ATRANS Research Project A-09/003

Possibility of Ethanol Usage as Diesel Substitute in Thai Transportation Sector

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ATRANS-OTP Round Table Meeting

"Sustainable Transport Development Aspect in Thailand: Transit-Oriented Development (TOD), Equity and the environment"

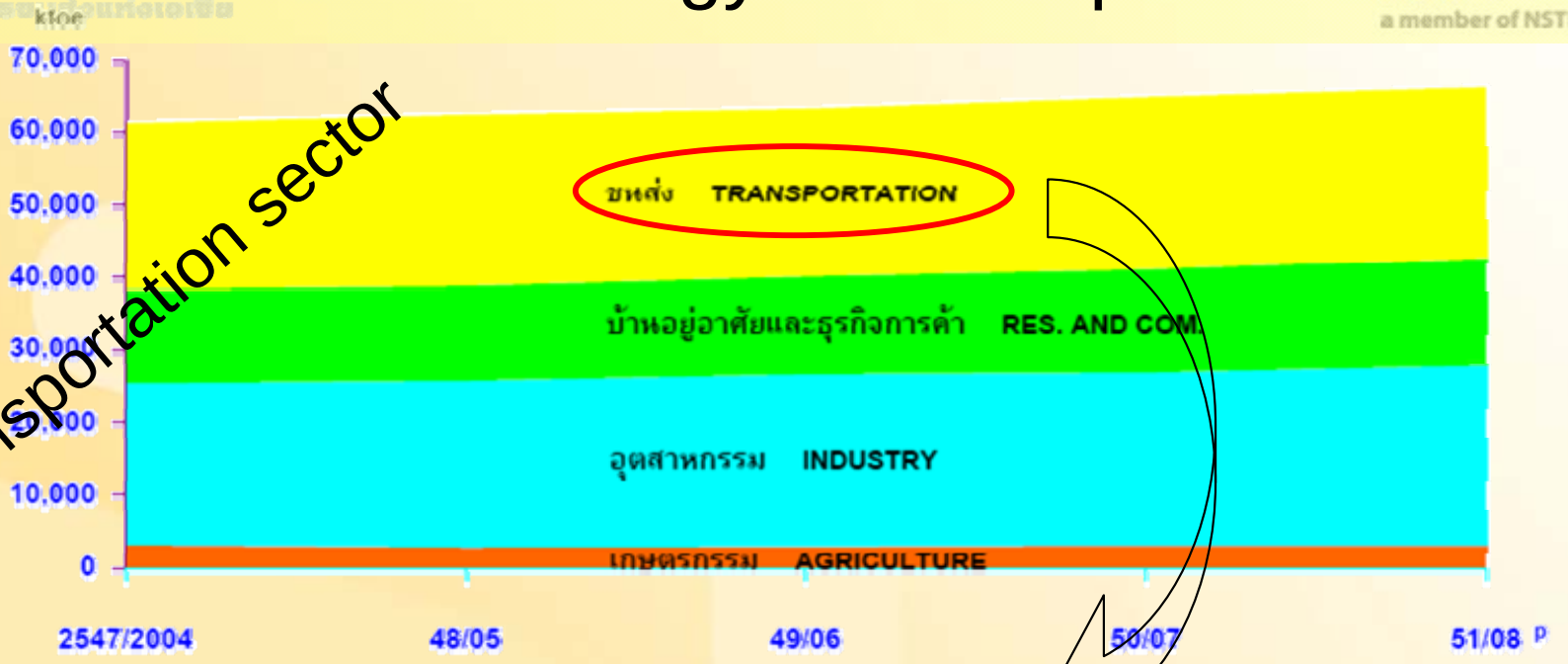
Friday 4th June 2010

Outline

- Brief introduction
  - Rationale & Current situation
  - Objective & Methodology
- Energy demand model construction (BAU)
  - Available record
  - Model assumption
  - Validation by historical record
- Scenario Model
  - Existing technology case for ethanol city bus (BMTA)
  - Assume technology penetration to inter city bus
  - Assume budget spent on developing indigenous technology (on diesel pickup truck etc.)
- Questions & comments?

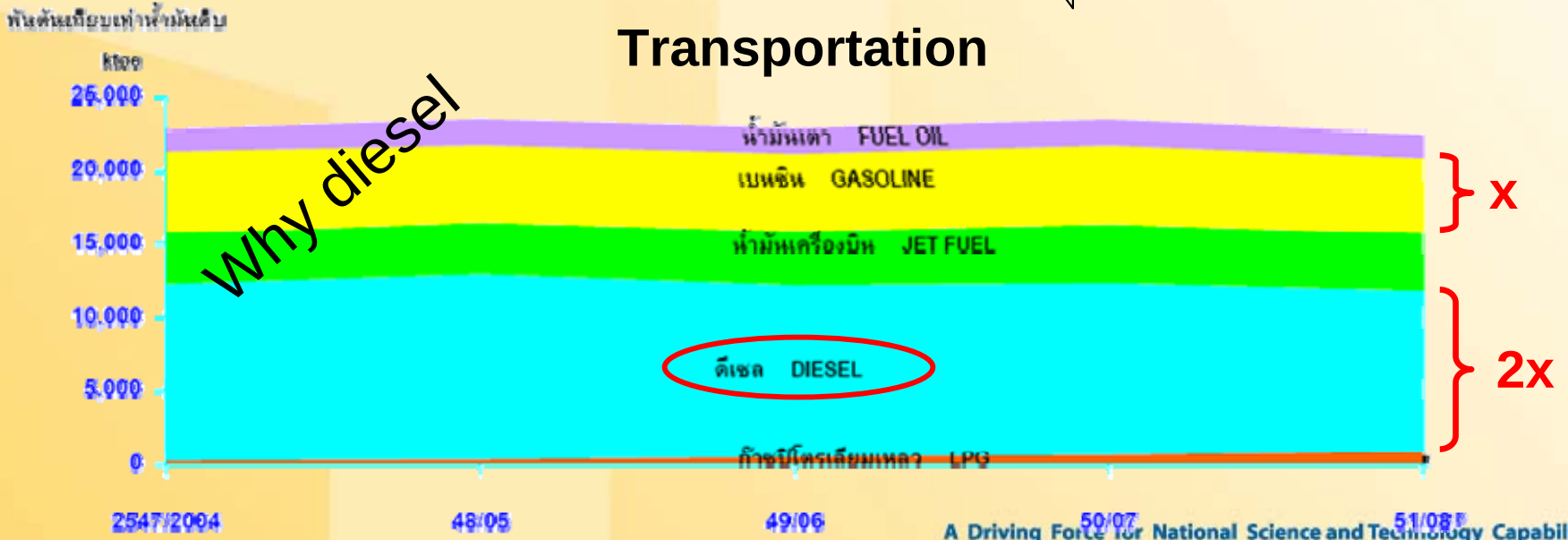
Thailand Energy Consumption

FIGURE 8 TRENDS OF FINAL ENERGY CONSUMPTION BY ECONOMIC SECTOR



Why transportation sector

FIGURE 11 TRENDS OF TRANSPORT ENERGY CONSUMPTION BY TYPE



Transportation

Why diesel

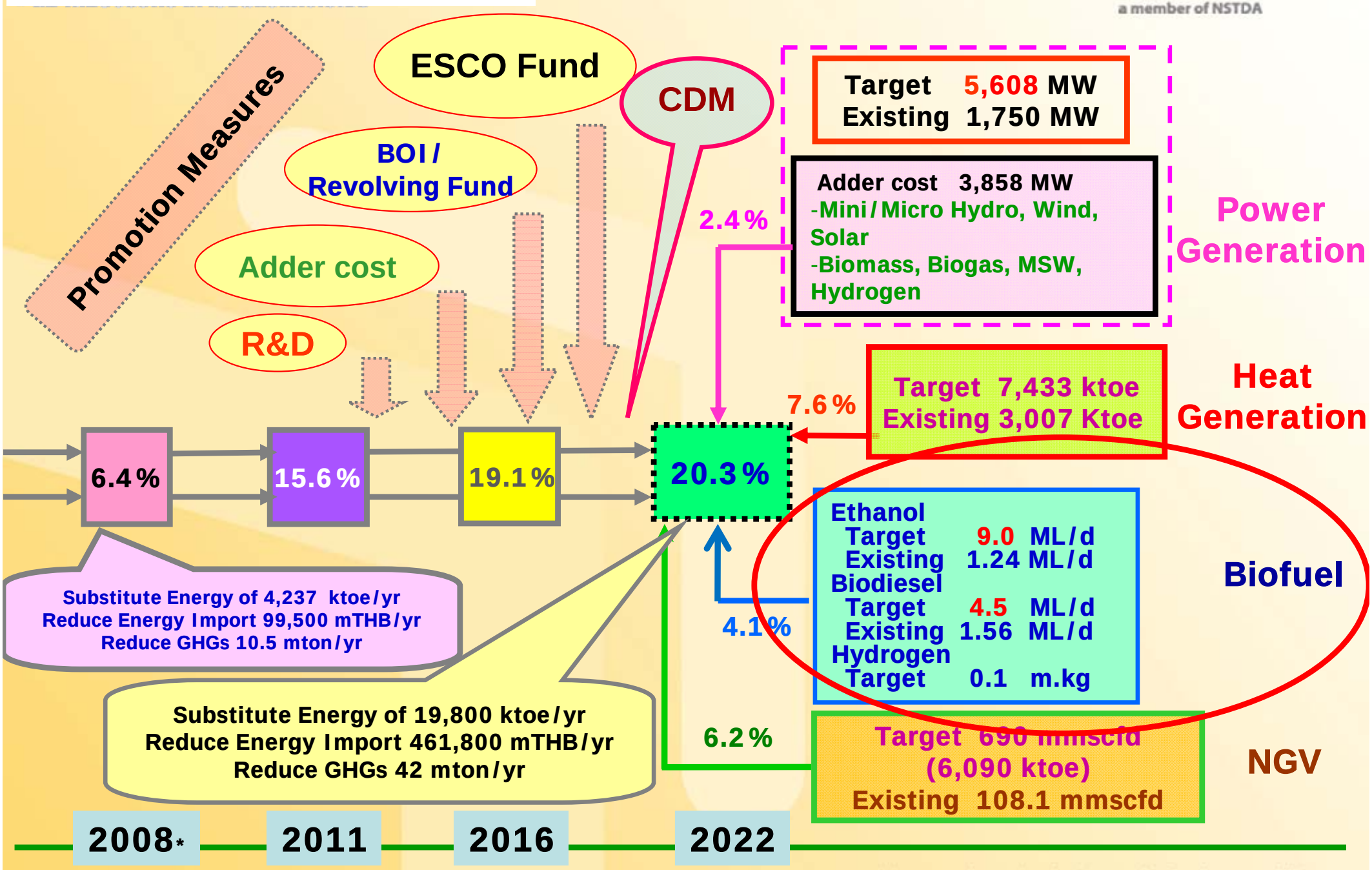
x

2x

Source: Department of Alternative Energy Development and Efficiency (DEDE)

กรมพัฒนาพลังงานทดแทน
และอนุรักษ์พลังงาน
กระทรวงพลังงาน

Development Strategy on Alternative Energy for 2008 - 2022

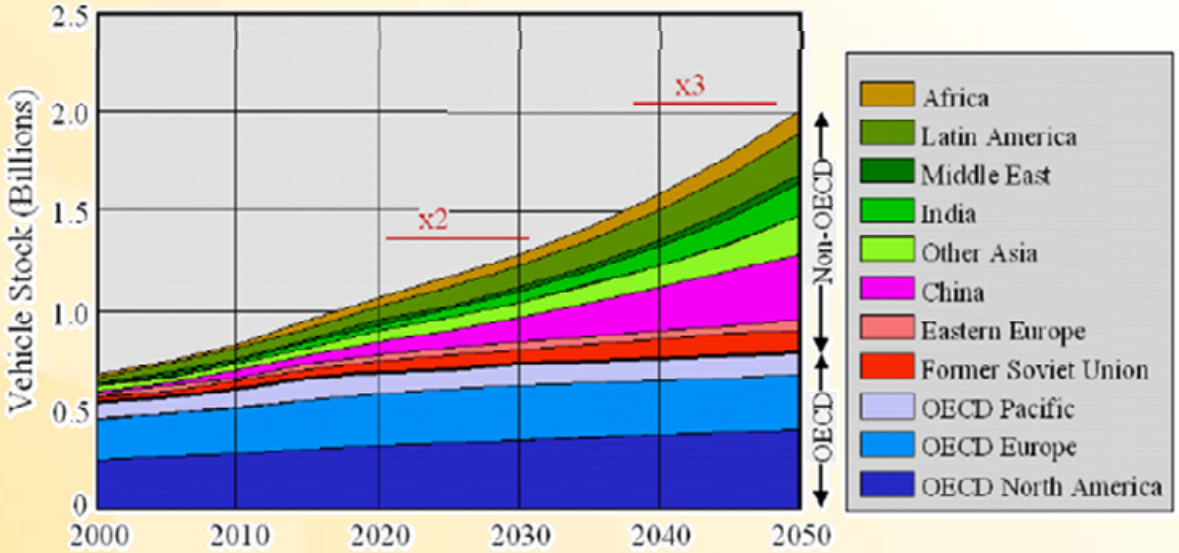


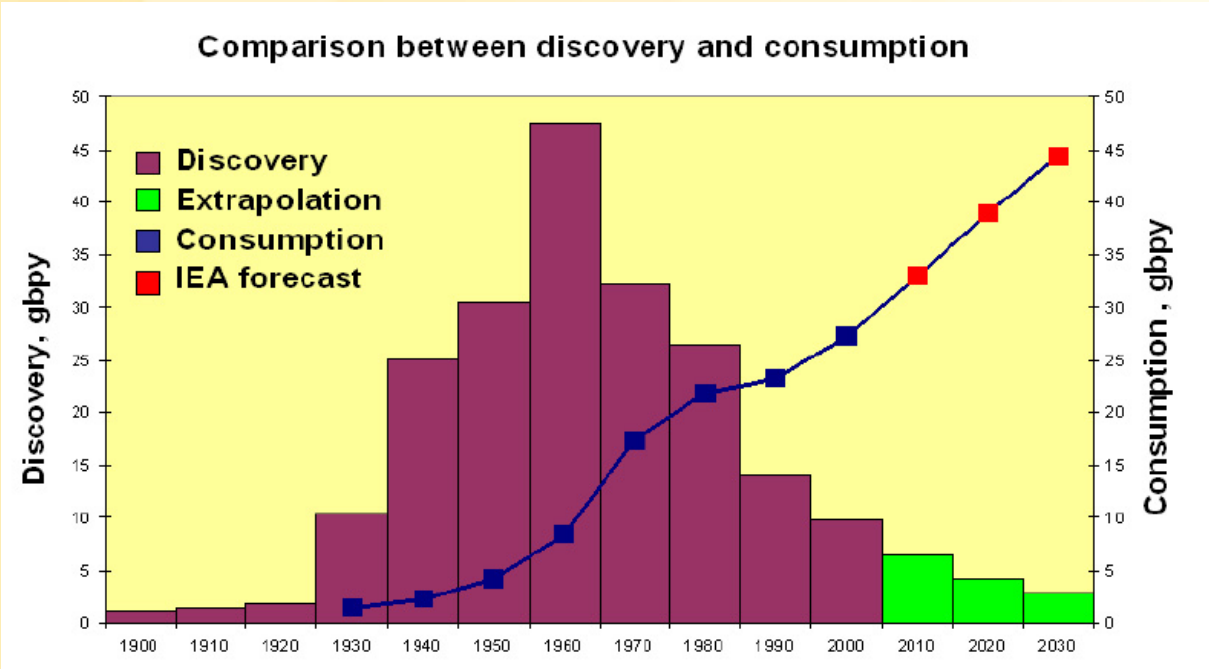
Projected with 2008 average crude oil price of $94.45/barrel

Remarks: * as of Jan 2009

Scania & Ethanol fuel

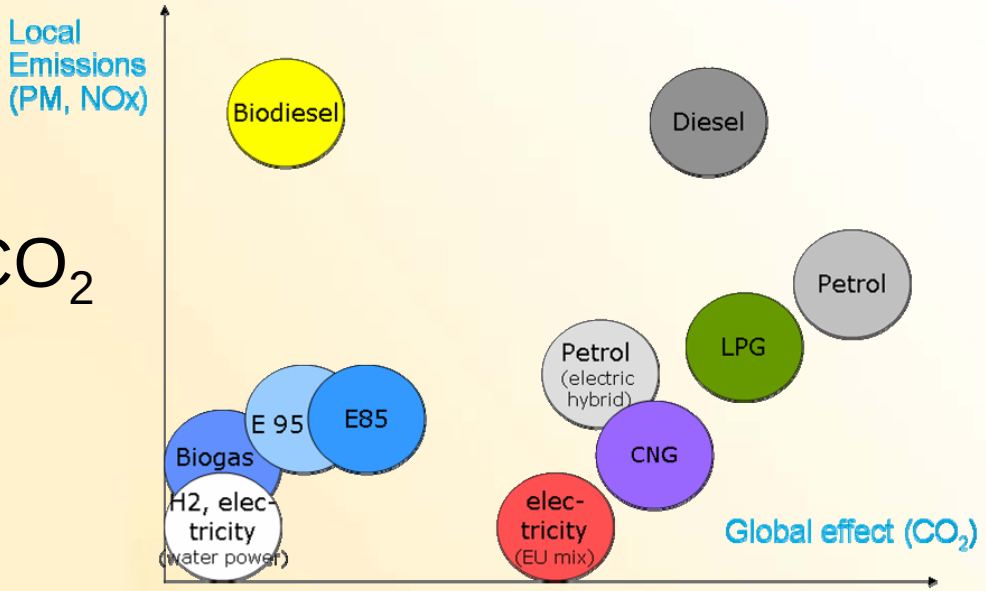
- Growing number of vehicles
- Less fossil fuel resource

