Climate policies: Insights from E3 and IA models

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Montreal, October 28, 2016

Outline

Outline

1. Introduction
   - Climate changes
   - E3 models
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   - Mitigation: Insights from TIMES
3. Conclusion

Strategies to address climate changes

- Human activities release **greenhouse gases** (GHGs) that trigger **climate changes** with negative impacts on the environment and human societies.
- Different **strategies** to address these threats:
  - **Mitigation** measures are options to **reduce GHG emission** levels (e.g., use renewables instead of fossil fuels).
  - **Adaptation** measures provide strategies to **reduce impacts** of climate changes (e.g., crops for new climate conditions, dykes to protect against sea level rises or medical preventions against spreading tropical diseases).
  - **Geoengineering** measures are options to **modify** the **climate system** (e.g., solar radiation management).

E3 model classification

- **Bottom-up**:
  - A techno-economic approach that leads to disaggregated models representing the energy sector with great details;
  - Example: **TIMES** (Loulou et al., 2005).
- **Top-down**:
  - A macro-economic approach that leads to aggregate models in the sense that they use aggregate economic variables;
  - Example: GEM-E3 (Capros et al., 1997).
- **Hybrid**:
  - Models that incorporate within the same framework both modeling approaches;
  - Example: MARKAL-MACRO (Manne and Wene, 1992).

Integrated assessment models

- **Integrated assessment** (IA) is an **interdisciplinary approach** that uses information from different fields of knowledge, in particular economy and climatology.
- **Integrated assessment models** (IAMs) are **tools** for conducting an integrated assessment, as they typically combine key elements of the economic and biophysical systems, elements that underlie the anthropogenic global climate change phenomenon.
- **Examples of IAMs** are **BaHaMa** (Bahn et al., 2008, 2010, 2012, 2015), DICE (Nordhaus, 1994, 2007), **MERGE** (Manne et al., 1995; Manne and Richels, 2005), RICE (Nordhaus and Yang, 1996) and TIAM (Loulou and Labriet, 2008).

Outline

Geoengineering strategy: A study with BaHaMa

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Is there room for geoengineering in the optimal climate policy mix?

CrossMark

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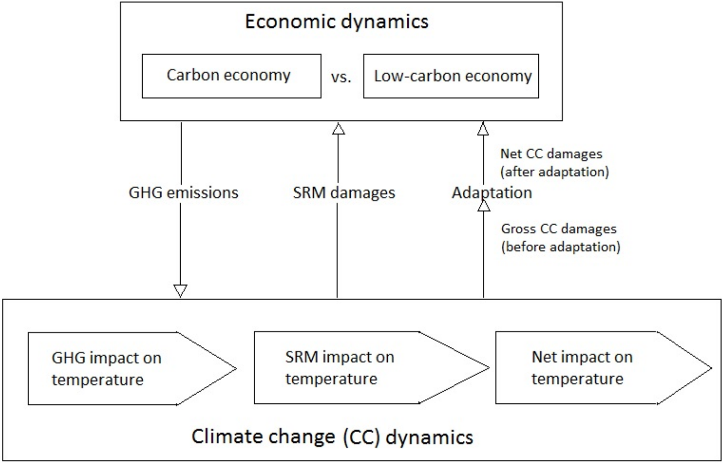
ABSTRACT

We investigate geoengineering as a possible substitute for mitigation and adaptation measures to address climate change. Relying on an integrated assessment model, we

BaHaMa: Modelling of an SRM strategy

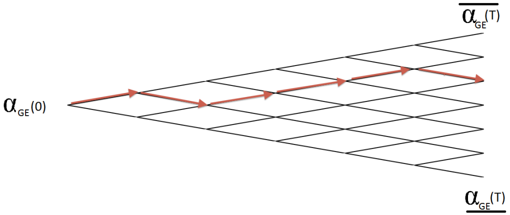
- **BaHaMa** includes a **Solar Radiation Management** (SRM) measure that targets the reduction of incoming solar radiation by injection of sulfur in the stratosphere.
- Possible **advantages** of SRM:
  - Ability to **keep temperature** levels **artificially low**, instead of reducing GHG emissions, at a low cost;
  - Provide quick and effective **temperature backstop** in case of abrupt climate changes, with rare but catastrophic impacts.
- SRM brings along **important risks**:
  - Cause **ozone depletion**;
  - **Alter ecosystems** and **trigger regional imbalances**;
  - Achieves only an **'artificial' reduction** in **temperature**: A disruption in sulphur injections would lead to a significant jump in temperatures (at the corresponding concentration level).

