Transportation End-Use Model Overview

28-29 January 2008

Outline

ecoENERGY
an ecoACTION initiative

- Office of Energy Efficiency (OEE)
- Transportation Sector Overview
- Light Duty Vehicles (LDV) Classification
- Data Sources for Stock/Sale of LDV
- Data Results
- Freight Transportation
- Data Issues

Office of Energy Efficiency (OEE)

ecoENERGY
an ecoACTION initiative

- OEE's mission:
  - The Office of Energy Efficiency (OEE), Canada's centre of excellence for energy conservation, energy efficiency and alternative fuels information, is playing a dynamic leadership role in helping Canadians save millions of dollars in energy costs while contributing to a healthier environment .
- The Demand Policy and Analysis Division (DPAD) has a slightly different role that includes:
  - Being an objective central source for Canada's energy use data;
  - Measuring the performance of OEE programs; and
  - Helping to develop new programs.
- Publications:
  - Energy Use Data Handbook
  - Energy Efficiency Trends In Canada

Transportation End-Use Model (TEUM)

ecoENERGY
an ecoACTION initiative

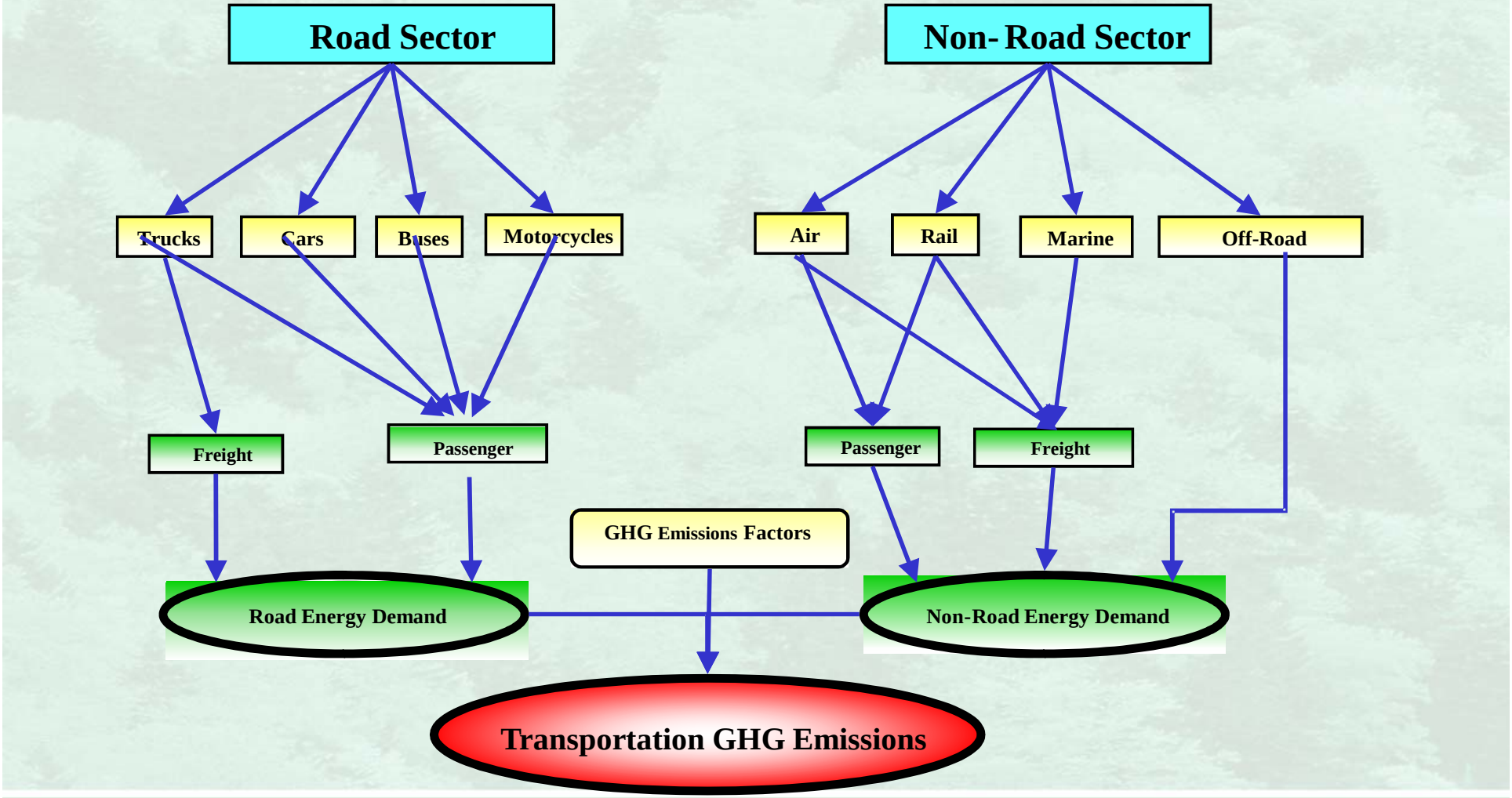
- **Data:**
  - Number of input variables in TEUM = approx. 56
  - Number of output variables in TEUM = approx. 67

- **Transportation Energy Use:**
  - Road
    - Cars (large, small)
    - Trucks (light, medium, heavy)
    - Buses (urban, intercity, school)
    - Motorcycles
  - Non-Road
    - Air
    - Rail
    - Marine
  - Off-Road

- **Measures of activity for the transportation sector:**
  - Passenger-kilometres (transport of 1 passenger over 1 kilometer)
  - Tonne kilometres (transport of 1 tonne over 1 kilometre)