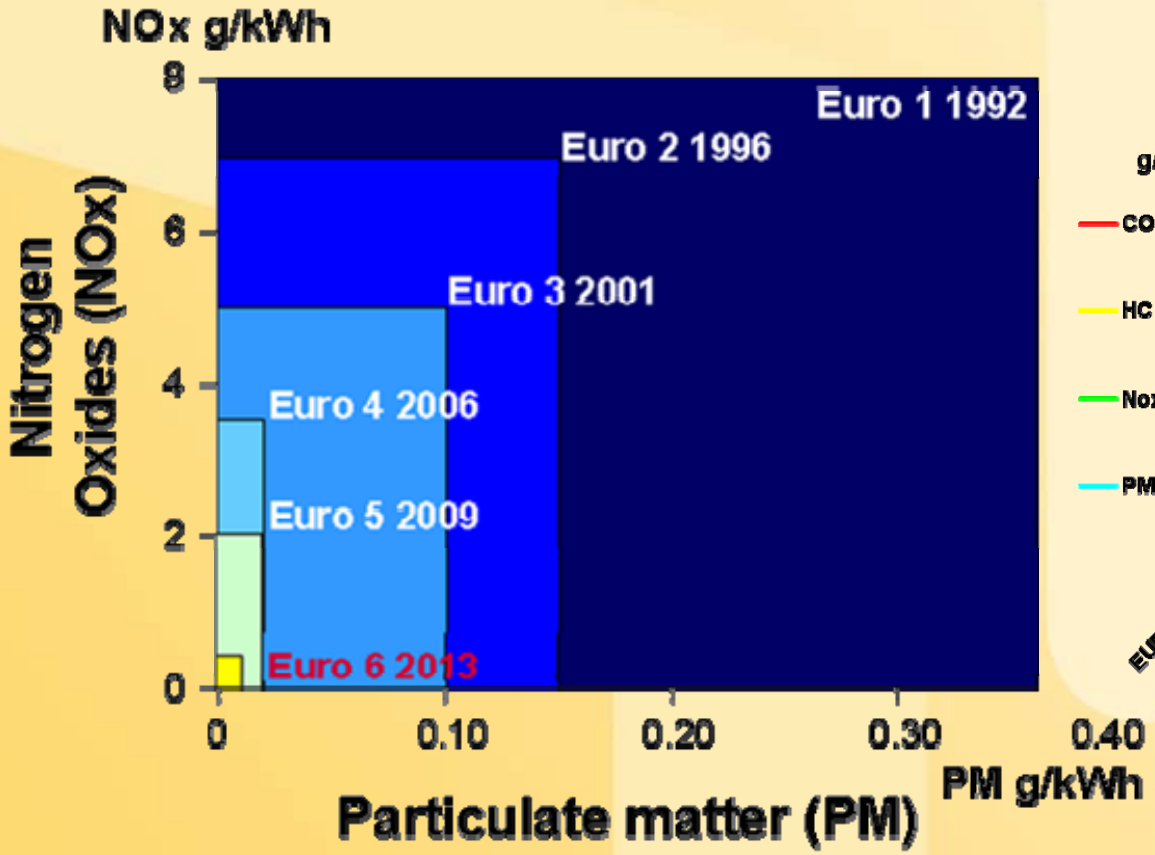


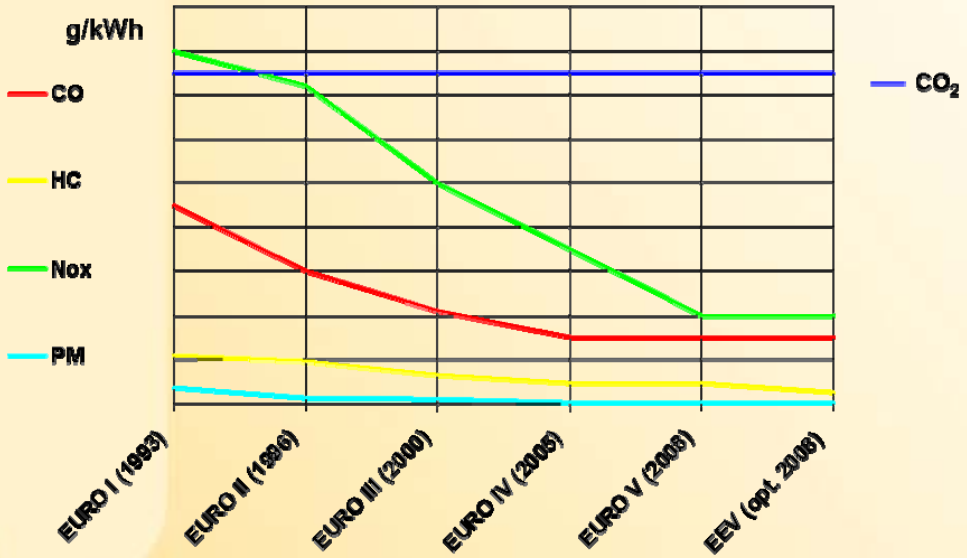


Scania & Ethanol fuel

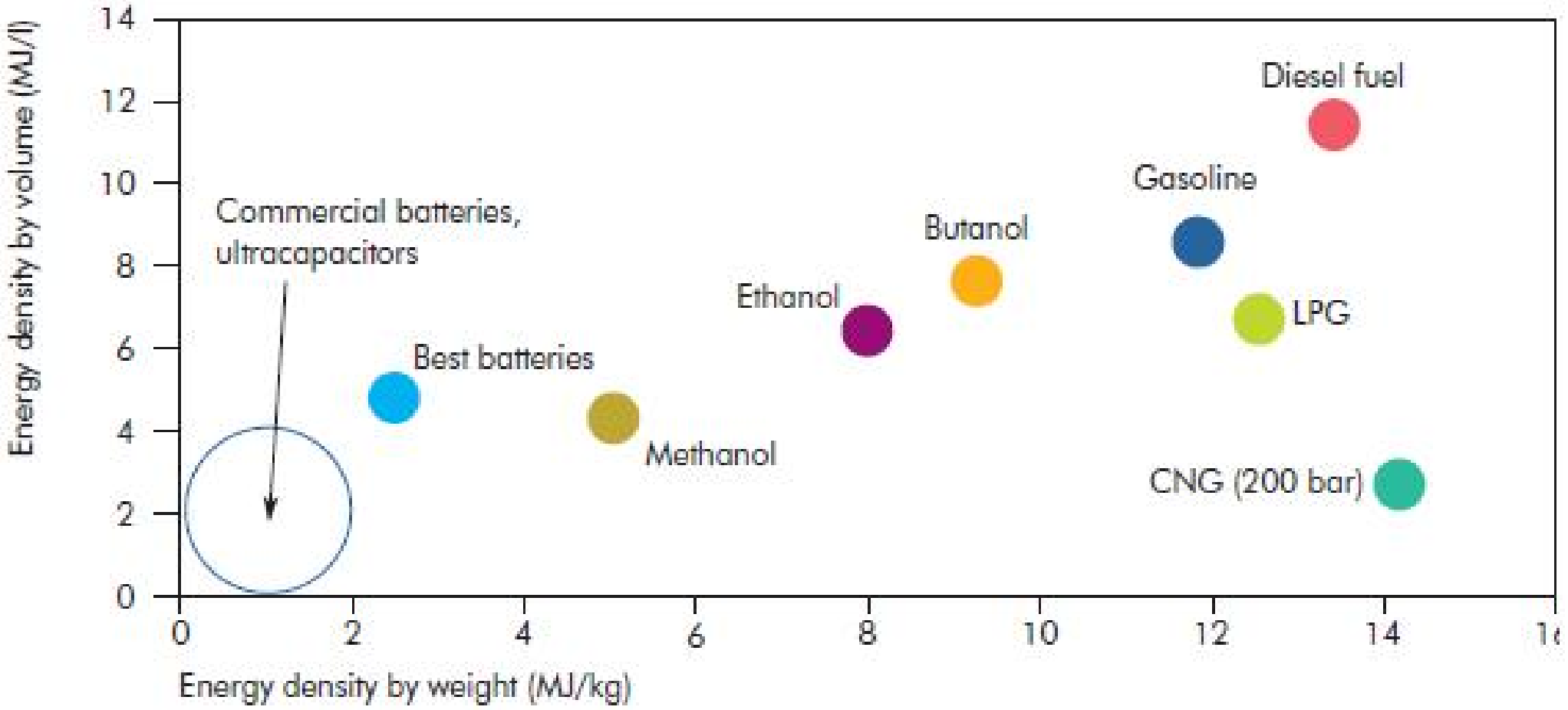
- Growing number of vehicles
- Less fossil fuel resource
- Emission regulation not after CO_2
  - Ethanol also helps reduce GHG







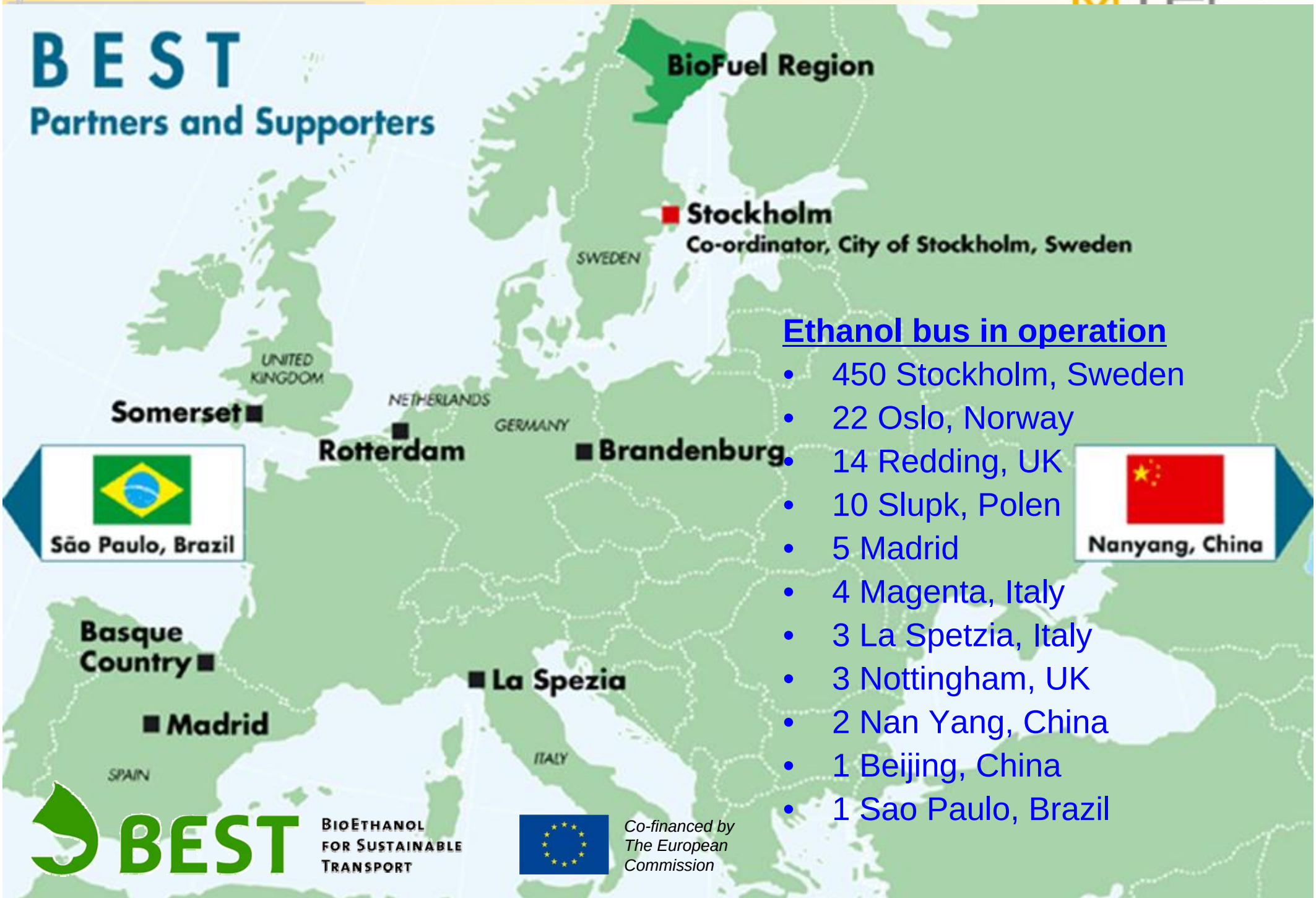
Liquid fuel still hard to beat



Source: Various, including IEA data on the relationship between volumetric and mass density of batteries and IEA assumptions on the efficiencies of engines (25% to 30% for internal combustion engines) and electric motors (90% to 95%).

Source: IEA Energy Technology Perspectives 208

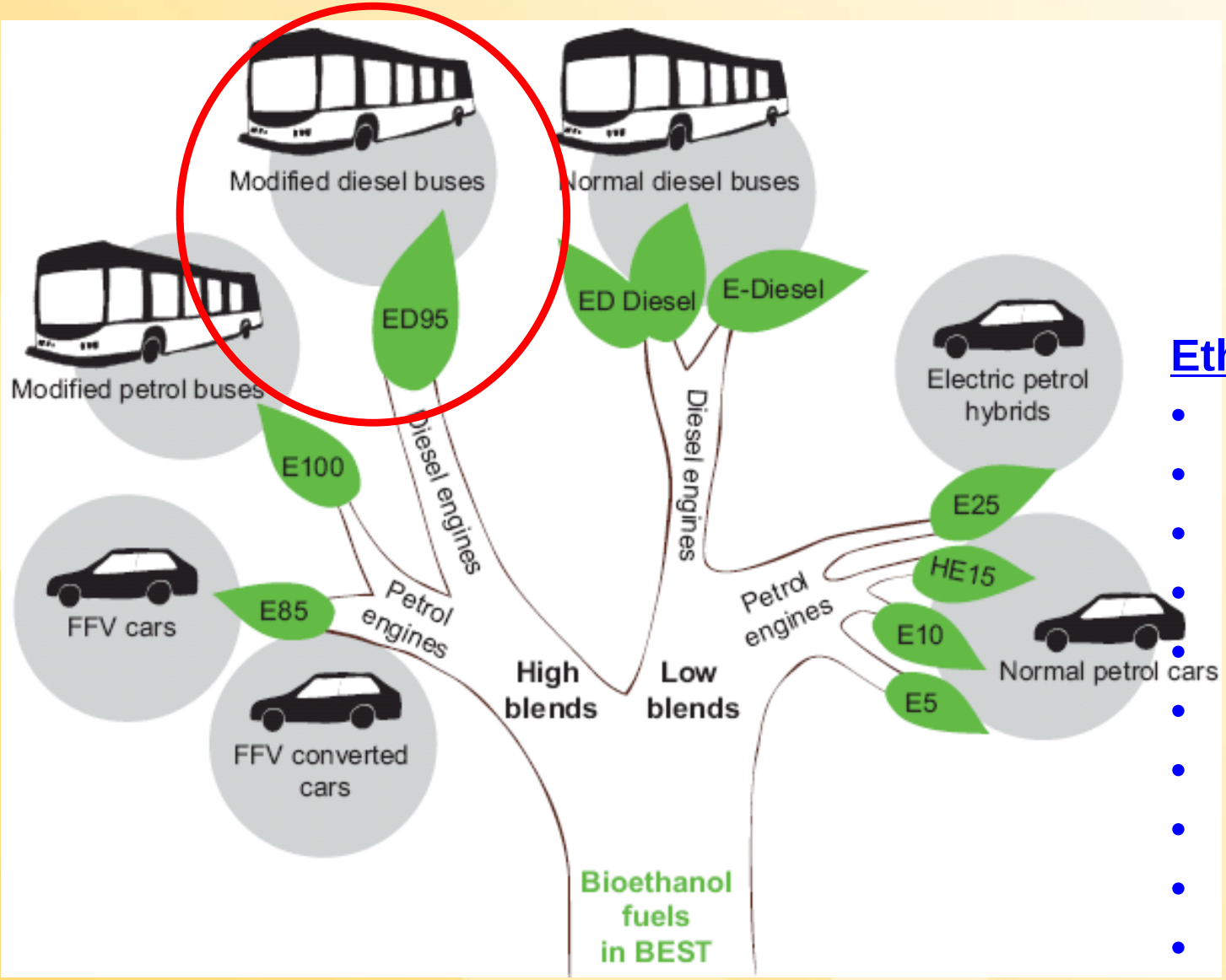
Ethanol Bus Worldwide



Ethanol bus in operation

- 450 Stockholm, Sweden
- 22 Oslo, Norway
- 14 Redding, UK
- 10 Slupk, Polen
- 5 Madrid
- 4 Magenta, Italy
- 3 La Spetzia, Italy
- 3 Nottingham, UK
- 2 Nan Yang, China
- 1 Beijing, China
- 1 Sao Paulo, Brazil

Ethanol Bus Worldwide



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- 450 Stockholm, Sweden
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BEST BioEthanol for Sustainable Transport

Co-financed by The European Commission

Ethanol Diesel Engine (ED95) & Additive

3rd generation diesel-ethanol engine

Highly efficient diesel combustion

9-litre diesel engine
270 hp, 1200 Nm

Euro 5 and EEV
Best available environmental standard

Thermal efficiency
Ethanol up to 43%
(With diesel up to 44%)

Up to 90% CO_2-saving

SCANIA

Ethanol piston 28:1 **Normal piston 17:1**

9-litre 270 hp ethanol 9-litre 270 hp diesel

Compromise: Cold-start capability vs. max cylinder pressure (power)

SCANIA

The fuel

SEKAB, EtamaxD™	**Pat. WO9505437**
▪ **Ethanol (95% by volume)**	**92.2% by weight**
▪ **Ignition improver***	**5% by weight**
▪ **MTBE + isobutyl alcohol**	**2.8% by weight**

Q_{LHV} = 25.7 MJ/kg (diesel = 44.5 MJ/kg)
Density = 0.82kg/litre (=diesel)
+ a lot of water: 6.4% by weight

*) poly-ethylene-glycol derivative from *Akzo Nobel, Beraid 3555*

- ED95 – 96.5 % hydrous bioethanol, 3.5 % additives – used in bioethanol buses, converted diesel vehicles and dedicated heavy diesel vehicles, such as waste collection trucks.