BaHaMa: Overview



Modelling the impacts of geoengineering

We rely on a binomial tree representation in order to model the evolution of side-effects over time (α_{GE}) and capture the uncertainty and variability in their size:



$$\alpha_{GE}(t) \rightarrow \begin{cases} \alpha_{GE}(t+1) = (1+u) \cdot \alpha_{GE}(t) & \text{with probability} \quad p \\ \alpha_{GE}(t+1) = (1+d) \cdot \alpha_{GE}(t) & \text{with probability} \quad (1-p) \end{cases}$$

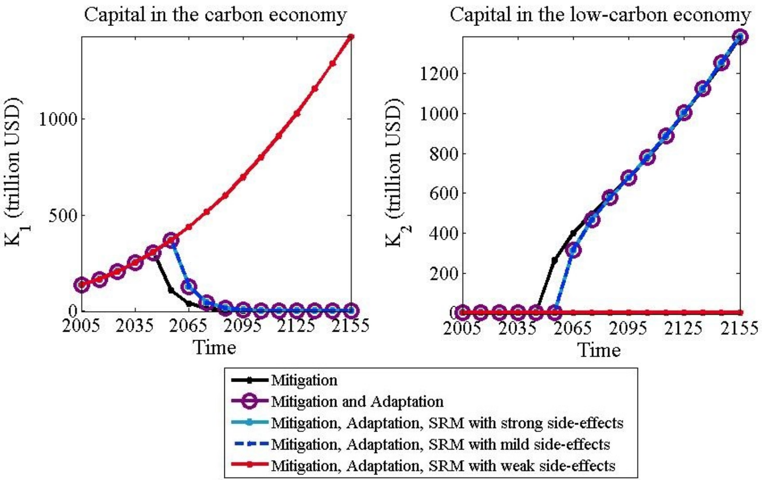
Scenarios

Five policy **scenarios** are analyzed:

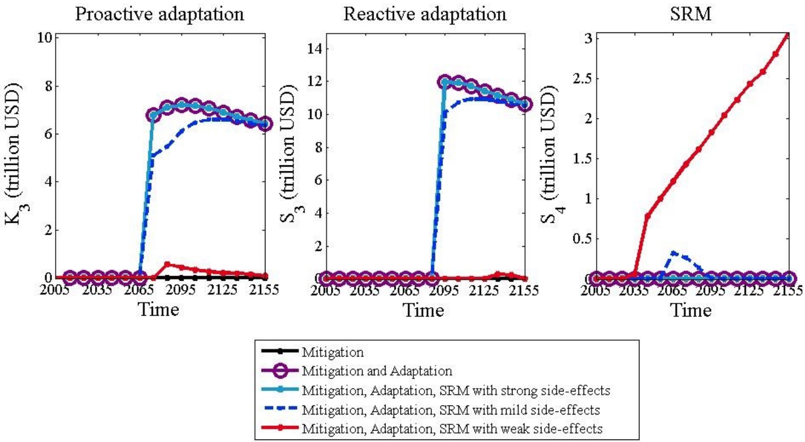
- '**Mitigation**' where mitigation is the only strategy available.
- '**Mitigation and Adaptation**' where both mitigation and adaptation are available, but not geoengineering.
- '**Mitigation, Adaptation, SRM**' where all strategies are available. Here we consider **three** illustrative **cases** for SRM side-effects:

  - '**Mild side-effects**': constant side-effects ($\alpha_{GE}(t) = 0.015$);
  - '**Strong side-effects**': α_{GE} increases monotonically to $\overline{\alpha_{GE}}$;
  - '**Weak side-effects**': α_{GE} decreases monotonically to $\underline{\alpha_{GE}}$.

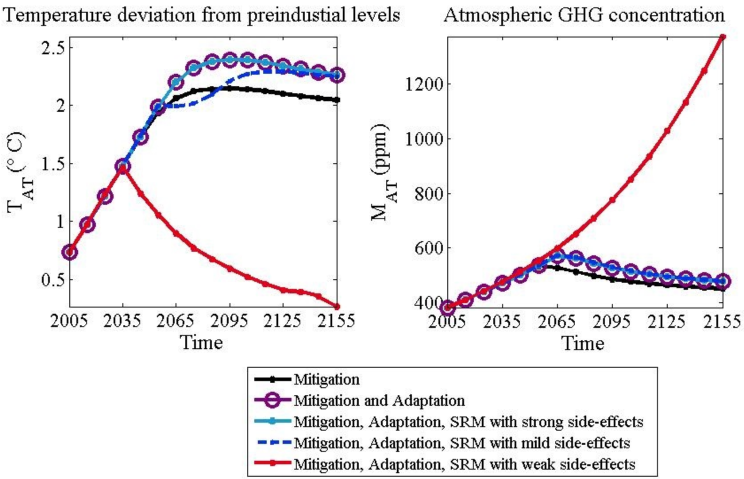
Results: Transition to the low-carbon economy