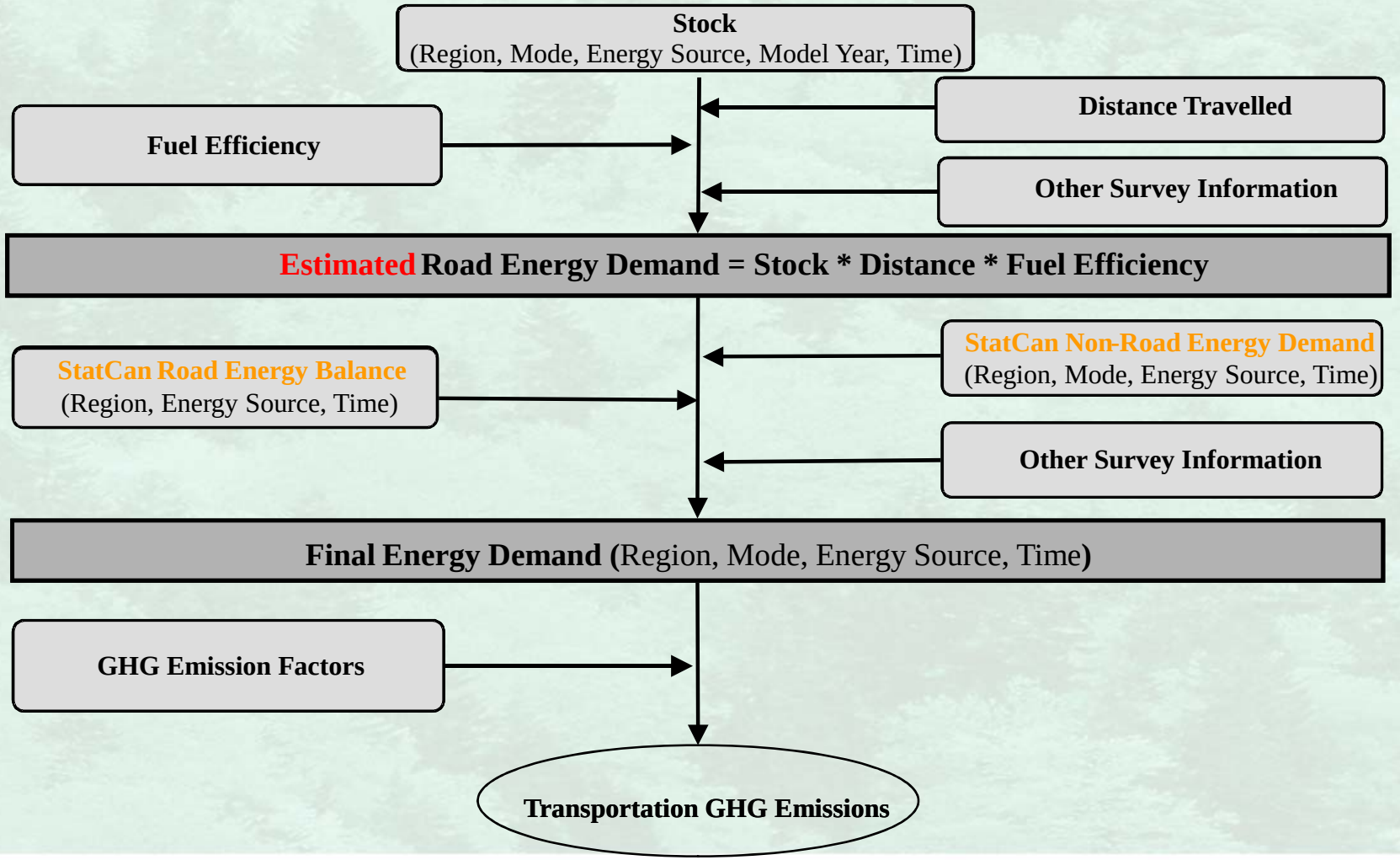
TEUM Design

ecoENERGY
an ecoACTION initiative



Schematic of TEUM

ecoENERGY
an ecoACTION initiative



LDV Classification

ecoENERGY
an ecoACTION initiative

- **Small Cars**
  - **A car with a gross vehicle weight of up to 1181 kg (2600 lb.).**
  - **VW Golf, Pontiac Vibe**

- **Large Cars**
  - **A car with a gross vehicle weight of 1182 kg (2601 lb.) or more.**
  - **VW Passat, Toyota Camry**

- **Light Trucks**
  - **A truck with a gross vehicle weight of up to 3855 kg (8500 lb.).**
  - **Include light passenger (SUVs, pickups) and light freight (delivery trucks)**

- **Motorcycles**

→ The gross vehicle weight is the weight of the empty vehicle plus the maximum anticipated load weight.

Data Sources for LDV stock/sales

ecoENERGY
an ecoACTION initiative

- Data for vehicle stock/sale in TEUM were obtained mainly from
  - Desrosier's *Canadian Vehicles in Operation Census* (CVIOC)
  - R.L. Polk & Co.'s *Trucking Industry Profile* (TIP).
- For years where the data from CVIOC and TIP was not available
  - STC's *Road Motor Vehicles Registrations* (Cat. No. 53-219-XIB)
  - The United States (U.S.) Department of Energy's *Transportation Energy Data Book, Edition 25*

CVIOC

ecoENERGY
an ecoACTION initiative

- The CVIOC database is an annual census of total light vehicles registered in Canada.
- The registration data is collected from each of the provinces.
- It captures changes in the fleet that have occurred with older vehicles (imports, exports, scrappage rates)
- The database contains the following information for each light duty vehicles:
  - Model Year of Vehicle
  - Make
  - Model
  - Fuel Type
  - …

TIP

ecoENERGY
an ecoACTION initiative

- Provides vehicles in operation and new truck registration information on light/medium/heavy commercial trucks and new commercial trailers.
- Database for trucks over 8,500 lbs
- The database contains the following information for trucks:
  - Model Year of Vehicle
  - Make
  - Model
  - Fuel Type
  - province

Average Distance Traveled – Canadian Vehicle Survey (CVS)

ecoENERGY
an ecoACTION initiative

- CVS
  - The survey provides quarterly and annual estimates of the amount of road travel, broken down by types of vehicles and characteristics, such as age and sex of driver, time of day and season.
- The survey collects data on over 27 variables.
- Data collected by Statistics Canada through trip-logs, telephone interviews and vehicle registration files.
- Provides On-road fuel efficiency

Average Distance Traveled

ecoENERGY
an ecoACTION initiative

Table - [Adjusted Average Car Distance]

File Edit Table View Window Help

SCRoadAdj/adjAvgCarDist/4 EETiC- June 26 2007

Adjusted Average Car Distance

province	carClass	usage	cviocFuel
NFLD	small	personal	mogas

province

time

modelYe...

