Annex IX Technical Conference

New developments related to the World multi-region MARKAL/TIMES model

Maryse Labriet*, Richard Loulou
Amit Kanudia, Kathleen Vaillancourt
Group for Research in Decision Analysis (GERAD)
Montreal, Canada

Energy Models Users' Group: Global and Regional Energy Modelling
Hosted by ETSAP / TEPA

Taipei, April 4-7, 2005

Outline

1. Introduction
   The recent version of the World Multi-Regional MARKAL model

2. Cost-effective CO_2 abatement options (exogenous target)
   Some technology and energy results

3. Cost-benefit approach (w/o pre-defined target)
   Integrated MARKAL

4. TIMES model
   Preliminary results

World Multi-Region MARKAL model

Motivations

- Analysis of global energy/environment issues
  ⇒ multi-regional global model
- Effects of energy decisions on economy
  ⇒ price-elasticities of demands, which capture the impact of the variations of energy prices on demands
- Non-cooperative behaviors
  ⇒ integrated version (mitigation costs and damages are balanced)

Two early versions

- Collaborations with the Energy Information Administration (US-DOE) www.eia.doe.gov/bookshelf/docs.html (SAGE variant)
- and with the International Energy Agency (ETP project)
- Technology additions and overall calibration

Several variants of the model !

World Multi-Region MARKAL model

15 regions

- CAN, USA, MEX, CSA, WEU, EEU, FSU, MEA, AFR, IND, ODA, JPN, CHI, AUS, SKO
- OPEC / Non-OPEC for extraction, transformation and trade of fossil fuels