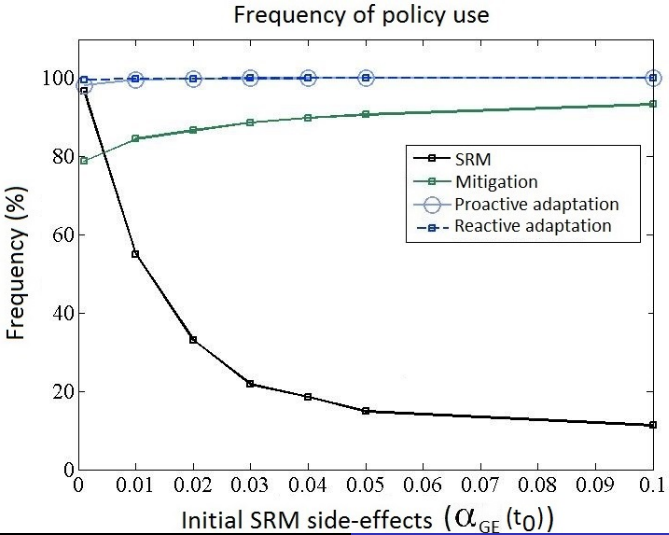
Results: Adaptation vs. SRM



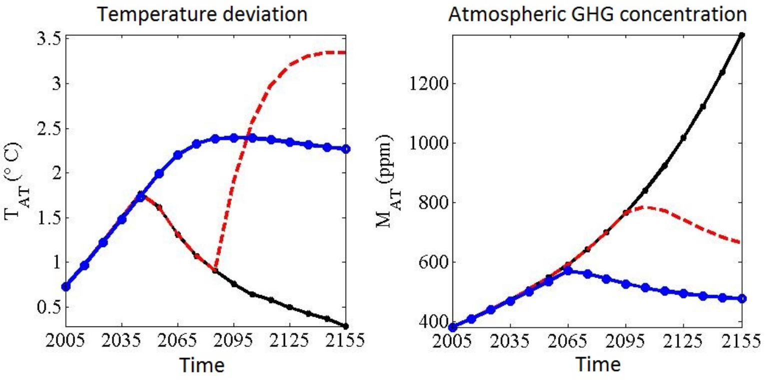
Results: Temperature and GHG concentrations



Results: Distributional analysis for SRM side-effects



Results: Impacts of unexpected SRM side-effects



Adaptation policies: A study with AD-MERGE

Les Cahiers du GERAD

ISSN: 0711–2440

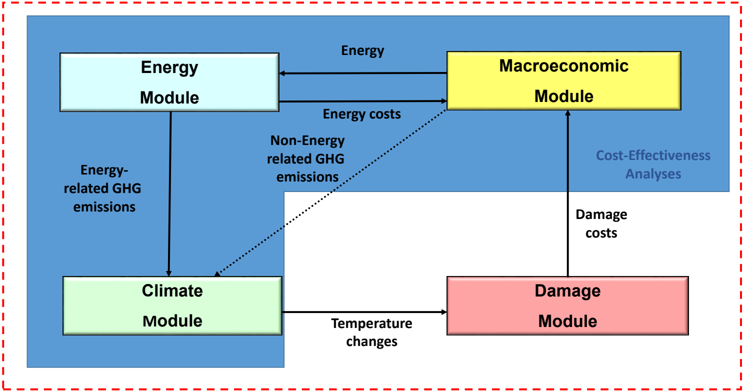
Will adaptation delay the transition to clean energy systems?

O. Bahn, K.C. de Bruin,
C. Fertel

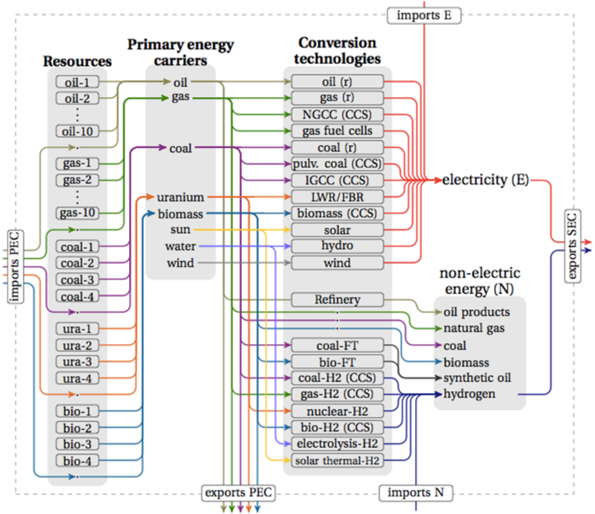
G–2015–79

September 2015

MERGE: Overview



MERGE: ETA


imports E
Resources
Primary energy carriers
Conversion technologies
oil-1
oil-2
oil-10
gas-1
gas-2
gas-10
coal-1
coal-2
coal-3
coal-4
ura-1
ura-2
ura-3
ura-4
bio-1
bio-2
bio-3
bio-4
oil
gas
coal
uranium
biomass
sun
water
wind
oil (r)
gas (r)
NGCC (CCS)
gas fuel cells
coal (r)
pulv. coal (CCS)
IGCC (CCS)
LWR/FBR
biomass (CCS)
solar
hydro
wind
Refinery
coal-FT
bio-FT
coal-H2 (CCS)
gas-H2 (CCS)
nuclear-H2
bio-H2 (CCS)
electrolysis-H2
solar thermal-H2
electricity (E)
non-electric energy (N)
oil products
natural gas
coal
biomass
synthetic oil
hydrogen
imports PEC
exports SEC
exports PEC
imports N

Scenarios

AD-MERGE database corresponds to **version 5** of the MERGE model except: i) key parameters of the **climate module** have been revised; ii) **damage module** has been revised and re-calibrated; and iii) **adaptation options** are modelled.