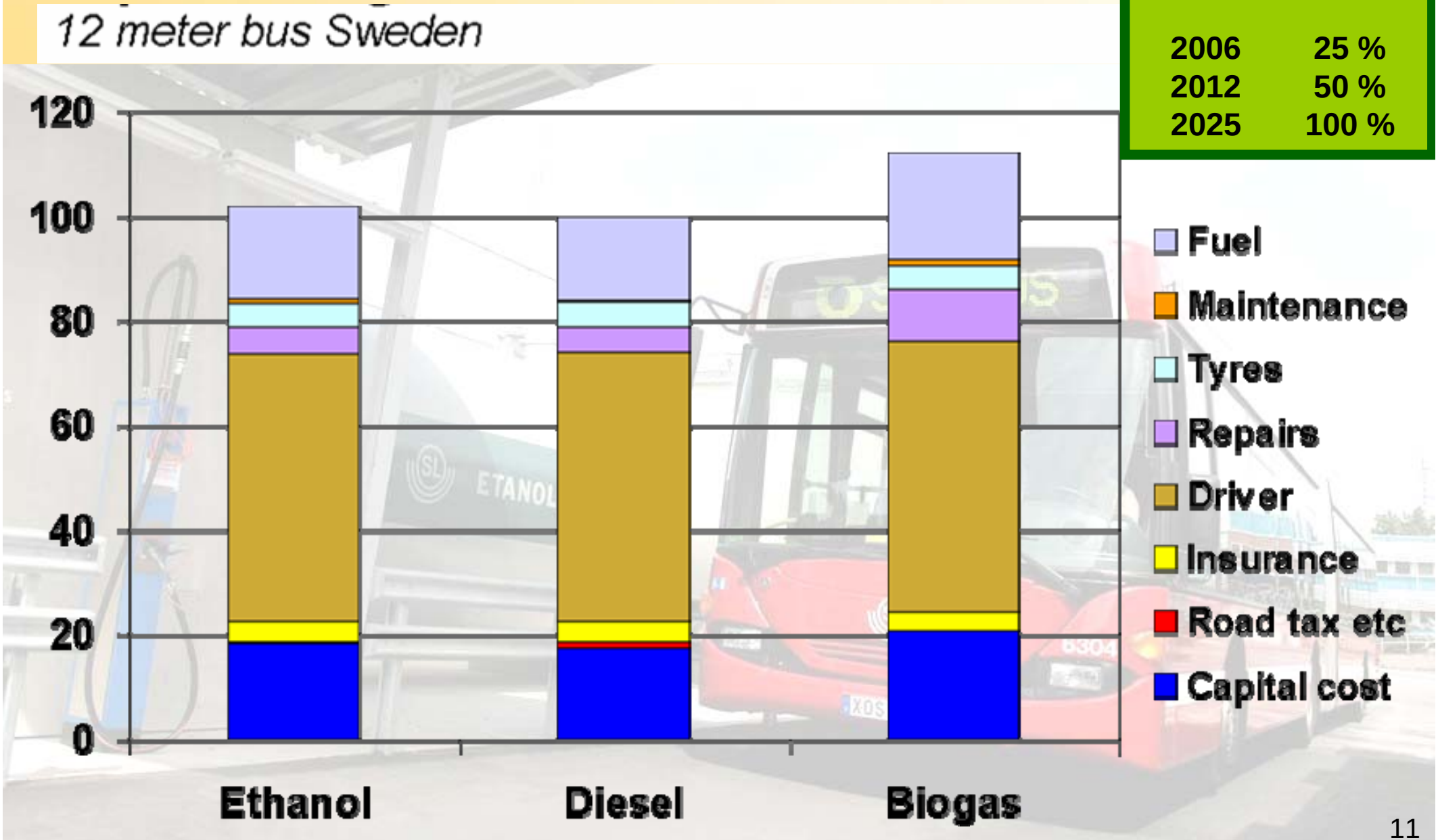
Bjorn Westman, Engineering Director, SCANIA

Operating Cost in Sweden
12 meter bus

Stockholm Public Transport's goals:

Buses on Renewable Fuels:

2006	**25 %**
2012	**50 %**
2025	**100 %**



EU Directive 2005/55/EC (28 Sep 2005)

►M1 1.3. ◄ **Ethanol for diesel engines** (1)

Parameter	Unit	Limits (2)		Test method (3)
		Minimum	Maximum	
Alcohol, mass	% m/m	92,4	—	ASTM D 5501
Other alcohol than ethanol contained in total alcohol, mass	% m/m	—	2	ADTM D 5501
Density at 15 °C	kg/m³	795	815	ASTM D 4052
Ash content	% m/m		0,001	ISO 6245
Flash point	°C	10		ISO 2719
Acidity, calculated as acetic acid	% m/m	—	0,0025	ISO 1388-2
Neutralisation (strong acid) number	KOH mg/l	—	1	
Colour	According to scale	—	10	ASTM D 1209
Dry residue at 100 °C	mg/kg		15	ISO 759
Water content	% m/m		6,5	ISO 760
Aldehydes calculated as acetic acid	% m/m		0,0025	ISO 1388-4
Sulphur content	mg/kg	—	10	ASTM D 5453
Esters, calculated as ethylacetate	% m/m	—	0,1	ASSTM D 1617

(1) Cetane improver, as specified by the engine manufacturer, may be added to the ethanol fuel. The maximum allowed amount is 10 % m/m.

(2) The values quoted in the specification are 'true values'. In establishment of their limit values the terms of ISO 4259, Petroleum products — Determination and application of precision data in relation to methods of test, have been applied and in fixing a minimum value, a minimum difference of 2R above zero has been taken into account; in fixing a maximum and minimum value, the minimum difference is 4R (R – reproducibility). Notwithstanding this measure, which is necessary for statistical reasons, the manufacturer of a fuel should nevertheless aim at a zero value where the stipulated maximum value is 2R and at the mean value in the case of quotations of maximum and minimum limits. Should it be necessary to clarify the question as to whether a fuel meets the requirements of the specification, the terms of ISO 4259 should be applied.

(3) Equivalent ISO methods will be adopted when issued for all properties listed above.

Project Objective

- Aims to assess feasibility of using ethanol in transportation sector (especially as diesel substitute)
  - Construct a database model for energy consumption in transportation
  - Analyze above model for various scenarios to reflect different levels of diesel substitution by ethanol
  - Assess technical-economical feasibility of using ethanol as diesel substitute in transportation sector

Methodology

- Use LEAP to construct energy demand model for transportation sector
- Run scenarios analysis on ED95 technology introduction

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Basic of energy demand calculation

$$\underset{\text{(energy demand)}}{ED.} = \underset{\text{(number of vehicle)}}{NV.} \times \underset{\text{(vehicle kilometer of travel)}}{VKT.} \times \underset{\text{(fuel economy)}}{FE.}$$

when :

$$ED = \sum_{\substack{i,\ \text{vehicle type} \\ j,\ \text{region}}} ED_{i,j}$$

$$ED_i = \sum_{k,\ \text{fuel used}} ED_k$$

- There are MANY fuel choices and MANY engine technology to calculate fuel consumption
- Issues with Bi- and Dual-fuel
- Need certain assumption in the calculation

Bi-fuel engine:

$$e.d. = FE_l \cdot DS_l + FE_g \cdot DS_g$$

Diesel Dual fuel:

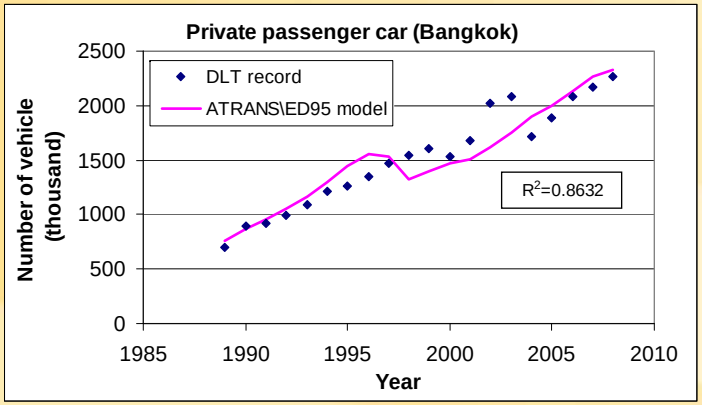
$$e.d. = FE_{DDF.} \cdot \left(DS_l + DS_g\right)$$

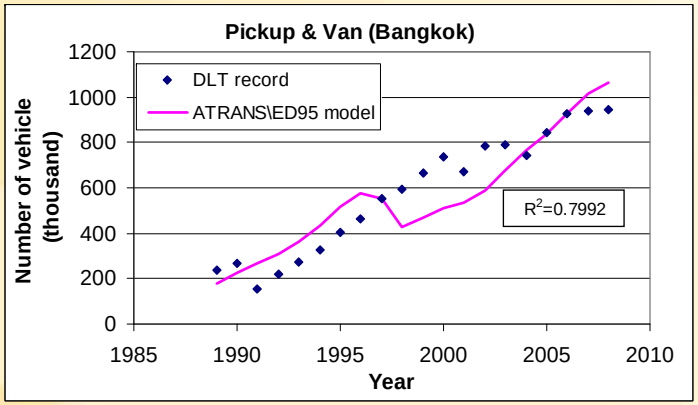
**note* *DS : Device share by energy unit*

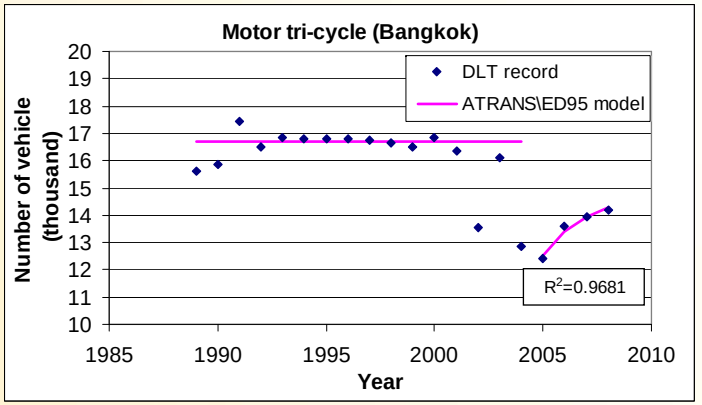
Vehicle type

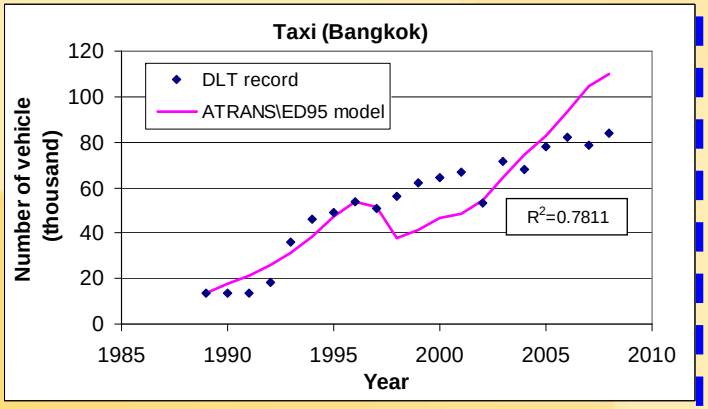
A. Total vehicle under motor vehicle act		B. Total vehicle under land transport act	
MV.1 Not more than 7 passengers	PC01 passenger car	Bus	
MV.2 Microbus & Passenger Van		- Fixed Route Bus	BUS01 Fixed route bus
MV.3 Van & Pick Up	PC02 pickup	- Non Fixed Route Bus	BUS02 Non fixed route bus
MV.4 Motortricycle	PC03 motor tri-cycle	- Private Bus	BUS03 Private bus
MV.7 Fixed Route Taxi (Subaru)		Small Rural Bus	sBus04 Small bus
MV.8 Motortricycle Taxi (Tuk Tuk)		Truck	
MV.6 Urban Taxi	PC04 taxi	- Non Fixed Route Truck	Truck01 Non fixed route truck
MV.5 Interprovincial Taxi	PC05 Commercial rent car	- Private Truck	Truck02 Private truck
MV.9 Hotel Taxi			
MV.10 Tour Taxi			
MV.11 Car for Hire			
MV.12 Motorcycle	PC06 Motor cycle		
MV.17 Public Motorcycle			
MV.13 Tractor	-		
MV.14 Road Roller			
MV.15 Farm Vehicle		record from DLT (Dec2009)	
MV.16 Automobile Trailer		http://apps.dlt.go.th/statistics_web/statistics.html	

