The performance of transportation options, in the context of climate Change

Luc Gagnon, Ph.D.,

Senior Advisor, Climate Change

Unité Environnement et développement durable,
Hydro-Québec

Gagnon.Luc@hydro.qc.ca

Climate has changed (IPCC); observations on averages

DECREASING

- Greenland and Antarctic Ice Sheets
- Glaciers and snow cover
- Arctic sea ice extent
- Area of seasonally frozen ground


Fig. 7.1a Muir Glacier, 1941


Fig. 7.1b Muir Glacier, 2004

IPCC, *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I*

Climate has changed; Observations on Extreme events

- More intense and longer droughts

INCREASES

- Extreme temperatures
- Frequency of heavy precipitation events
- Hurricane intensity

IPCC, *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I*

Future warming: vulnerable ecosystems

Speed of warming too fast to allow adaptation

- Tundra
- Boreal forests
- Coastal ecosystems: mangroves
- Coral reefs:
  essential for 30% of marine species

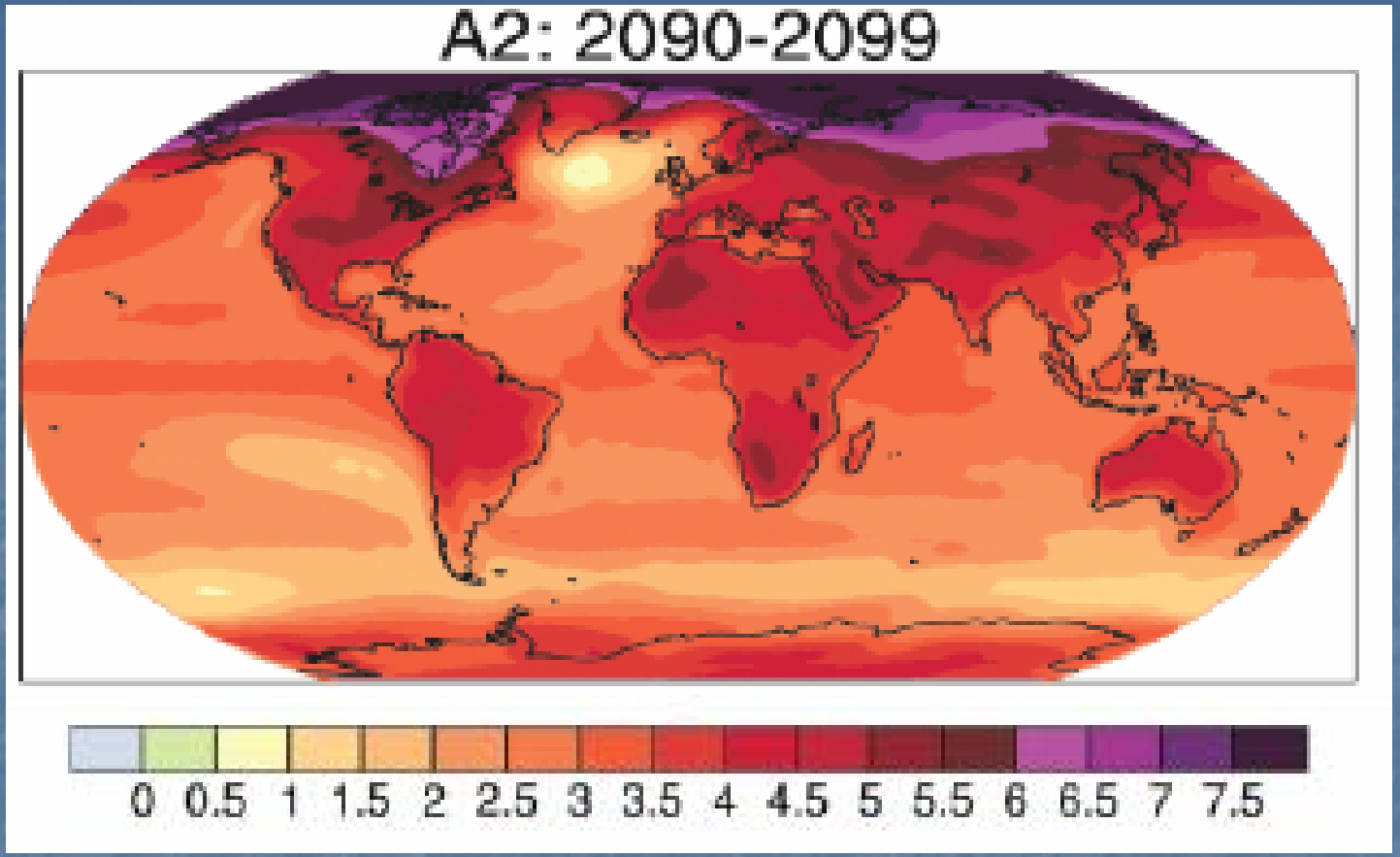
4°C warming → Nearly all coral reefs dead

