Forecasting & Measuring Outcomes of Energy Efficiency & GHG Emission Reduction Initiatives

Review of "Micro" Models

March 21, 2011

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Agenda:

1. Review of Context/Process	9:00 - 9:15
2. Review of Models • *Building Energy Simulations* • *Process Energy Tools* • *Large/Energy Intensive Industry* • *Transportation* • *Waste & Wastewater* • *Decision Support Tools*	9:15 – 11:00
3. Methods, Tools and Models Recommended for Further Investigation	11:00 - 11:30
4. Next steps/Discussion	11:30 – to end

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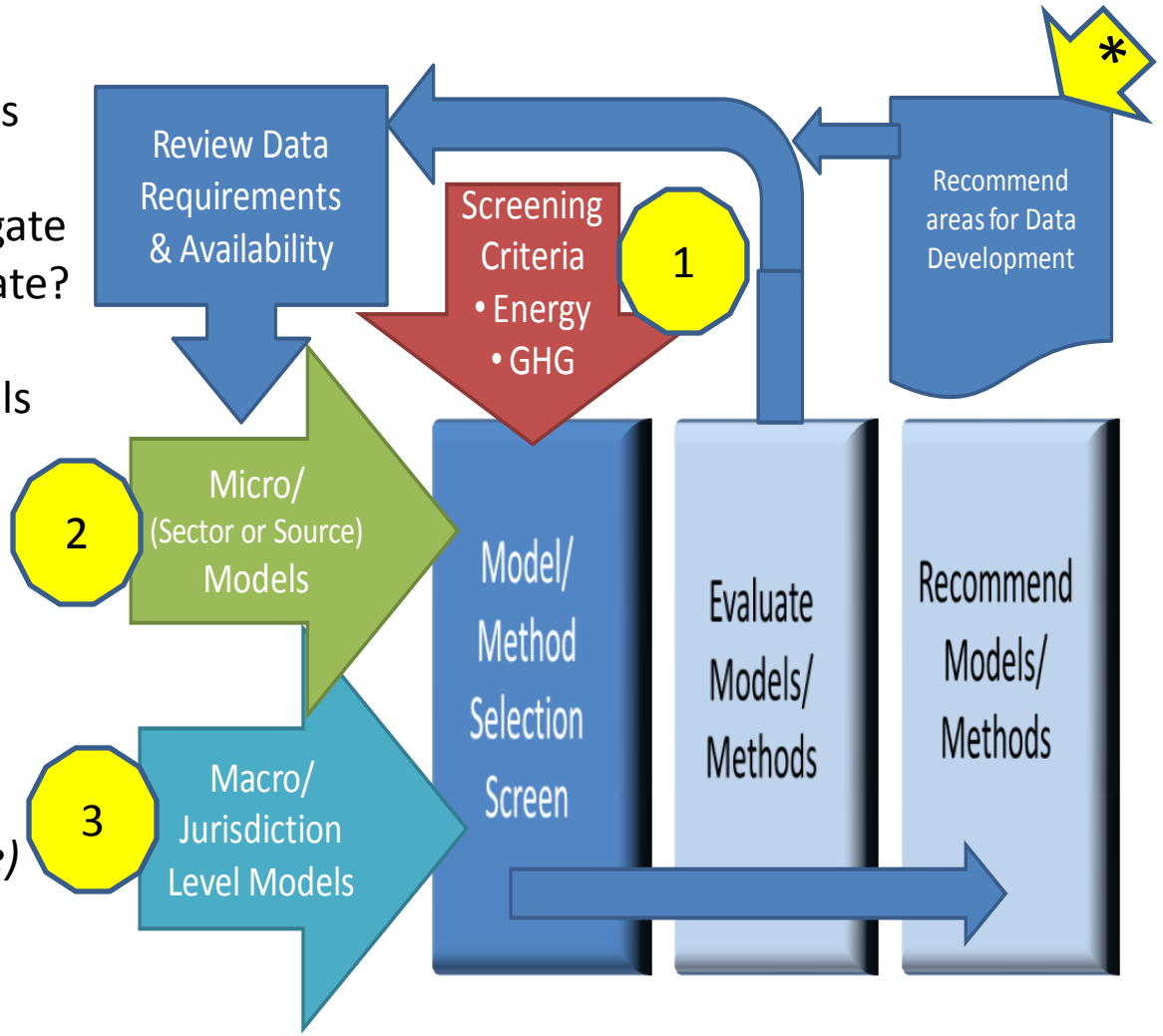
Context and Process Review

Proposed Review Process

1. CCEEET Objectives/criteria
2. Identify/review Micro models
   - Identify/Screen
   - Present list (5-6) to investigate
   - Review -Applicable? Accurate?
   - Data requirements/issues
3. Identify/review Macro models
   - High level inventory
   - Identify/summarize
   - Linkages to micro?
   - Review/compare using CCEEET criteria/objectives.
   - "Fit" with current tools?
   - Identify data needs/issues

   (expect data to be a key issue)
4. Develop Draft/Final Reports



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Screening Criteria

1. Select models that match to the pattern of energy use and GHG emissions in NL
2. Models should accurately reflect actual energy use and emissions and are applicable in the NL context
3. Give preference to models that can be used with or linked to existing models and potential macro models.
4. Consider resource availability for model & data.

   (Note – 3rd criteria will be considered further in next phase of project while reviewing macro models).

