



# ***APEREC Transport Modelling: BAU***

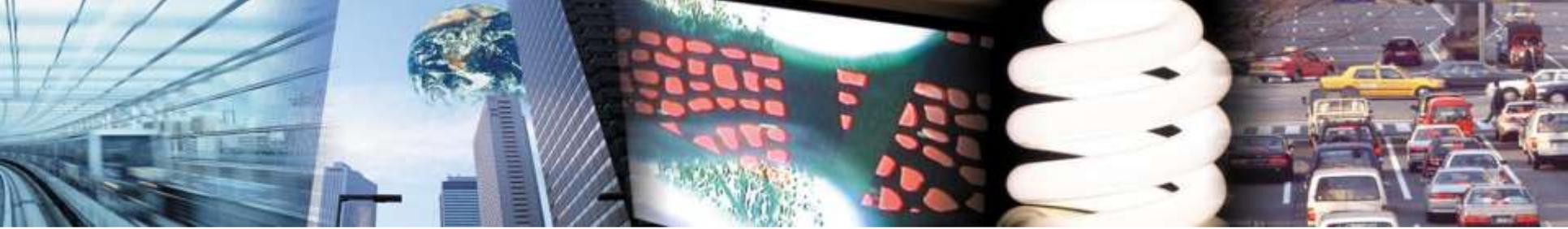
44 Meeting of the APEC Expert Group on Energy Efficiency and Conservation (EGEE&C)

Martin Brown-Santirso

*20-21 October 2014*

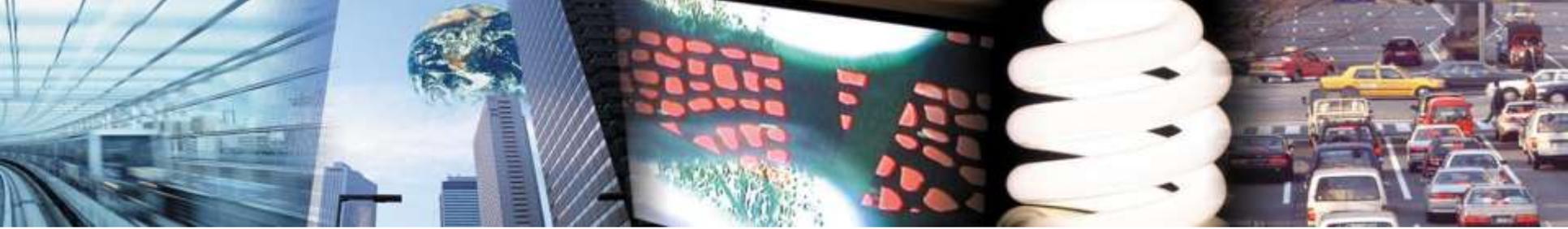


Asia-Pacific  
Economic Cooperation



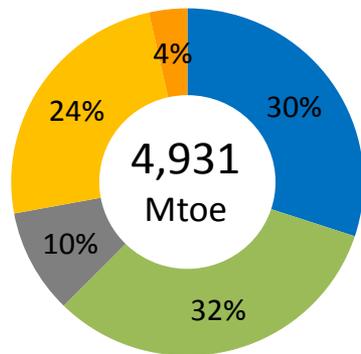
## Outline

- Brief on APERC's transport model
- Results of BAU case
  - Total transport energy demand
    - *by transport mode*
    - *by fuel type*
  - Road energy demand
    - *by vehicle type*
  - Vehicle stock
    - *by technology*



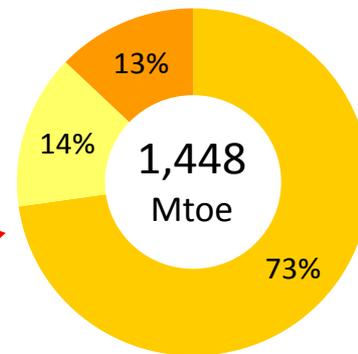
# Transport Energy Demand in APEC Region

**APEC Final Energy Demand by Sector in 2010**  
*(5<sup>th</sup> Ed. APEC Energy Outlook)*

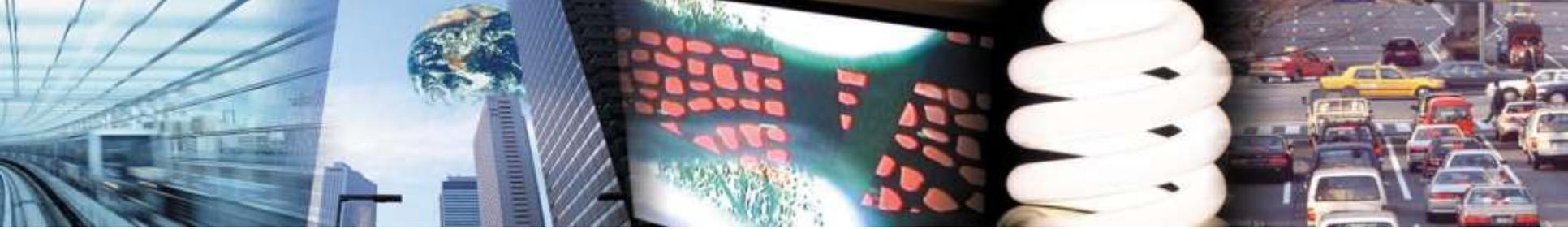


- Industry
- Other
- Non-Energy
- Domestic Transport
- International Transport

**APEC Transport Final Energy Demand in 2011**  
*(IEA Energy Data 2013)*



- Domestic Road Transport
- Domestic Non-Road Transport
- International Transport

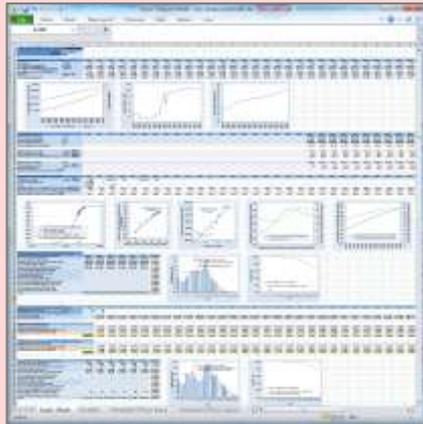


# *Transport Sector Modelling Techniques*

Transport sub-sector	Sub-mode/ vehicle class	Model	Energy Demand in 2011 (Mtoe)	Percent
Domestic Road Transport	<ul style="list-style-type: none"> <li>- Light and Heavy vehicles</li> <li>- Motorcycles</li> </ul>	Bottom-up (Fleet Model)	1,053	73%
Domestic Non-Road Transport	<ul style="list-style-type: none"> <li>- Rail</li> <li>- Pipeline</li> <li>- Water</li> <li>- Air</li> <li>- Non-specific</li> </ul>	Top-down (Econometric Model)	37 53 33 80 6	3% 4% 2% 6% 0.4%
International Non-Road Transport	<ul style="list-style-type: none"> <li>- Maritime</li> <li>- Aviation</li> </ul>	Top-down (Econometric Model)	109 78	8% 5%

# APERC's Vehicle Fleet Model

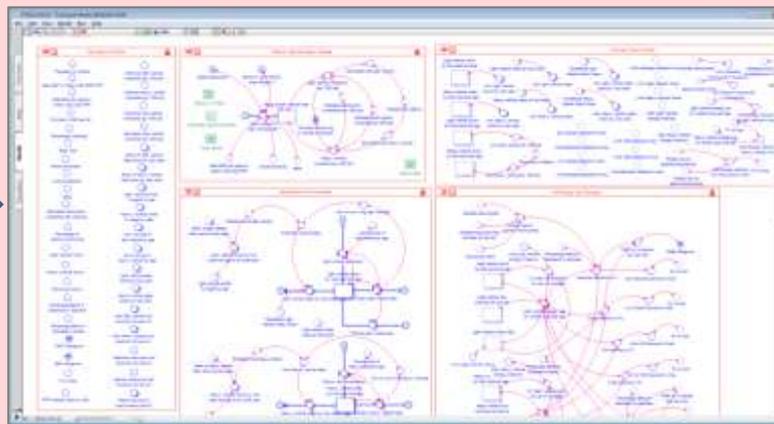
(1980-2011)



- ❖ **Macroeconomic data**
  - ✓ GDP & Population
  - ✓ Urbanisation
  - ✓ Crude oil price
- ❖ **Vehicle data**
  - ✓ Vehicle population
  - ✓ Vehicle age distribution
  - ✓ Vehicle sales
  - ✓ Vehicle fuel economy
  - ✓ Vehicle travel distance
- ❖ **Energy data**
  - ✓ Retail fuel prices
  - ✓ Blend ratio of biofuel
  - ✓ IEA road energy use

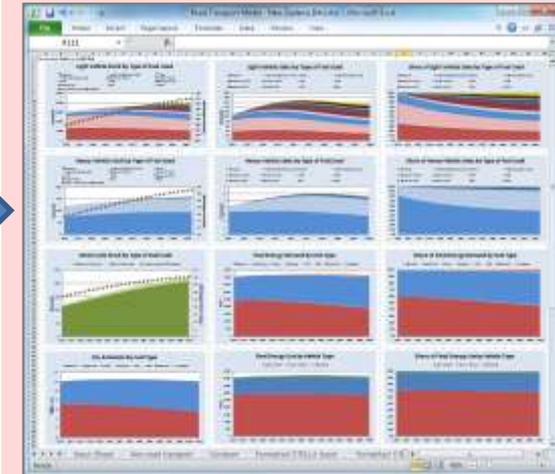
**Input**  
(Microsoft Excel)