IPCC, *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II*

Future warming: human risks

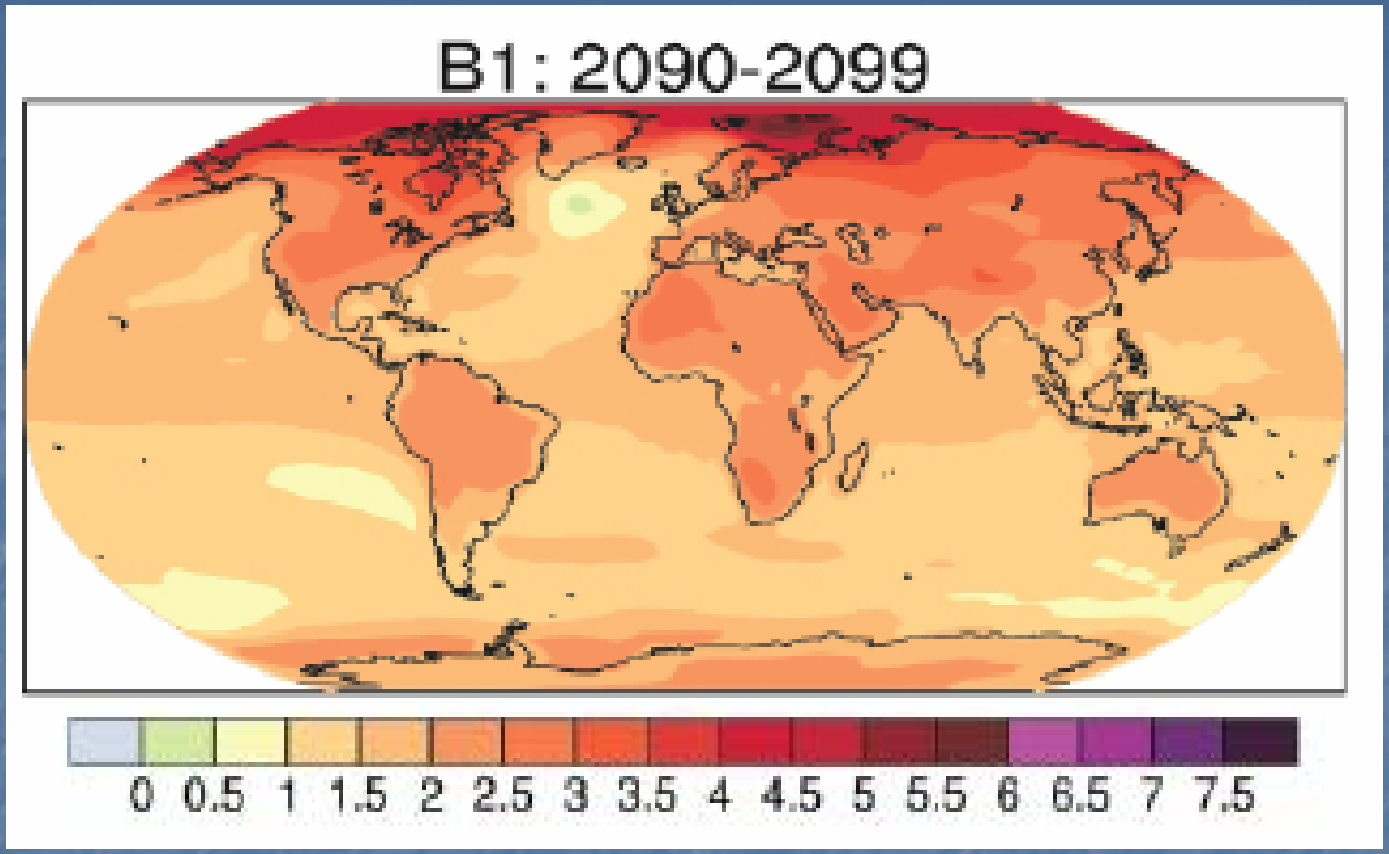
- **Most vulnerable regions** are
  Africa,
  Asian mega-deltas,
  small islands,
  Arctic
- **Most vulnerable sectors** are:
  - water in the dry tropics
  - agriculture in the low latitudes
  - human health in poor countries

IPCC scenario for about +4° C



Emission Reductions in 2050	
Developing countries	**Industrial countries**
Reductions in all regions, except Africa Relative to business-as-usual	About **55%** Relative to 1990

IPCC scenario for +2° C



Emission Reductions in 2050	
Developing countries	**Industrial countries**
Reductions in all countries Relative to business-as-usual	About **85%** Relative to 1990

Road Transportation and total GHG emissions in Canada

	% of total
Fuel used directly	**31 %**
LCA • fuel processing: +25% of final energy • building vehicles: +14% of fuel used	**13 %**
Average HFC leakage from air conditioning	**3 %**
Vehicle maintenance (lubricants, garages, tires…)	**1 %**
Activities required to build/maintain roads: • Concrete /metals for road and bridges • Energy to light highways	**4 %**
Urban sprawl imposes additional needs (increased length) for infrastructures: • sewers/ aqueducts • electricity/ gas distribution/ public lighting	**+**
	> 52 %