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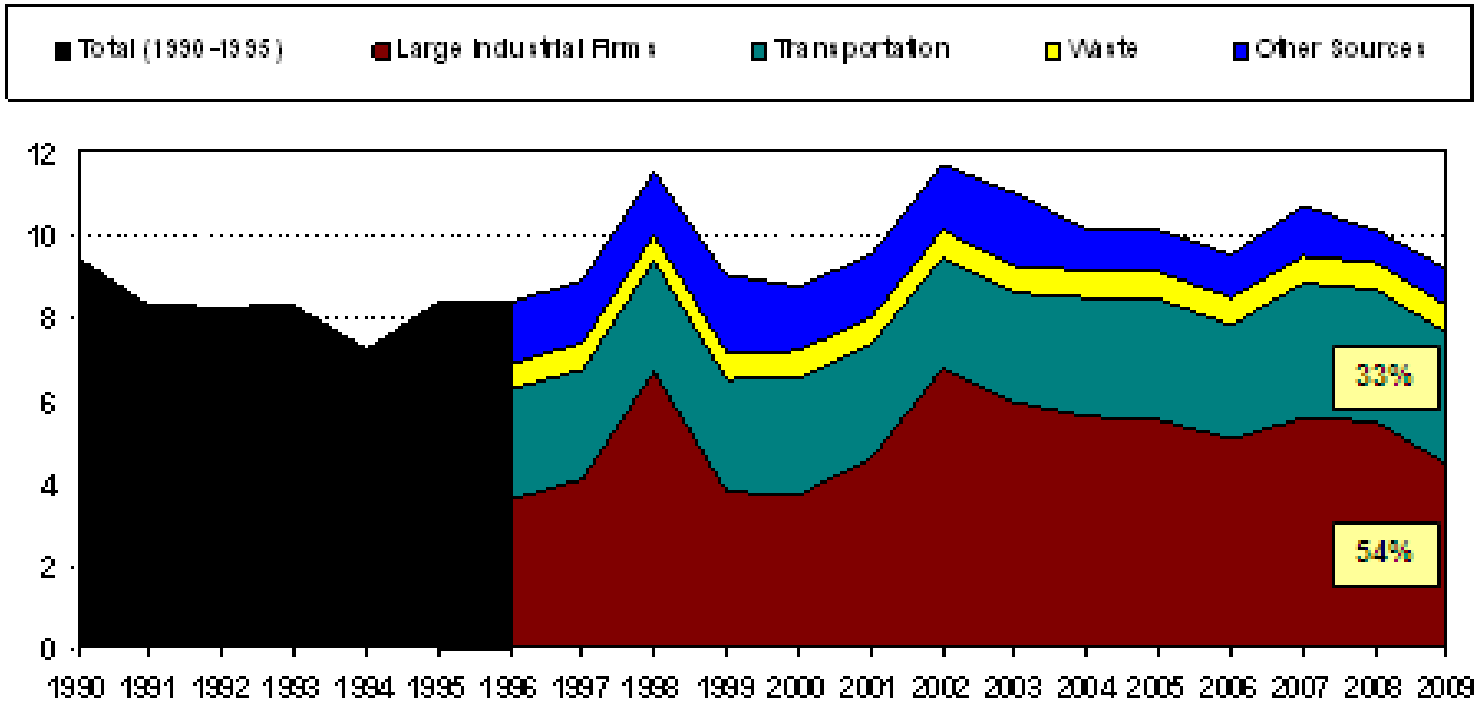
Historic Pattern of GHG Emissions

(MT)



Source: Estimated from National Inventory Reports and reported facility data, Environment Canada, and internal estimates. Fugitive emissions from oil refineries and net forestry emissions not included in provincial data.

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Characteristics of NL GHG Emissions

Sector	Approx. Share of GHG Emissions	Characteristics of Sector	Emission Types

Large Industry
 	
(*8 reporting facilities totalled 4.38Mt CO2e in 2009).*
	46%	• <10 large facilities
		  ○ 3 mines
		  ○ 3 oil and gas facilities
		  ○ 1 Petroleum Refinery
		• Includes off-road transportation (about 6.3% of total provincial GHG emission)
			Energy-related
			Process
			Fugitive

Transportation	33%	• 80% due to road transportation • 10% marine • 10% domestic air travel • International air travel not included in Inventory.	Energy-related (primarily)
Power Sector	8%	• Holyrood GS owned by NL Hydro	Energy-related
Waste/ Wastewater	6%	• Over 200 landfills sites of various sizes (3 large); expected to be reduced to about 40 sites by 2020. • Wastewater sites assumed to also be concentrated.	Primarily process related –
Other **(Residential, commercial and light industrial buildings and processes)**	7%	• Diffuse decision making. • Limited end use or sub-sector data	Energy-related

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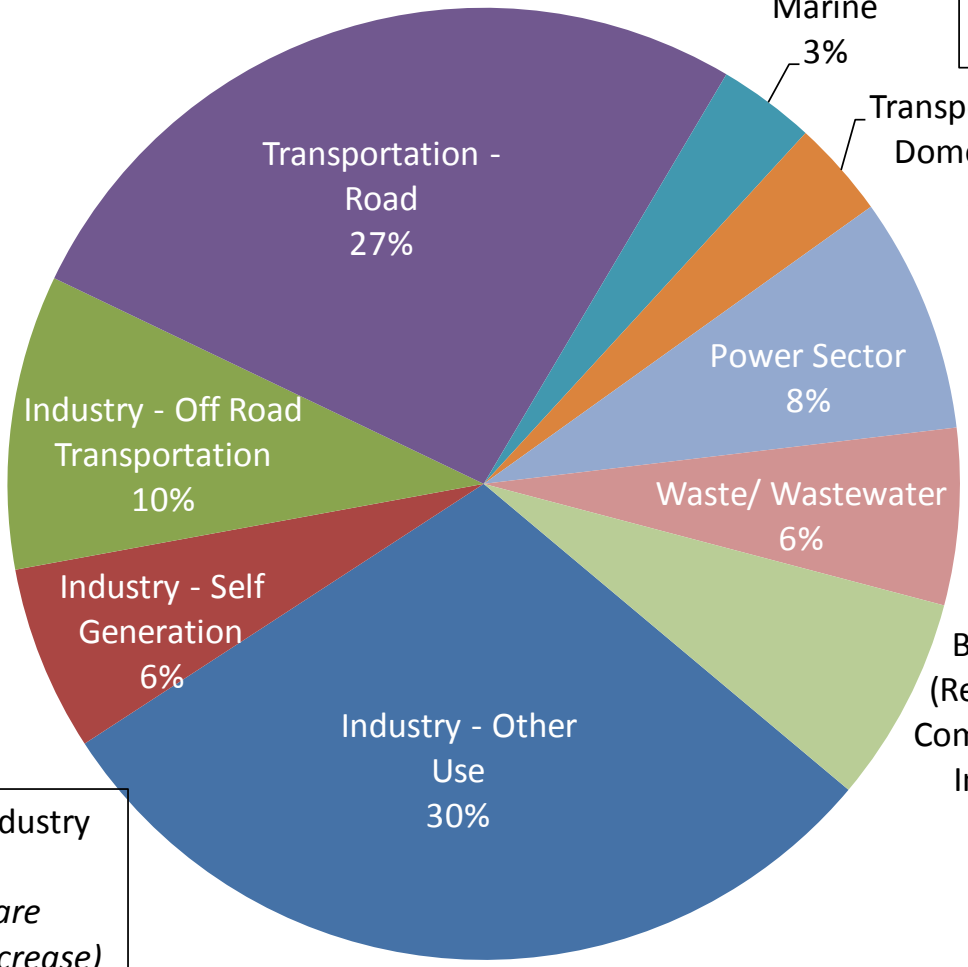
Approximate Distribution of GHG Emissions