(2011-2040)

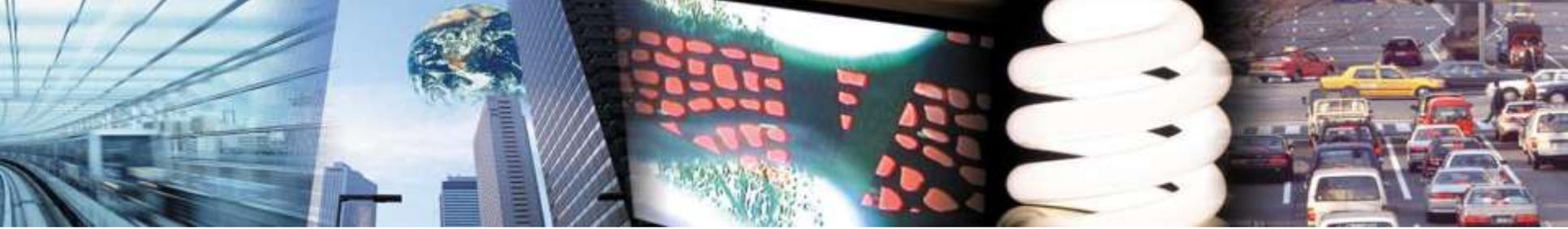


- **Vehicle ownership model -> vehicle stock**  
*(GDP per capita, vehicle saturation, total vehicle population, income elasticity, urban density)*
- **Vehicle stock turnover model -> vehicle sales and vehicle retirement**  
*(vehicle population by type and vehicle distribution by age)*
- **Vehicle consumer choice model -> share of vehicle technologies**  
*(fuel cost, purchase prices, driving range, refueling infrastructure, etc..)*
- **Vehicle travel model -> travel distance**  
*(fuel cost, income, vehicle ownership, efficiency improvement, urban density)*

**Main Model**  
(STELLA – System Dynamic Software)

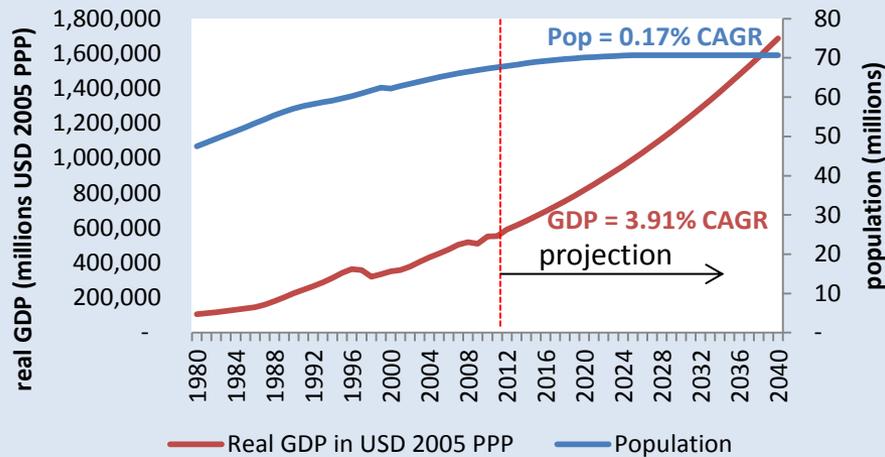


**Output**  
(Microsoft Excel)<sup>5</sup>

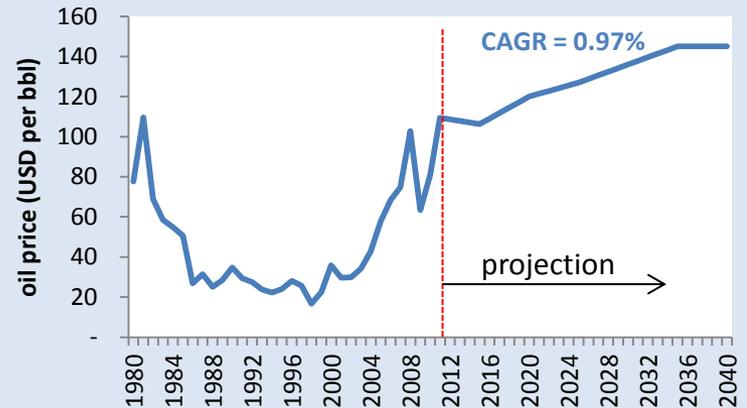


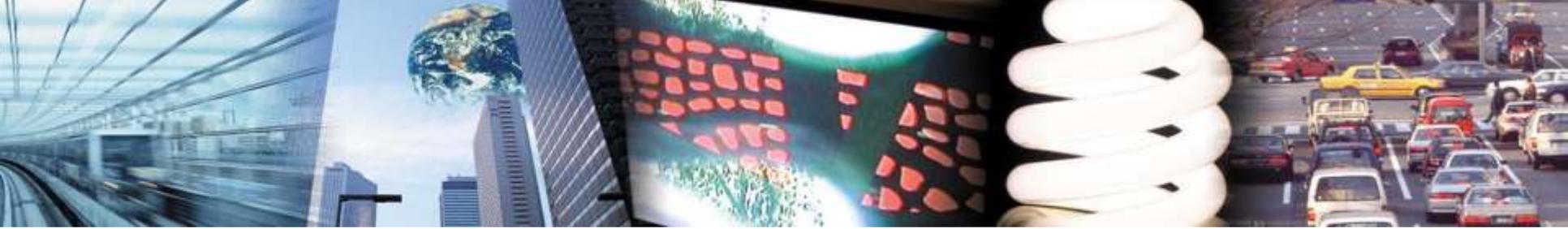
# Key Assumptions: GDP, Population, Oil price

## Thailand's GDP and Population



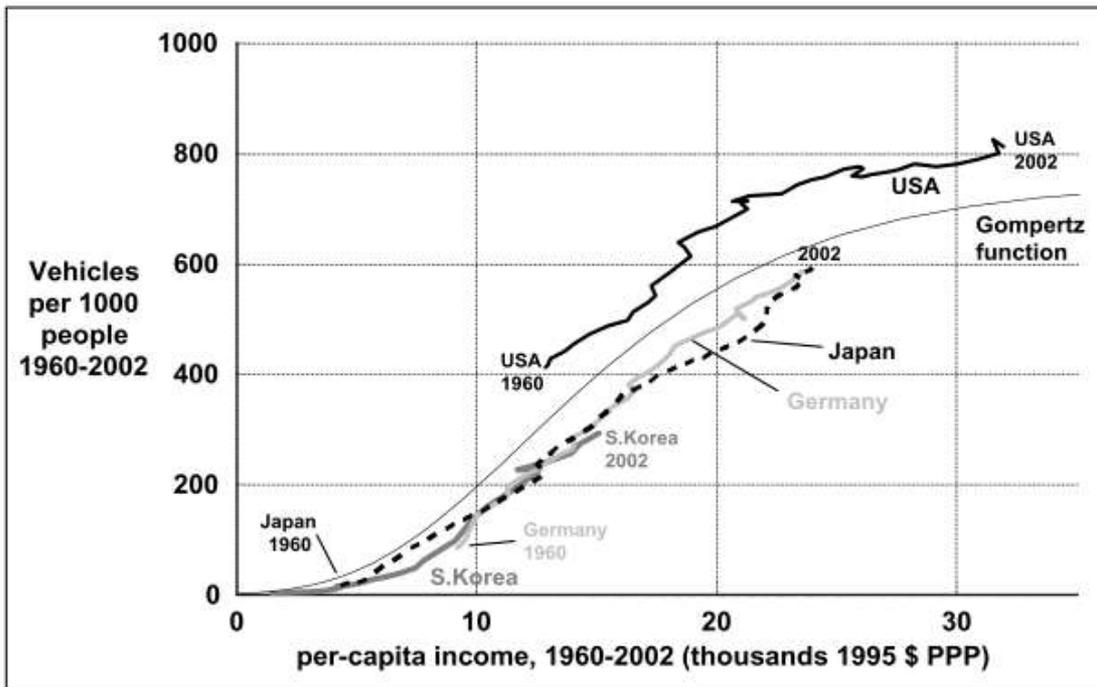
## Crude oil price projection (WEO, IEA 2013)