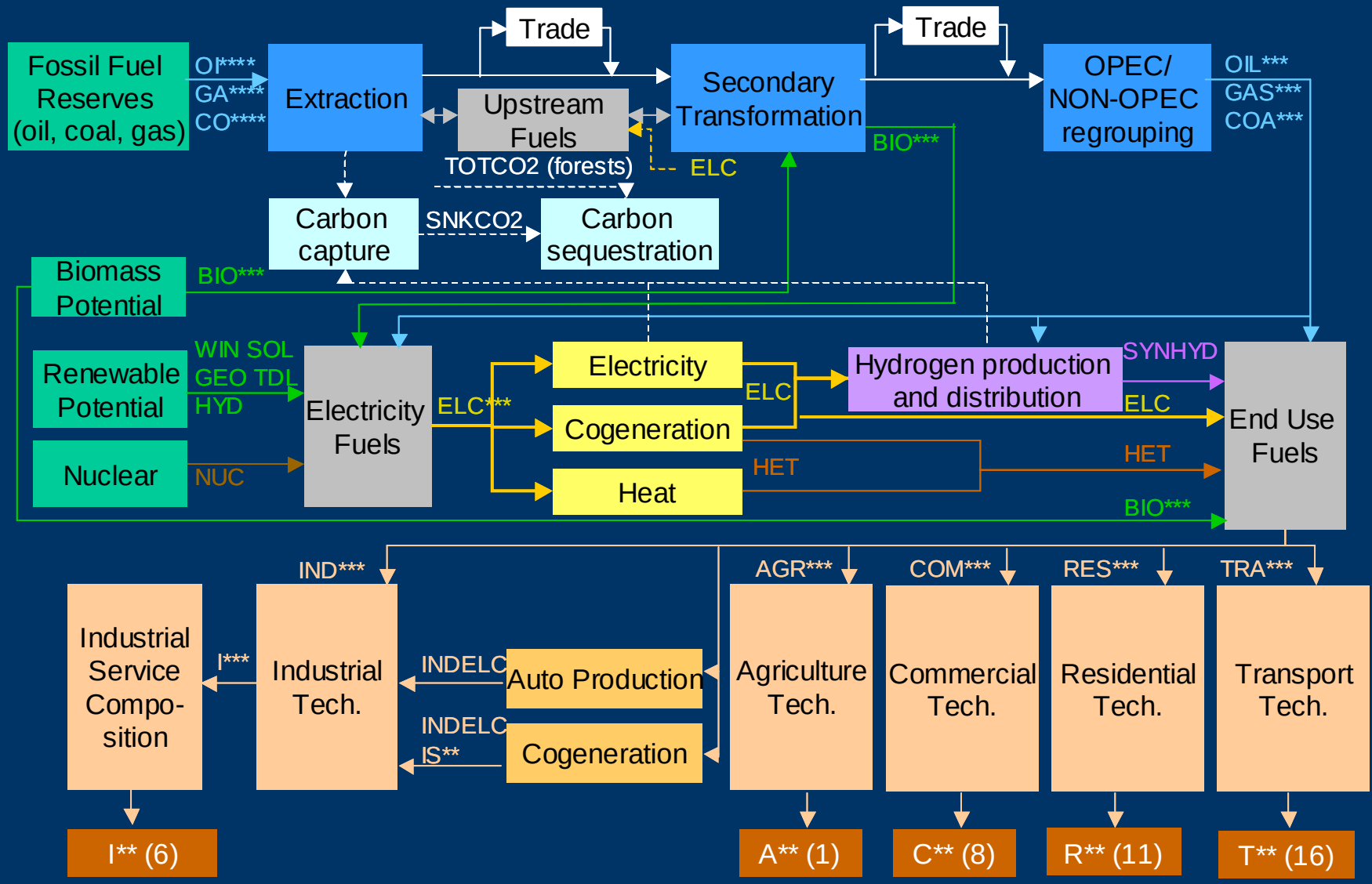
User-defined constraints

- To reflect specific policies or reproduce specific behaviors
- Eg: Nuclear policies
  Rate of penetration of new technologies and fuel substitution in end-use sectors (progressively relaxed in future)

Competitive energy markets except oil

- Gas, LNG and coal: endogenous international prices and trade
- Oil: exogenous price (cartel by OPEC)

Reference Energy System



42 energy services (exogenous) to be satisfied

Ex: veh-km driven by car, tonnes aluminum to produce, number apartments to heat, etc.