Total Transportation
37%
(plus Off Road)

Total Large Industry
46%
(Note: Share expected to increase)

Models Reviewed

Models & Tools Reviewed*

Energy Simulators Buildings/Equipment	Transportation	Waste & Wastewater	Other
Residential HOT2000 & HOT3000	*On Road*: GREET, MOBILE6/MOVES, GHGenius, COMMUTER.	*Waste Management*: WARM, IWM, Cdn. Calculator	RETScreen (renewables and energy efficiency decision support tool)
Commercial EE4, eQuest	*Off Road* – NONROAD	*Landfill Gas*: LandGEM	*Large Industry* – Benchmarking & Best Practices.
Industrial end-use tools (from US DOE/NRCan -) CanMOST, AIRMASTER+, FSAT, PHAST, Boiler Calc., Daylighting123)	*Marine* – TEAMS		
	Air – ICAO Carbon Calculator		

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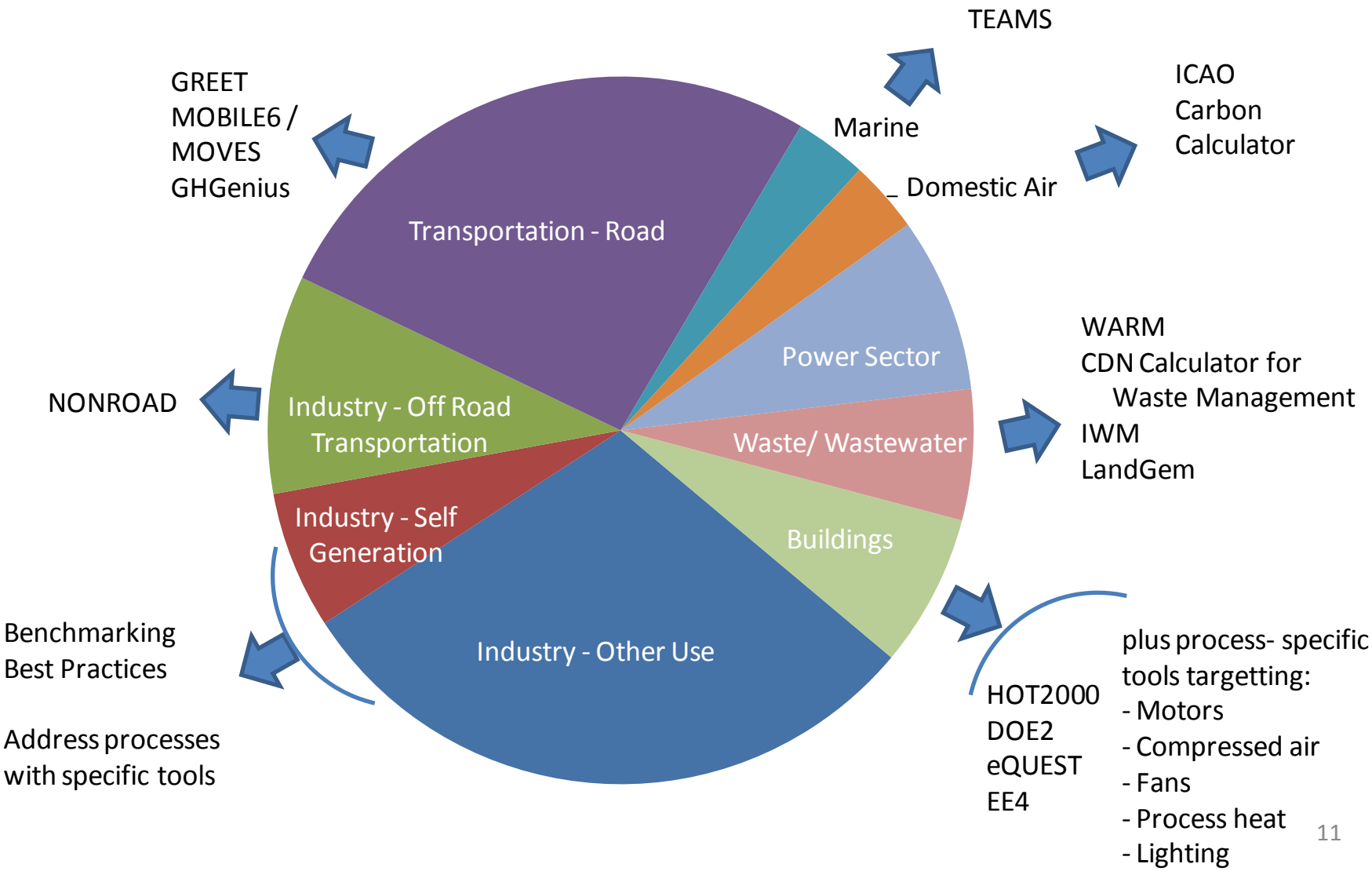
* Note: Macro models can also be used to model most areas.