# Vehicle Ownership Model – Gompertz Function

$$V_t = \gamma e^{\alpha e^{\beta GDP_t}}$$



$V_t$  = Vehicle population

$\gamma$  = saturation of vehicle ownership

$\alpha$  = shape coefficient

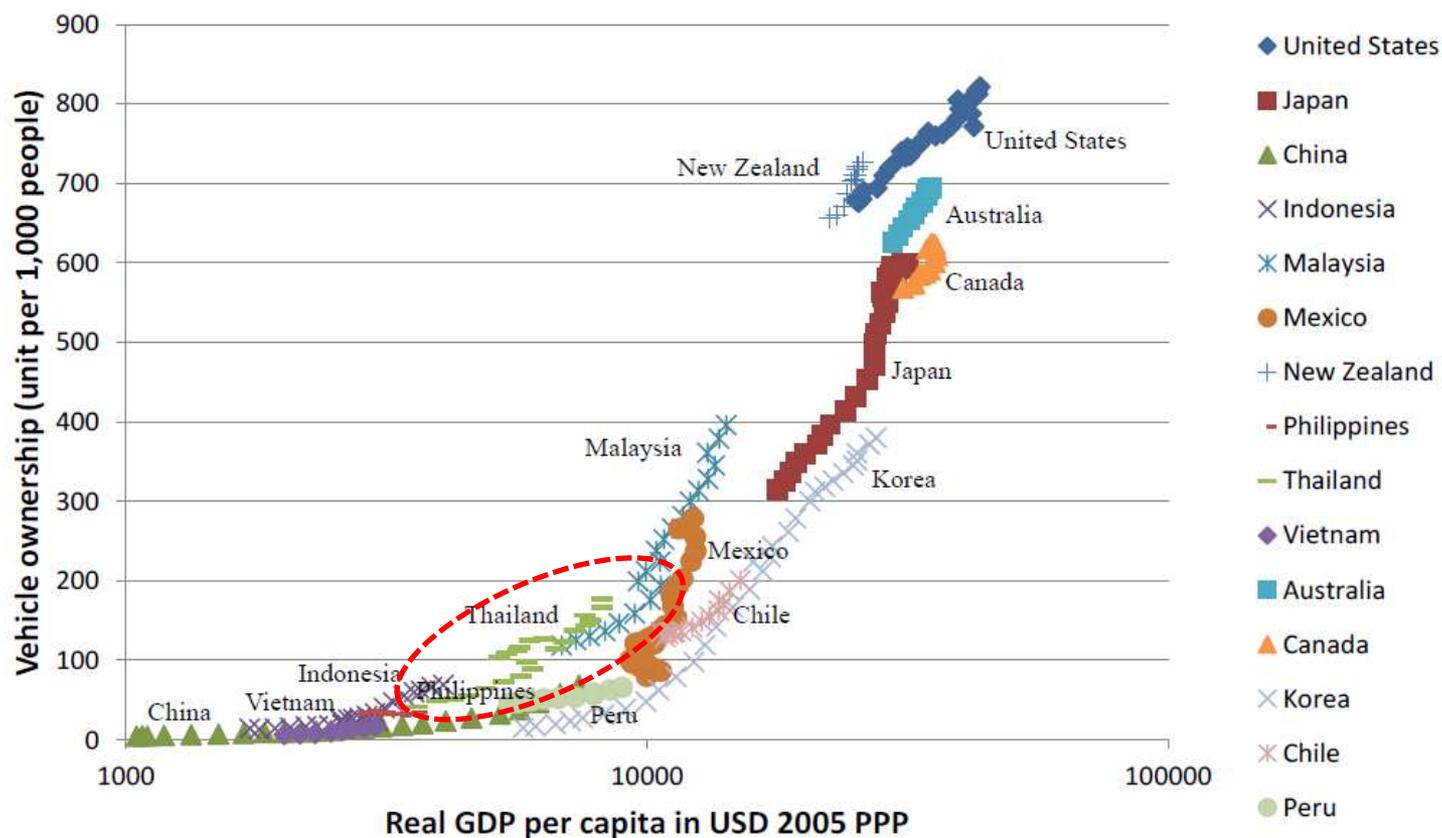
$\beta$  = rate coefficient

$GDP_t$  = GDP (real) PPP

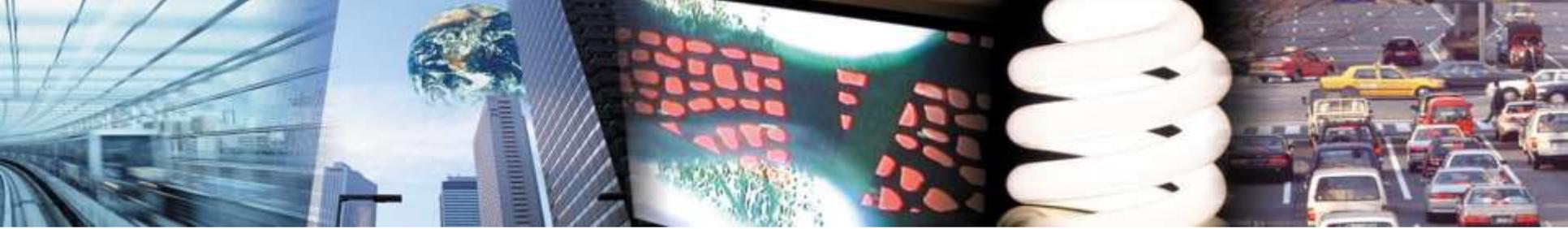
\*Source - Dargay J, Gately D and Sommer M (2007) Vehicle Ownership and Income Growth, Worldwide: 1960-2030.



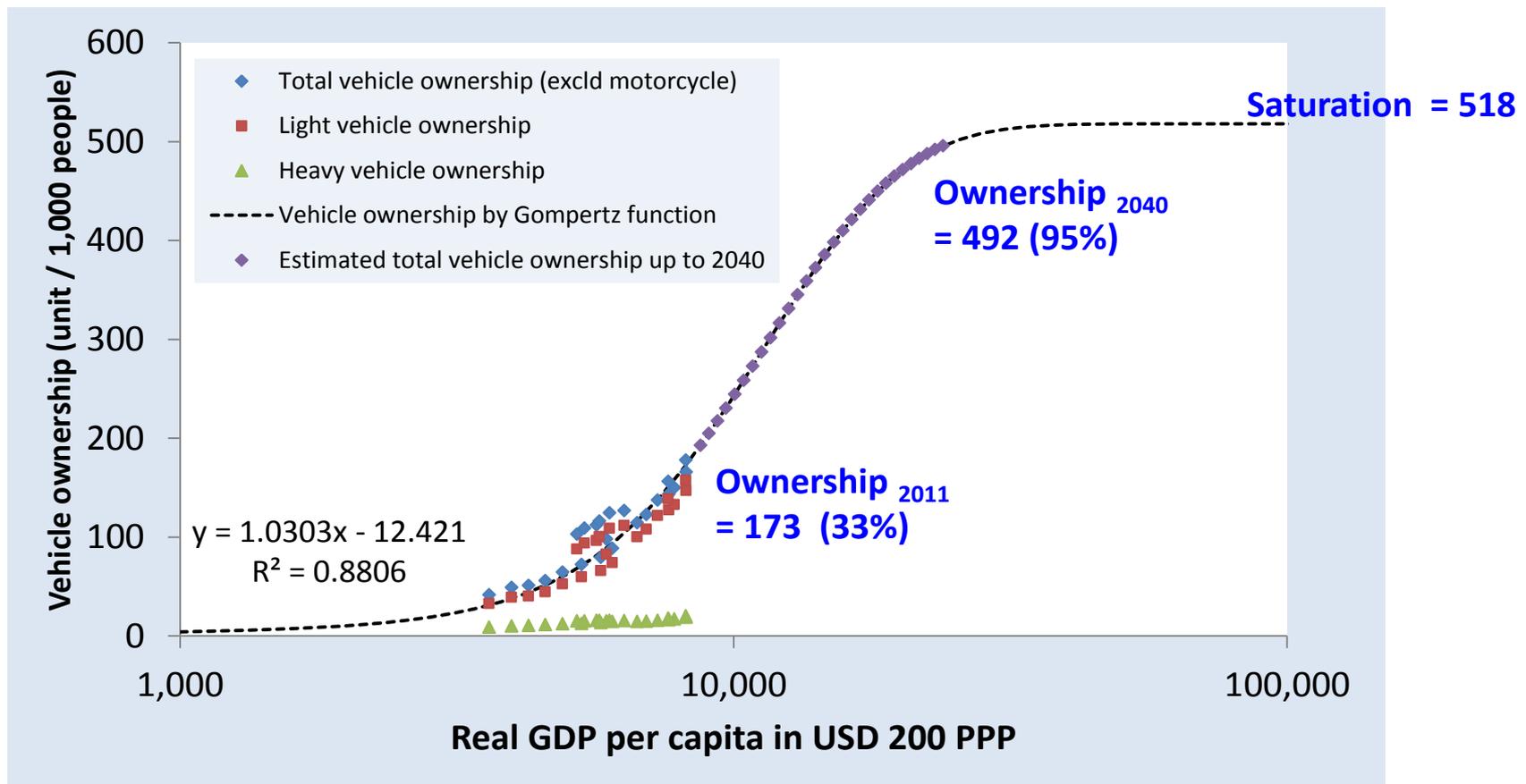
## Historical vehicle ownership curves of APEC economies (1980-2011)



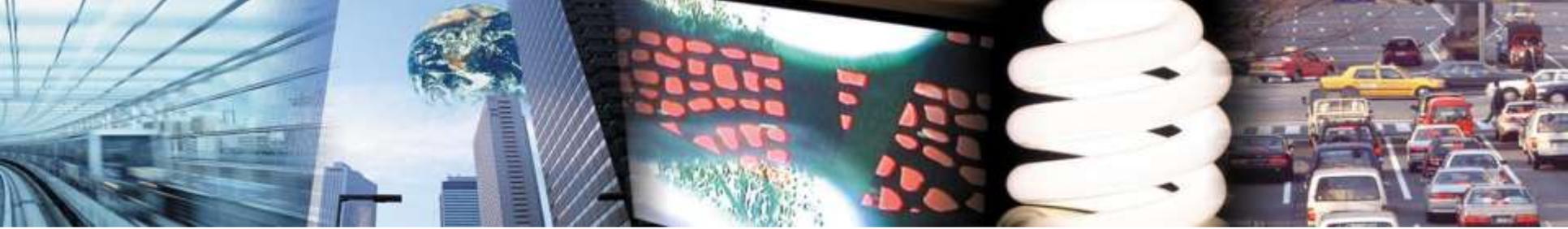
(Source: APERC, 2014)