Five scenarios are analyzed:

- A counterfactual '**Baseline**' where **climate change damages are not felt** and consequently where GHG emissions are not limited.
- In the next four policy scenarios, climate change damages are felt and regions react following a cost-benefit approach. **Mitigation is always** a **possible** option, but adaptation may only be available on a limited basis:

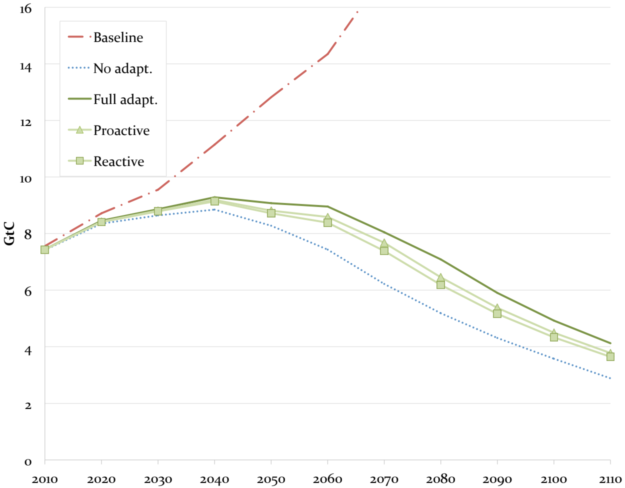
  - '**No-adapt.**': **adaptation** is **not possible**;

  - '**Proactive**': **only proactive** (stock) adaptation is available;

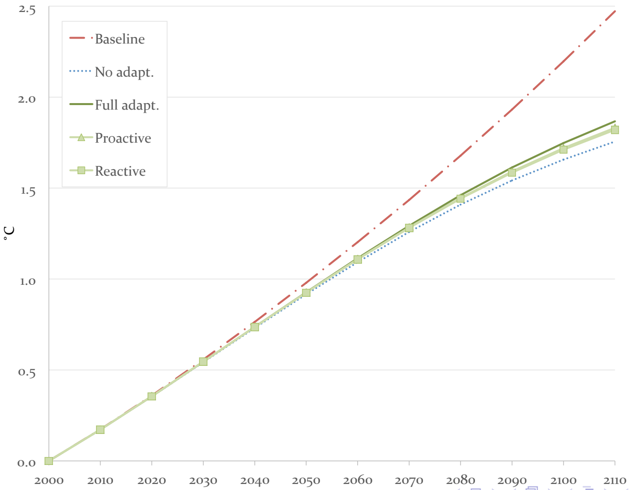
  - '**Reactive**': **only reactive** (flow) adaptation is available;

  - '**Full-adapt.**': **all forms** of **adaptation** are available.

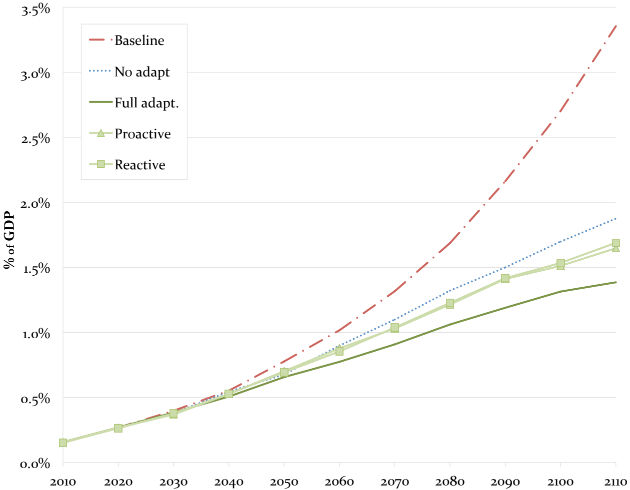
Results: World energy-related CO_2 emissions



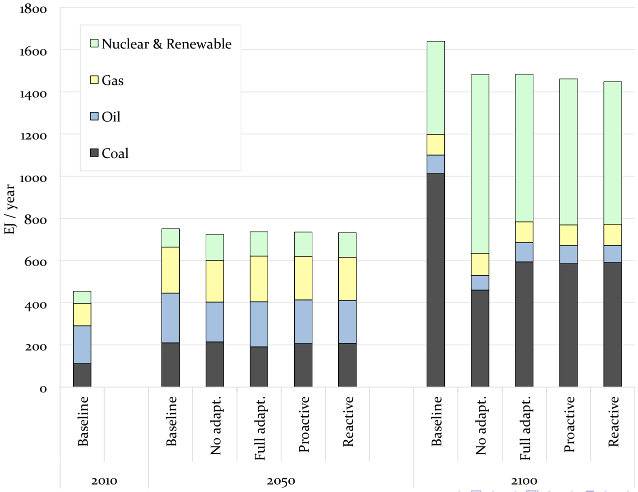
Results: Temperature increase (from 2000)