Mapping of Tools to GHG Emissions



Building Simulations

Building Simulations

- Building related energy use accounts for about 7% of NL emissions and roughly double that share of energy use plus a share of electricity market).
- Simpler models used for residential housing/more complex for commercial, institutional and industrial
- Most building simulations for commercial buildings built around DOE2 (industry standard with long history of development).
- DOE2 complex process requiring detailed inputs, not easy to use - requires knowledge of both model and building science.
- NOTE – All of the models reviewed in this project are available at no charge – most from government sources

Building Simulations – HOT2000

- Developed by NRCan – tested by IEA BESTEST
- Widely used (685,000 home ratings) – and as compliance program.
- Addresses envelope, HVAC, DHW and electric base loads.
- Models interactions between infiltration/ventilation, effective R value in walls & windows, thermal mass, etc.
- Easy to use, GUI interface, templates available – though user can specify inputs.
- Includes climate data for 9 NL locations
- Working group discussing means of improving ability to match actual energy use. (i.e. doesn't explicitly recognize devices such as low flow showerheads, aerators, front loading washers but water demand can be adjusted by user)

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Building Simulations – HOT3000

- One of variants of HOT2000.
- Used to test new designs and non-standard designs
- More versatile calculation engine – ESP-r
- Allows improved evaluation of designs including passive solar, TOU rates, load shifting/thermal storage systems, multiple thermostats, and scheduled internal gains.
- Inputs and process otherwise similar to HOT2000.

Building Simulations – eQUEST

- US DOE model based on DOE2 – but simplified
- Goal to allow modelling of “state of the art” building technologies without extensive modelling experience.
- Compromise between complexity and ease of use.
- Hourly model of energy use for a one ear period.
- Uses wizards to assist in building creation and energy choices
- Schematic design wizard allows user to describe key architectural/mechanical systems for initial design in <1 hour
- Energy efficiency wizard helps user to build and compare up to 9 alternative designs
- Design wizard used later in process for more detailed design.
- User can specify inputs or use defaults.

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Building Simulations – EE4 (v1.7)

- Developed by NRCan & NRC as MNECB compliance model.
- Recognized by Cdn. Green Building Council for LEED certification & by some utilities for incentive programs.
- Automatically develops 'reference building' based on user inputs (advantage to designers).
- Detailed energy transmission, solar, internal & ventilation checks built in, range of primary/secondary systems & components & allows flexible scheduling of occupancy/loads.
- NOT designed to simulate all loads in buildings or predict ACTUAL building energy use.
- Detailed inputs (potentially thousands) – user can specify.
- Includes a number of unalterable assumptions (compliance).

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Building Simulations (Commercial)

Comparison – eQUEST & EE4

EE4

- Automatically models a 'reference' building that meets MNECB
- Limited ability to model building that don't meet MNECB (due to built in assumptions)
- Not designed to match actual building energy use.

eQUEST

- Must build own reference building.
- More flexible in modelling "non-compliant" buildings or non-standard features or designs.

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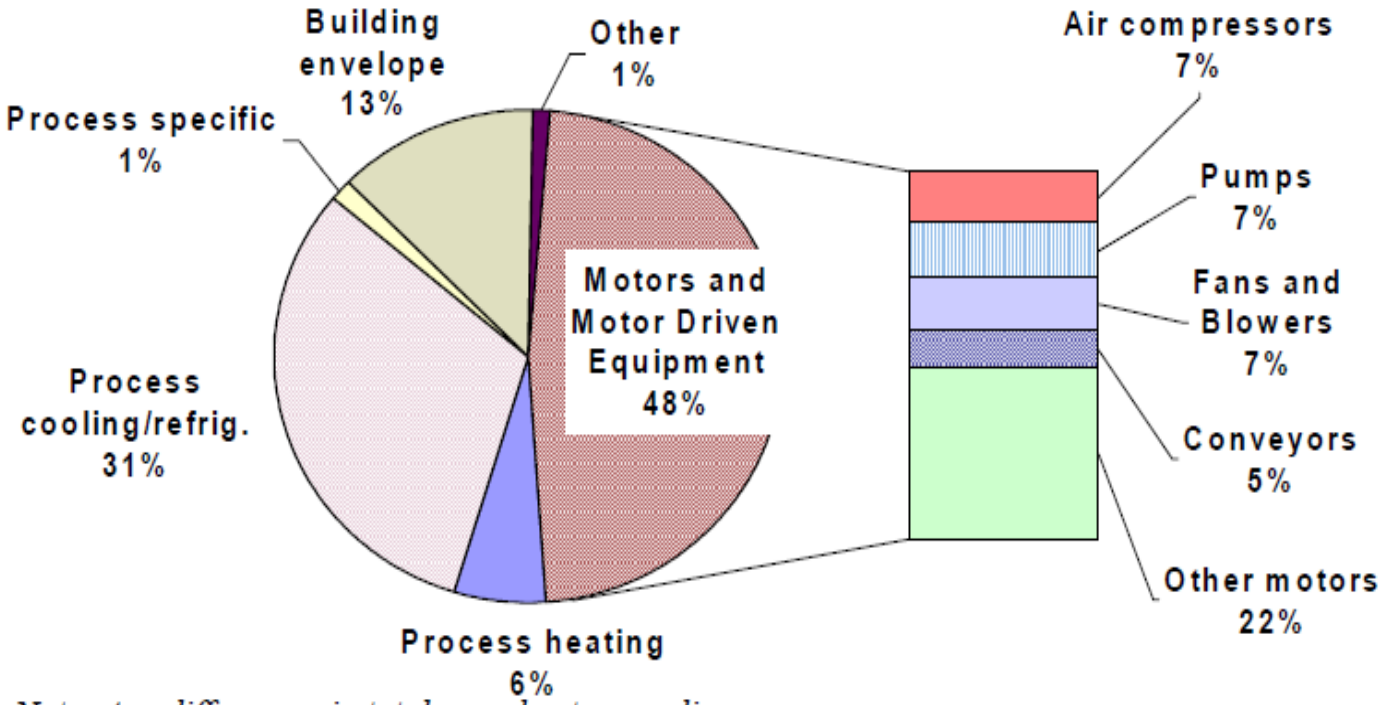
Process Energy Tools

Process Energy Tools



* from Marbek Industry sector study.