## Vehicle Ownership Curves – Thailand case



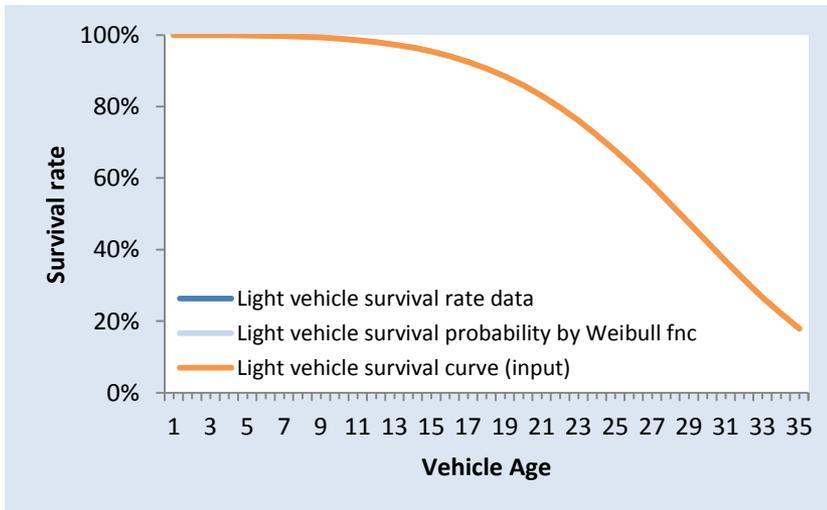
(Source: APERC, 2014)



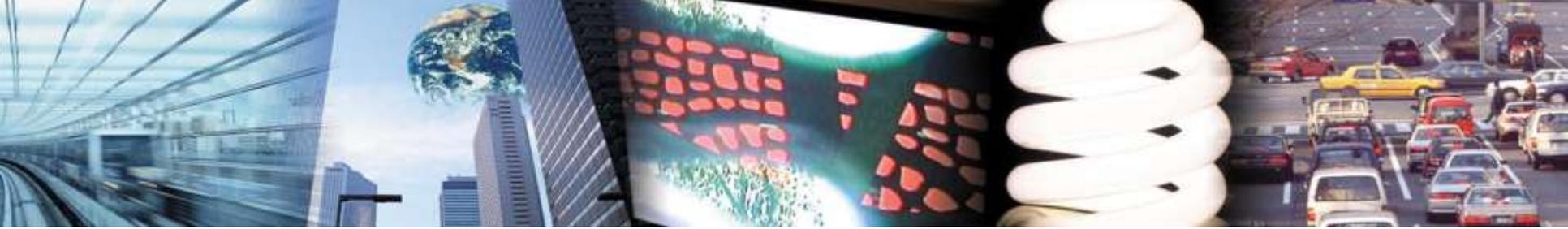
# Vehicle Stock Model

$$\text{Vehicle Sales}_t = \text{Expected Stock}_t - (\text{Vehicle Stock}_{t-1} - \text{Vehicle Retirement})$$

*Surviving Stock*



*Vehicle survival curve*



# Vehicle Consumer Choice Model

Market Share (S) =

$$\frac{e^{(\beta_{FC}U_{FC} + \beta_{PP}U_{PP} + \beta_{DR}U_{DR} + \beta_{CMDD}U_{CMDD} + \beta_{PLDD}U_{PLDD})}}{\sum_i e^{(\beta_{FC}U_{FC} + \beta_{PP}U_{PP} + \beta_{DR}U_{DR} + \beta_{CMDD}U_{CMDD} + \beta_{PLDD}U_{PLDD})}}$$

## Type of Vehicle Technology

Powertrain Technology	Fuel Type
Internal Combustion Engine (ICE)	Gasoline Diesel LPG CNG
Hybrid Electric Vehicles (HEV)	Gasoline/Diesel
Plug-in Hybrid Electric Vehicles (PHEV)	Gasoline/Diesel Electricity
Battery Electric Vehicles (BEV)	Electricity
Fuel Cell Electric Vehicle (FCEV)	Hydrogen

$\beta$  = vehicle choice coefficient

$U$  = utility coefficient

Note: Fuel cost (FC)

Purchase price (PP)

Driving radius (DR)

Convenient medium distance destinations (CMDD)

Possible long distance destinations (PLDD)

## Logit vehicle choice coefficient ( $\beta$ )

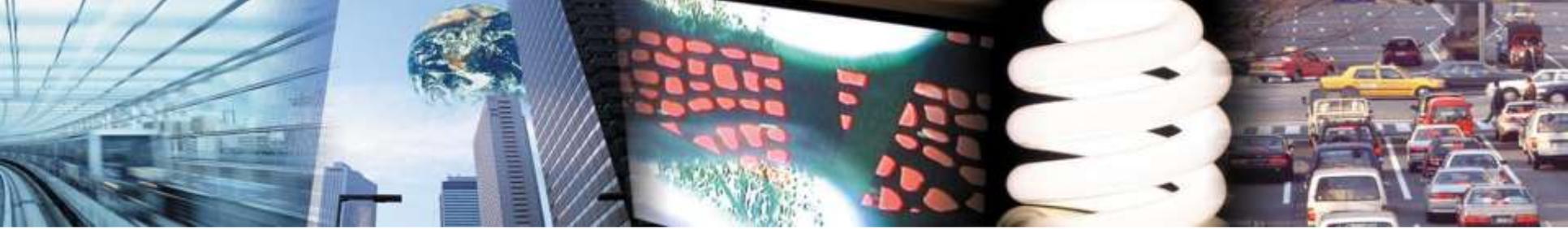
Variable	Coefficient
Fuel cost	-1.066
Purchase price	-2.327
Driving radius	0.382
CMDD	0.517
PLDD	0.997



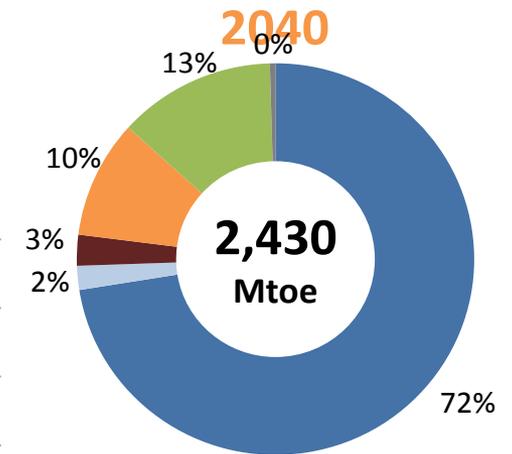
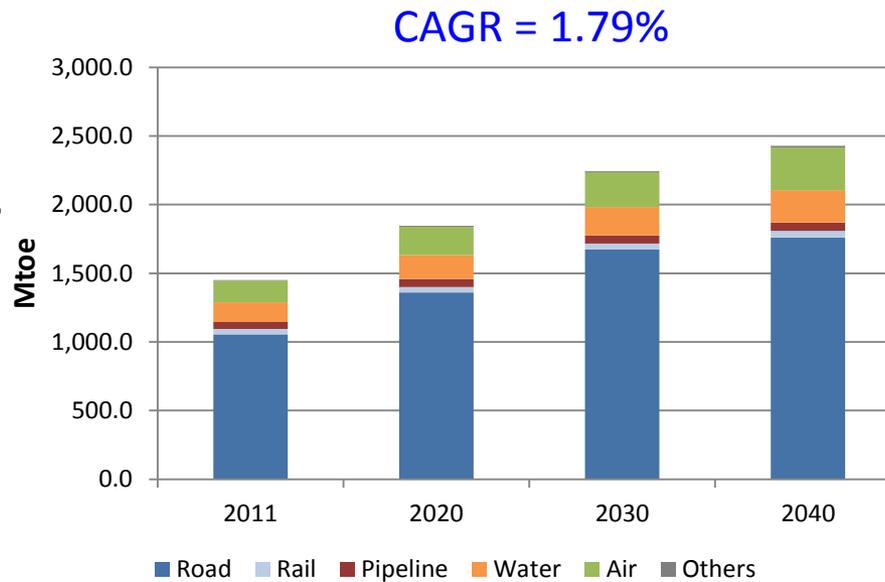
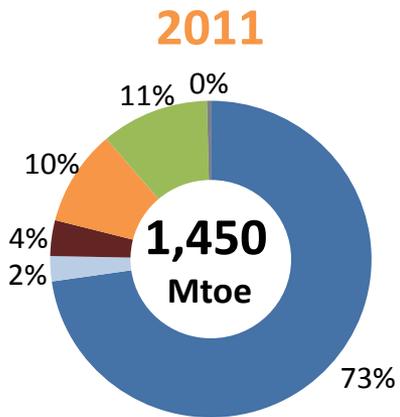
*Results of BAU case*  
*- APEC Region -*