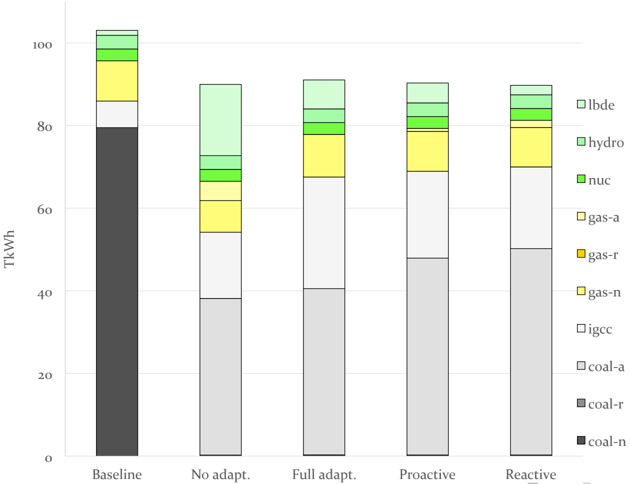
Results: Net damages



Results: World primary energy supply



Results: World electricity generation in 2100



THC preservation policies: A study with MERGE

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Energy policies avoiding a tipping point in the climate system

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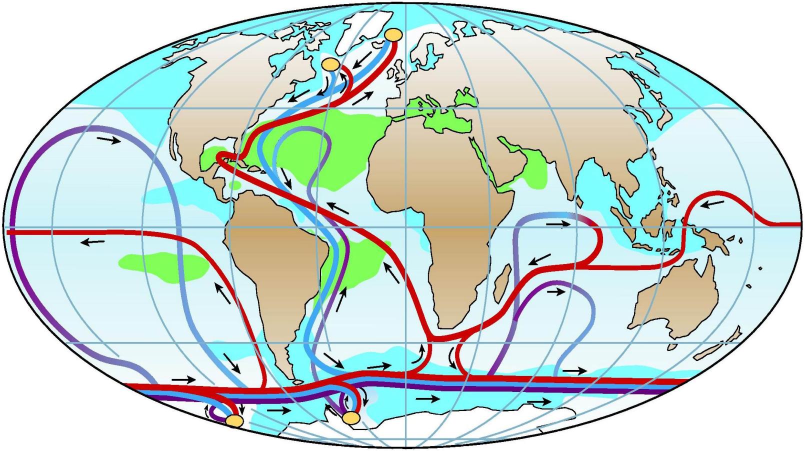
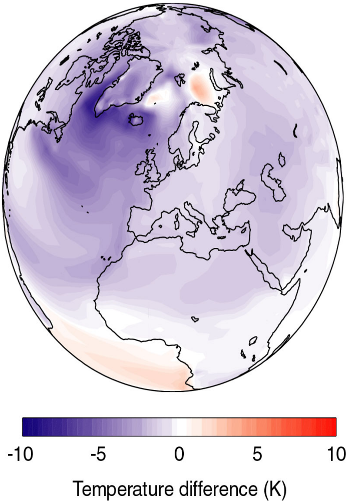
ABSTRACT

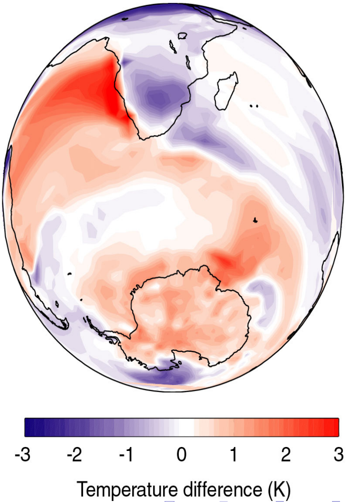
Paleoclimate evidence and climate models indicate that certain elements of the climate system may exhibit thresholds, with small changes in greenhouse gas emissions resulting in non-linear and potentially irreversible regime shifts with serious consequences for socio-economic systems. Such thresholds or tipping points in the climate system are likely to depend on both the magnitude and rate of change of surface warming. The collapse of the Atlantic thermohaline circulation (THC) is one example of such a threshold. To evaluate mitigation policies that curb greenhouse gas emissions to levels that prevent such a climate threshold being reached, we use the MERGE model of Manne, Mendelsohn and Richels. Depending on assumptions on climate sensitivity and technological progress,