- Applies to both purchased and self-generated electricity
- Key end uses for electricity – motor drives, fans & pumps, and compressed air.
- Assume process heat/boilers are key non-electric end uses.

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Process Energy Tools

- The bulk of Large Industry energy use and GHG emissions *(>1/2 of total for province)* arise from industrial processes.

CanMOST

- NRCan Motor selection tool based on US DOE MotorMaster.
- For 3-phase motor purchase, repair and replace decisions.
- Database of 43,000 motors, including 575V CDN only motors
- Identify inefficient and oversized motors.
- Calculates energy savings, simple payback, cash flow, NPV and ROI before/after taxes as well GHG reductions.
- Province-specific rates & power system mix.

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Process Energy Tools

AIRMASTER+

- Compressed air management tool from US DOE
- Allows users to analyse existing systems & evaluate upgrades
- Models rotary screw, reciprocating, and centrifugal compressors in different configurations
- Evaluates options including reduced leaks, pressure, run time, improved efficiency of end use devices, loading/unloading sequencer, cascading set points, and addition of primary receiver volume.
- Evaluates energy use, operating and life cycle costs.

FSAT

- US DOE program to evaluate how well existing systems are operating and economics of upgrades.
- Calculates energy and cost savings (not GHG emissions)

Process Energy Tools

Daylighting123

- NRCan and NRC developed tool allowing user to easily develop 3D building model to test daylighting schemes.
- Can evaluate integrated thermal/lighting impacts.
- Uses latest occupant behaviour models.
- Models windows, skylights and effects of shading devices
- Estimates monthly demand & energy use for lighting, cooling and heating under alternate designs.
- Graphic & tabular output plus 3D building image & lighting metrics.

Process Energy Tools

Process Heat Assessment Tool (PHAST)

- US DOE tool to assess electro-technologies and fuel-fired process heat improvements – (different models for electric/fuel).
- Helps users survey process heat equipment, identify most energy intensive equipment and develop heat balance for selected pieces of equipment (produces Sankey graph of losses).
- Allows user to compare energy and costs under different operating conditions.

Boiler Efficiency Calculator

- NRCan tool to quickly analyse boiler efficiency and savings from upgrades including non-condensing economizers.
- Simplified model focuses on 80-90% of losses.

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Large, Energy & Emission Intensive Industry

Large Energy Intensive Industry

- Modeling and forecasting challenge - *requires specific knowledge of industry and economic future* - scenario approach suggested.
- **Benchmarking** – performance vs. comparable industries, with comparable processes. NRCan has benchmarked several of key industries (mining, refineries, P&P)
- **Best Practice** – provides guidance as to what has been done *(not necessarily indicative of what could be done). i.e. CAPP re fugitives.*
- **Process Tools**

  - Apply to many common end uses and applications.
- Can be used to evaluate potential & economics of projects.

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Transportation

On-Road, Off-Road, Marine & Air

Transportation

- Transportation energy demand and emissions driven by travel demand (VMT), freight demand (tonne-miles), mode choices, vehicle technology and fuel choices, and operator behaviour (i.e. Speed, idling, etc.).
- Different micro/macro models are used to look at travel demand and vehicle/fuel issues.
- Some emission models focus only on energy and emissions arising from operation. Others take life cycle assessment approach.
- Some LCA models address only fuel cycle (wells-to-wheels or WTW or well-to-pump – WTP) while others include vehicle life cycle as well.