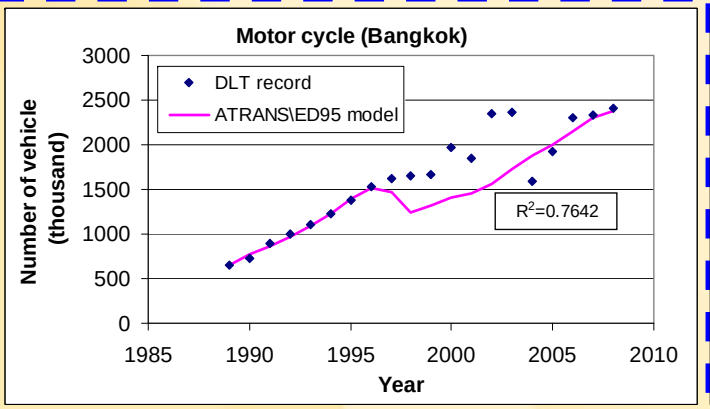
Number of vehicle in Bangkok

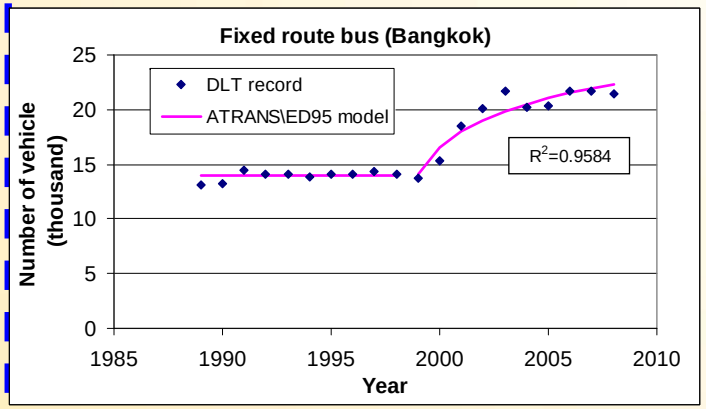


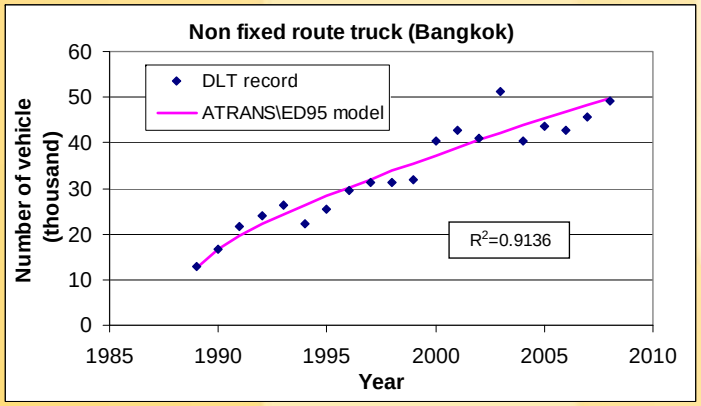


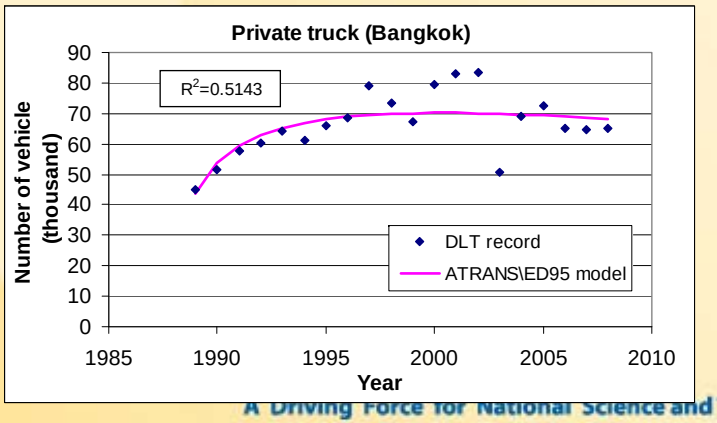




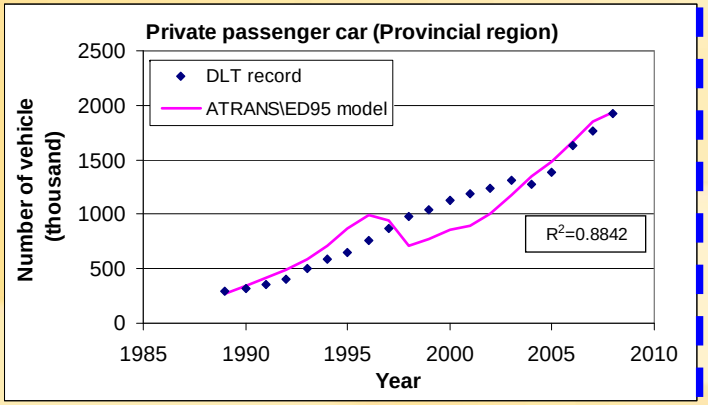


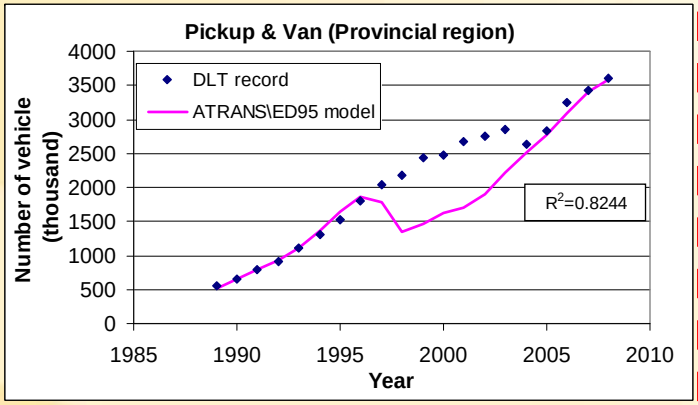


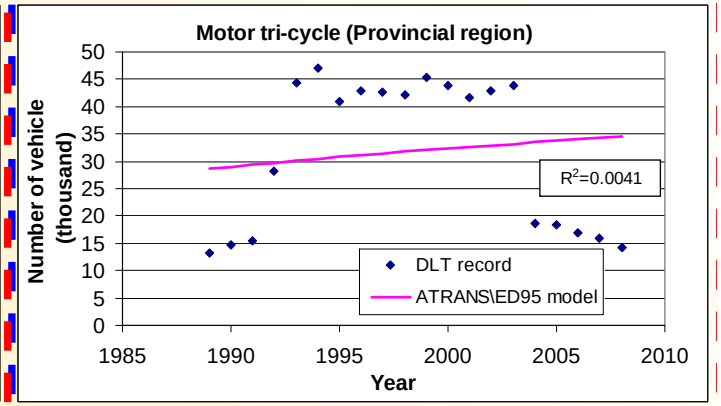


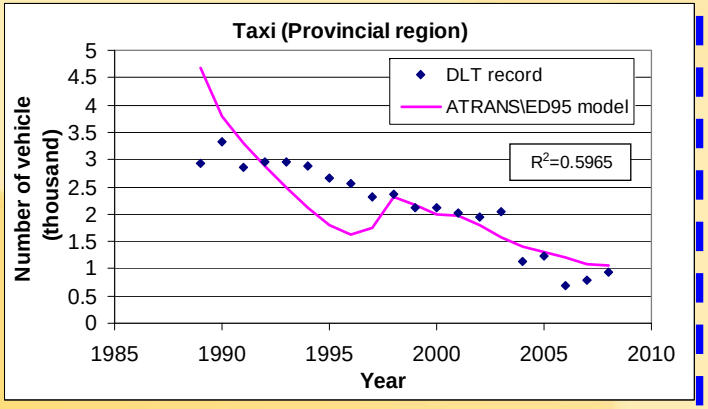


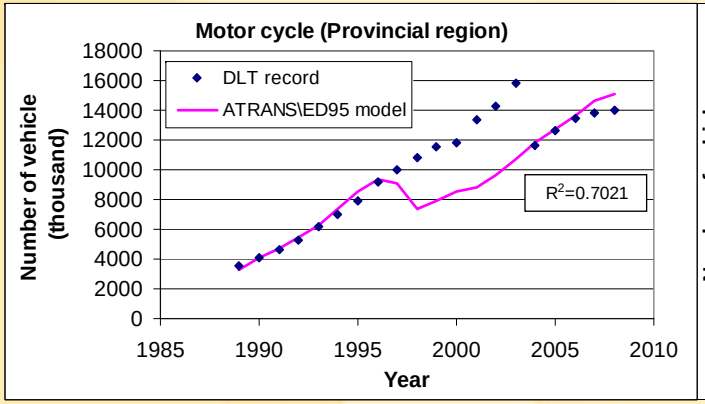
Number of vehicle in provincial region

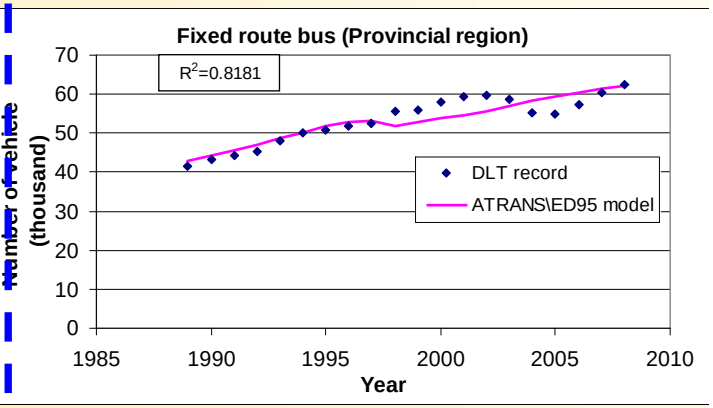


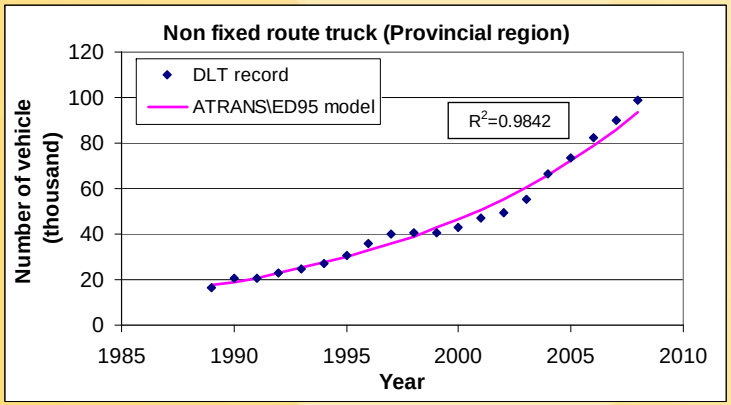


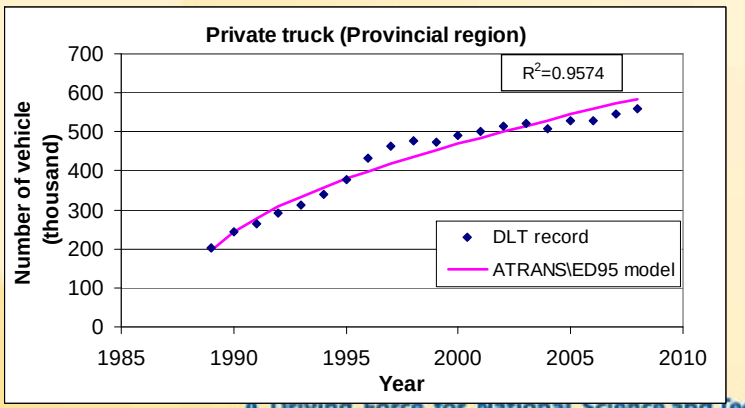












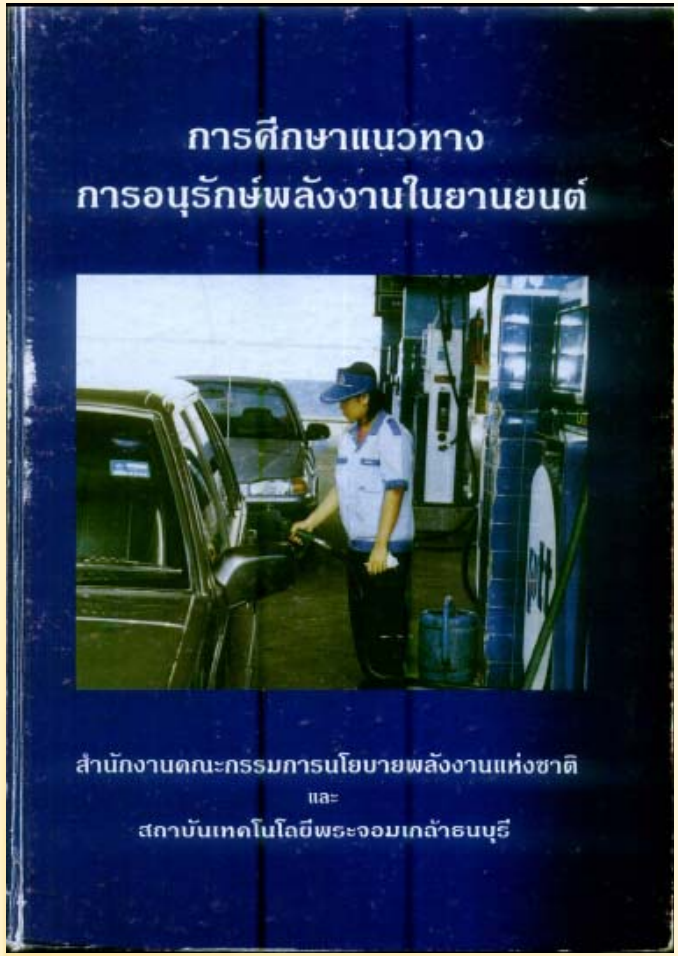
Percent share of fuel used in vehicle stocks

	Single liquid fuel engine				Dual-fuel engine				Dedicated gas	
	SI Engine			CI Engine	Bi-fuel SI LPG	Bi-fuel SI CNG	DDF LPG	DDF CNG	LPG dedic.	CNG dedic
	Gasoline	E10	E20							
PC01 private passenger car	78.16			20.38%	1.46%	0.00%	0.00%	0.00%	0.00%	0.00%
	42.86%	56.57%	0.57%							
PC02 pickup	5.25%			94.75%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	67.95%	32.05%	0.00%							
PC03 motor tri-cycle	42.26%			0.00%	17.84%	0.00%	0.00%	0.00%	37.48%	2.22%
	79.58%	20.42%	0.00%							
PC04 taxi	14.61%			0.00%	77.00%	7.62%	0.00%	0.00%	1.37%	0.00%
	42.86%	56.57%	0.57%							
PC05 commercial rent car	69.73%			26.92%	3.35%					0.00%
	42.86%	56.57%	0.57%							
PC06 motor cycle	100.00%			0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	65.57%	34.43%	0.00%							
Bus07 fixed route bus	1.24%			94.77%	2.39%	0.00%	0.00%	0.00%	0.00%	1.60%
	100.00%	0.00%	0.00%							
Bus08 non fixed route bus	0.39			99.61%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	100.00%	0.00%	0.00%							
Bus09 private bus	0.80%			99.20%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	100.00%	0.00%	0.00%							
Truck10 non fixed route truck	0.00%			99.30%	0.00%	0.00%	0.22%	0.48%	0.00%	0.00%
	100.00%	0.00%	0.00%							
Truck11 private truck	0.39%			99.61%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00
	100.00%	0.00%	0.00%							

Small amount ~ 0%

Fuel economy and Vehicle Kilometer of Travel

EPPO report, 2008



NEPO & KMUTT, 1997

Fuel economy (BKK)

km/litre	Single fuel engine				Dual fuel engine				Dedicated engine	
	SI Engine			Diesel	Bi-fuel SI LPG	Bi-fuel SI CNG	Diesel DDF LPG	Diesel DDF CNG	LPG dedic.	CNG dedic
	Gasoline	Gasohol E10	Gasohol E20**							
PC01	10.62*	11.30*	9.85	11.44*					9.87*	10.85*
PC02	10.00*	9.64**	9.28	11.21*					11.57*	11.33*
PC03	10.92**	10.52**	10.13	12.00**					9.71*	9.29*
PC04	10.58**	10.20**	9.82	11.63**					9.83**	10.81**
PC05	11.83**	11.40**	10.97	13.00**					10.99**	12.08**
PC06	32.77*	29.24*	-	-					-	-
Bus01	2.18**	2.10**	2.03	2.40*					2.03**	1.86*
Bus02	2.09**	2.01**	1.94	2.30**					1.94**	2.13**
Bus03	2.10**	2.02**	1.95	2.31**					1.95**	2.14**
Truck01	2.57**	2.48**	2.38	2.83*					2.39**	2.63**
Truck02	2.22**	2.14**	2.06	2.44**					2.07**	2.27**

**Calculation method shown next pages

*EPPO report, 2008

**Estimate in this work by referring to NEPO & KMUTT, 1997

Fuel Economy for Single Fuel Engine: Derivation from 1997 data

- ***Assumption***: The fuel economy is depended only on the vehicle (engine) size and the engine technology.
  a) So, the ***FE ratio*** (SI to SI, or CI to CI) between two vehicle types are constant during the consideration year.

$$FE. \propto \left\{ \begin{array}{c} \text{engine size,} \\ \text{engine technology} \end{array} \right\}$$

  b) And also the ***FE ratio*** between two engine technology (SI to CI) of each vehicle type are constant by the same manner.

km/litre	SI Engine			Diesel
	Gasoline	Gasohol E10	Gasohol E20**	
PC01	1	-	-	1.0763
PC02	1.0552	-	-	1.1597
PC03	1.0601	-	-	1.2116
PC04	0.9881	-	-	1.1294

NEPO & KMUTT 1997

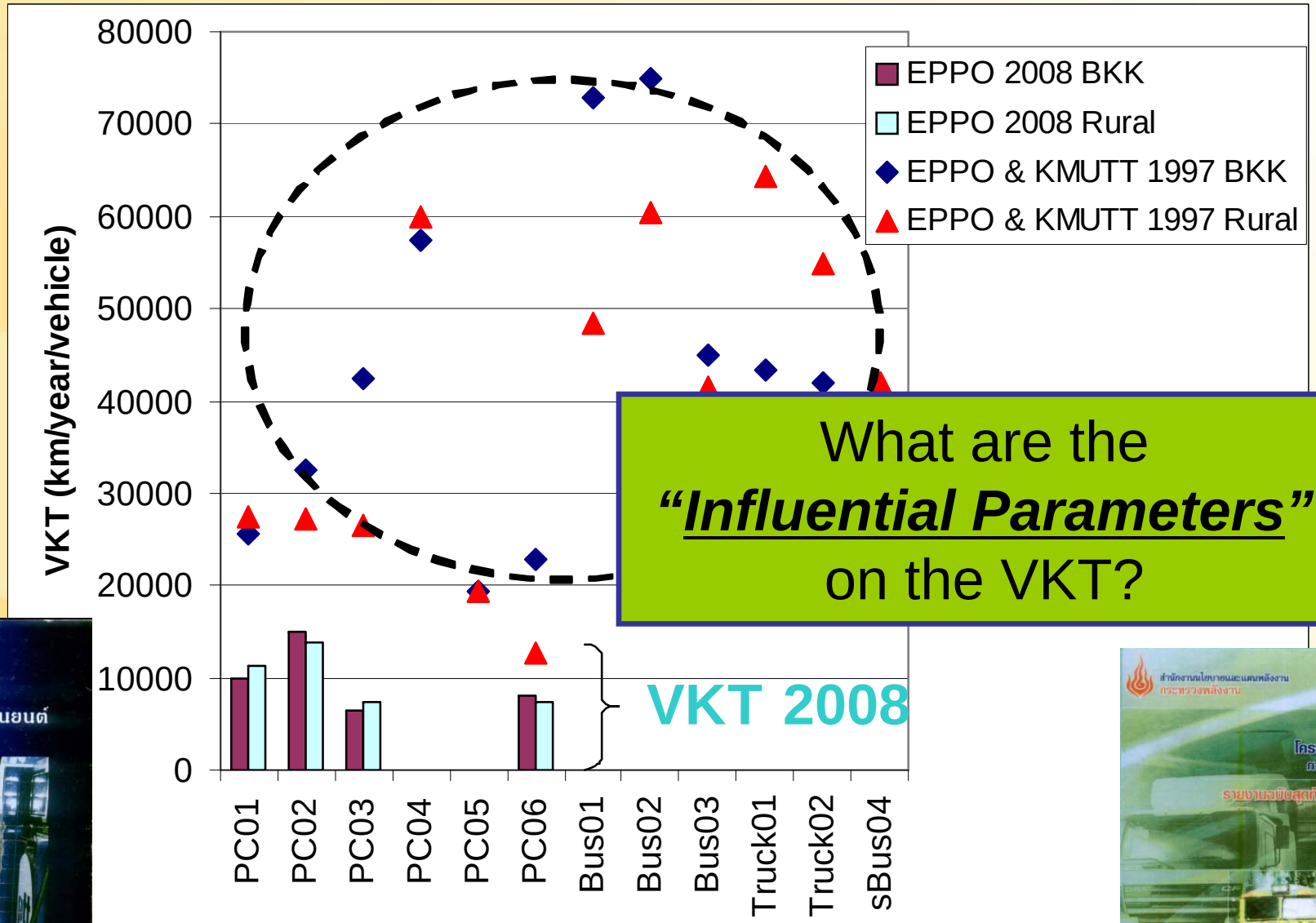
	Gasoline	Gasohol E10	Gasohol E20**	Diesel
PC01	10.62*	11.30*	-	11.44*
PC02	10.00*	-	-	11.21*
PC03	-			
PC04	-	-	-	-