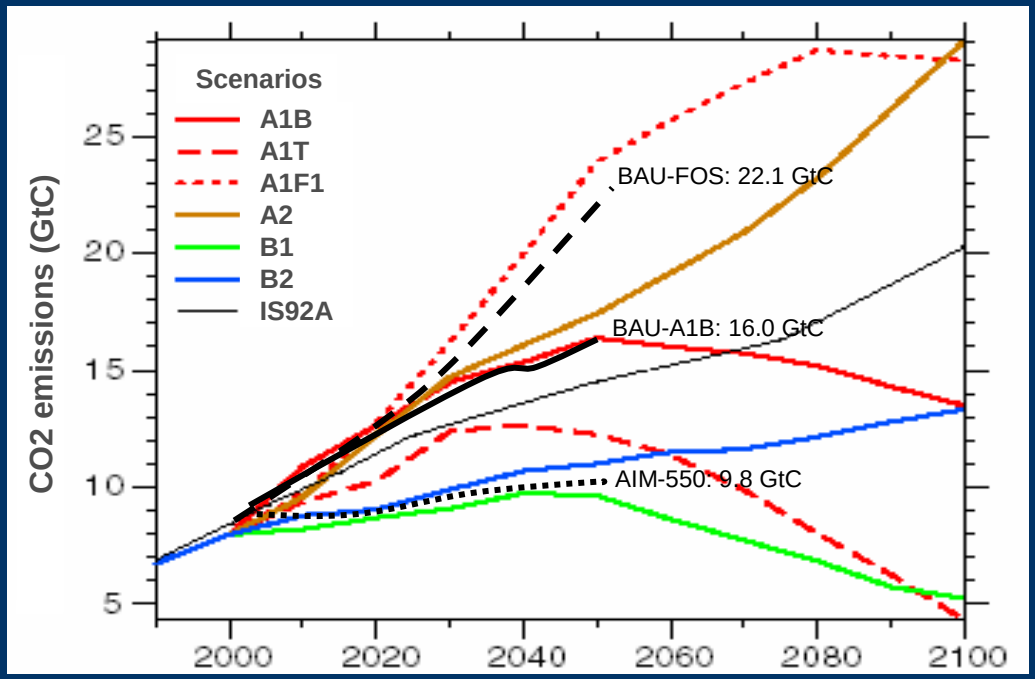
Calibration and CO_2 constraint

A1B-AIM (IPCC): economic growth, new technologies – reference scenario frequently cited in the literature

Alternative FOS scenario: lower (more realistic?) future share of non-emitting electricity generation (nuclear, renewable)

Exogenous CO_2 target: AIM-550ppm stabilisation trajectory ⇒ equivalent to a globally agreed CO_2 target

⇒ *Run in dynamic mode 2000-2050*



2. Cost-effective approach

Some CO_2 abatement options

Electricity generation and sequestration

Reduction	Sequestration = Up to 63% in 2050 (FOS)
Options	CCGT → CCGT-capture → coal-capture
Sensitivity	Marginal cost $CO2_{NO\ SINK-2050}$ x 2
Uncertainties	Potentiel? Technologies? Permanence?

Substitution in end-use sectors

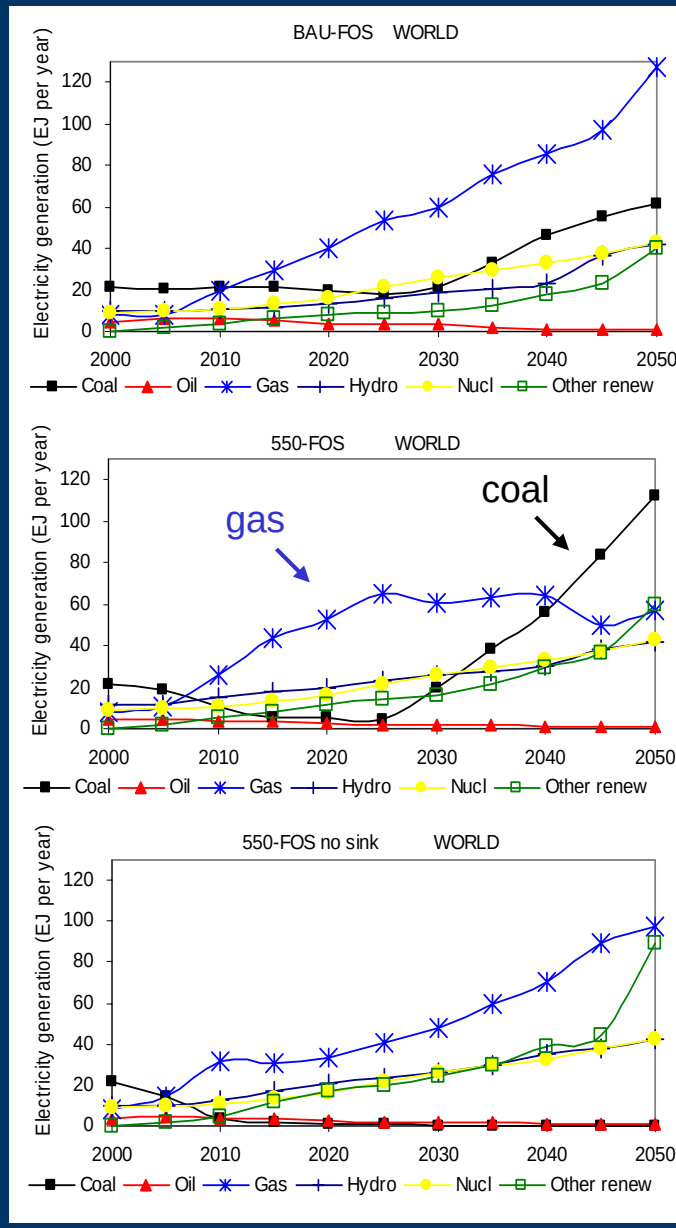
Transport	Biomass and enhanced efficiency
	Electricity, gas, hydrogen unchanged
Industry	Oil/Coal → Gas/Electricity
Resid/Comm	Few changes