Thermohaline circulation

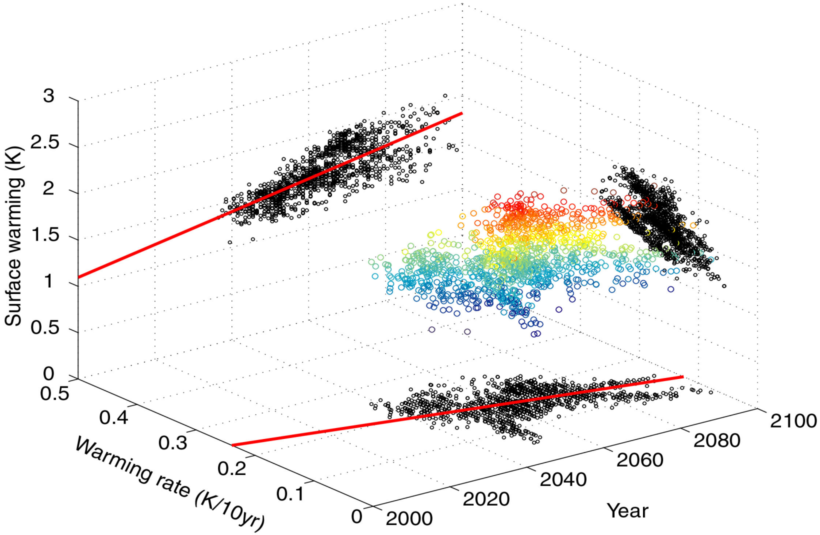


Rupture of the THC





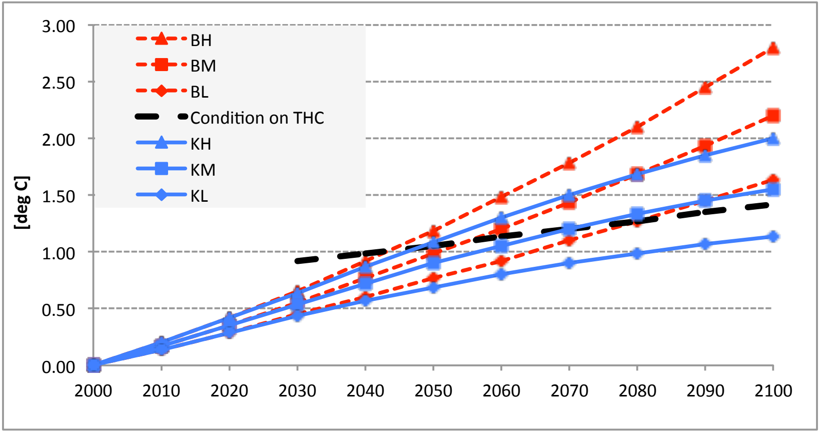
Preservation of the THC



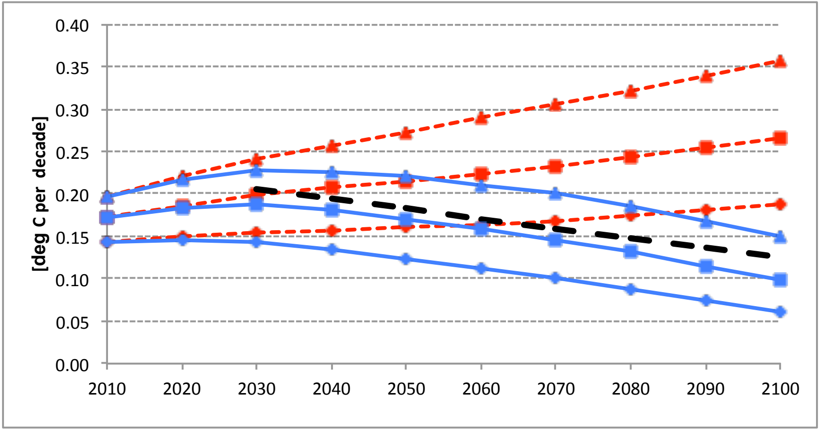
THC scenarios

- Different levels of climate sensitivity:
  - '**Low CS**', with **low** climate sensitivity (1.5 °C) and **short** lag for ocean warming (45 years);
  - '**Medium CS**', with **medium** climate sensitivity (3 °C) and **mean** lag (57 years), that is our original parameterization;
  - '**High CS**', with **high** climate sensitivity (4.5 °C) and **long** lag (77 years).
- Three scenarios:
  - A counterfactual '**Baseline**' where **climate change damages are not felt** and consequently where GHG emissions are not limited.
  - '**Post-Kyoto**' scenarios where **constraints on CO_2 emissions** are imposed (AI: 2010 Kyoto, then -10% per decade; Non-AI: -5% per decade from 2030).
  - '**THC preservation**' scenarios where **constraints on maximum absolute warming** and **maximum warming rate** are imposed.

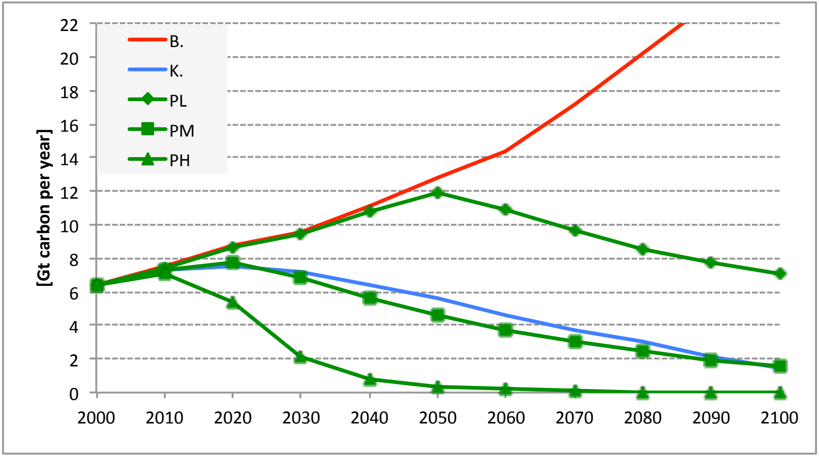
THC: Temperature increase (from 2000)