EPPO 2008

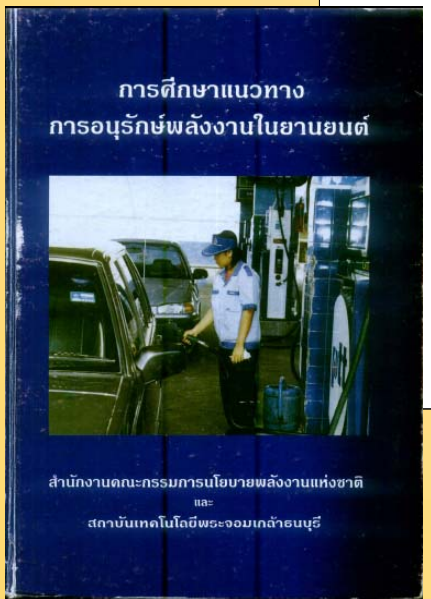
yr.1997 => yr.2008

km/litre	SI Engine			Diesel
	Gasoline	Gasohol E10	Gasohol E20**	
PC01	10.62*	11.30*	9.85	11.44*
PC02	10.00*	9.64**	9.28	11.21*
PC03	10.92**	10.52**	10.13	12.00**
PC04	10.58**	10.20**	9.82	11.63**
PC05	11.83**	11.40**	10.97	13.00**

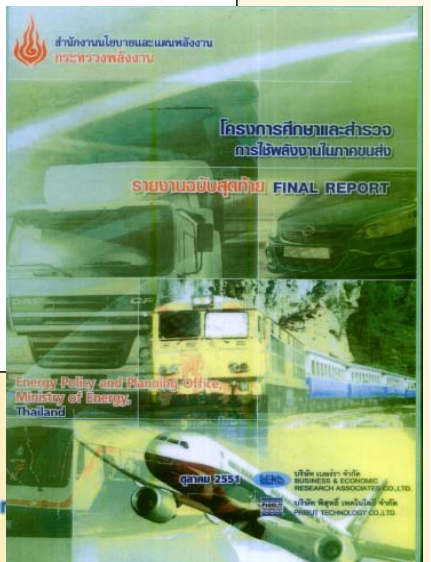
Vehicle Kilometer of Travel



What are the
"Influential Parameters"
on the VKT?



NEPO & KMUTT 1997



EPPO 2008

Road distance & Number of vehicle

Year	Total road distance (Rural)	Total number of vehicles	
		Bangkok	Rural
1996	53,768	3,549,082	12,544,814
1997	55,321	3,872,327	13,793,913
1998	57,233	4,016,594	14,843,918
1999	59,306	4,162,846	15,933,690
• • •	• • •		
2004	63,287	4,288,468	16,336,251
2005	63,062	4,899,969	17,671,093
2006	63,773	5,557,111	19,250,186
2007	64,745	5,715,078	19,903,369

Simplest model to estimate VKT!!!

over time

$$\frac{Rd_2}{Rd_1} = \frac{VKT_2}{VKT_1} \cdot \frac{\sum NV_2}{\sum NV_1}$$

km supply $\propto$ km demand

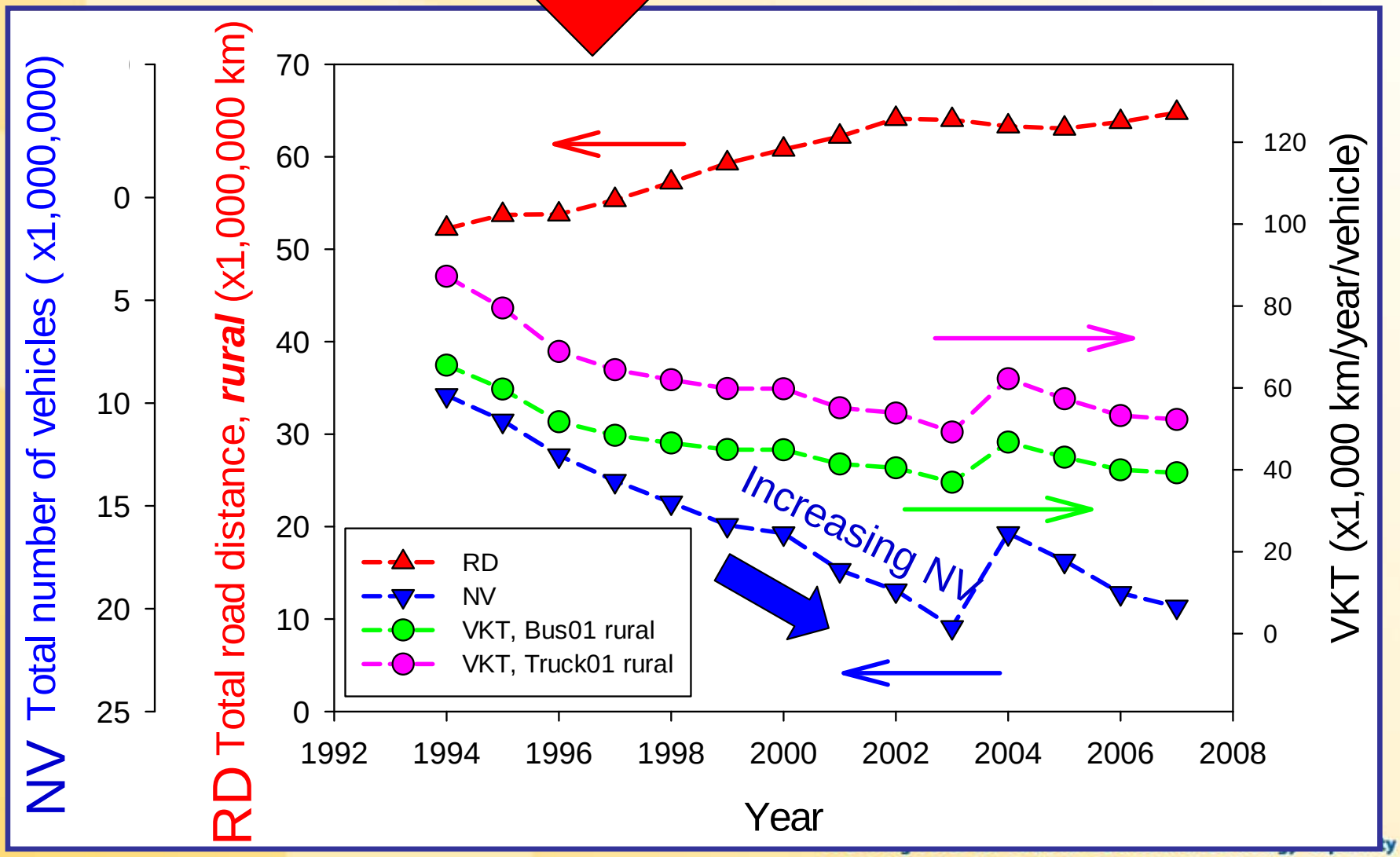
sum over VKT x NV of each vehicle type

Assume road expansion mostly from provincial region
(data obtained from Department of Highways)

Thailand transport portal ***(Rural)***
http://vigportal.mot.go.th/portal/site/PortalMOT/stat/index6URL/

Road distance & Number of vehicle

$$\frac{Rd_2}{Rd_1} = \frac{VKT_2}{VKT_1} \cdot \frac{\sum NV_2}{\sum NV_1}$$



Vehicle Kilometer of Travel

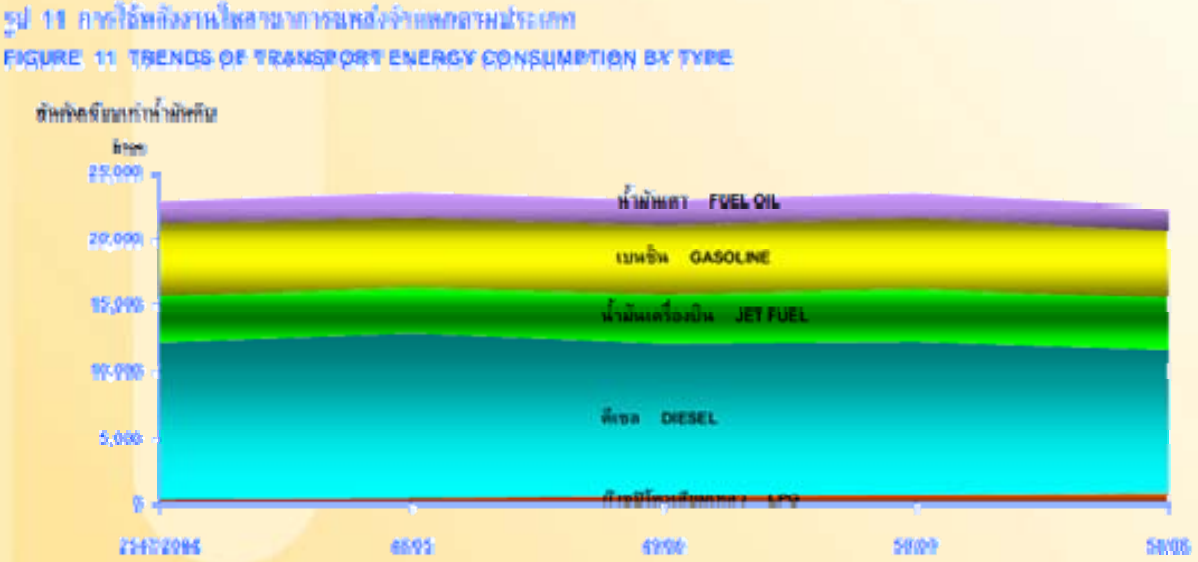
	Bangkok	Province
PC01 passenger car	9,887*	11,264*
PC02 pickup	15,008*	13,746*
PC03 Motor tri-cycle	6,500*	7,475*
PC04 Taxi	39,982**	49,208**
PC05 Commercial rent car	13,407**	15,808**
PC06 Motor cycle	8,097*	7,414*
Bus01 Fixed route bus	50,746**	39,687**
Bus02 Non fixed route bus	52,168**	49,559**
Bus03 Private bus	31,301**	34,018**
sBus04 Small bus	-	34,433**
Truck01 Non fixed route truck	30,211**	52,845**
Truck02 Fixed route truck	29,128**	44,924**

*EPPO report, 2008

**Estimate in this work by referring to NEPO & KMUTT, 1997

Model Validation/Calibration

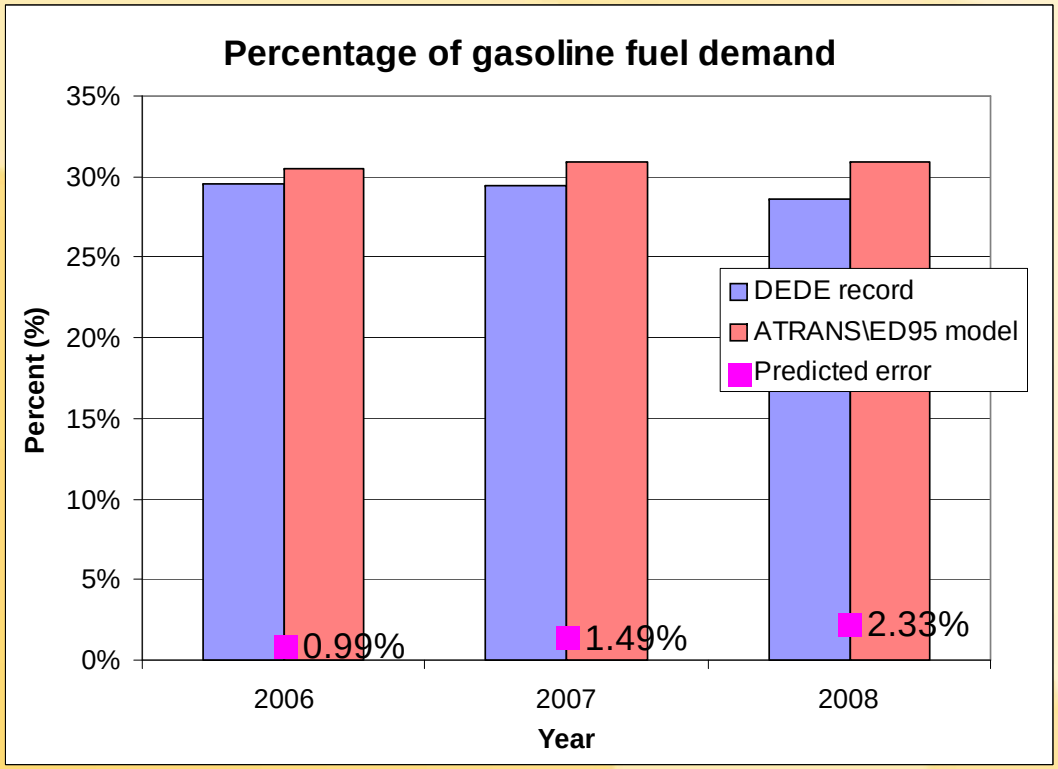
- DEDE, “Thailand Energy Situation”, 2008
- Validation year: 2006
- Calibration years: 2006-2008
- Only gasoline-based, diesel and gas considered (exclude fuel oil & jet fuel)