	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
1959																
1960	11847.45															
1961	12190.54	12128.88														
1962	13285.49	12480.13	12109.13													
1963	14007.61	13601.08	12459.80	12035.64												
1964	14592.24	14340.35	13578.93	12384.19	11137.11											
1965	15519.97	14938.87	14317.00	13496.52	11459.64	11073.79										
1966	16128.13	15888.64	14914.55	14230.11	12488.93	11394.49	11742.80									
1967	17032.33	16511.25	15862.77	14824.03	13167.75	12417.93	12082.87	11135.33								
1968	17884.50	17436.93	16484.36	15766.49	13717.33	13092.89	13168.14	11457.80	10488.22							
1969	18542.21	18309.34	17408.53	16384.32	14589.44	13639.35	13883.88	12486.93	10791.96	9820.01						
1970	19767.21	18982.68	18279.53	17302.88	15161.14	14506.50	14463.35	13165.65	11761.28	10104.40	9610.50					
1971	20803.94	20236.78	18951.77	18168.59	16011.12	15074.95	15382.88	13715.14	12400.55	11011.96	9888.82	9729.75				
1972	21531.01	21298.13	20203.82	18836.75	16812.20	15920.10	15985.68	14587.10	12918.11	11610.51	10777.02	10011.52	9969.90			
1973	22550.40	22042.48	21263.45	20081.20	17430.48	16716.62	16881.89	15158.71	13739.40	12095.09	11362.80	10910.75	10258.63	10537.56	9387.92	
1974	23805.13	23086.08	22006.58	21134.40	18582.03	17331.38	17726.53	16008.56	14277.79	12864.06	11837.04	11503.79	11180.05	10842.73		
1975	24871.58	24370.61	23048.49	21873.02	19556.60	18476.39	18378.43	16809.51	15078.25	13368.15	12589.61	11983.92	11787.73	11816.61		
1976	25941.76	25462.40	24330.93	22908.60	20240.08	19445.42	19592.61	17427.69	15832.66	14117.61	13082.94	12745.82	12279.71	12458.89	11414.05	
1977		26557.99	25420.94	24183.26	21198.35	20125.01	20620.18	18579.06	16414.91	14823.96	13816.41	13245.28	13060.42	12978.88	12034.45	11434
1978			26514.75	25266.66	22377.85	21077.83	21340.83	19553.47	17499.37	15369.11	14507.69	13987.85	13572.20	13804.04	12536.73	12055
1979				26353.83	23380.36	22250.63	22351.22	20236.84	18417.16	16384.48	15041.21	14687.70	14333.10	14344.97	13333.78	12559
1980					24386.37	23247.44	23594.86	21194.96	19060.82	17243.80	16034.92	15227.85	15050.23	15149.19	13856.28	13357
1981						24247.73	24651.90	22374.27	19963.25	17846.45	16875.90	16233.89	15603.71	15907.15	14633.10	13881
1982							25712.62	23376.62	21074.03	18691.39	17465.69	17085.30	16634.57	16492.14	15365.24	14659
1983								24382.47	22018.13	19731.40	18292.61	17682.41	17507.00	17581.70	15930.30	15392
1984									22965.53	20615.35	19310.43	18519.59	18118.85	18503.80	16982.74	15958
1985										21502.39	20175.52	19550.04	18976.69	19150.49	17873.43	17013
1986											21043.63	20425.87	20032.57	20057.17	18498.09	17905
1987												21304.75	20930.02	21173.17	19373.88	18531
1988													21830.60	22121.72	20451.87	19408

ecoENERGY
an ecoACTION initiative

Data Results

TEUM 2005

TEUM Variables

ecoENERGY
an ecoACTION initiative

- **Energy Data**
  - by Transportation Mode
  - by Energy Source
  - by Region
- **Activity Data**
  - Stock of vehicles, vehicle kilometers traveled, fuel efficiency, people/vehicle, load, tonne-km, passenger-km
- **Green House Gas (GHG) Emissions**
  - by Transportation Mode
  - by Energy Source
  - by Region
- **Decomposition Analysis – Log-Mean Divisia Index I (LMDI I)**

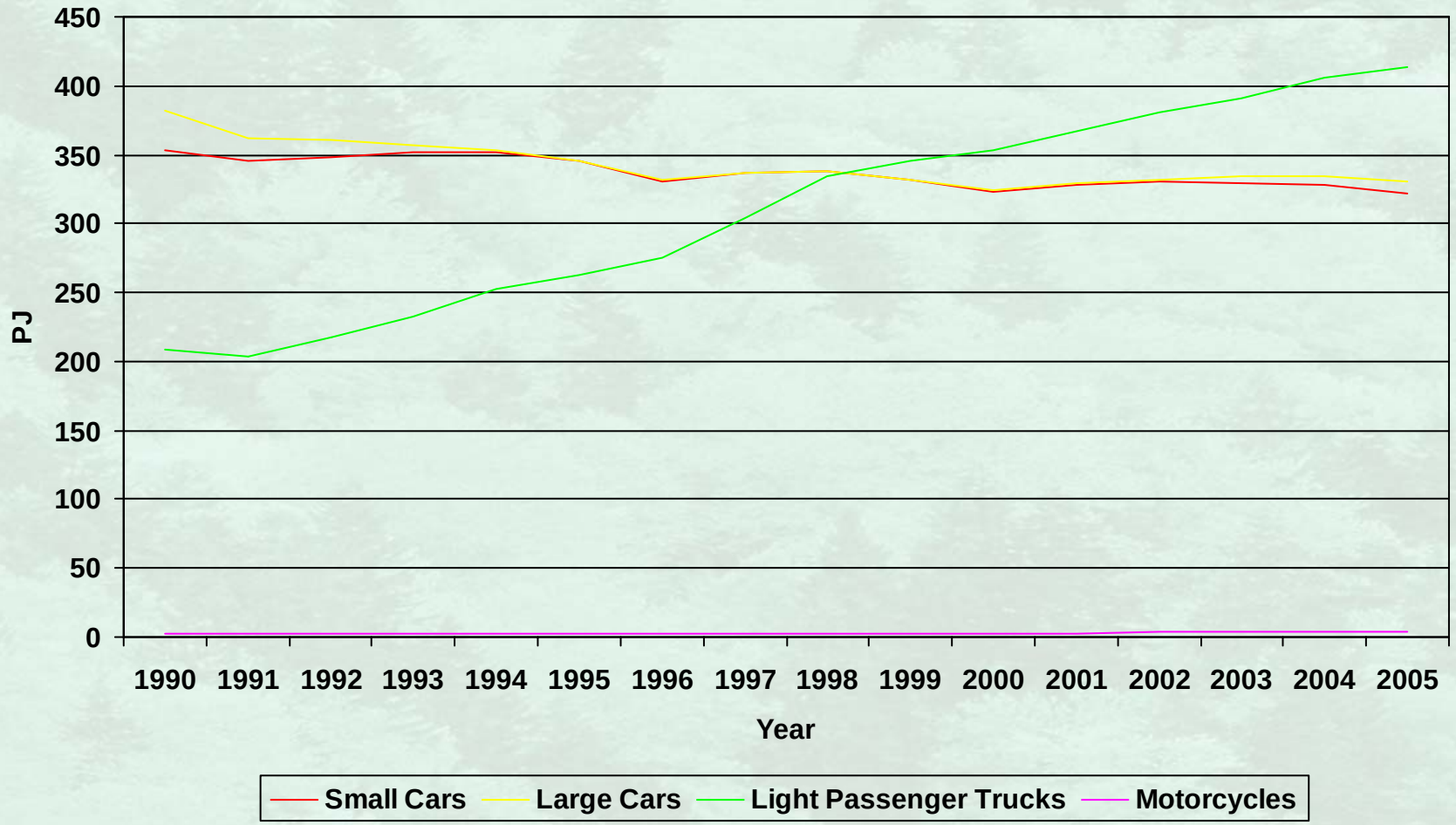
Outputs: what variables do the stock/sale data feed?

