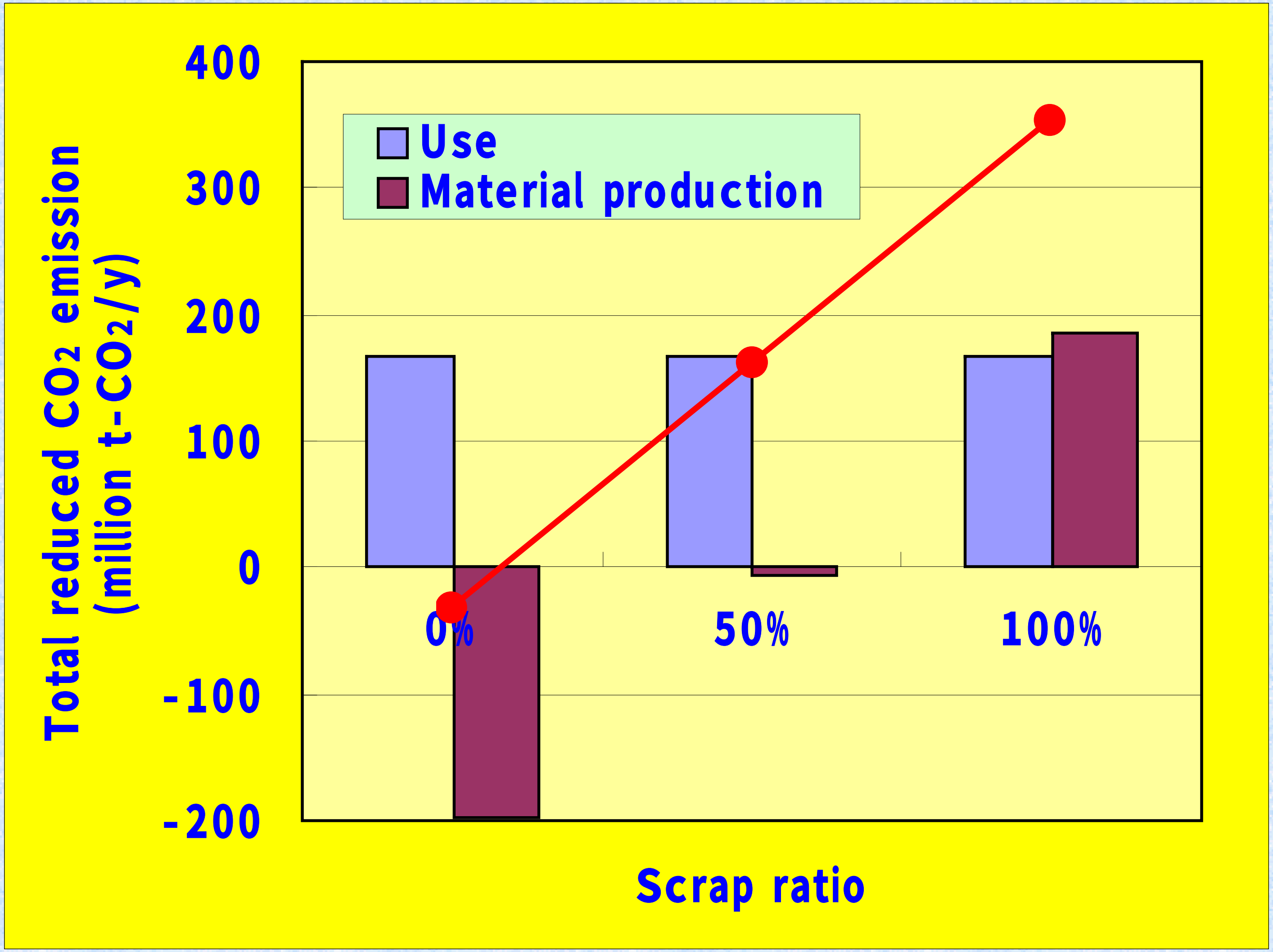


Reduction of domestic CO_2 emission by substituting steel parts with aluminum

Reduction in domestic CO_2 emission



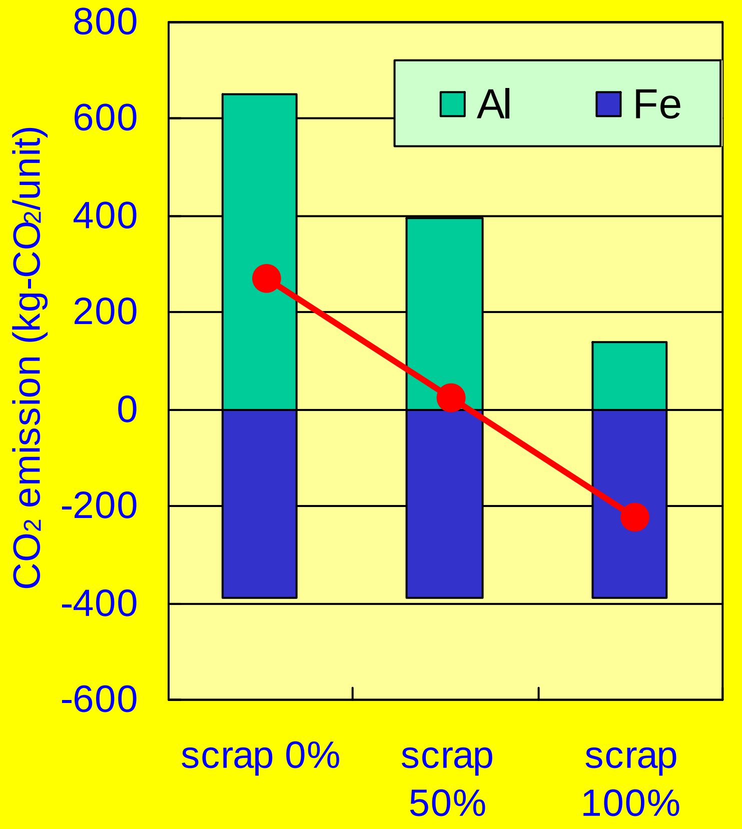
Reduction in total CO_2 emissions



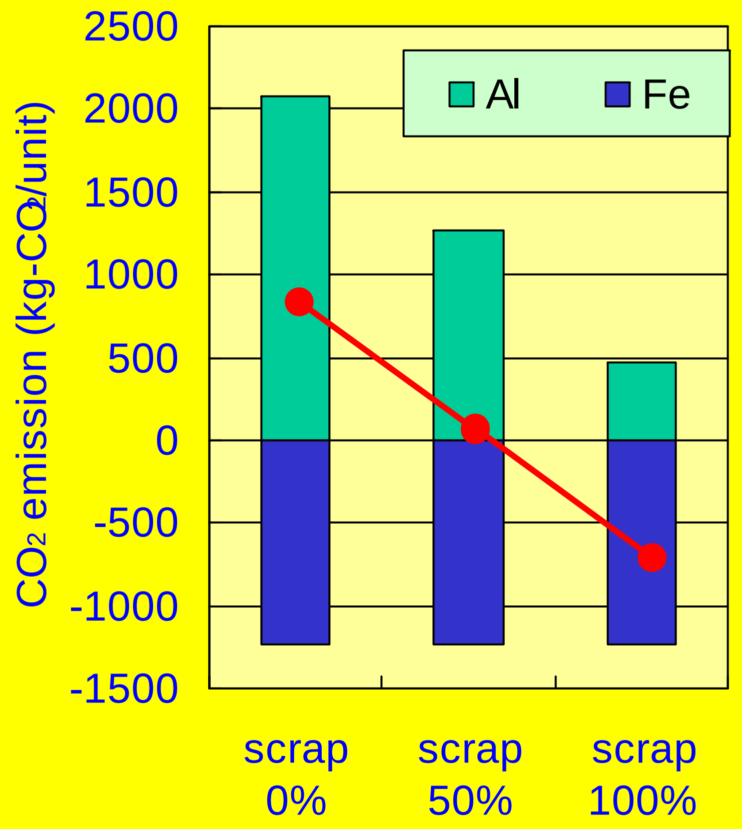
Afterword

- The Japan Research and Development Center for Metals (JRCM) is planning to launch a survey project on "Development of specific technologies for the promotion of aluminum applications" in fiscal 2002.
- JRCM is also planning "A survey on establishing the business model on 'Wrought aluminum to Wrought aluminum' recycling system for car production" aimed at preservation of material and energy resources.
- For the latter survey, we are responsible to conduct LCA survey for automobiles in a three-year period.
- We expect the cooperation from the people concerned in our efforts to establish an LCA assessment model.