Marginal costs

US$2000 / t CO2	2050
550-A1B	92.8
550-A1B not elastic	105.7
550-A1B no sink	191.8
550-FOS	113.2
550-FOS not elastic	124.5
550-FOS no sink	423.5

Detailed results available

- Emissions, primary and final energy, regional and sectoral costs
- Sensitivity: A1B/FOS, sinks, coal, decentralized elec, elasticity



Integrated MARKAL

How to model non-cooperative scenarios?

Facilitating hypothese (empirically verified):

Cumulative (2000-2050) damages* depend only on total cumulative emissions, irrespective of the shape of the trajectory, and the relationship is linear

$Cum\ D_i = a_i \times Cum\ Emi_{world} + b_i$

**Climate model and damages: Nordhaus and Boyer, 1999*

$\Rightarrow$ From the point of view of MARKAL, the decisions taken by region i depend only on the emissions of i

$min_i\ [C_i(X_i,E_i) + a_i\ (\Sigma_k E_k) + b_i] \Leftrightarrow min_i\ [C_i(X_i,E_i) + a_i^* E_i]$

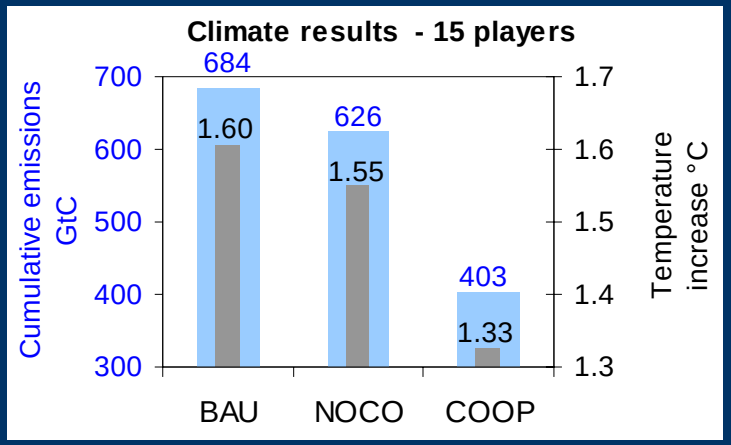
In MARKAL: Local optimisation problems with the appropriate damage factor

No-COOP $\Rightarrow a_i$ COOP $\Rightarrow \Sigma a_i$

Resulting emissions are endogenously computed (no pre-defined emission target)

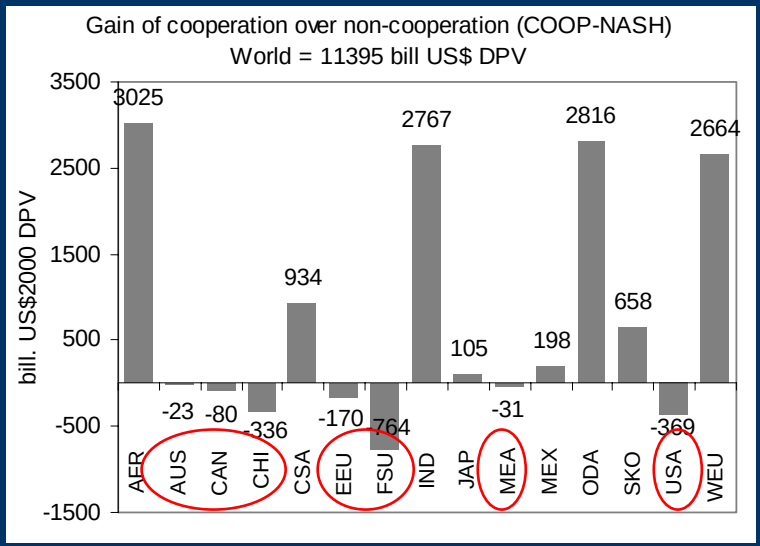
	a (US$/tCO2
AFR	4.15
AUS	0.01
CAN	0.02
CHI	0.68
CSA	1.84
EEU	0.04
FSU	-0.03
IND	3.66
JAP	0.31
MEA	1.33
MEX	0.65
ODA	4.15
SKO	1.06
USA	0.79
WEU	4.10
World	22.75