ecoENERGY
an ecoACTION initiative

- **Passenger-kilometre (Pkm):** An activity measure in the passenger transportation sub-sector describing the transportation of one passenger over a distance of one kilometre.
- **Energy Intensity (MJ/Pkm):** Energy Use divided by passenger
- **Estimated Road Energy demand**: Stock * Distance * Fuel Efficiency
- **GHG Emissions**: Energy Use multiplied by GHG emissions factors
- **Decomposition Analysis:** A statistical analysis, based on the Log-Mean Divisia Index I (LMDI I) approach, is used to separate changes in energy use into five factors: activity, structure, weather, service level and energy efficiency.

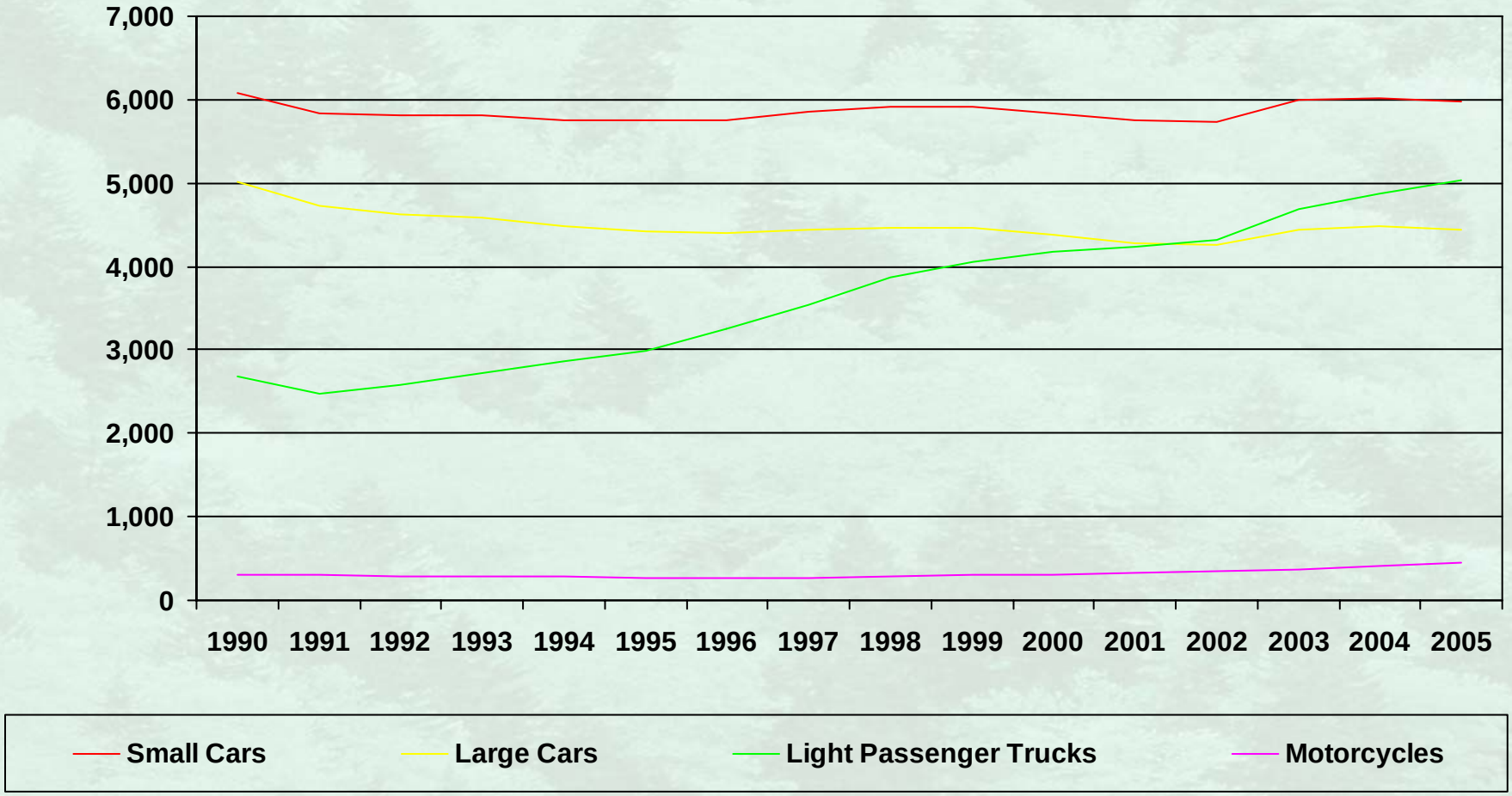
LDV Energy Use (PJ/year)

