GHGENIUS

Natural Resources Canada

Office of Energy Efficiency

and

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Agenda

- Model Background
- Model capabilities
- Fuel and Vehicle Pathways
- Typical Output

Model Background

- Based on a Lotus 123 spreadsheet model developed by Dr. Mark Delucchi, University of California, Davis in the late 1980's for estimating transportation emissions
- In 1998 Delucchi added some specific Canada information for a US DOE, NRCan project
- In 1999, Levelton Engineering was asked by NRCan to use the model for the Transportation Table of the National Climate Change Process

Model Background

- Since 1999 the model, now called GHGENIUS, has been used for studies for Agricultural and Agri-Food Canada, Natural Resources Canada, a number of the Provinces and some industries
- Many new pathways have been added so that there are now over 200 transportation fuel pathways in the model. Much more Canadian specific data in the model
- An Excel version is now available with an updated guide.
- Documentation includes an over 500 page GHGENIUS guide and numerous reports. Some Delucchi documentation is still relevant

Why GHGENIUS?

- Follows an accepted LCA process
- Transportation specific but covers most energy sources and many materials manufacturing processes and land use changes
- Best Canadian database available
- Good American database
  - Allows comparison of Canadian and US applications of the same process
  - There are some significant differences in the industrial infrastructure between the countries
- Has some economic tools incorporated

Model Scope

- Covers raw materials production to end use.
- Lifecycle Stages
  - Raw Materials Acquisition
    - Feedstock production and recovery
    - Feedstock transmission
    - Fertilizer manufacture
    - Land use changes
    - Leaks and flaring associated with fossil fuels
  - Manufacturing
    - Fuel production
    - Fuel storage and dispensing
    - Fuel dispensing
    - Emissions displaced by co-products
  - Vehicle operation
  - Vehicle materials, assembly and transport.

Inventory Data

- A variety of data sources used for inventory data
  - For existing processes,
    - Statistics Canada
    - Industry reports
    - GHG Registries (formerly VCR)
  - For new to Canada processes
    - Foreign operating data
    - Engineering studies
    - Basic scientific assessment

Inventory Data

- Where possible relies on public data. US data relies heavily on US Census and DOE EIA data
- Generally uses industry averages rather than plant specific data
- The model is dynamic in that changes in one fuel cycle can effect many other cycles. Iterates to solve circular references
- Unlike some other models it allows the inputs to be in common units and the model calculates the energy impacts

Model Impact Assessment

- Capable of estimating life cycle emissions of the primary greenhouse gases, the criteria air contaminants (CAC), and the energy balance
- Greenhouse Gases (GHG)
  - Uses IPCC weighting factors as default values
  - Carbon dioxide
  - Methane
  - Nitrous Oxide
  - Chlorofluorocarbons and Hydrofluorocarbons

Model Impact Assessment

- Criteria Air Contaminants
  - Carbon monoxide,
  - Nitrogen oxides,
  - Non-methane organic compounds,
  - Sulphur dioxide,
  - Total Particulate Matter.
- Energy required per unit of energy produced
- Calculates cost effectiveness ($/tonne CO2 eq displaced) versus gasoline and diesel engines

Interpretation Capabilities

- GHGENIUS can calculate emissions for any year between 1996 and 2050
  - Correlations for changes in energy and process parameters with time are stored in the model. Based on historical trends or in some cases forecasts, e.g. NEB for power and oil production
- Results are calculated for each stage of the lifecycle and for each contaminant
- Capable of estimating emissions in Canada, the United States, Mexico as well as regionally, east, central, or west in North America, and India
- Some pathways can be analyzed provincially

How it Works

- Generally follows ISO 14000 guidelines
  - Does calculate emissions associated with vehicle manufacture
  - Does calculate energy consumption and emissions for the manufacture and maintenance of trucks, tractors, trains and ships used to make and transport the fuels
  - Does not include production plant
- Co-products calculated based on system expansion if possible, and the displacement method

How it Works

- Criteria emissions for gasoline and diesel powered vehicles uses algorithm to mimic Mobile6.2C results
  - Tank to Wheel portion
- Mobile6.2C provides fleet average emissions for a year and GHGENIUS produces average emissions over vehicle life
- Alternative fuel criteria emissions are also calculated on a relative basis to gasoline and diesel fuel

Model Capabilities

- Capable of modelling many vehicle types
  - Light duty vehicles
    - Internal combustion engines
    - Fuel Cells
    - Battery powered vehicles
  - Heavy duty vehicles
    - Trucks and buses (separately and combined)
    - Internal combustion engines and fuel cells