Life-cycle GHG emissions of a compact car

in California (Chester and Horvath 2009)

	g /passenger km travelled
Direct emissions from car (Internal combustion engine, consumption of 9 litres /100km)	**225**
Vehicle manufacture	28
Fuel production	37
Vehicle maintenance, tire production, insurance and administration	19
Roadway construction	32
Parking construction, maintenance	5
Road/ parking lighting	8
	354

Life-cycle assessment increase direct emissions by ≈ 60%

Direct emissions of urban transportation
(not life-cycle)

Option	Load factor	kJ / pass .km	CO_2 g. / pass .km
Sports utility vehicle (17 l /100 km)	1	5950	Gasoline = 405
Compact car (9 l /100 km)	1	3150	Gasoline = 214
	3	1100	
Diesel bus	50%	800	Diesel = 56
	100%	450	32
Electric tram	100%	300	Hydro ≈ 0
Metro (electric)	100%	130	Hydro ≈ 0
Pedestrian		150	Wheat = 2 (LCA)
Cyclist		60	Wheat = 1 (LCA)

Direct emissions of freight transportation
(not life-cycle)

Option	Load factor	kJ / tonne .km	CO_2 g /tonne .km
Diesel truck: large		600-1000	Diesel = 42-71
Train	100%	280-400	Diesel = 20-28
Boat	Average	Less than 200	Oil = less than 14
Pipeline	Average	170	
Freight plane	Average	7000-15000	Kerosene = 476-1020

Life-cycle assessment of technologies and alternative fuels

Included:

- Fuel extraction and processing
- Distribution of fuels
- Use of vehicles

Often excluded in assessment

- Building of cars
- Infrastructures

Fuel cells: Do they improve efficiency ?

Type of vehicle	Production and conversion steps	Efficiency of step	Overall efficiency
Conventional vehicle	-Oil process/ delivery	83%	15%
	-Internal combustion engine	20%	
	-Gears in transmission	≈ 90%	
Fuel cell vehicle; Central reforming of gas to H	-Gas process/ delivery	85 %	18%
	-Reforming of gas	67 %	
	-Compression, delivery H	90 %	
	-Electric conversion in fuel cell	40 %	
	-Electric motor	90 %	

Efficiency and GHG Emissions of Transportation Technologies

Source	Technology + upstream process	Vehicle Efficiency	Upstream Energy System Efficiency	Life cycle Efficiency	Life cycle CO_2 reductions
Gaso-line	ICE	17%	83%	**14%**	**Base**
	Hybrid electric	32%	83%	**27%**	**47-51%**
Coal Modern plant	Fuel cell, H by electrolysis	40%	Coal: 30% Electrolysis 70%	**8%**	**87% increase**
	Battery powered electric	80%	30%	**24%**	**20-30%**
	Tram; Overhead line	95%	30%	**29%**	**82%**

Efficiency and GHG Emissions of Transportation Technologies

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Gaso-line	ICE	17%	83%	**14%**	**Base**
Gaso-line 50%, **Hydro** 50%	Plug-in hybrid electric	32% 80%	83% 93%	**50%**	**72%**
Hydro	Battery powered electric	80%	93%	**74%**	**98%**

Performance of Ethanol Options

Energy Source	Energy Payback ratio	Life cycle CO_2 relative to gasoline	Source of data
Corn	1.4	+13% -13% -25% to -32%	Delucchi 2004 Farrell *et al.* 2006 Wang 2001, 2005
Sugar Cane	8.3	-87% to -96%	Macebo *et al.* 2004
Cellu-losic	10.3	-75%	Wang 2005 Tahara 2001

Performance of Bio-diesel Options

Energy Source	Energy Payback ratio	Life cycle CO2 relative to diesel	Source of data
Waste vegetable oil	5 to 6	-92%	Elsayed *et al.* 2003 Beer *et al.* 2001
Rapeseed	1.4 to 3 3	-40% -21%	Azevedo 2005 ADEME/DIREM 2002 Larivé 2005 Armstrong et al. 2002
Soybeans	1.4 to 3.4	+107% U.S. -53% Netherlands	Azevedo 2005 Delucchi 2003 NOVEM 2003

Life-cycle Assessment of biofuels: methodological issues

Input:
- Oil for tractors and machinery
- Natural gas in fertilizer
- Source of electricity in processing

GHG emissions often reduced due to natural gas and clean electricity

- GHG emission factors of biofuels do not consider alternative use of soil: if a forest is cut to produce biofuels, overall emissions can be larger than oil

Conclusions

- The most efficient option:
  direct use of electricity in public transit:
  trolleybuses, trams, electric trains
- Some biofuels can help reduce GHG emissions,
  but not ethanol from corn
- For cars and trucks:
  - Now Hybrid electric
  - In a few years Plug-in hybrid electric
  - Mid term Battery powered electric

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