Gap between COOP and No-COOP (15 regions)



- No-COOP is closer to BAU than to COOP ⇒ collective problem
- World Gain = Cost No-COOP (15 singletons) - Cost COOP (efficient solution) ⇒ available for side-payments

How to share the surplus of cooperation to deter any free-riding behavior?



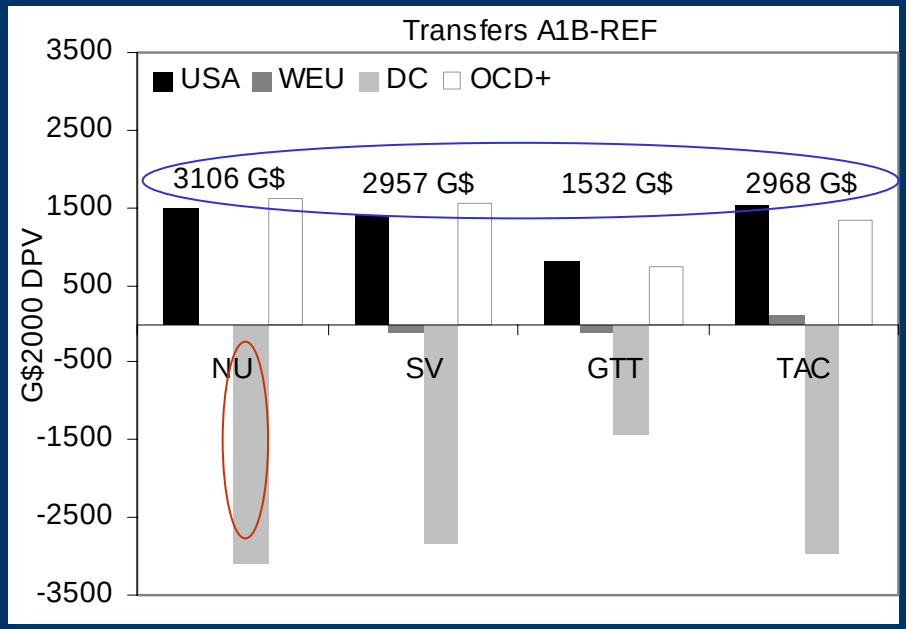
Assumptions:

- Allocation rules inspired from Game-Theory
- 4 players ⇒ to study 15 coalition structures ⇒ 15 runs ~ 30h

1 = USA
2 = WEU
3 = DC (Dev countries)
4 = OCD+ (Econony in transition + other OECD)

Ex. coalitions
1234; 123 4; 12 3 4; 234 1; etc.

Transfers (example)



DC "pays" to ensure cooperation.
DC is ready to "loose" a part of its gain under cooperation: DC is the region with the highest damages ⇒ highest gain under cooperation

USA and OCD+ won't cooperate w/o transfer

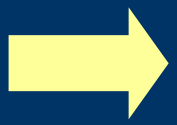
Other damages ⇒ a donor can become a receiver

Amount of transfers: smaller = easier implementation?