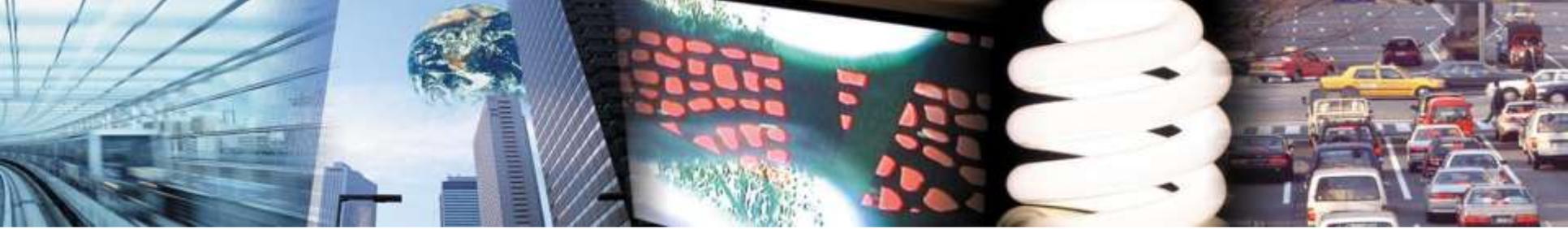


Asia-Pacific  
Economic Cooperation

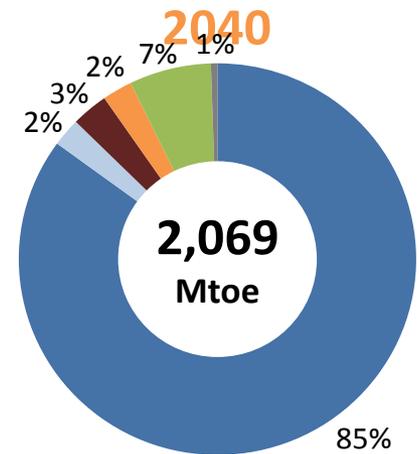
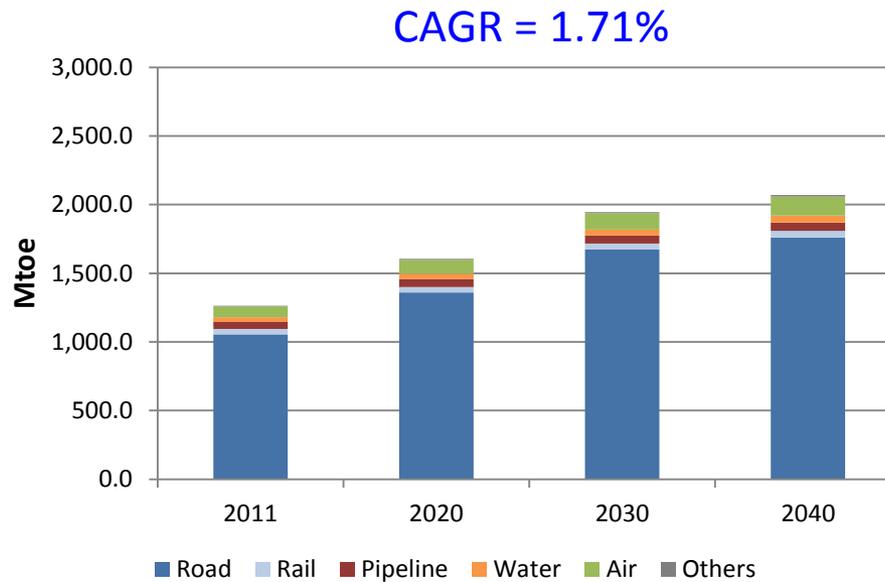
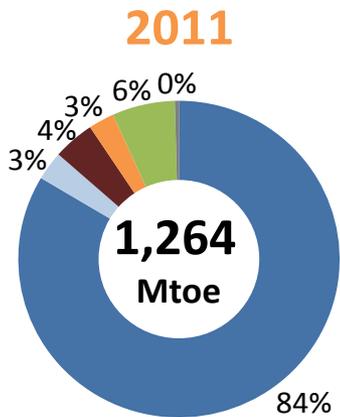


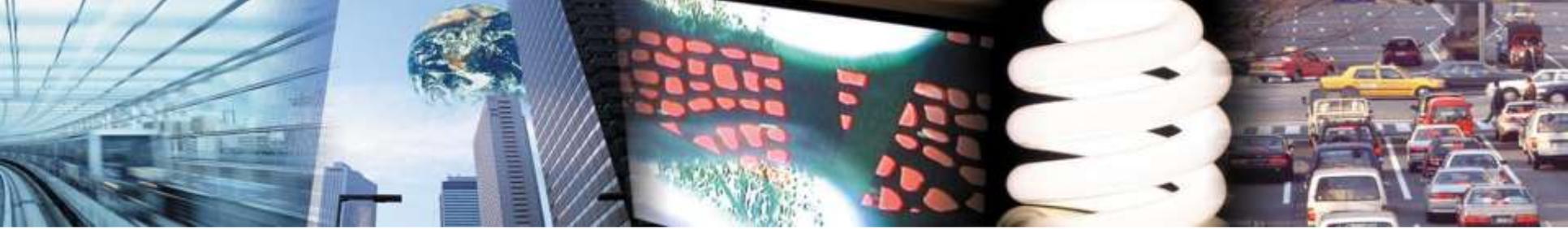
# Total Transport Energy Demand by Mode





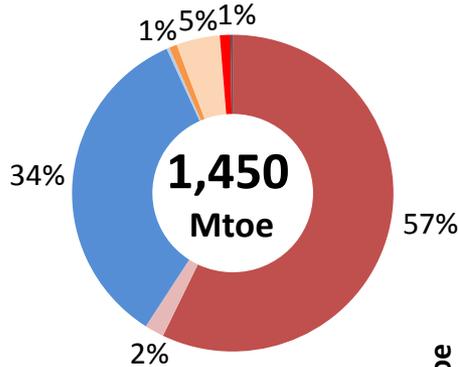
# Total Transport Energy Demand by Mode (excd. Inter)