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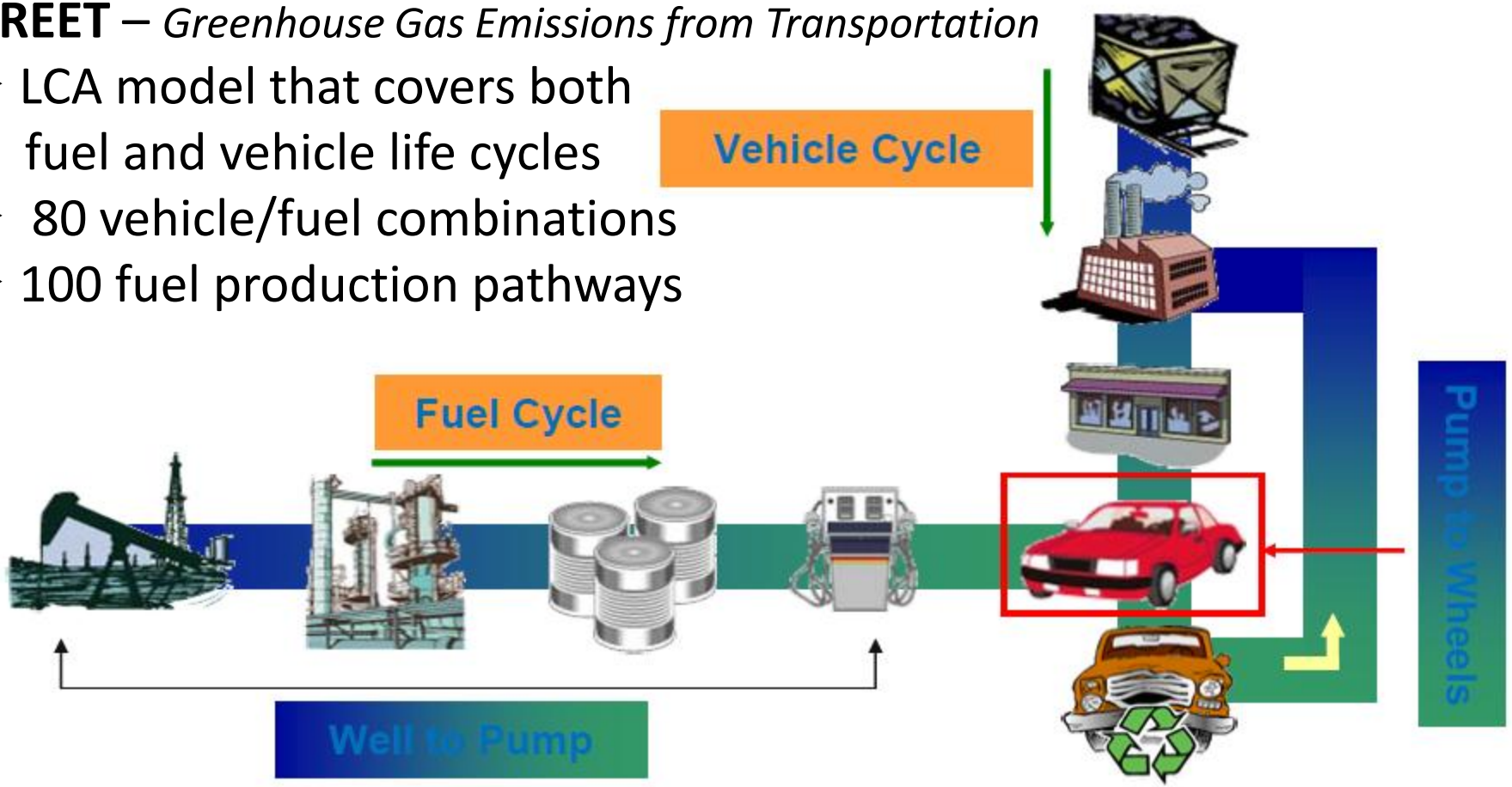
Transportation - Road

GREET – *Greenhouse Gas Emissions from Transportation*

- LCA model that covers both fuel and vehicle life cycles
- 80 vehicle/fuel combinations
- 100 fuel production pathways



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Transportation - Road

GREET *(cont'd.)*

- Heavy *(freight)* vehicles or other modes *(i.e. rail)* not modelled
- Estimates energy consumption and GHG/CAC emissions
- Calculated WTW, WTP, and WTW from proposed initiative.
- User can specify electric generation mix & key assumptions for each 5 year projected interval.
- Produces outputs on per mile basis – for urban, rural and total.

MOBILE6

- Industry standard model for air emissions developed in 1970's by US EPA.
- Now being replaced by MOVES.

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Transportation - Road

MOVES

- US EPA compliance model designed to replace MOBILE, NONROAD and National Mobile Emissions Model
- Currently only addresses only “On Road” emissions.
- Includes vehicle standards changes starting in 2012.
- Provides accurate estimate of GHG emissions – accounts for vehicle type, age, stock, operating speed, etc..
- For US results produced down to county level – not designed for Canada.
- Used for inventory development & policy evaluation (technologies, fuels, travel incentives)
- Detailed outputs in database format – emissions by type down to 1-hour intervals; plus activity indicators (population, distance travelled, etc.)

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Transportation - Road

GHGenius

- NRCan tool based on LEM (Lifecycle Emissions Model).
- calculates full fuel/vehicle cycle GHG/CAC emissions.
- Default data provided to simplify use; user can specify inputs.
- Light vehicles - 65 fuel types (plus fuel cells).
- Freight - 16 fuel types.
- Default values from Canadian and US sources; emissions based on CDN version of MOBILE plus EPA AP-42.
- Model can be run for a region, national or continent.
- Outputs include CO2e by fuel cycle stage, vehicle manufacture, and fuel/vehicle combinations.
- Sensitivity solver and Monte Carlo tool built in.

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Transportation - Road

COMMUTER

- Developed by US EPA to assist planners to estimate impact of commuter and travel demand management programs.
- Tool estimate CAC/CO2 impact of VMT reduction initiatives.
- Simplified TDM model - allows limited inputs & ease of use
- Trade off – doesn't consider vehicle mix, speed, etc..
- Uses default emission factors from MOBILE6; TDM from FHWA
- Uses a Logit model based on US travel data.
- Can run multiple strategies together, for different densities.
- User can supply key inputs, but model operates based on information re US travel patterns.

Transportation - Off Road

- About 6% of provincial emissions due to off-road energy use.

NONROAD

- US EPA model to estimate off road emissions (to quantify for compliance, etc.) – excluding commercial marine & rail.
- Estimates both GHG's and CAC's from 80 basic and 260 specific types of off-road equipment.
- Fuel types – gas, diesel, CNG, LPG.
- Uses information on equipment population, Hp, average load factors, hours of use, emission factors and deterioration to estimate emissions – back to 1970 or out to 2050.
- Outputs by geographic area (US), equipment type, source class, and fuel (can be imported into Excel).

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Transportation - Marine

TEAMS – Total Energy & Emissions Analysis for Marine Systems model

- Energy use and emissions driven by vessel design, fuel choice, distance and speed (logistics) as well as engine technology.
- TEAM development sponsored by US DOT; uses same method for fuel life cycle analysis as GREET (all up/down stream stages of fuel cycle) to estimate 3 GHG's/6 CAC's.
- Provides well-to-hull energy and emissions for passenger ferry, cargo and container ships; for inventory or to evaluate alternative modes, fuels and technologies.
- User can modify some fields – most for fuel cycle.
- Outputs energy use/emissions and change by fuel cycle stage and provide separate results for main/auxiliary engines/fuels.