Also available:
- Regional allocation of the gain
- Sensitivity cases: level of climatic damages, distribution of damages, A1B&FOS

Different normative rules ⇒ Different allocations of the surplus and of transfers ⇒ Flexibility in policy-making

TIMES: The Integrated MARKAL-EFOM System



Will be standard tool for ETSAP and for the work done by ETSAP with EMF-22 (climate policies in the long term)

New features: Time horizon 2100, Variable length of periods, Vintaging, Flexible technologies (input/output), Demands based on drivers (POP, GDP, etc.)

Structure of the database: Mainly the same as MARKAL

Regions: 15

Data handling tools (VEDA_FE and VEDA_BE): upgraded

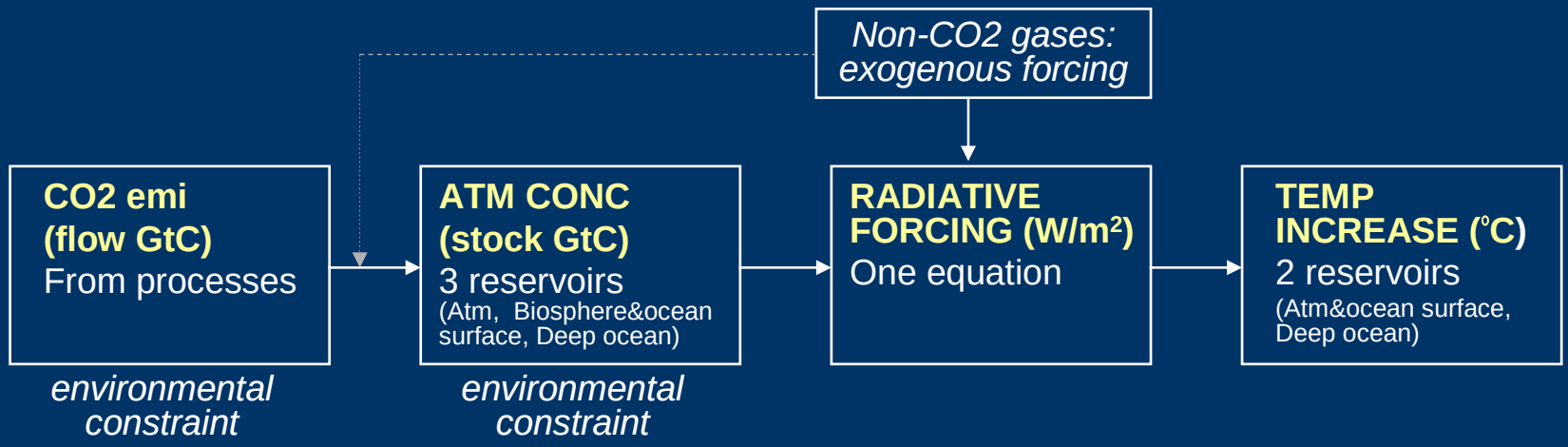
Calibration:

Calibrated to the Common POLES-IMAGE (used in the *Innovation Modelling Comparison Project*)

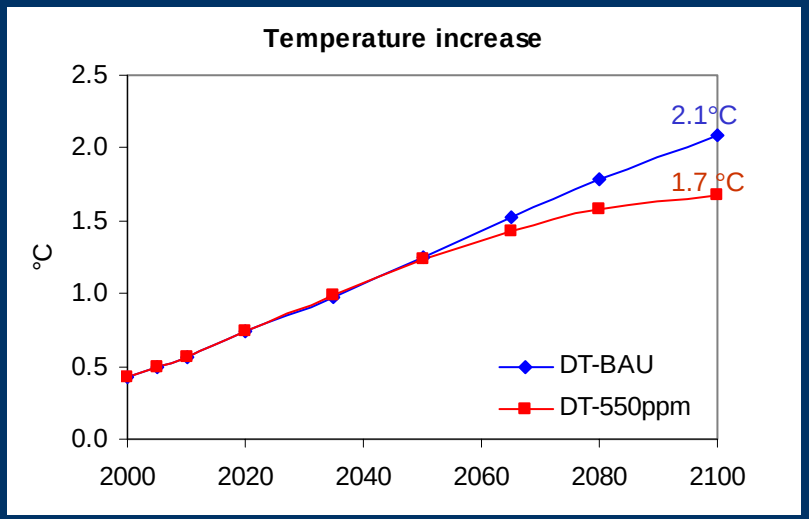
New assumptions related to availability of resources, future technologies (cost, efficiency), etc.