ecoENERGY
an ecoACTION initiative



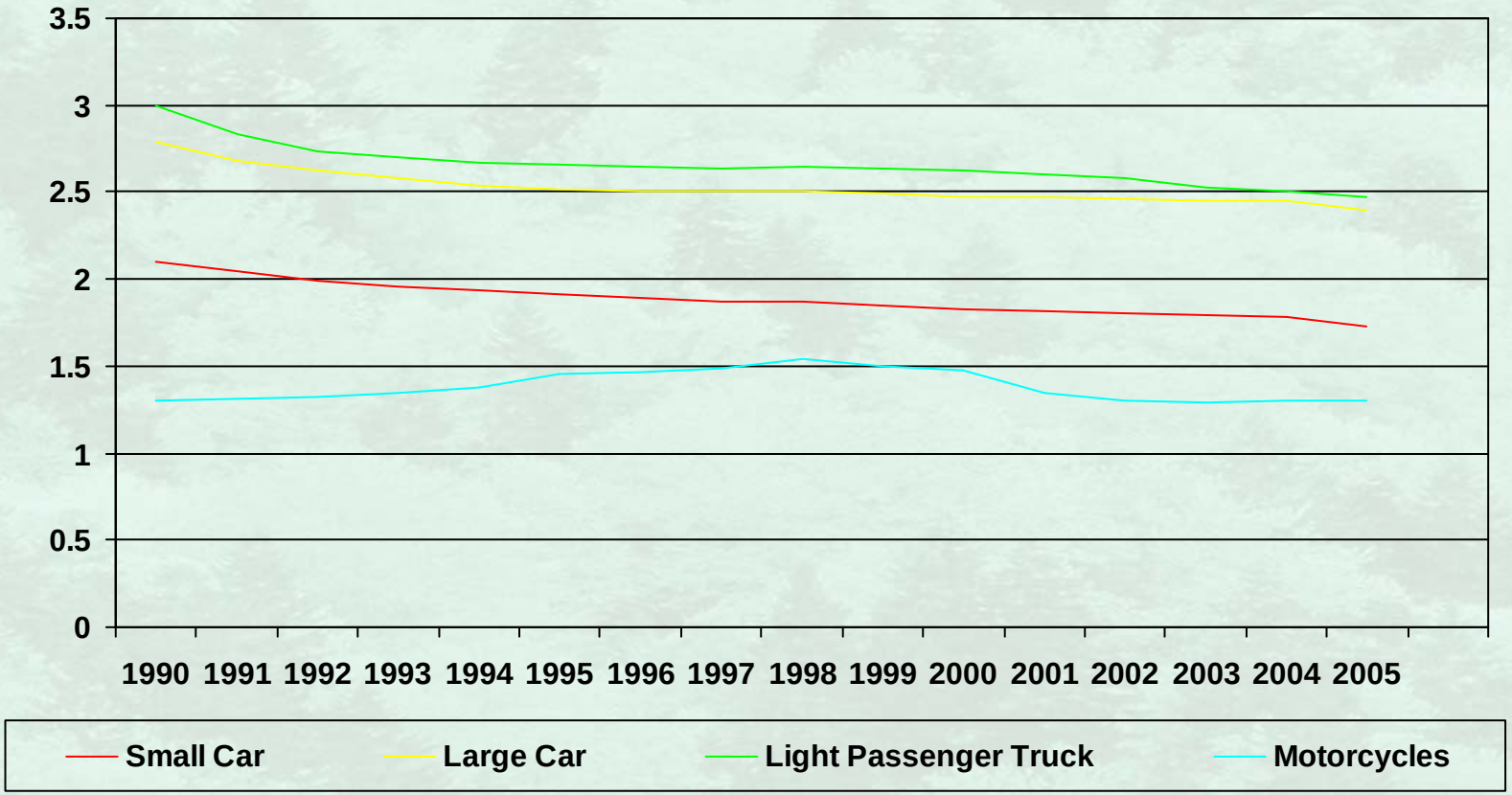
Stock of LDV (thousands)

ecoENERGY
an ecoACTION initiative



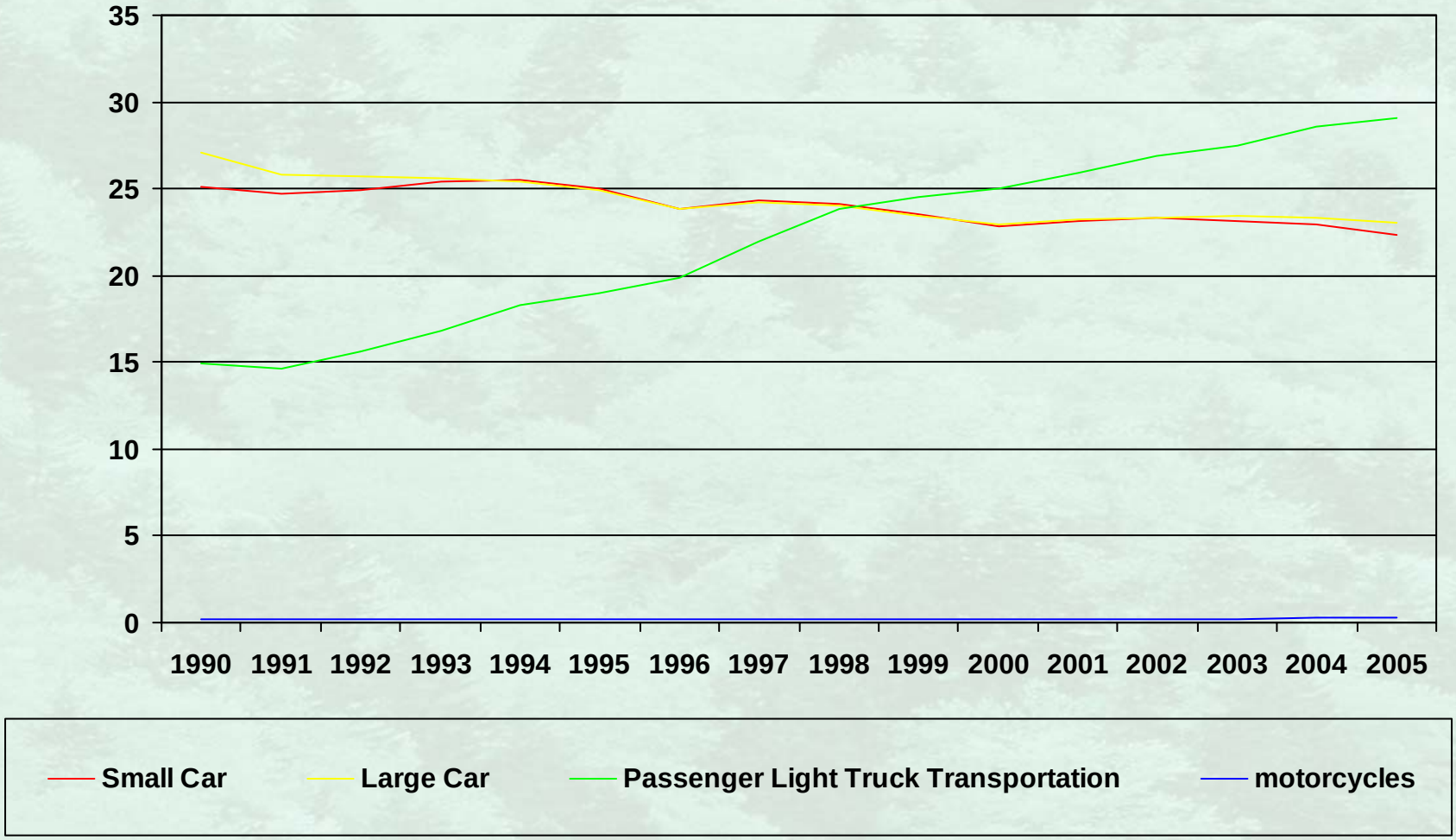
Energy Intensity (MJ/Pkm)