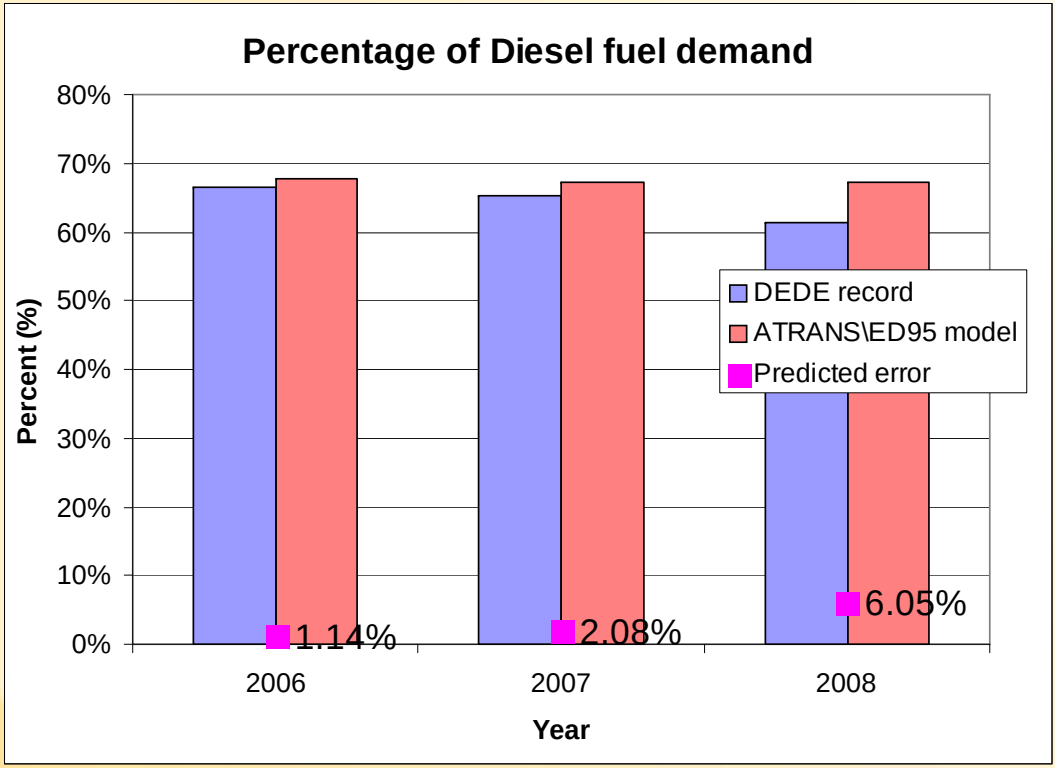


http://www.dede.go.th/dede/fileadmin/upload/nov50/nov52/ener1_2551.pdf

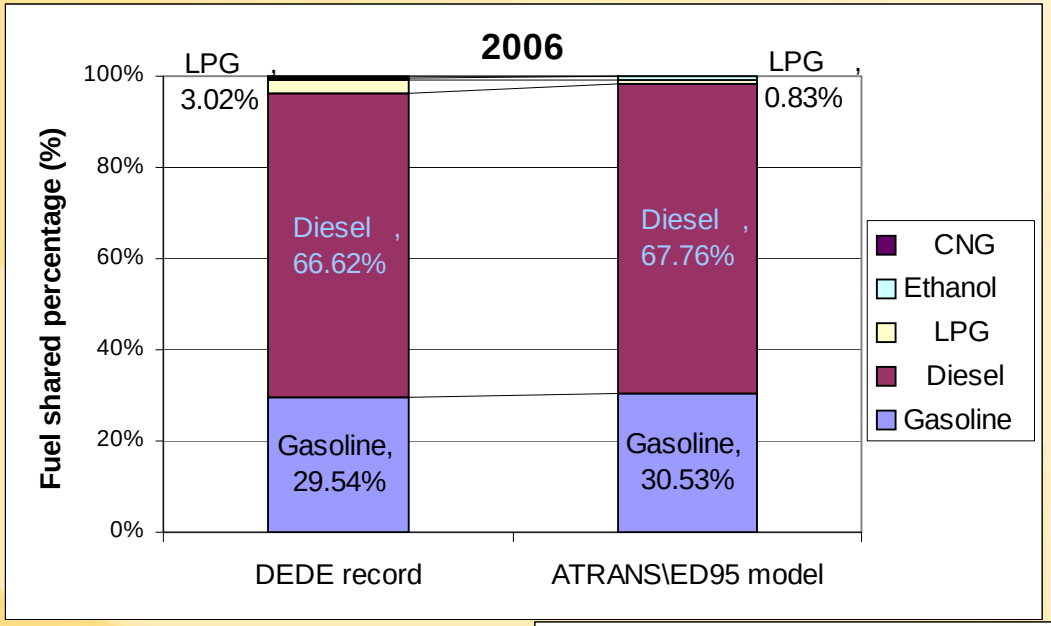
Remarks on Model Validation

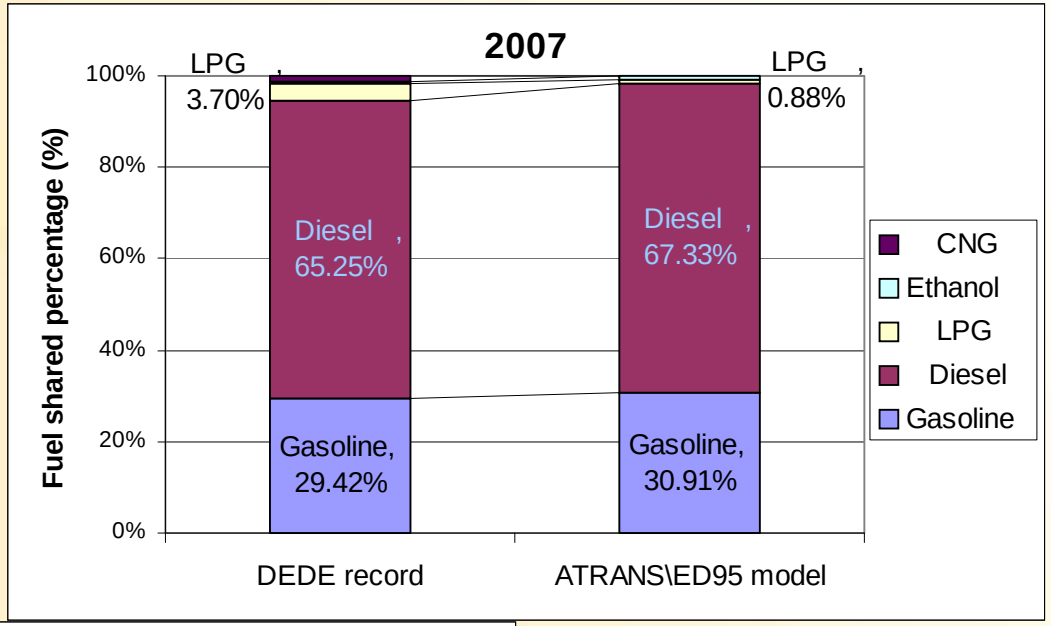
- Absolute difference may seem large (<10% in base year 2006 while up to 30% in validated year 2008)
- However, percentage difference much smaller
  - Other fuels significantly affecting, e.g. LPG, CNG
  - Fuel sharing assumption

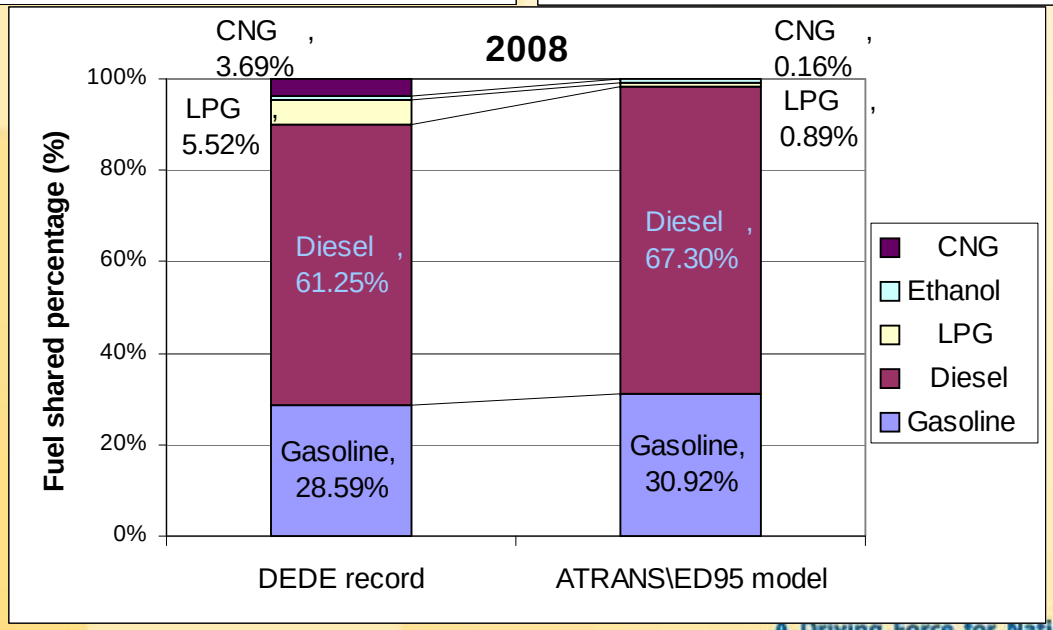




Model Validation in %







Outline

- Brief introduction
  - Rationale & Current situation
  - Objective & Methodology
- Energy demand model construction (BAU)
  - Available record
  - Model assumption
  - Validation by historical record
- Scenario Model
  - Existing technology case for ethanol city bus (BMTA)
  - Assume technology penetration to inter city bus
  - Assume budget spent on developing indigenous technology (on diesel pickup truck etc.)
- Questions & comments?

Scenarios Model

A. Business As Usual model
   - The ethanol fuel consumption in transportation sector expands only in gasoline fuel for *small SI vehicles*.

B. Existing technology case for ethanol city bus (BMTA)
   - The ethanol city bus with Ethanol Diesel (ED95) technology will be introduced up to half of the new *Bangkok city bus* (only the BMTA) over a period of time.

C. Future fuel penetration to Inter City Bus
   - The ED95 technology will be expanded to *Non fixed route bus and private bus* after demonstration with BMTA.

D. R&D case for funding a development of indigenous technology
   - The indigenous technology will be developed by governmental funding on R&D project for wider expansion of ED95 technology in diesel market.


Thank you…
Comments & Remarks

VKT's influence parameter

- G. Corpuz, M. McCabe, K. Ryszawa, "The Development of Sydney VKT Regression Model", 29th Australasian Transport Research Forum

(square root of the household VKT) = 3.9270 + (2.4510 * number of vehicles if the household) + (0.0124 * closest distance to major centre or CBD) + (-1.8057 * land use mix) + (-0.0021 * local employment) + (-0.0099 * housing density) + (0.0084 * distance to nearest train, ferry, light rail or high frequency bus)

1. Total number of vehicles
2. Closet distance to major center => inversely depended on Road distance

Vehicle Kilometer of Travel

Assume little road expansion

$$\frac{Rd_2}{Rd_1} = \frac{VKT_2}{VKT_1} \cdot \frac{\sum NV_2}{\sum NV_1}$$

$$\frac{Rd_2}{Rd_1}(\cong 1) = \frac{VKT_2}{VKT_1} \cdot \frac{\sum NV_2}{\sum NV_1}$$

$$\frac{VKT_2}{VKT_1} = \frac{\sum NV_1}{\sum NV_2}$$

$$= 0.6956$$

$$= 69.56\%$$

Bangkok

$$\frac{Rd_2}{Rd_1} = \frac{VKT_2}{VKT_1} \cdot \frac{\sum NV_2}{\sum NV_1}$$

$$\frac{VKT_2}{VKT_1} = \frac{Rd_2}{Rd_1} \cdot \frac{\sum NV_1}{\sum NV_2}$$

$$= 0.8201$$

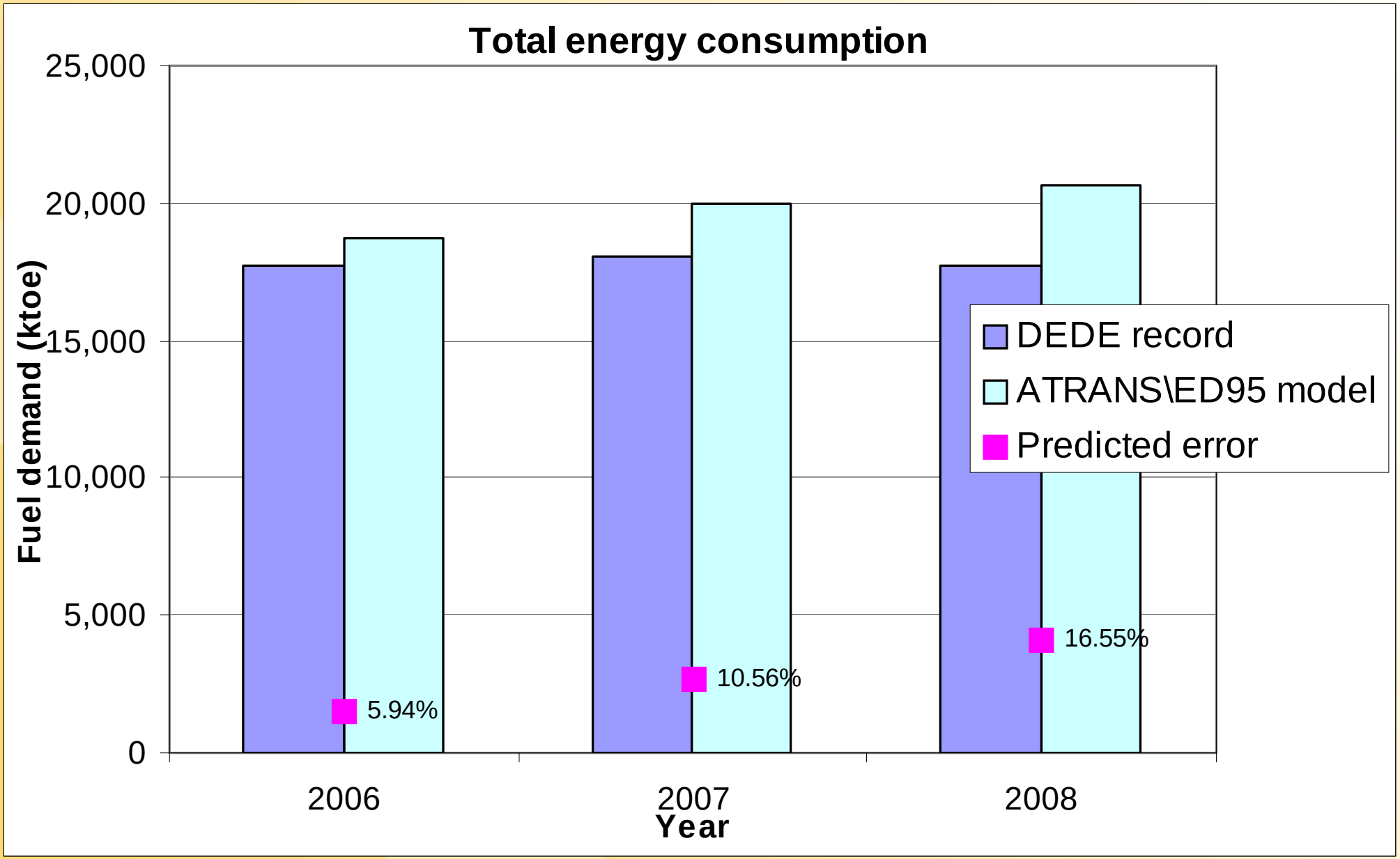
$$= 82.01\%$$

Provincial area

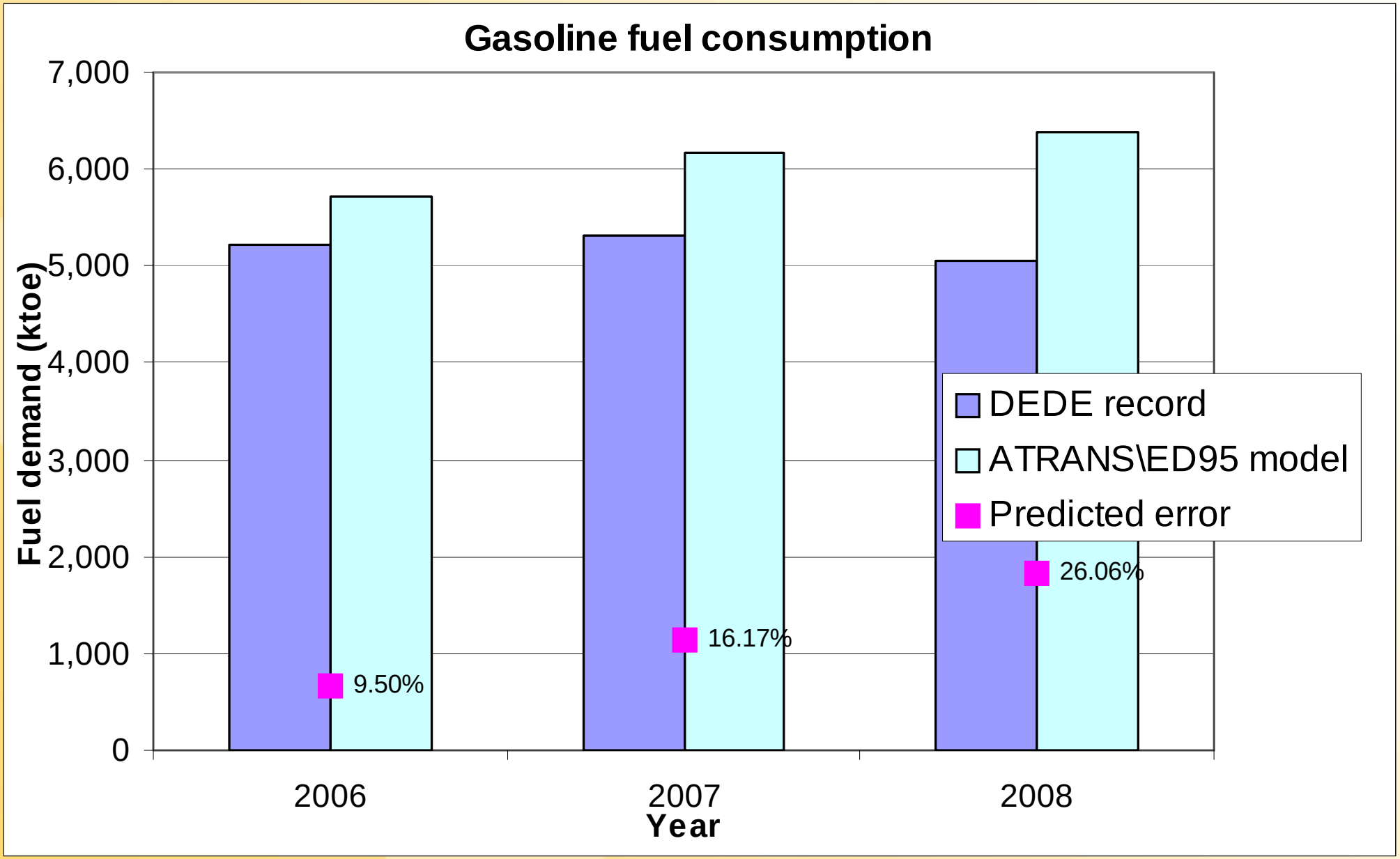
Yr 1 is 1997 (NEPO & KMUTT data)
Yr 2 is 2008 (EPPO data)