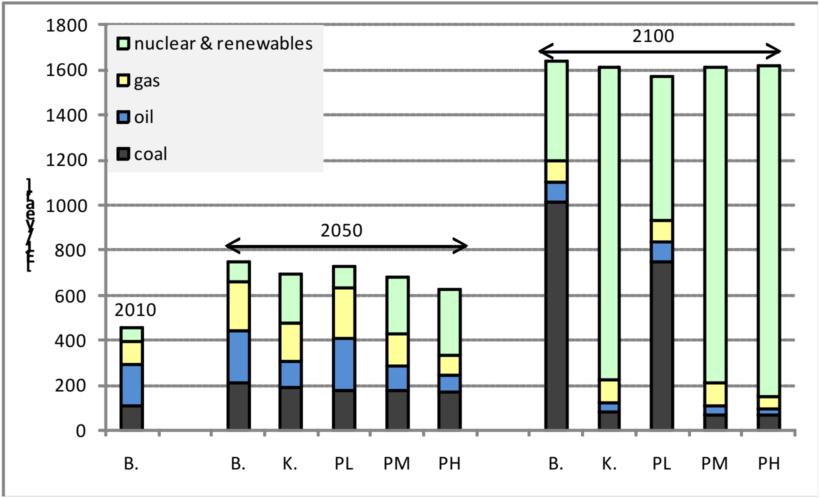
THC: Temperature increase rate



THC: CO_2 emissions



THC: World primary energy use



Mitigation policies: A study with TIMES

CANADA'S CHALLENGE & OPPORTUNITY

Transformations for major reductions in GHG emissions

PROJET TROTTIER POUR L'AVENIR ÉNERGÉTIQUE
TROTTIER ENERGY FUTURES PROJECT

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April 2016

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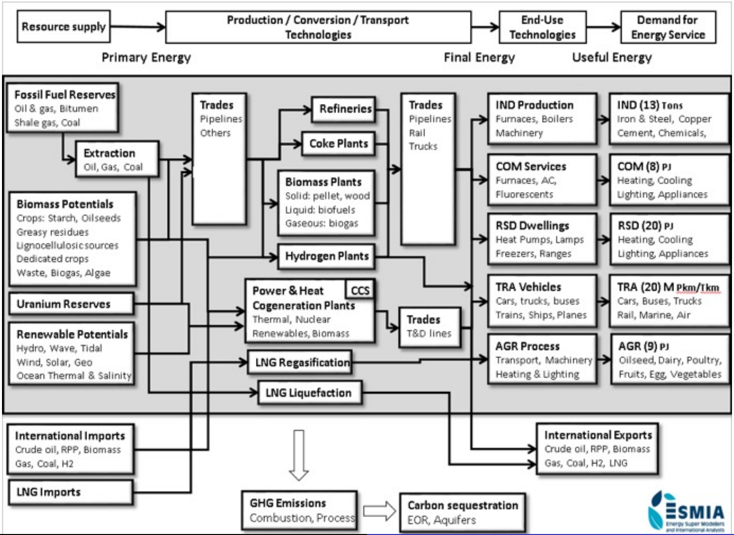
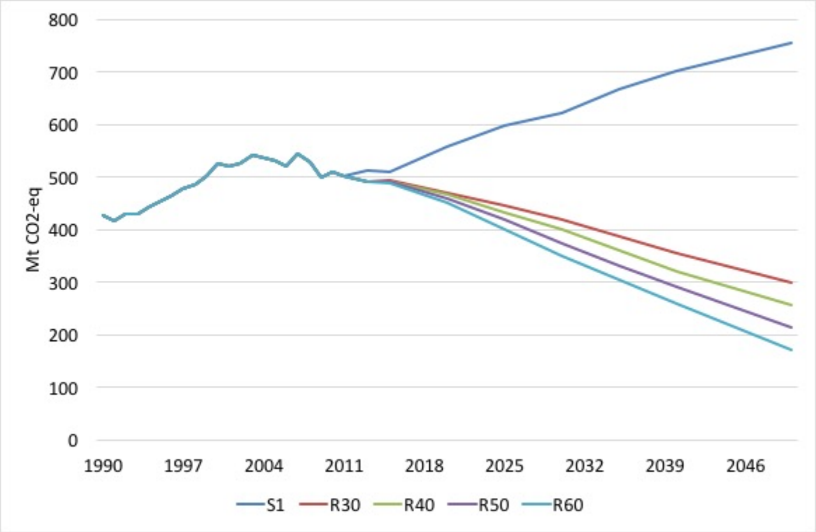
TIMES: Overview of the RES in NATEM