ecoENERGY
an ecoACTION initiative



GHG Emissions Results (Mt)

ecoENERGY
an ecoACTION initiative



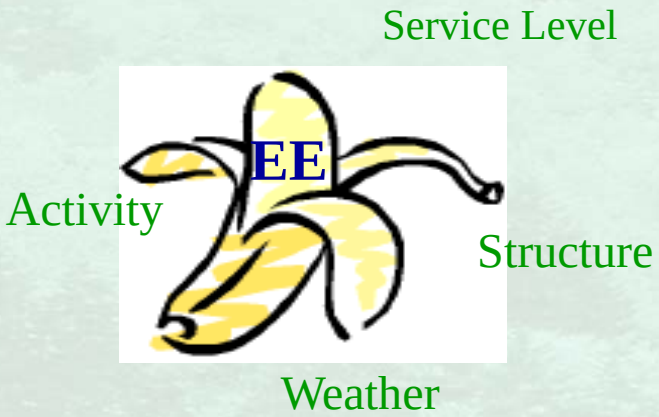
Why do we decompose the Change in Energy?

ecoENERGY
an ecoACTION initiative

- **Our analysis is based on the LMDI I factorization technique that is used and recognized internationally**

- **It allows us to "peel" away the impact of:**

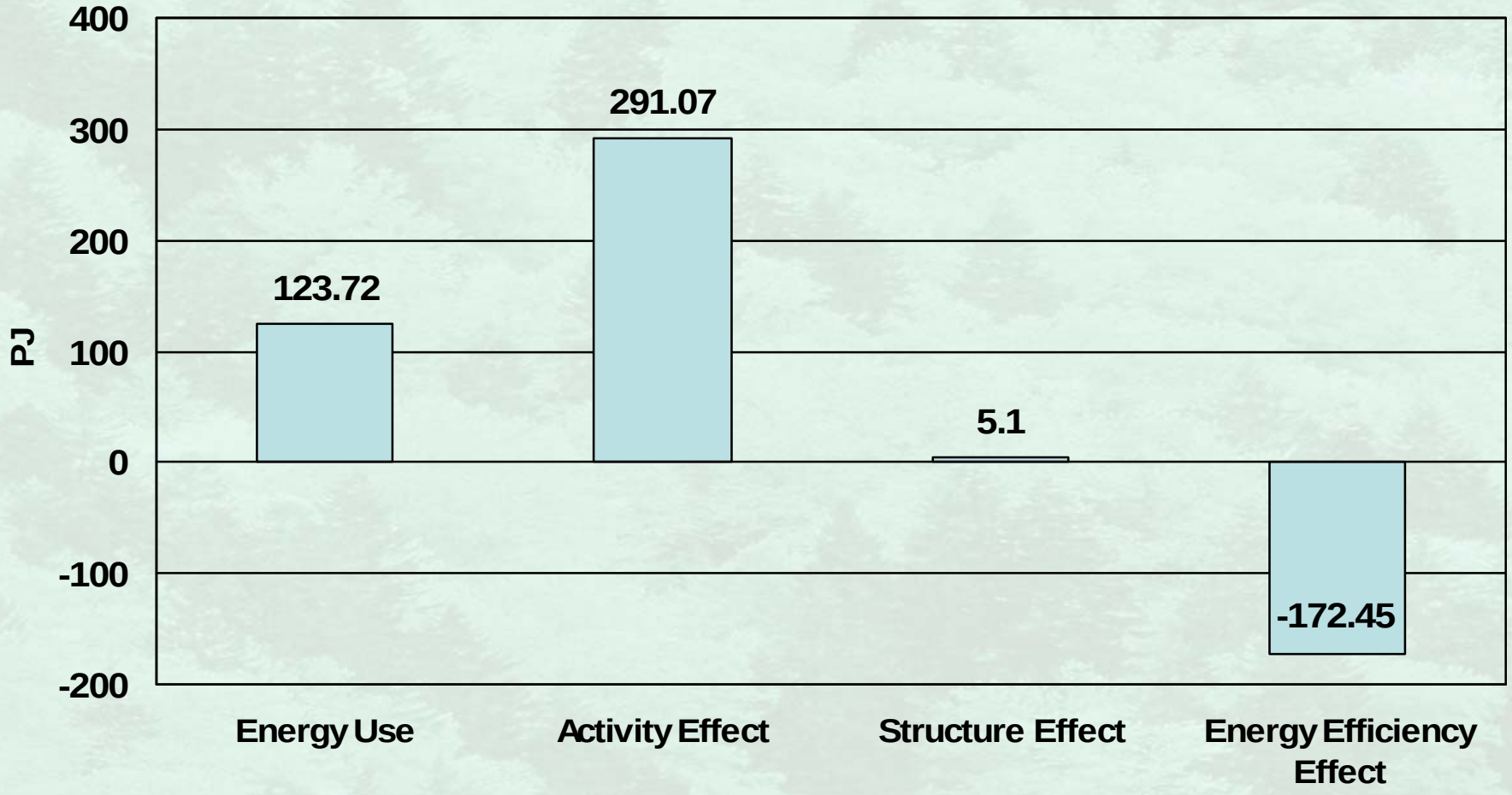
  - **changes in the level of activity**
  - **changes in the weather**
  - **changes in the structure of each sector**
  - **changes in the service level**