Survey of VKT only available in this two years

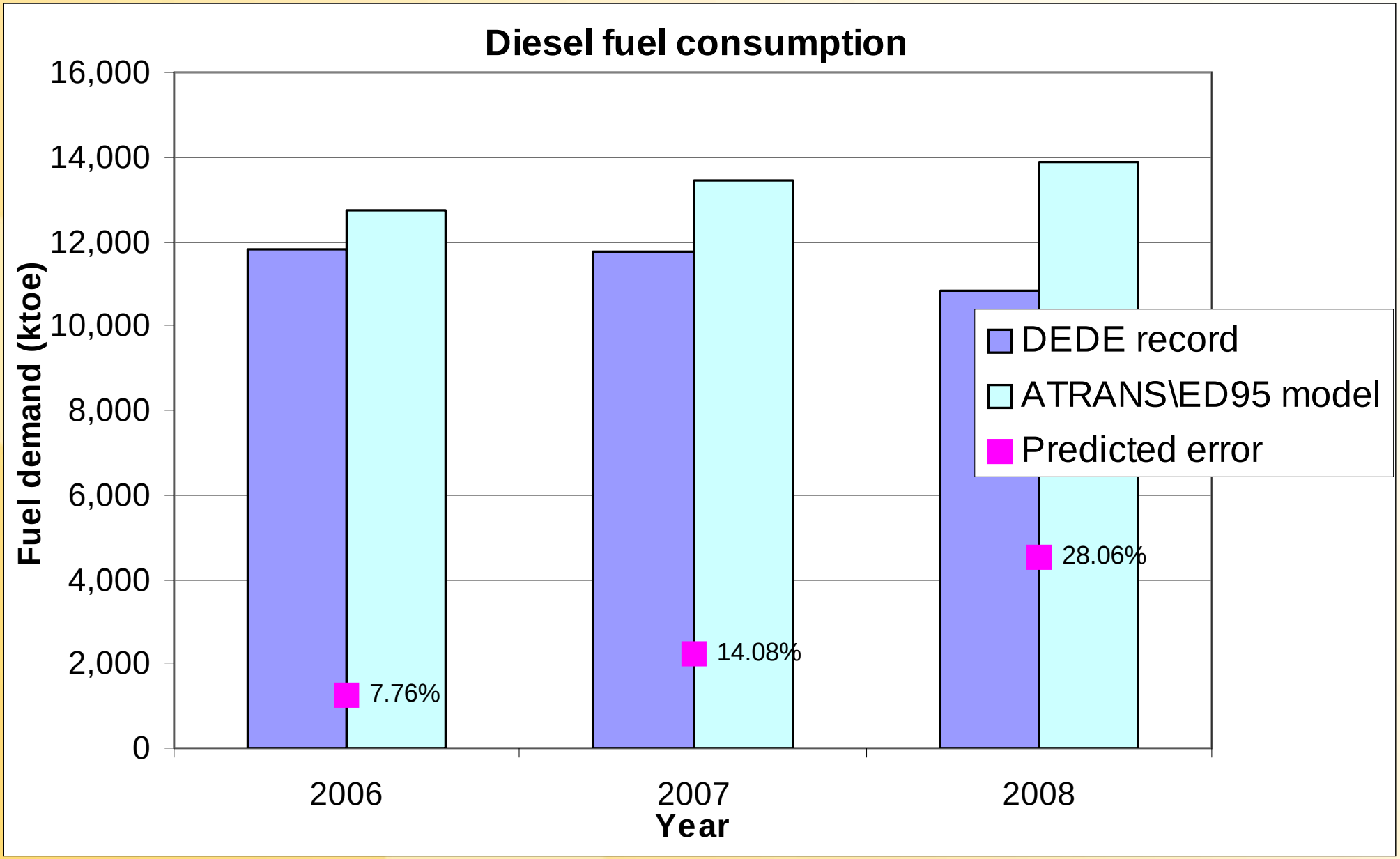
Model Validation



Model Validation



Model Validation

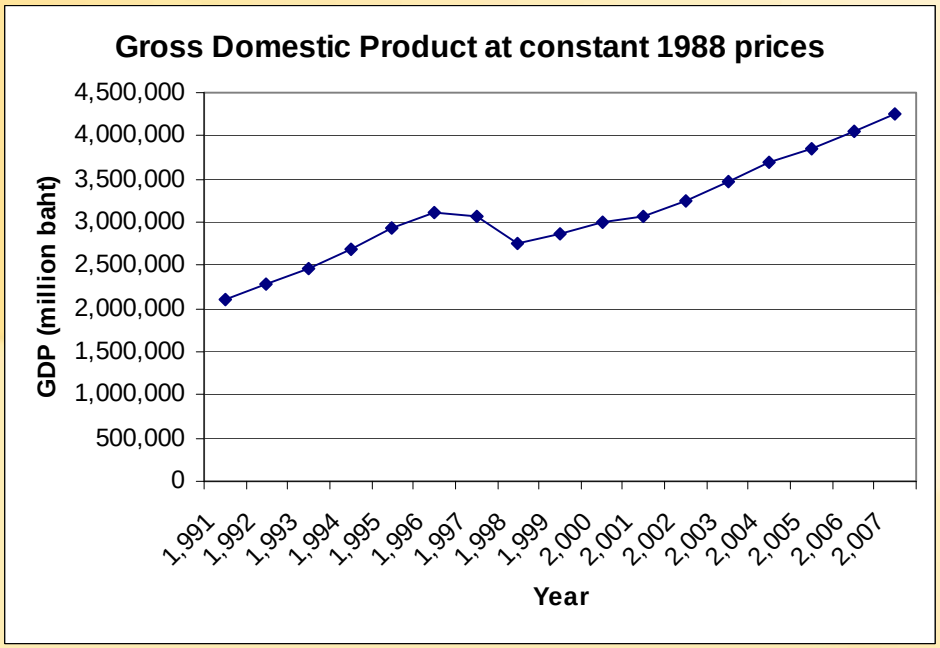


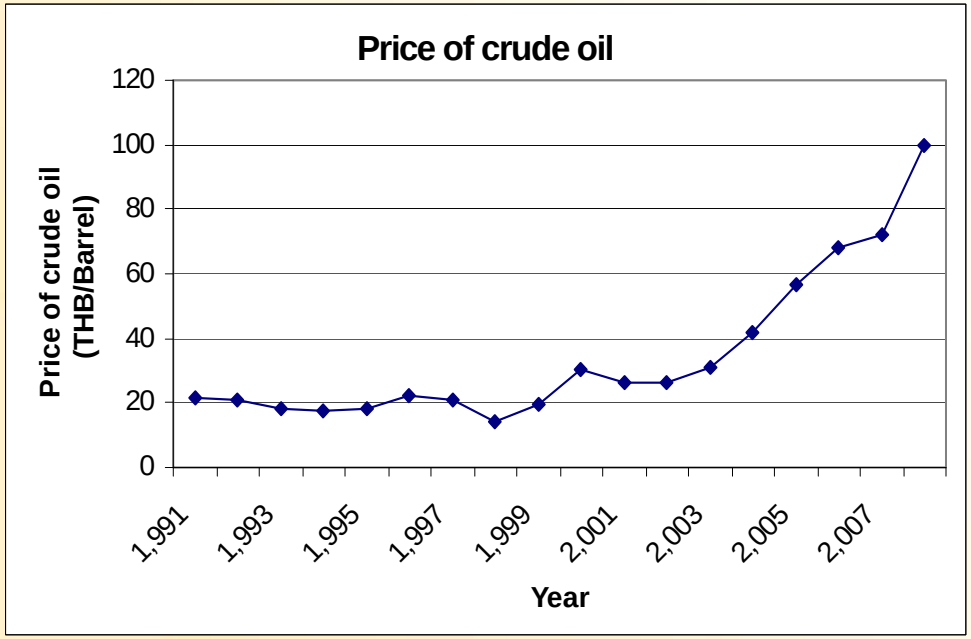
Why over prediction in absolute term?

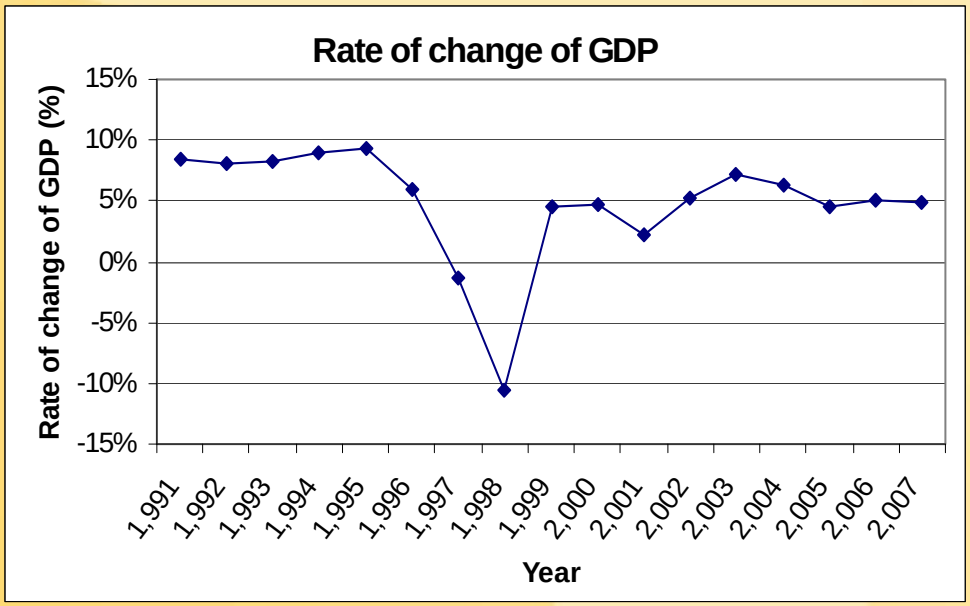
$$ED. = NV. \times VKT. \times FE.$$

- ***Gross Domestic Product (GDP)***: is a complex predicted variable. The estimated value can differ from real value at the considered year. Since NV $\propto$ f(GDP), GDP could affect ED.
- ***Vehicle Kilometer of Travel (VKT)***: Too few historic records of VKT for reference and/or extrapolate. Finding VKT $\propto$ f(year) is also challenging!
- ***Fuel share***: The driver's fuel chosen is dynamically changing and difficult to be specified in the model.
- ***Others externalities***: economic downturn, crude oil crisis, political crisis, drivers' behavior changing etc.

Energy Demand Factors







From wikipedia.org (accessed on 26/03/2010)

- Asian financial crisis (Tom yum kung crisis, July 1997)
- Economic effects from the September 11 attacks (September 11th, 2001)
- Sub-prime mortgage crisis (Hamburger crisis, January 3rd, 2007)
- 2000s energy crisis (2003-2005)
- 2003-2008 world oil market chronology (September 2003)

VKT as a function of time & fuel price

METRICS

HANNAH FAIRFIELD

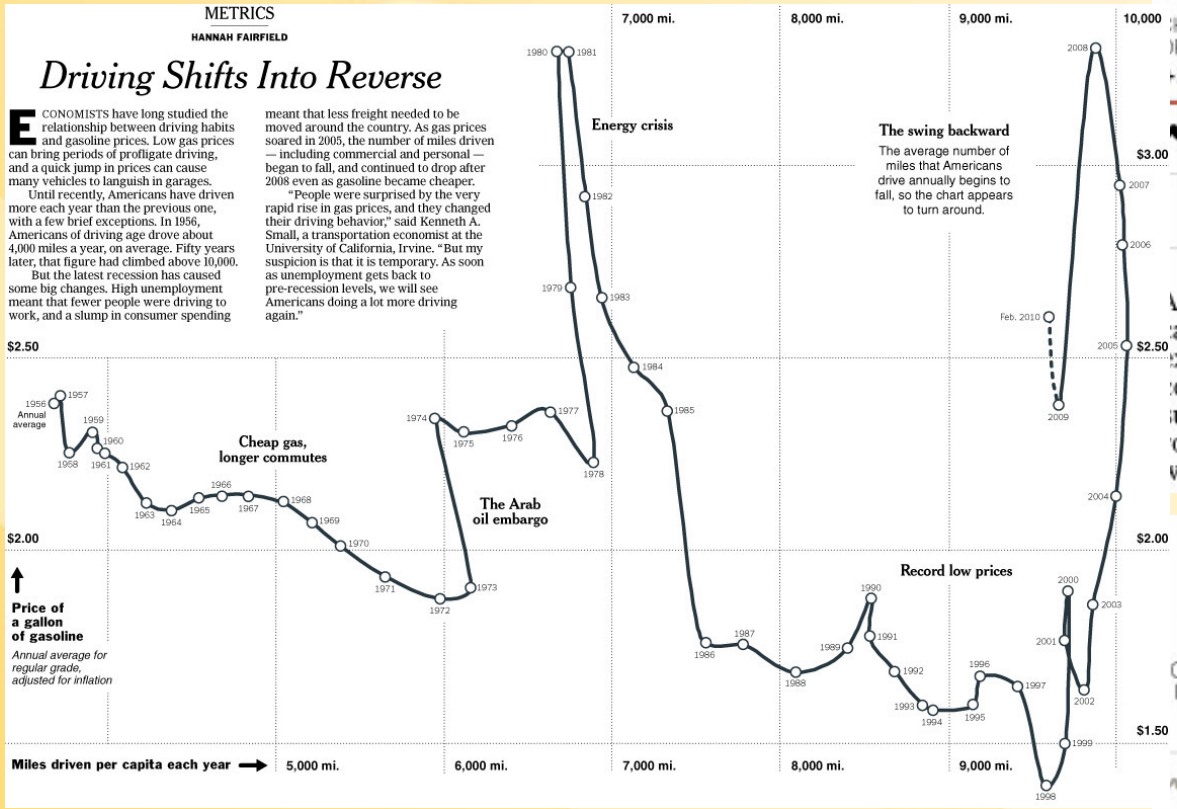
Driving Shifts Into Reverse

ECONOMISTS have long studied the relationship between driving habits and gasoline prices. Low gas prices can bring periods of profligate driving, and a quick jump in prices can cause many vehicles to languish in garages.

Until recently, Americans have driven more each year than the previous one, with a few brief exceptions. In 1956, Americans of driving age drove about 4,000 miles a year, on average. Fifty years later, that figure had climbed above 10,000.

But the latest recession has caused some big changes. High unemployment meant that fewer people were driving to work, and a slump in consumer spending meant that less freight needed to be moved around the country. As gas prices soared in 2005, the number of miles driven — including commercial and personal — began to fall, and continued to drop after 2008 even as gasoline became cheaper.

"People were surprised by the very rapid rise in gas prices, and they changed their driving behavior," said Kenneth A. Small, a transportation economist at the University of California, Irvine. "But my suspicion is that it is temporary. As soon as unemployment gets back to pre-recession levels, we will see Americans doing a lot more driving again."



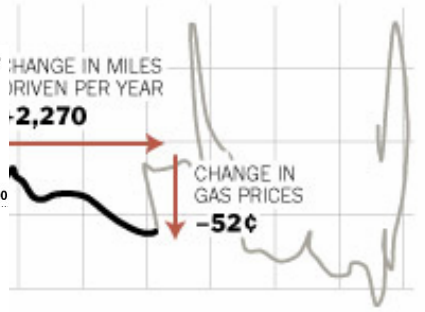
Miles driven per capita each year →

Post in The New York Times Company

Energy information Admin.; Federal Highway Admin.; Brookings Inst.

1956-72

Cheap gas, longer commutes



Americans spent more time in their cars as highways networks expanded and more workers commuted from new, far-flung suburbs. The number of commuters rose as more women joined the work force.

1973-74

The Arab oil embargo

In 1973, many Arab oil-producing countries declared an oil embargo against the United States because of its support of Israel in the Middle East. The supply disruption caused oil prices to rise sharply, and gas consumption declined.

1978-81

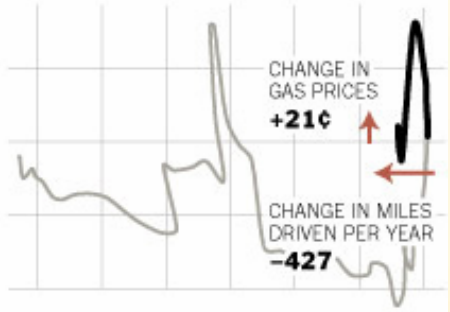
Energy crisis

Gas prices jumped as the Iranian revolution and the Iran-Iraq war caused a rift in the global oil supply. United States energy policy turned to conservation, and Congress imposed the first fuel-efficiency standards for cars.