Fuel Pathways

- There are many fuel pathways in the model
- Some are indirect
  - Natural gas to methanol, and then methanol to hydrogen
- There are also many fuel blends
  - Gasoline and ethanol
  - Diesel and one of six biodiesels
- Also has a few fuel pathways for power generation and space heating

Fuel Pathways

	Coal	Gasoline	Gasoline Lo S	Diesel	Fuel Oil	Still Gas	LPG	Coke	FT Distillate	Super Cetane	CNG	LNG	Hydrogen	Methanol	Ethanol	Butanol	Biodiesel	DME	Mixed Alcohols	Electricity
Coal	X									X		X	X	X	X					X
Crude Oil		X	X	X	X	X	X	X												X
Natural Gas							X		X		X	X	X	X					X	X
Uranium													X							X
Electricity													X							
Wood									X		X	X	X	X	X				X	X
Grass													X		X					
Corn													X		X	X				
Wheat													X		X					
Sugarcane															X					
Sugar beets															X					
Canola										X								X		
Soybeans																		X		
Palm																		X		
Tallow										X								X		
Yellow Grease																		X		
Fish Oil																		X		
RDF									X										X	
LFG														X	X					

Fuel Pathways

- Gasoline and diesel fuel are the baseline fuels
  - Four types of crude oil
    - Conventional (onshore or offshore), conventional heavy, bitumen, synthetic
    - Some international oil data since more than half of crude oil refined in Canada is imported
    - Proportions of each modelled for three regions of Canada or user set
  - Sulphur content of fuel can be set by the model or user
  - Refinery energy use based on regional differences

Pathways

- Light Duty
  - Internal combustion engine
    - Gasoline (conventional and low sulphur)
    - Diesel (low sulphur and ultra low sulphur)
    - LPG (refinery or field source)
    - NG (CNG or LNG) (fossil or biomass)
    - Hydrogen (SMR or electrolysis)
  - Hybrids (gasoline and diesel) and Plug in Hybrids
  - Battery powered vehicles (national and regional power mix). Electricity is modelled provincially
  - Fuel cell engine (13 hydrogen pathways or methanol (3), ethanol (5), gasoline or FT distillate reformed onboard)

Fuel Pathways

- Light Duty Fuel Blends
  - Gasoline blends
    - Ethanol gasoline (low level and high level)
      - Six feedstock families (ten feedstocks)
    - Butanol gasoline (low level and high level)
    - Methanol gasoline (low level and high level)
      - Four feedstocks
    - Mixed Alcohols (low level and high level)
      - Three Feedstocks
  - Biodiesel blends
  - Hythane (Hydrogen – Natural Gas)
      - Two hydrogen sources

Fuel Pathways

- Heavy Duty ICE Vehicles
  - Buses and Trucks, combined or separate
    - Diesel
    - FT Distillate (3 feedstocks)
    - LPG (2 sources)
    - NG (CNG, LNG, fossil and biomass)
    - DME
    - Hydrogen (2 sources)
    - Ethanol (6 feedstock families)
    - Butanol
    - Methanol (4 feedstocks)
    - Mixed alcohol (2 feedstocks)
    - SuperCetane (2 feedstocks)
    - Diesel hybrid

GHGENIUS Website

- www.ghgenius.ca
- Public area for:
  - Information on the model
  - Links to other sites of interest
- Area for registered users
  - Reports that have been prepared using GHGENIUS
  - Model for download
  - User forum

Conventional Fuels

General fuel -->	LD Gasoline	HD Petrol Diesel
Fuel specification -->	RFG30ppm S	0.001% S
Feedstock -->	Crude oil	Crude Oil
	Grams CO_2 /km	Grams CO_2/km
Vehicle operation	211.6	1,110.9
Fuel dispensing	0.5	2.2
Fuel storage and distribution	2.0	7.8
Fuel production	43.4	139.9
Feedstock transport	3.1	15.3
Feedstock and fertilizer production	27.7	135.2
CH_4 and CO_2 leaks and flares	8.8	47.3
Emissions displaced by co-products	0.0	0.0
Sub total (fuelcycle)	297.1	1,458.6
Vehicle assembly and transport	5.6	10.5
Materials in vehicles (incl. storage)& lube oil	29.6	33.4
Grand total	332.3	1,502.5

Discussion and Questions