which provide us with a more accurate indicator of energy efficiency for the economy and each sector.

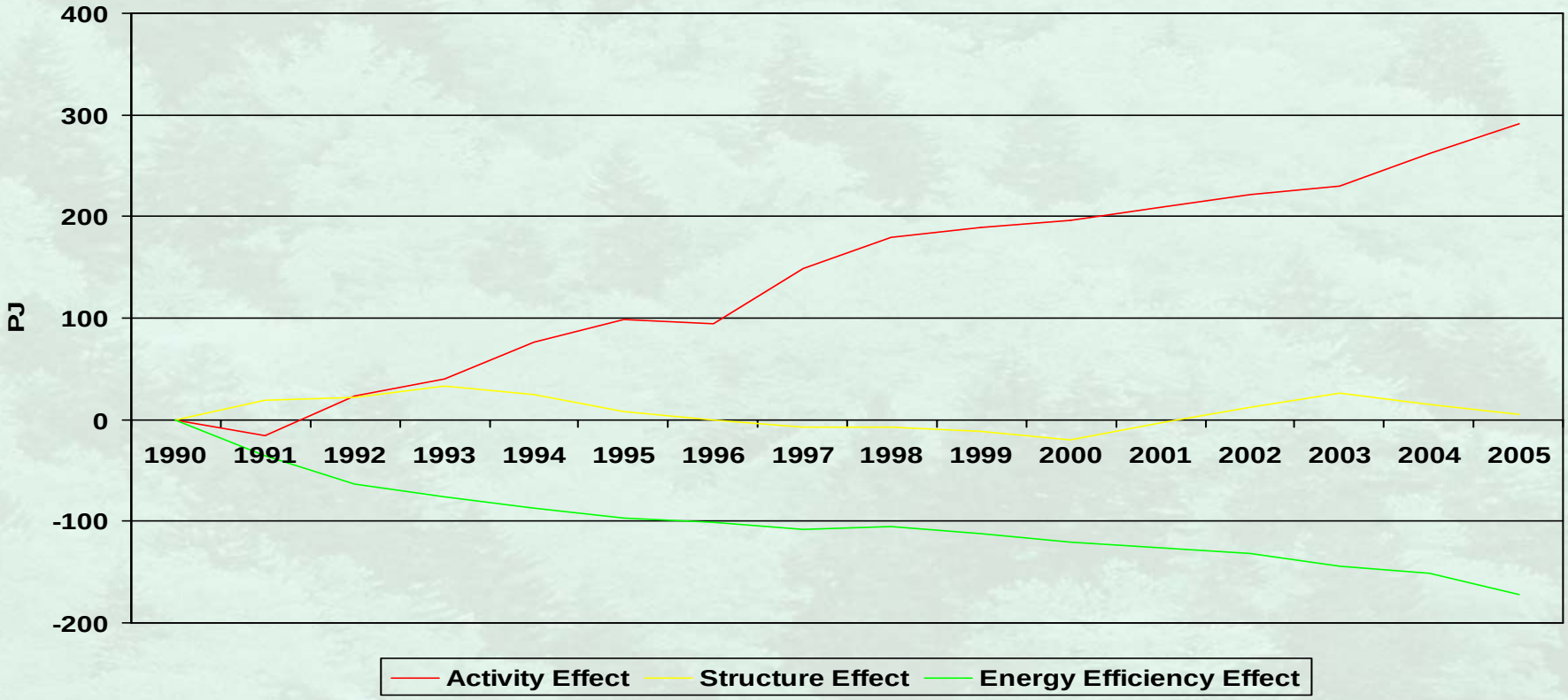
Impact of Activity, Structure and Energy Efficiency on Energy Use, 1990-2005 for LDV

ecoENERGY
an ecoACTION initiative



Changes in Energy Use Due to Activity, Weather, Structure and Energy Efficiency, 1990-2005

ecoENERGY
an ecoACTION initiative



Freight Transportation

ecoENERGY
an ecoACTION initiative

- Within the transportation sector, passenger modes accounted for 55 percent of total energy use, while the freight subsector used 41 percent and off-road vehicles the remaining 4 percent.
- Freight was the fastest growing subsector, accounting for 63 percent of the change in total transportation energy use.
- Energy-related GHGs produced by freight transportation were 61 percent higher, from 46.4 Mt in 1990 to 74.5 Mt in 2005.
- Just-in-time delivery
  - limits the use of warehouse space for inventory and instead relies on orders arriving to the company just as they are required for production.