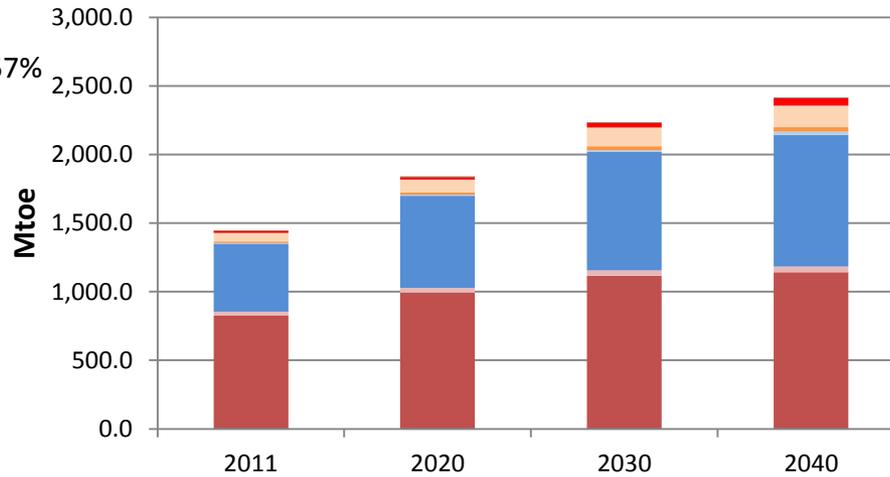


# Total Transport Energy Demand by Fuel Type

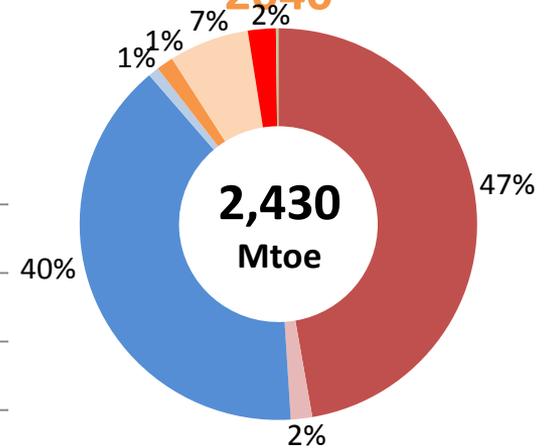
2011



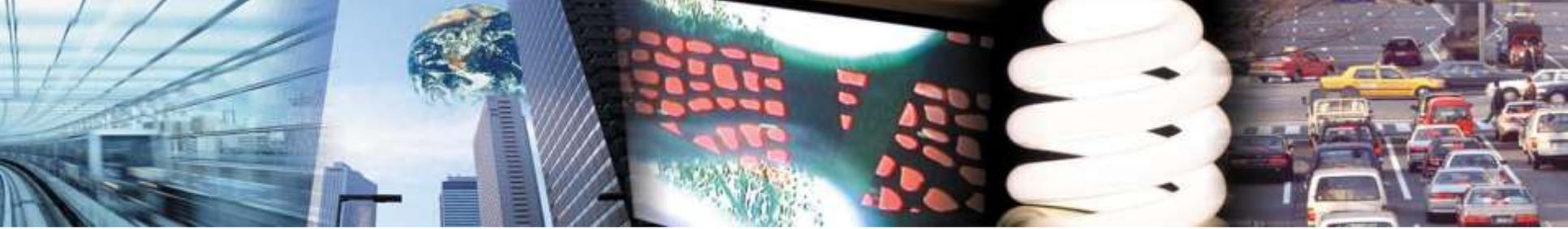
CAGR = 1.79%



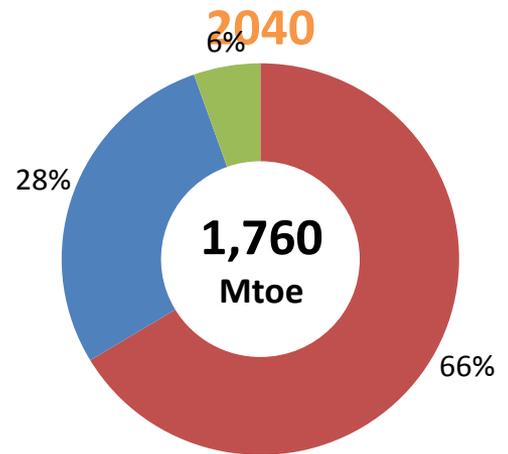
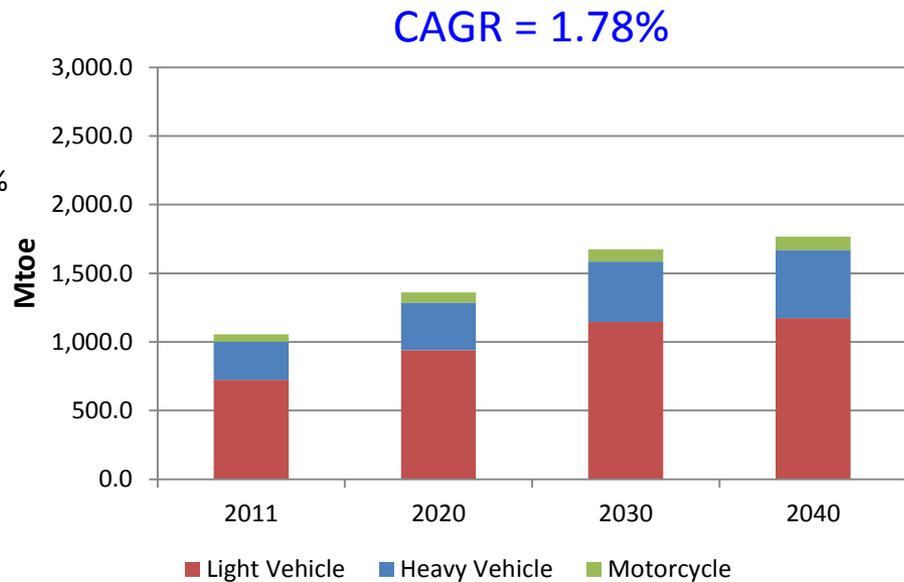
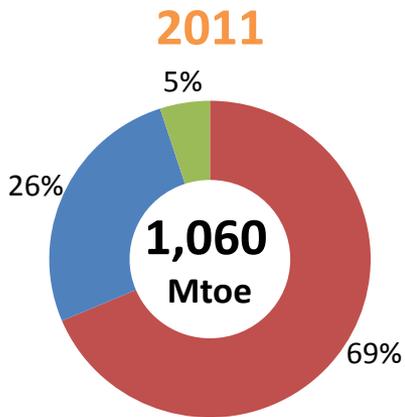
2040

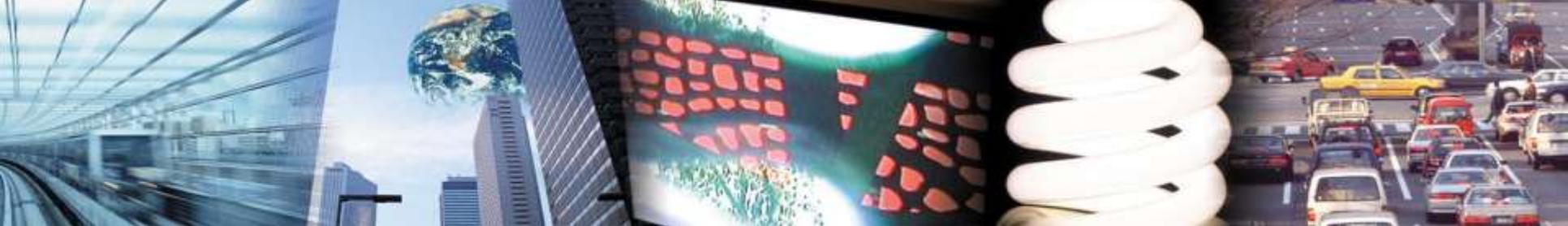


- Gasoline
- Bioethanol
- Diesel
- Biodiesel
- LPG
- Natural Gas
- Electricity
- Hydrogen
- Others

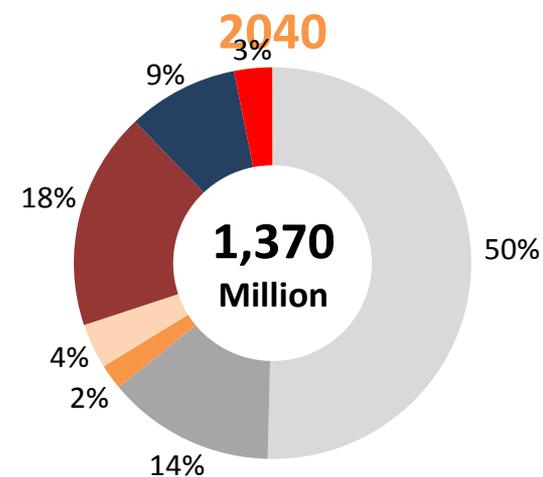
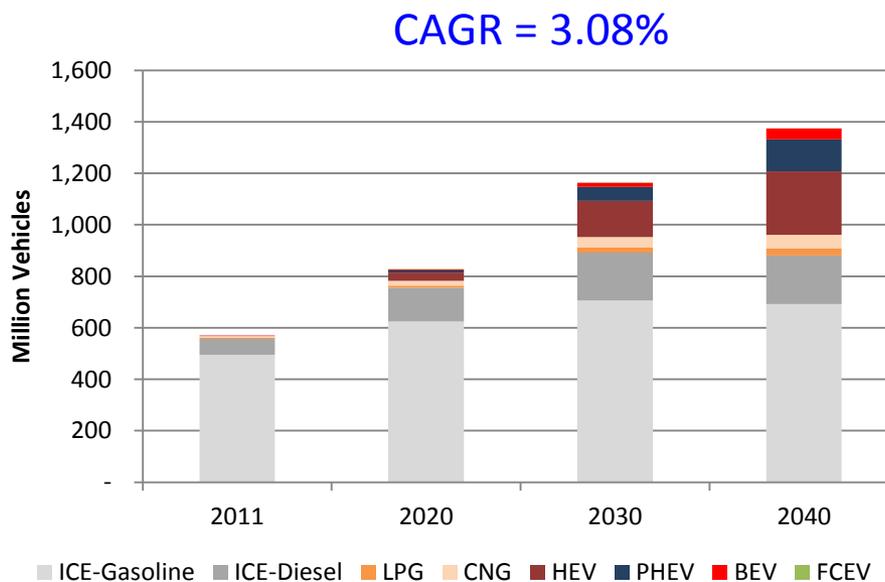
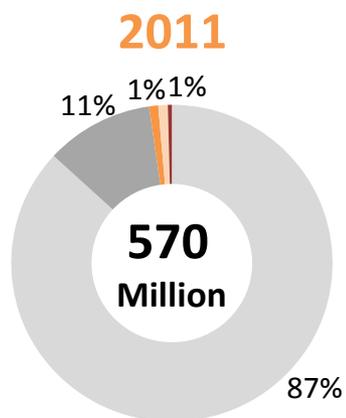


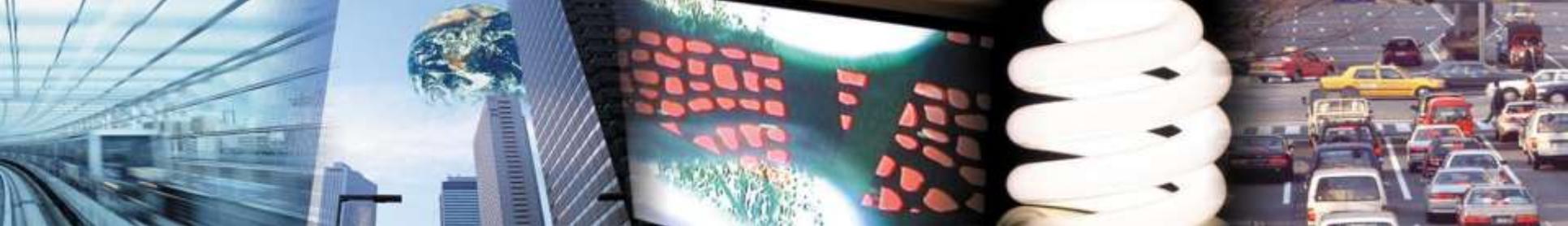
# Road Transport Energy Demand by Vehicle Type