CO_2 emission at material production

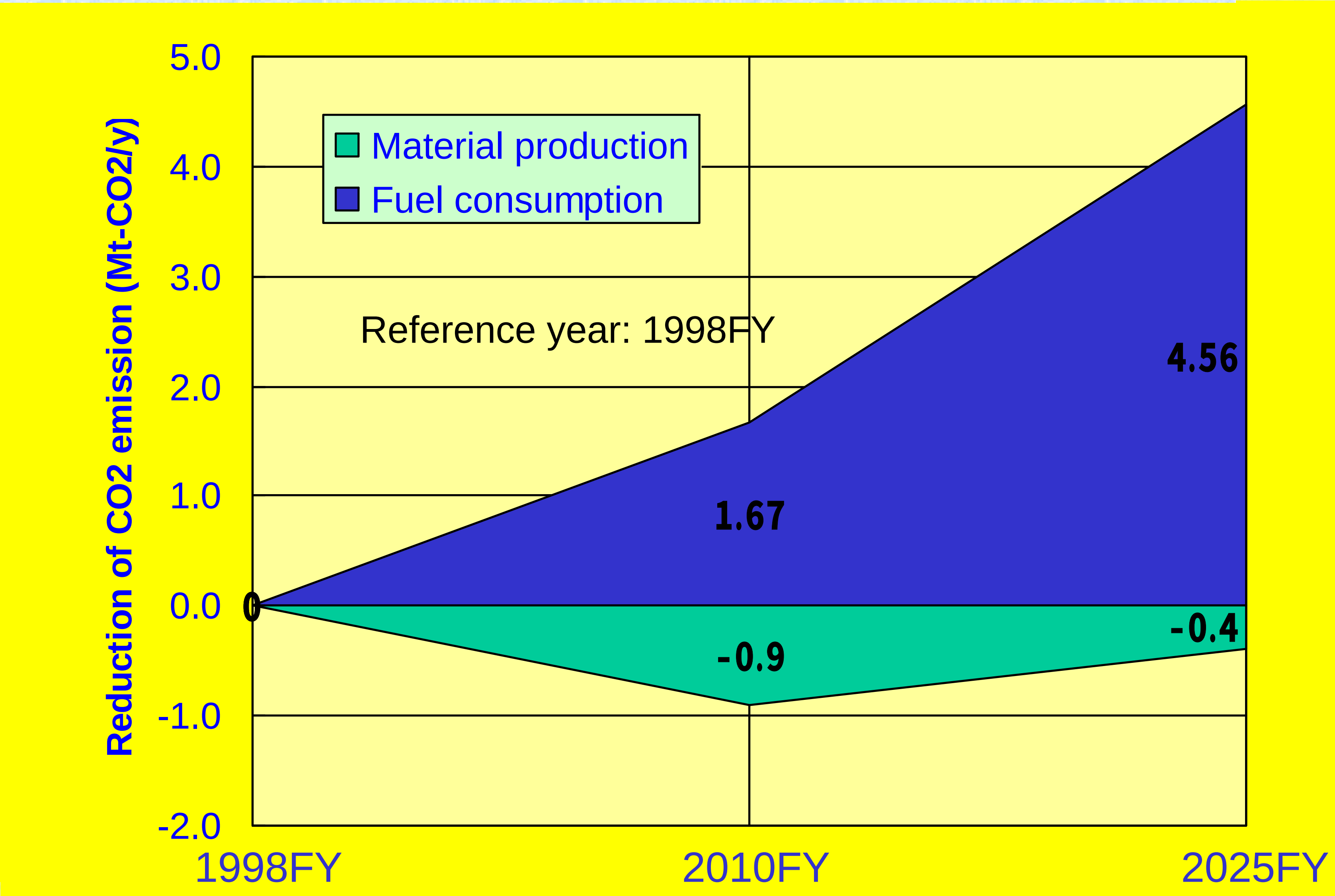


In 2010FY

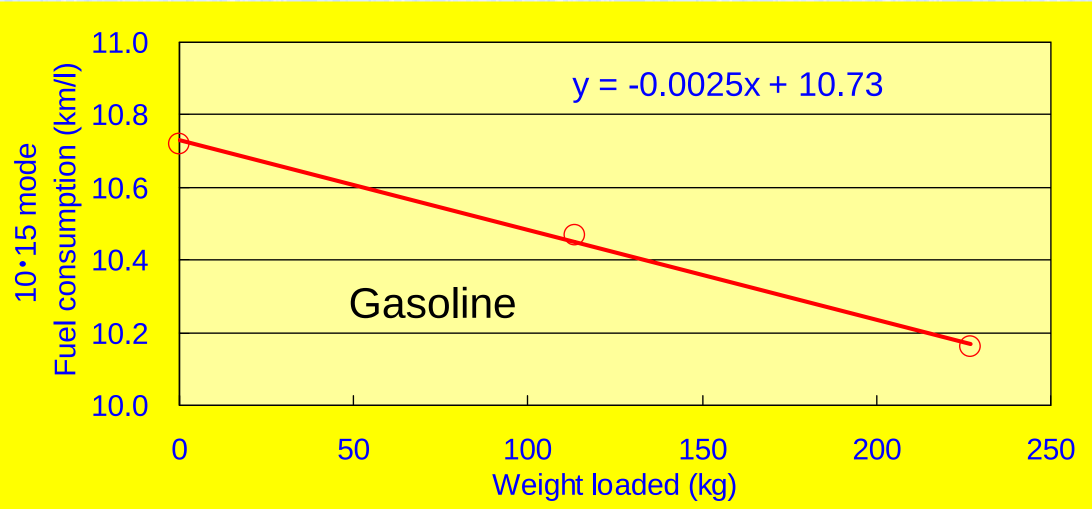


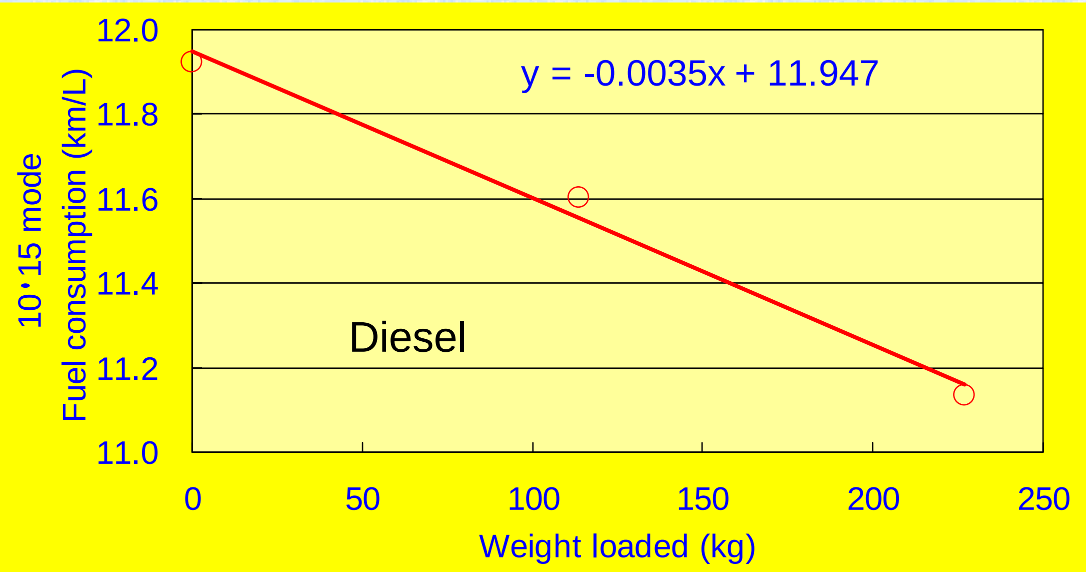
In 2025FY

Reduction in total CO_2 emission



Effect of weight change on fuel consumption





Test conditions

– 10-15 mode measurement

– Type of vehicle: van
  TOYOTA Townace-G
  Townace-D

– Curb weight:
  1,280 kg (G)
  1,350 kg (D)

– Engine capacity
  1.78 L (G)
  2.18 L (D)

Tested by AIST, 2001