	1990	2005	1990-2005 Growth
Total Energy Use (PJ)	1,877.89	2,501.84	33.23%
Passenger Transportation (PJ)	1,187.65	1,376.12	15.87%
Freight Transportation (PJ)	636.89	1,028.33	61.46%
Off-Road (PJ)	53.35	97.39	82.55%

Data Issues

ecoENERGY
an ecoACTION initiative

- **Motorcycles**
  - general lack of info
- **Historical Trends Analysis**
  - Car and Truck Backcasts
- **Vehicle Identification Numbers (VIN) Files**
- **Freight Transportation**
  - Monitoring energy use (US vs Canada)
  - Load factors
  - Stock growth rates

ecoENERGY
an ecoACTION initiative

For Questions Please Contact

Dominic Demers
Demand Policy and Analysis Division
ddemers@nrcan.gc.ca

ecoENERGY
an ecoACTION initiative

Natural Resources Canada
Ressources naturelles Canada

Canada

ecoENERGY
an ecoACTION initiative

- Extra slides
- Not to be distributed

Transportation Structure Chart

ecoENERGY
an ecoACTION initiative

Passenger Transportation
- Small Car
- Large Car
- Light Truck
- Motorcycle
- School Bus
- Urban Bus
- Inter-city Bus
- Air
- Rail

Freight Transportation
- Light Truck
- Medium Truck
- Heavy Truck
- Rail
- Marine

LDV
- Small Car
- Large Car
- Light Truck
- Motorcycle

Rail
(No Structure)

Air
(No Structure)

Bus
- School Bus
- Urban Bus
- Inter-city Bus

Marine
(No Structure)

Rail
(No Structure)

Truck
- Light Truck
- Medium Truck
- heavy Truck

Small Car
- Motor Gasoline
- Diesel
- Natural Gas
- Propane

Large Car
- Motor Gasoline
- Diesel
- Natural Gas
- Propane

Light Truck
- Motor Gasoline
- Diesel
- Natural Gas
- Propane

Motorcycle
(No Structure)
Only Motor Gasoline

School
- Motor Gasoline
- Diesel
- Natural Gas
- Propane

Urban
- Motor Gasoline
- Diesel
- Natural Gas
- Propane
- Electricity

Inter-City
- Motor Gasoline
- Diesel
- Natural Gas
- Propane

Light
- Motor Gasoline
- Diesel
- Natural Gas
- Propane

Medium
- Motor Gasoline
- Diesel
- Natural Gas
- Propane

Heavy
(No Structure)
Only Diesel

Level One = Energy Weighted Average of Level Two Structure
Level Two = Share of Activity by Vehicle Type
Level Three = Share of Activity by Vehicle Type
Level Four = Share of Activity by Fuel Type

The Change in Energy

ecoENERGY
an ecoACTION initiative

- Going back to the identity and looking at the problem as continuous

$$E_T - E_0 = \int_0^T \frac{\partial}{\partial t} E$$

$$E_T - E_0 = \int_0^T \frac{\partial}{\partial t} \sum_i A \bullet S_i \bullet I_i$$

$$E_T - E_0 = \sum_i \int_0^T \frac{\partial \left(A \bullet S_i \bullet I_i \right)}{\partial t}$$

$$E_T - E_0 = \sum_i \int_0^T \left(\frac{\partial A}{\partial t} \bullet S_i \bullet I_i + \frac{\partial S_i}{\partial t} \bullet A \bullet I_i + \frac{\partial I_i}{\partial t} \bullet A \bullet S_i \right)$$

LMD Methodology

ecoENERGY
an ecoACTION initiative

$$E_T - E_0 = \sum_i \int_0^T \left(\frac{\partial A}{\partial t} \bullet \frac{A}{A} \bullet S_i \bullet I_i + \frac{\partial S_i}{\partial t} \bullet A \bullet \frac{S_i}{S_i} \bullet I_i + \frac{\partial I_i}{\partial t} \bullet A \bullet S_i \bullet \frac{I_i}{I_i} \right)$$

$$E_T - E_0 = \sum_i \int_0^T (A \bullet S_i \bullet I_i) \bullet \left[\left(\frac{1}{A} \frac{\partial A}{\partial t} \right) + \left(\frac{1}{S_i} \frac{\partial S_i}{\partial t} \right) + \left(\frac{1}{I_i} \frac{\partial I_i}{\partial t} \right) \right]$$

$$E_T - E_0 = \sum_i \int_0^T e_i \bullet \left[\left(\frac{\partial \ln(A)}{\partial t} \right) + \left(\frac{\partial \ln(S_i)}{\partial t} \right) + \left(\frac{\partial \ln(I_i)}{\partial t} \right) \right]$$

LMD Methodology

ecoENERGY
an ecoACTION initiative

$$E_T - E_0 = \sum_i \int_0^T e_i \bullet \left[\left(\frac{\partial \ln(A)}{\partial t} \right) + \left(\frac{\partial \ln(S_i)}{\partial t} \right) + \left(\frac{\partial \ln(I_i)}{\partial t} \right) \right]$$

$$\int_0^T f(x)g(x) = f(c)\int_0^T g(x) \qquad \textit{where} \quad 0 < c > T,$$

$$f(x) = E_i \qquad \textit{and}$$

$$g(x) = \left(\frac{\partial \ln A}{\partial t} + \frac{\partial \ln S_i}{\partial t} + \frac{\partial \ln I_i}{\partial t} \right)$$

we have : $$E_T - E_0 = \sum_i f(c)\left((\ln A_T - \ln A_0) + (\ln S_{iT} - \ln S_{i0}) + (\ln I_{iT} - \ln I_{i0})\right)$$

Applying the mean value theorem where:

Proposed LMD1 Methodology

ecoENERGY
an ecoACTION initiative

- LMD1 =>$f(c) \cong \frac{e_{iT} - e_{i0}}{\ln\left(e_{iT} / e_{i0}\right)}$

$$E_T - E_0 = \sum_i \frac{e_{iT} - e_{i0}}{\ln\left(e_{iT} / e_{i0}\right)} \bullet \left((\ln A_T - \ln A_0) + (\ln S_{iT} - \ln S_{i0}) + (\ln I_{iT} - \ln I_{i0})\right)$$

Proposed LMD1 Methodology

ecoENERGY
an ecoACTION initiative

$$E_T - E_0 = \sum_i \frac{e_{iT} - e_{i0}}{\ln\left(e_{iT} / e_{i0}\right)} \bullet (\ln A_T - \ln A_0) \longrightarrow \boxed{= \text{Activity Effect}}$$

$$+ \sum_i \frac{e_{iT} - e_{i0}}{\ln\left(e_{iT} / e_{i0}\right)} \bullet (\ln S_{iT} - \ln S_{i0}) \longrightarrow \boxed{= \text{Structure Effect}}$$

$$+ \sum_i \frac{e_{iT} - e_{i0}}{\ln\left(e_{iT} / e_{i0}\right)} \bullet (\ln I_{iT} - \ln I_{i0}) \longrightarrow \boxed{= \text{Intensity Effect}}$$