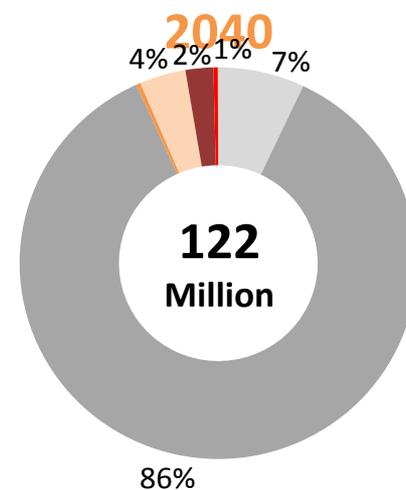
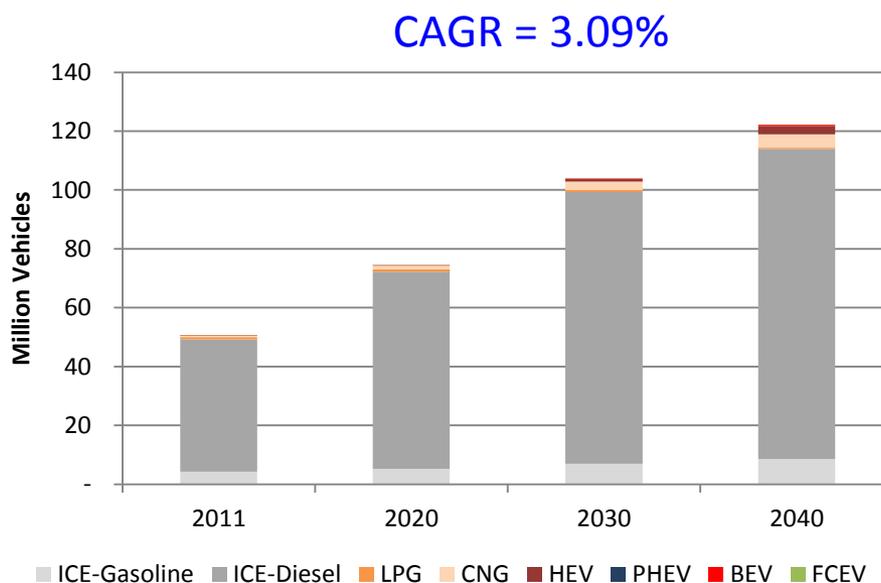
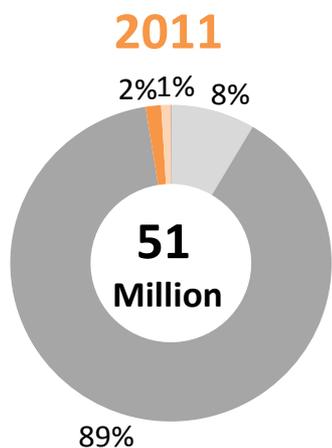


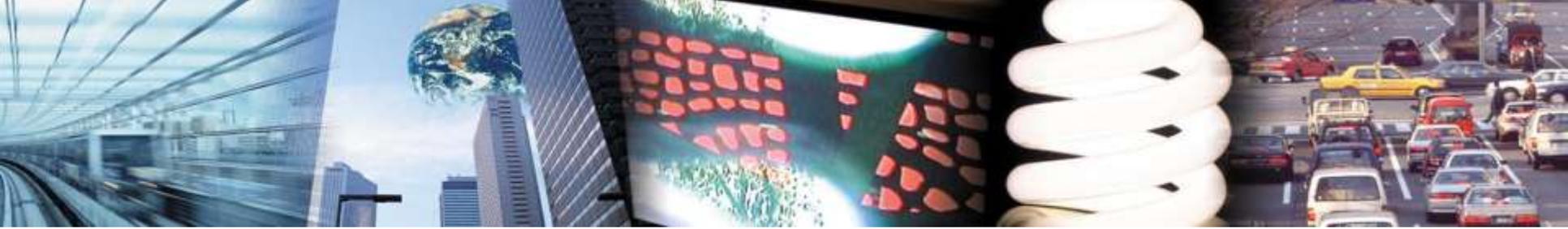
# Light Vehicle Stock by Technology



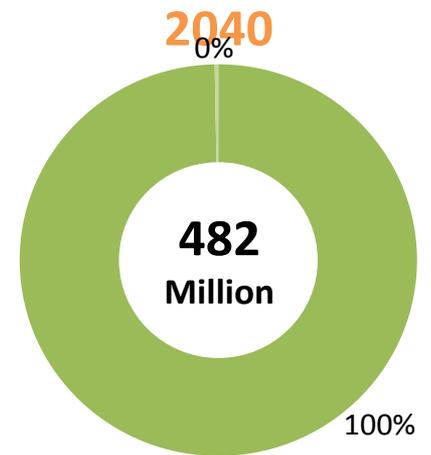
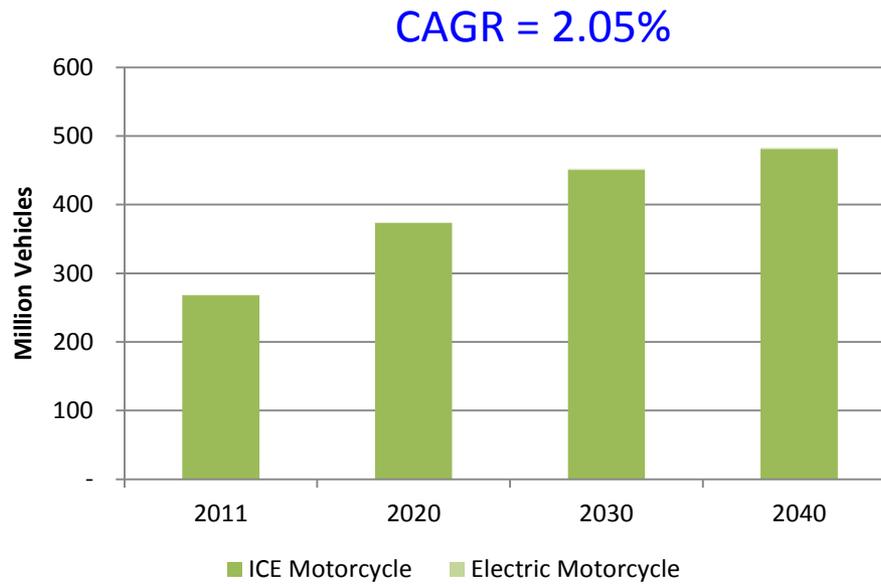
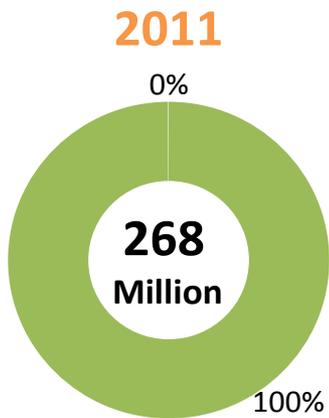


# Heavy Vehicle Stock by Technology





## Motorcycle Stock by Technology





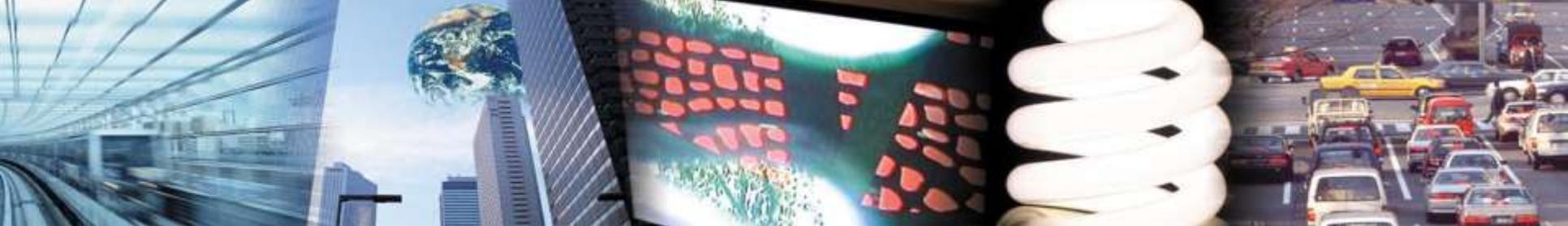
## Vehicle Ownership by Economy

	Vehicle per 1,000 Population				% Saturation		Saturation
	2011	2020	2030	2040	2011	2040	
Canada	623	664	702	735	79.9	94.3	780
United States	817	827	839	852	92.8	96.8	880
Mexico	253	369	452	481	51.9	98.5	488
Peru	67	147	264	356	15.9	84.8	420
Chile	193	304	403	463	38.3	92.0	503
Russia	299	393	480	536	49.8	89.4	600
Korea	387	438	462	473	80.6	98.5	480
Japan	594	611	618	620	95.8	99.9	620
China	62	205	374	460	12.4	92.2	499
Chinese Taipei	313	323	327	328	94.7	99.3	330
Hong Kong	84	85	86	86	93.2	95.9	90
Singapore	159	164	167	168	93.3	98.8	170
Thailand	164	291	421	492	31.7	95.0	518
Malaysia	365	492	570	602	59.1	97.6	617
Indonesia	47	99	201	339	9.9	72.0	470
Philippines	72	139	264	371	16.9	86.7	428
Vietnam	17	36	90	205	3.6	44.6	460
Brunei Darussalam	537	536	537	538	99.4	99.6	540
Papua New Guinea	9	16	35	83	1.3	11.9	700
Australia	694	732	756	769	89.0	98.6	780
New Zealand	718	741	760	773	92.1	99.1	780
<b>APEC</b>	<b>217</b>	<b>314</b>	<b>428</b>	<b>500</b>	<b>39.2</b>	<b>90.3</b>	<b>554</b>