A Driving Force for National S

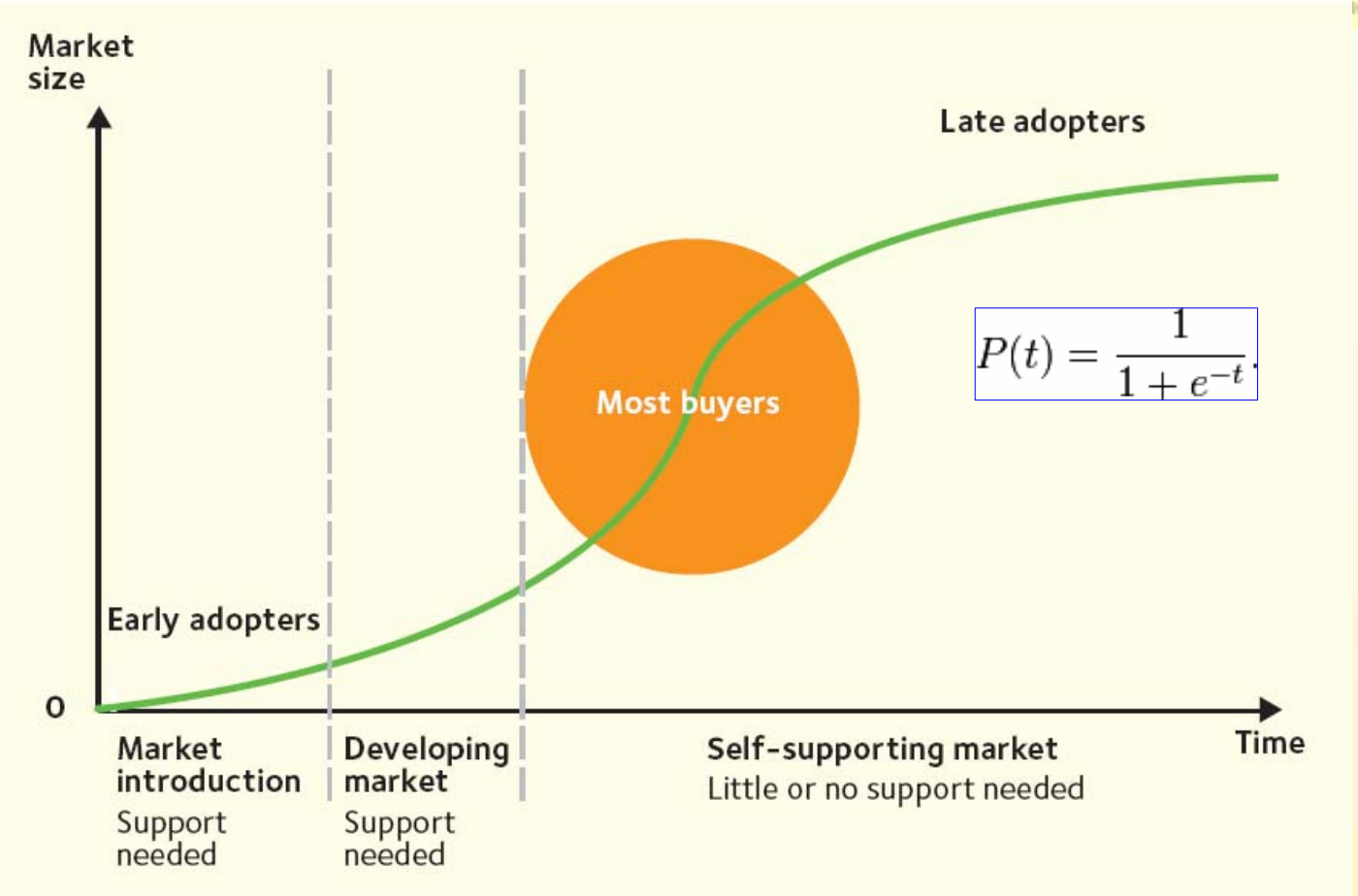
2005-10

The swing backward



The growth in driving faltered as gas prices started to climb. But much of the sharp reduction in driving was caused by the long recession and its high unemployment rate. A small but growing number of thrifty and carbon-conscious commuters switched to bicycles and public transportation.

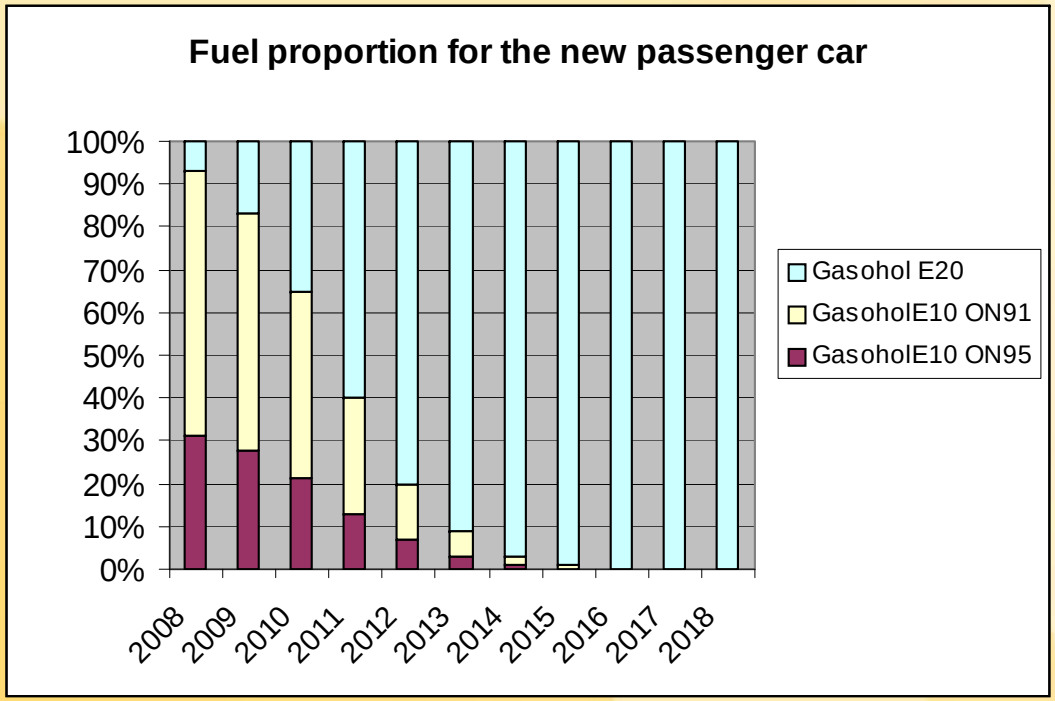
Market penetration of new technology

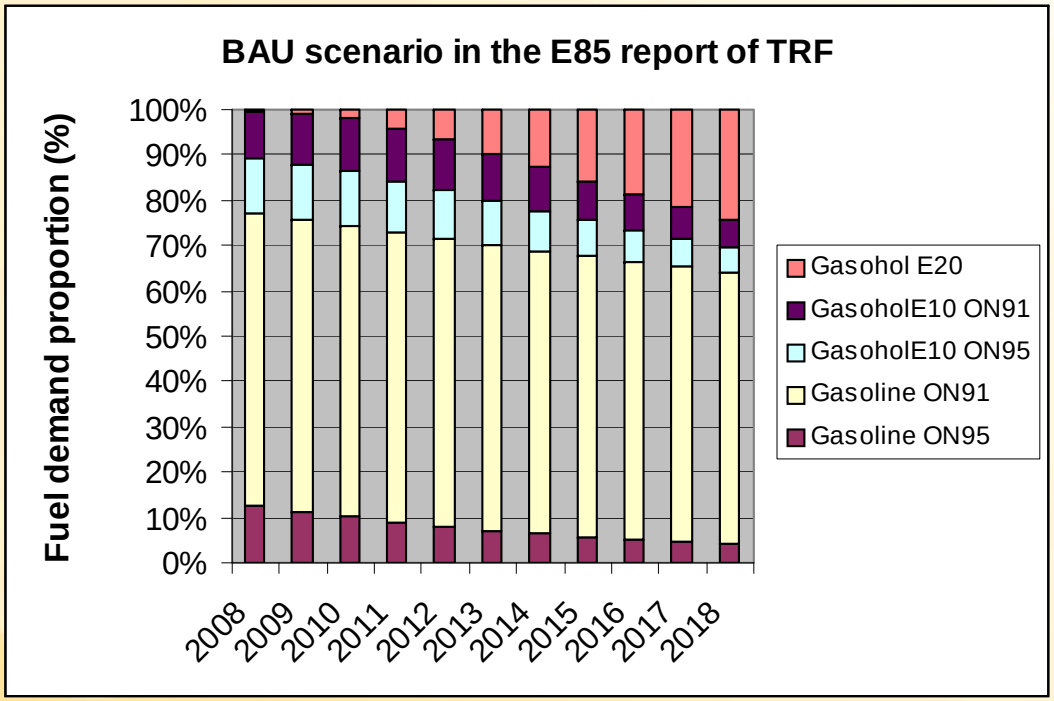


- Relationship between time and market penetration of new technology.
  - Market introduction
  - Developing market
  - Self-supported market

A. Business As Usual model

- Follow the assumption of BAU scenario in the E85 report by JGSEE submitted to TRF (2008).
  - New passenger car after 2008 use: Gasohol_E10 and Gasohol_E20. And the new E20 passenger car proportion growth until 100% in ten years.
  - But motor-cycle and pick-up truck still use the gasoline fuel





B. Ethanol City-bus (BMTA) and C. Inter City Bus

B. Ethanol City-bus (BMTA)

The ethanol city bus with Ethanol Diesel (ED95) technology will be introduced up to half of the new Bangkok City Bus (only for the BMTA sector).

- Applied sector: Fixed Route Bus in the Bangkok metropolitan
- Required technology: Ethanol Diesel Technology for city bus (Scania)
- Market penetration: Substitute on new BMTA bus up to *50: 50* for *Ethanol Diesel: NGV* City-bus

C. Future market penetration to the Inter City bus

The future market penetration to the Inter City Bus (Non fixed route bus and Private bus) for both Bangkok and Provincial Region

- Applied sector: expand from the Ethanol City-bus scenario to the Non fixed route bus and Private bus for both Bangkok and Provincial region
- Required technology: Ethanol Diesel Technology (Scania and ?)
- Market penetration: Substitute on the *Inter City bus* as the *S-curve* of market penetration

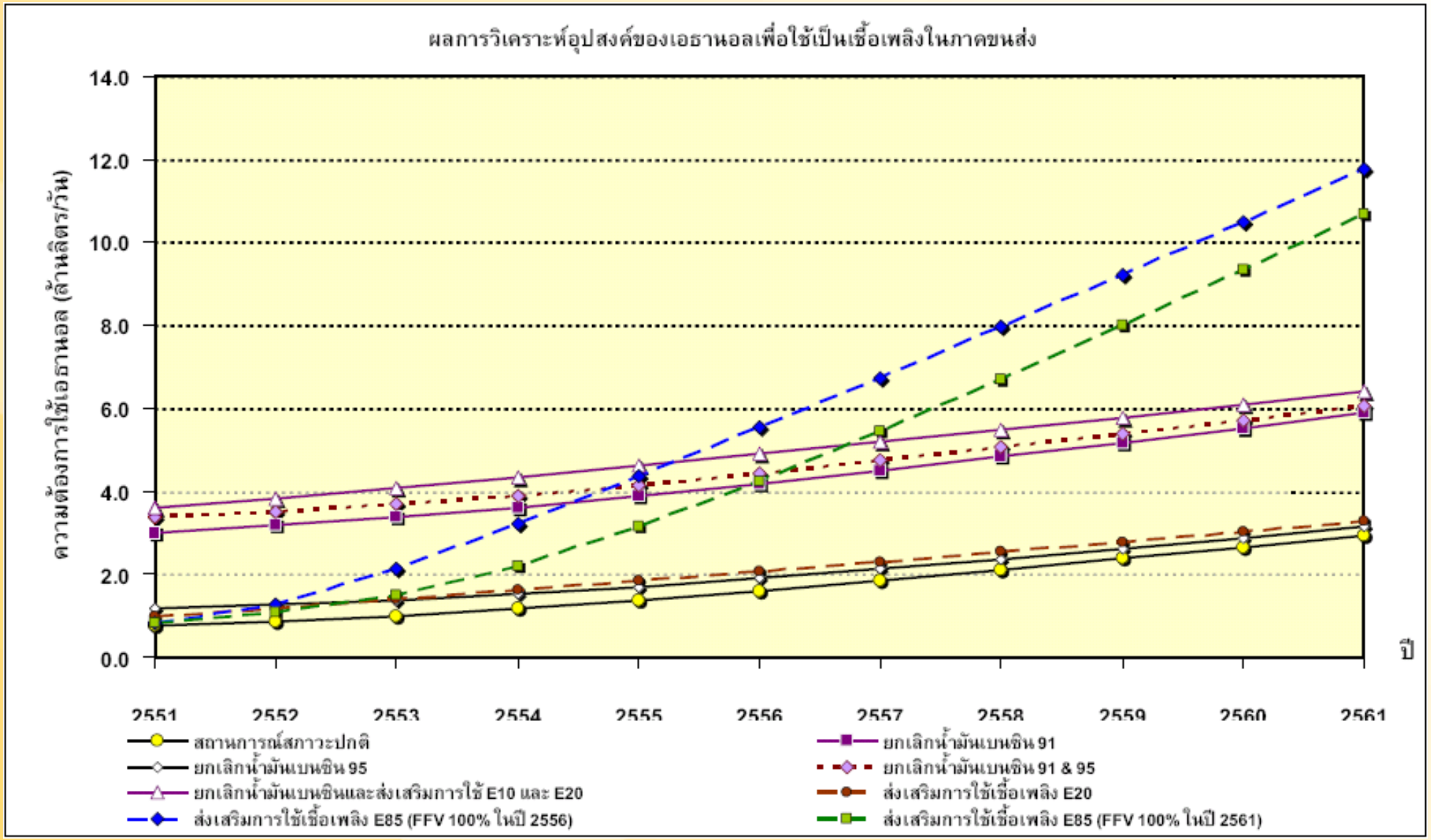
D. R&D Case for Funding Research Project

- Assume budget spent on developing indigenous technology for utilizing ethanol fuel as diesel substitution for all sectors
  - Applied sector: expand from the ethanol city-bus and Inter-city bus scenarios to the pickup truck for both Bangkok and provincial regions
  - Required technology: the ethanol Diesel technology (ED95) for small vehicle's engine (help from BSR?)
  - Market penetration: Substitute on the *pickup truck* as the *S-curve* of market penetration

Proposed Timelines

Tasks	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Inception report due **(1 Nov)**												
I. Data collection												
Identify & obtain necessary data for the model (interview if necessary)												
Project meeting 1												
Progress report presentation **(28 Jan)**												
II. LEAP model construction												
Construct & validate LEAP model with BAU												
Project meeting 2												
Interim report submission **(30 April)**												
III. Scenarios analysis												
Analyze various scenarios to assess economical feasibility/impact of diesel substitution by ethanol												
Assess technical feasibility of ethanol usage in CI engine												
Project meeting 3												
Final presentation **(27 Aug)**												
IV. Final report												
ATRANS symposium **(2-3 Sep)**												
Final report submission **(31 Oct)**												

Ethanol demand in E85 report of TRF



ED95: ethanol for CI engine

- ED95 = Hydrous ethanol (95% purity) + 5% additive (cetane improver)
- Preliminary test with single cylinder engine at KMUTT (increase compression ratio)

SAFETY DATA SHEET

According to Regulation (EC) No 1907/2006 of the European Parliament and of the Council

1. IDENTIFICATION OF THE SUBSTANCE/PREPARATION AND OF THE COMPANY/UNDERTAKING

Identification of the substance or preparation:	**ADDITIVE ED95 100**
Use of the substance/preparation:	Additive for ethanol used as motor fuel
Company/undertaking identification:	**SEKAB BioFuels & Chemicals AB** Box 286 S-891 26 Örnsköldsvik Sweden
Contact:	Mona Lindström, Telephone +46 660 758 00; fax +46 660 571 31 www.sekab.com mona.lindstrom@sekab.com
Emergency telephone:	+46 112, ask for the Chemical Emergency in Sweden.
Date of issue:	Revised: 2009-01-01 Previous issue: 2008-02-26

3. COMPOSITION/INFORMATION ON INGREDIENTS

Substances	CAS No.	EEC No.	Conc. weight-%	Symbol letters; R phrases*
Ethanol 95%	64-17-5	200-57-86	20-25	F; R11
Beraid (glycerol ethoxylate)	31694-55-0	500-075-4	40-50	
Methyl-t-butyl ether	1634-04-4	216-653-1	17-21	F; R11 Xi; R38
Isobutanol	78-83-1	201-148-0	3-5	R10 Xi; R37/38 R41 R67
Morpholin (Promax)	110-91-8	203-815-1	<0,2	R10 R20/21/22 C; R34
Lubricant	25307-17-9	246-807-3	7-9	R22 C; R34 N;R50**

* Classification and R phrases as given in Council Directive 67/548/EEC on the approximation of laws, regulations and administrative provisions relating to the classification, packaging and labelling of dangerous substances.

** Classified by the supplier

R phrases are explained under heading 16.