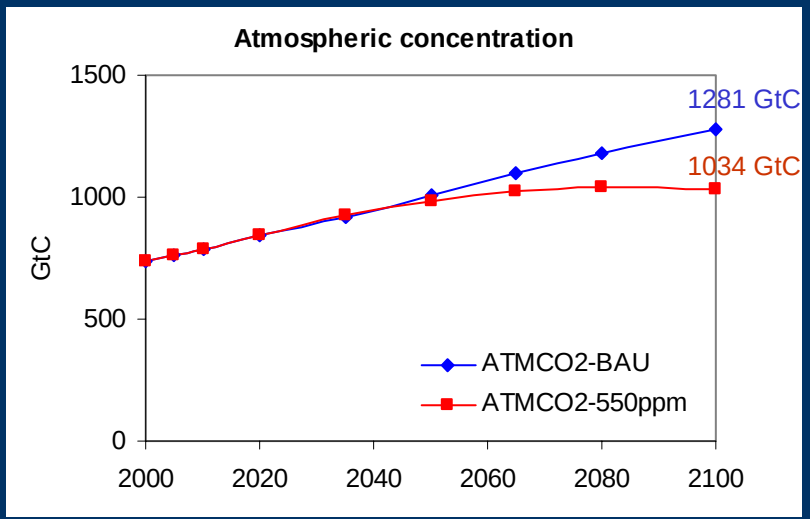
Climate module: Integrated in the structure of the model

The climate-module

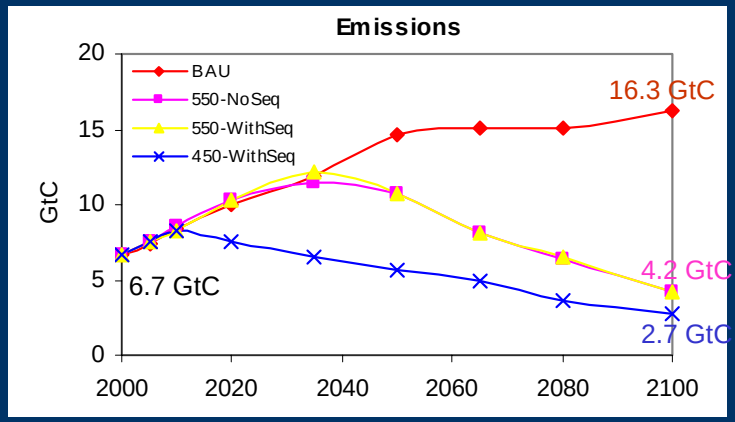


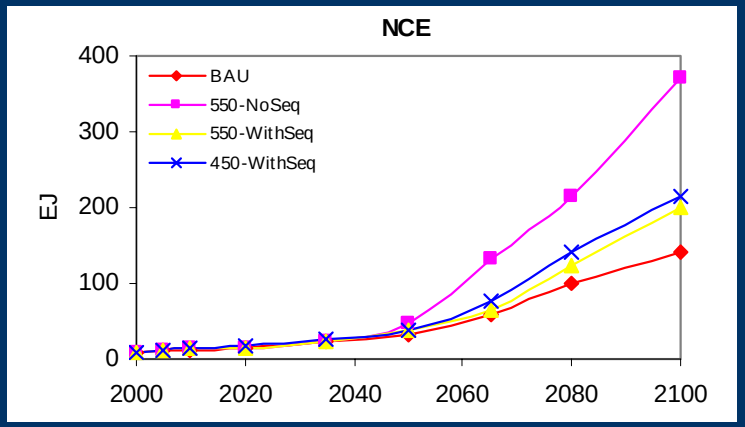
** Equations adapted from Nordhaus and Boyer (1999)*