Transportation – Air Travel

ICAO Carbon Emissions Calculator

- Provides a tool for estimating emissions associated with air travel, reductions achievable through travel demand management initiatives.
- Designed for consumer (ease of use), but methods reasonable & transparent. Use 50 archetype aircraft, addresses passenger load/class and cargo ratios.
- Assumptions (i.e. allocation between passenger and freight) clearly indicated; but not adjustable.
- Provides estimate of CO2e emissions for flight.

Waste & Wastewater

Waste & Wastewater

- Two types of models:
  1. Tools to evaluate alternative waste management strategies.
  2. Tools to estimate GHG emissions from a landfill facility.
- Waste Management evaluation tools estimate life cycle emissions – but definition of life cycle varies:
  - Full life cycle of materials – WARM, Canadian Calculator.
  - Life cycle from point of disposal – IWM tool.
- WARM developed by US EPA.
- Environment Canada built Canadian Calculator based on WARM (same methods but with some CDN additions and customization).

Waste & Wastewater

WARM

- US EPA tool designed to assess GHG emissions from alternative waste management practices (widely used in US).
- Develops baseline and alternate life cycle assessment.
- Covers 26 materials and 8 mixed waste streams, but doesn't address some (construction materials, electronics, household items, white goods).
- Default values & assumptions can be changed by user – *GWP values, landfill gas recovery practices.*
- Includes landfill carbon sequestration *(others don't).*
- One run required for each alternative case.

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Waste & Wastewater

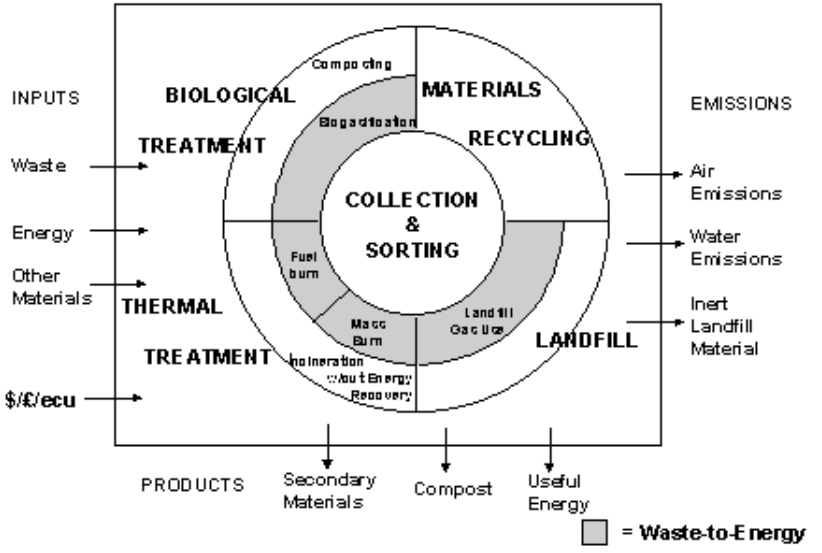
Canadian GHG Calculator for Waste Management

- Environment Canada (EC) model based on EPA WARM model adapted to CDN conditions.
- Includes recycling, anaerobic digestion, composting, combustion, and landfilling.
- Inputs and Outputs similar to WARM.
- EC adding materials – electronics and large appliances.
- Assumed waste stream based on Canadian data.
- Estimates GHG emissions from power sector based on provincial generation mix.

Waste & Wastewater

IWM – Integrated Waste Management model

- Developed by CSR (Corporations Supporting Recycling) and EPIC (Environmental and Plastic Industry Council); with later support from Environment Canada and others.
- Life cycle assessment model, but only from point of disposal.
- Assumes like-for-like recycling.
- Available from University of Waterloo Faculty of Environment.
- Limited information available when researched – site under renovation.



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Waste & Wastewater

LandGEM

- US EPA tool to calculate GHG emissions from a landfill facility.
- Uses relatively simple approach based on first order decomposition to estimate methane, CO2 and air pollutants.
- Default data based on actual data from US landfills.
- Comparison of model results with actual methane generation from 35 CDN landfills found this tool had most accurate results.
- Excel based (9 worksheet) model based on inputs re waste acceptance rates, years of operation (max. 80 years).
- Provides report on emissions, waste in place, etc.. Modelled methane output must be adjusted for air infiltration to estimate actual output.

Decision Support Tools

Decision Support – RETScreen

- Developed by NRCan with UN agency – used internationally.
- Decision support tool – provides common project assessment approach to renewable and energy efficiency projects.
- Covers wind, solar (passive, active, DHW, PV), biomass heat, GSHP, CHP, plus ocean and wave power (actually separate models).
- Climate data for some 6,500 ground stations from NASA
- Compares proposed system to conventional base case to estimate costs, energy production and emissions.
- User describes proposed system, costs, financial parameters, etc. – for simple (pre-feasibility) or full (feasibility) study.
- Report summarizes project, assumptions, energy production and financial performance (IRR, cash flow, ROI and NPV).

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Methods, Tools &Models Recommended for Further Review

Recommendations:

Sector	Recommended Method, Tool, or Model	Rationale for Selection
Buildings & Processes		
Residential	HOT2000	Industry standard for residential housing energy evaluation in Canada. Relative ease of use and flexibility allow adaptation to NL conditions. Model is used by other Canadian jurisdictions and subject to continued improvement and efforts to improve accuracy relative to actual energy use.
Commercial, Industrial and Other	eQUEST	Relatively easy to use, but offers flexibility for incorporating 'non-standard' design features or to apply to NL conditions. Reasonable level of support available. Provides most accurate representation of actual building use.
Processes Energy	Recommend use of all of tools presented as appropriate. Further analysis in this area not required. Tools selected could be expanded as information regarding key NL end uses is improved.	
Large Industry	Use of Benchmarking & Best Practices offers the most realistic means of evaluating the impacts of potential initiative for these customers. Accurately projecting future energy use and emissions will depend on both industry/organization specific information as well as the ability to project broader economic trends affecting the industries.	