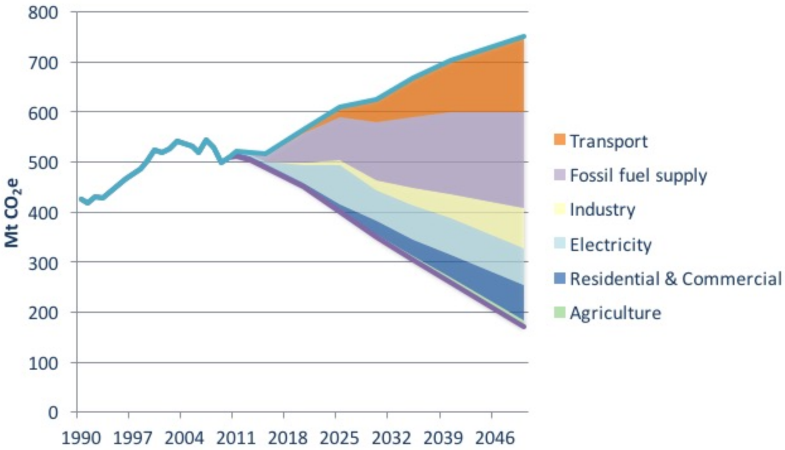
TEFP: Scenarios

Premises Included	High Fossil Fuel Production								Low Fossil Fuel Production		
	S1	S2	S3	S4	S5	S6	S7	S8	S1a	S3a	S8a
No Targeted Reductions in GHG Emissions	X								X		
Targeted Reductions in GHG Emissions		X	X	X	X	X	X	X		X	X
No New High-voltage Interconnections		X									
New High-voltage Interconnections			X	X	X	X	X	X		X	X
Changes in Urban Form				X							
Second Generation Biofuels					X			X			X
Carbon Capture and Storage (CCUS)					X			X			X
Increased Electricity Export to United States						X					
No New Nuclear Power Generation							X				
Biojet Fuel								X			X
Bioenergy with CCUS (BECCS)								X			X
New Large-scale Hydro in B.C.								X			X

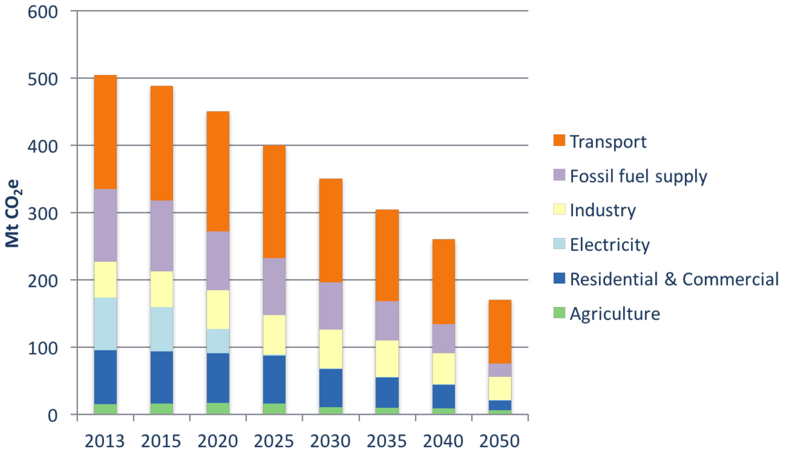
TEFP: GHG emission targets



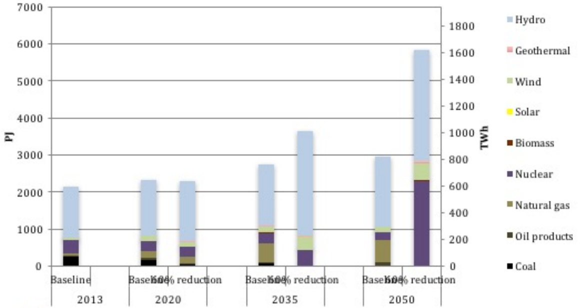
TEFP S3a-R60: GHG emission reductions by sector

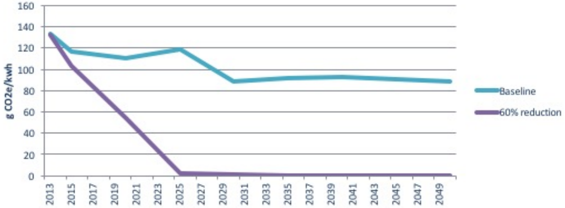


TEFP S3a-R60: GHG emissions by sector



TEFP S3a-R60: Decarbonization of electricity supply





TEFP S3a-R60: Strategies for deep decarbonization

The **main transformations** needed to achieve deep decarbonization can be grouped into three main categories:

1. **Electrification of end-use sectors**: Electricity is mainly used for space and water heating, road transportation and industrial and agricultural processes.
2. **Decarbonization of electricity supply**: Massive investments in renewable (hydro, but also wind) and nuclear generation.
3. **Efficiency improvements**: The biggest gains are achieved in the transport sector (EV for road transportations); the second ones in residential and commercial buildings (e.g., efficient appliances and improved building envelopes).

Outline

Conclusion

- **Geoengineering** (SRM measure) brings along important risks (it may produce unintended consequences and harmful side-effects): It does **not** appear to be a **robust component** of an optimal climate policy.
- **Adaptation** is an important complement to **mitigation**: the **combination** of both strategies is efficient to reduce GDP losses, but may delay the needed transition to ‘clean’ energy systems.
- Avoiding abrupt climate changes may require a faster decarbonization path (**precautionary principle**).
- In **Canada**, **deep decarbonization** can be achieved through massive electrification coupled with a decarbonized electricity supply and significant efficiency gains.