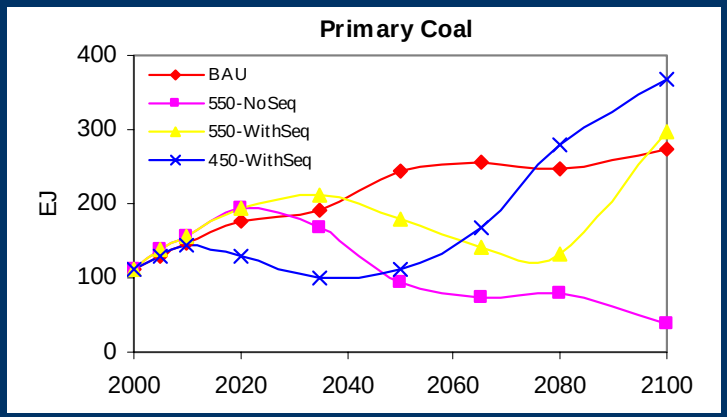


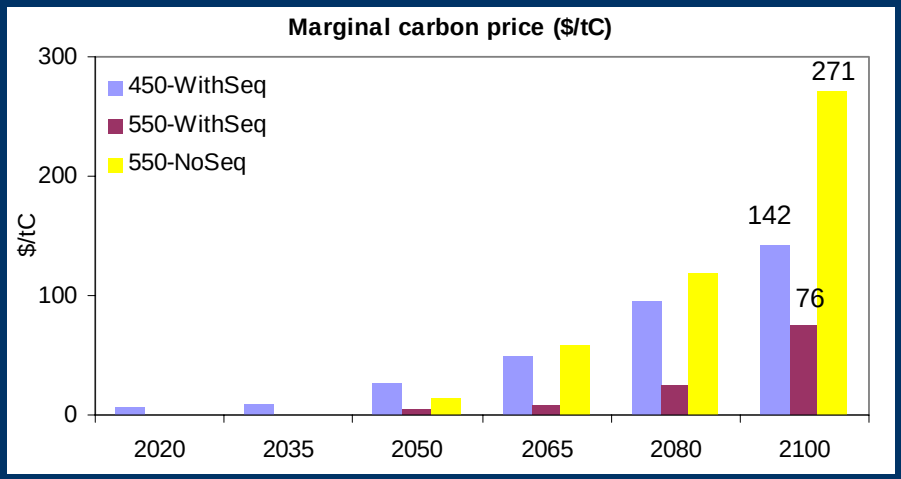


Some preliminary results









MARKAL / TIMES models available

Several variants and applications of the World Multi-Region MARKAL and TIMES Models

Include: Elastic demands, Climate module, Capture and sequestration, Hydrogen, Endogenous trade, Damages (only in MARKAL)

Further work:

- Regular update of technologies
- Hydrogen production and end-uses technologies
- Availability and costs of CO_2 capture and sequestration
- Proper modeling and calibration of non-CO_2 greenhouse gases and non-energy emissions (participation of ETSAP to the EMF-22)
- Trade of oil
- Number of regions (non-cooperative scenarios) and damages analysis (longer term, other damage functions)

Groupe d'Études et de Recherche en Analyse des Décisions (GERAD)
Group for Research in Decision Analysis
3000 chemin de la Côte Sainte Catherine
Montréal (Qc), H3T 2A7, Canada
Tel.: (514) 340-6053 ext.6033
Fax: (514) 340-5665

maryse.labriet@gerad.ca

Thank you