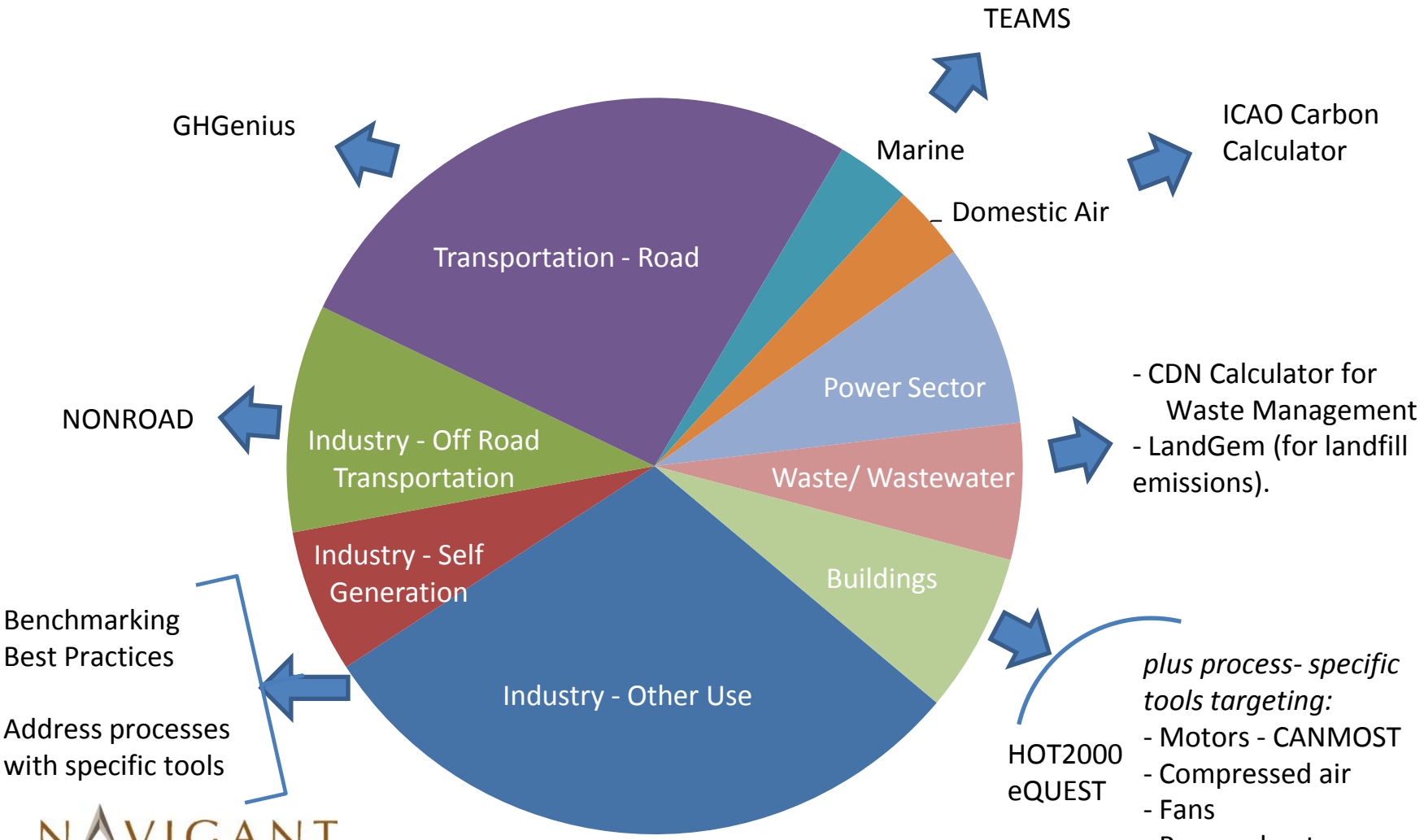
Recommendations:

Sector	Recommended Method, Tool, or Model	Rationale for Selection
Transportation		
Road – Vehicles	GHGenius	Quality/appropriateness of data critical to LCA. This tool based on CDN data. Provides ability to model full cycle emissions using a model customized to the Canadian context.
Road – Demand	Commuter	Relatively simple and easy to use model of transportation demand. Requires limited inputs. Builds on well established mission factors from MOBILE6. Drawback is that data used in assessing transportation choices is based on US data. Further investigation could evaluate whether this data is realistic in the Canadian and NL context.
Off Road	NONROAD	Industry standard for reviewing energy use and emissions from off-road equipment. Provides detail for different equipment types (i.e. excavators, trucks). If this capability is incorporated into the MOVES model as intended then consideration could be given to using MOVES rather than GHGenius and NONROAD.
Marine	TEAMS	Only known model to address marine transportation sector.
Air Travel	ICAO Carbon Calculator	Provides realistic and reasonably transparent methodology for assessing carbon emissions from domestic air travel. Methodology is available for review. Does not address issues of demand for domestic air travel. This could be

Recommendations:

Sector	Recommended Method, Tool, or Model	Rationale for Selection
Waste and Wastewater		
Waste Management Practices	Canadian GHG Calculator for Waste Management	Provides full life cycle emissions analysis based on industry standard US mode (WARM) adapted to Canadian conditions.
Landfill Gas Emissions	LandGEM	Widely used across US and Canada. Provides realistic representation of GHG generation compared to other available models. Reasonably easy to use. Default data provided for quick initial analysis, but can use site-specific data where available.

Recommended Tools Mapped to NL GHG Emissions



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Next Steps?

- Further investigation of selected “micro” models?
- Review of Macro models.
- Identify potential micro/macro interactions & data issues.

Thank you.

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