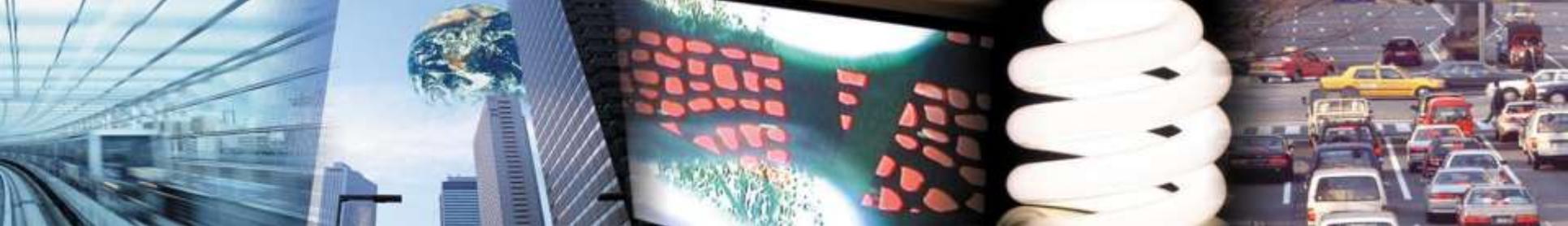
## Vehicle Stock by Economy

	Vehicle Stock (millions)				Compound Annual Growth Rates			
	2011	2020	2030	2040	2011-2020	2020-2030	2030-2040	2011-2040
Canada	21.41	24.69	27.98	30.80	1.6%	1.3%	1.0%	1.26%
United States	255.71	278.67	303.49	326.57	1.0%	0.9%	0.7%	0.85%
Mexico	29.10	46.48	61.21	68.01	5.3%	2.8%	1.1%	2.97%
Peru	1.97	4.78	9.39	13.41	10.4%	7.0%	3.6%	6.84%
Chile	3.33	5.63	7.88	9.26	6.0%	3.4%	1.6%	3.59%
Russia	42.70	55.44	65.46	70.39	2.9%	1.7%	0.7%	1.74%
Korea	18.71	21.80	23.26	23.33	1.7%	0.7%	0.0%	0.76%
Japan	75.16	76.28	74.34	70.85	0.2%	-0.3%	-0.5%	-0.20%
China	83.38	283.99	520.54	626.02	14.6%	6.2%	1.9%	7.20%
Chinese Taipei	7.26	7.63	7.70	7.44	0.6%	0.1%	-0.3%	0.09%
Hong Kong	0.60	0.66	0.73	0.77	1.2%	0.9%	0.6%	0.89%
Singapore	0.82	0.92	1.00	1.03	1.2%	0.8%	0.3%	0.78%
Thailand	11.40	20.95	30.86	35.91	7.0%	3.9%	1.5%	4.04%
Malaysia	10.53	16.24	21.24	24.58	4.9%	2.7%	1.5%	2.97%
Indonesia	11.28	25.93	56.19	98.27	9.7%	8.0%	5.7%	7.75%
Philippines	6.85	15.30	33.40	52.56	9.3%	8.1%	4.6%	7.28%
Vietnam	1.47	3.45	9.16	21.36	9.9%	10.3%	8.8%	9.67%
Brunei Darussalam	0.22	0.25	0.28	0.31	1.5%	1.2%	0.9%	1.17%
Papua New Guinea	0.06	0.13	0.36	0.99	8.4%	10.5%	10.6%	9.90%
Australia	15.70	18.48	21.00	22.91	1.8%	1.3%	0.9%	1.31%
New Zealand	3.17	3.58	3.96	4.24	1.3%	1.0%	0.7%	1.00%
<b>APEC</b>	<b>600.8</b>	<b>911.3</b>	<b>1,279.4</b>	<b>1,509.0</b>	<b>4.7%</b>	<b>3.5%</b>	<b>1.7%</b>	<b>3.23%</b>



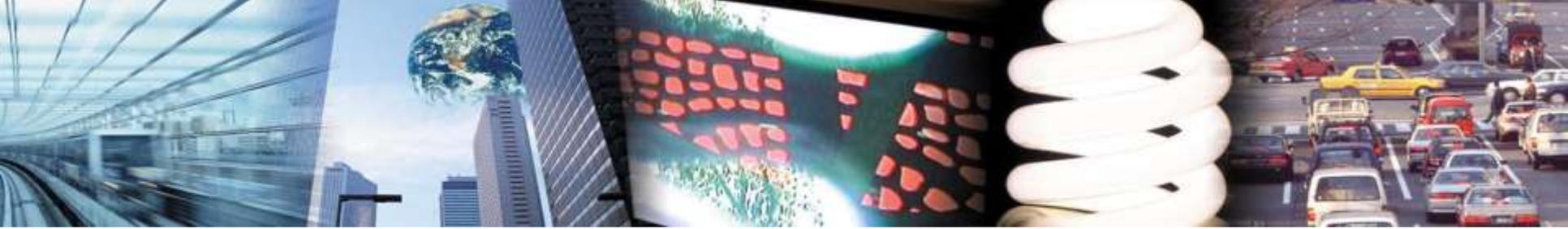
## Vehicle Sales by Economy

	Vehicle Sales (millions)				Compound Annual Growth Rates			
	2012	2020	2030	2040	2012-2020	2020-2030	2030-2040	2012-2040
Canada	1.48	1.70	1.84	1.97	1.8%	0.8%	0.7%	1.04%
United States	15.26	18.41	19.45	20.75	2.4%	0.6%	0.7%	1.10%
Mexico	3.49	3.58	3.73	3.95	0.3%	0.4%	0.6%	0.44%
Peru	0.29	0.51	0.66	0.74	7.4%	2.6%	1.3%	3.46%
Chile	0.32	0.48	0.55	0.59	5.1%	1.4%	0.7%	2.17%
Russia	3.14	3.48	3.44	3.62	1.3%	-0.1%	0.5%	0.52%
Korea	1.01	1.19	1.13	1.09	2.2%	-0.5%	-0.4%	0.30%
Japan	5.33	4.95	4.78	4.52	-0.9%	-0.3%	-0.6%	-0.58%
China	20.14	36.15	42.79	44.37	7.6%	1.7%	0.4%	2.86%
Chinese Taipei	0.37	0.48	0.43	0.44	3.2%	-1.0%	0.0%	0.58%
Hong Kong	0.04	0.05	0.05	0.05	1.2%	0.4%	0.5%	0.67%
Singapore	0.10	0.12	0.13	0.13	1.7%	0.6%	0.2%	0.77%
Thailand	1.48	1.72	1.76	1.89	1.9%	0.2%	0.7%	0.88%
Malaysia	0.70	0.80	1.07	1.05	1.7%	2.9%	-0.2%	1.45%
Indonesia	1.50	2.61	4.94	6.02	7.2%	6.6%	2.0%	5.09%
Philippines	0.39	1.15	2.01	1.99	14.6%	5.7%	-0.1%	6.03%
Vietnam	0.16	0.38	1.05	1.75	11.7%	10.7%	5.3%	8.99%
Brunei Darussalam	0.01	0.02	0.02	0.02	4.1%	0.4%	0.9%	1.63%
Papua New Guinea	0.01	0.02	0.05	0.11	11.7%	10.6%	9.4%	10.50%
Australia	0.96	1.00	1.03	1.12	0.6%	0.3%	0.8%	0.55%
New Zealand	0.11	0.17	0.18	0.16	5.1%	0.6%	-0.8%	1.37%
APEC	56.3	79.0	91.1	96.3	4.3%	1.4%	0.6%	1.94%



## Road Transport Energy Demand by Economy

	Energy Demand (Mtoe)				Compound Annual Growth Rates			
	2011	2020	2030	2040	2011-2020	2020-2030	2030-2040	2012-2040
Canada*	49.17	51.04	51.64	49.98	0.4%	0.1%	-0.3%	0.06%
United States*	509.48	500.49	481.85	450.40	-0.2%	-0.4%	-0.7%	-0.42%
Mexico*	51.78	69.83	81.84	82.76	3.4%	1.6%	0.1%	1.63%
Peru	5.80	11.42	20.24	26.68	7.8%	5.9%	2.8%	5.41%
Chile*	6.42	8.71	10.81	11.50	3.5%	2.2%	0.6%	2.03%
Russia	48.33	54.31	57.32	55.54	1.3%	0.5%	-0.3%	0.48%
Korea*	28.53	28.61	26.74	23.79	0.0%	-0.7%	-1.2%	-0.62%
Japan*	67.34	61.49	52.10	44.38	-1.0%	-1.6%	-1.6%	-1.43%
China	157.88	387.14	611.40	647.15	10.5%	4.7%	0.6%	4.98%
Chinese Taipei	11.82	12.24	13.12	13.18	0.4%	0.7%	0.0%	0.38%
Hong Kong	1.81	1.85	1.95	1.98	0.3%	0.5%	0.1%	0.31%
Singapore	2.74	2.82	2.80	2.64	0.3%	-0.1%	-0.6%	-0.12%
Thailand	19.64	28.76	37.70	39.68	4.3%	2.7%	0.5%	2.45%
Malaysia	13.68	17.49	21.40	24.02	2.8%	2.0%	1.2%	1.96%
Indonesia	34.45	59.10	101.09	144.89	6.2%	5.5%	3.7%	5.08%
Philippines	6.73	14.31	31.62	47.02	8.7%	8.3%	4.0%	6.93%
Vietnam	10.80	18.97	33.87	57.89	6.5%	6.0%	5.5%	5.96%
Brunei Darussalam	0.43	0.45	0.48	0.49	0.5%	0.6%	0.3%	0.46%
Papua New Guinea	0.44	0.67	1.41	3.20	4.8%	7.7%	8.6%	7.09%
Australia*	24.85	26.61	27.88	27.96	0.8%	0.5%	0.0%	0.41%
New Zealand*	4.11	4.20	4.30	4.28	0.3%	0.2%	-0.1%	0.14%
<b>APEC</b>	<b>1,056.2</b>	<b>1,360.5</b>	<b>1,671.6</b>	<b>1,759.4</b>	<b>2.9%</b>	<b>2.1%</b>	<b>0.5%</b>	<b>1.78%</b>



Thank you

Questions & Comments