# Cost Savings of a Multi-Gas Climate Policy*

L.Drouet, A.Sceia, P.Thalmann, M.Vielle
Research lab on the Economics and Management of the Environment.
École Polytechnique Fédérale de Lausanne.

March 16, 2007

## 1 Introduction

This short note completes the work done in [5] and analyzes for Switzerland the benefits of a multi-gas greenhouse gas (GHG) abatement strategy. Appendix A provides the modeling framework for non $CO_2$ GHG in the GEMINI-E3 model [1].

## 2 Scenarios

On top of the reference scenario as presented in [5], we consider two additional scenarios: in the first scenario (*Kyoto2020GHG*), Switzerland reaches the same GHG abatement as in scenario *Kyoto2020* (see [5]) but this target is obtained through a multi-gas strategy in which all GHG emissions are taxed. All gases are converted to $CO_2$-equivalent based on the 100-year Global Warming Potentials (GWPs). In the second scenario (*Kyoto2050GHG*), we applied the same methodology but we used the same target as in the scenario *Kyoto2050*. Comparing the

*The authors gratefully acknowledge the support of the Swiss Federal Office for the Environment, Federal Office of Energy and Swiss National Centre of Competence in Research on Climate (NCCR-Climate)

scenarios *Kyoto2020GHG* and *Kyoto2050GHG* with the previous scenarios allows assessing the benefits of a multi-gas strategy. Assumptions concerning international environment (energy prices, climate policies in other regions, etc) are constant across scenarios.

## 2.1 Scenario Kyoto2020GHG

In this scenario, Switzerland reduces its emissions by 20% (compared to 1990 level) by the year 2020. Table 1 presents the simulation results : the $CO_2$ tax and the welfare cost associated with scenarios Kyoto2020 and Kyoto2020GHG. When a multi-gas strategy is implemented the cost of abatement is significantly reduced. The $CO_2$ tax in 2020 is reduced by 28% and the welfare cost is reduced by 42% to 1 850 millions CHF.

Table 1: Tax and Welfare Cost in Switzerland

| | 2010 | 2020 |
|---|---|---|
| Tax in $CHF_{2001}$ | | |
| $CO_2$ tax (*Kyoto2020*) | 111 | 790 |
| GHG tax in eq. $CO_2$ (*Kyoto2020GHG*) | 58 | 570 |
| | | |
| Welfare effect in millions CHF | | |
| *Kyoto2020* | -288 | -3’211 |
| *Kyoto2020GHG* | -50 | -1’850 |
| | | |
| Welfare effect as % of total household consumption | | |
| *Kyoto2020* | -0.10% | -1.01% |
| *Kyoto2020GHG* | -0.02% | -0.58% |

Table 2 provides the GHG emissions abatement for both 2020 scenarios. Non $CO_2$ GHG emissions are already lower in the Kyoto2020 scenario than in the baseline scenario due to the slowdown in the energy sectors caused by the abatement of $CO_2$ emissions. Similarly, the non $CO_2$ GHG emissions in the agriculture sector are also reduced due to a slight decrease in agriculture production in Switzerland. These abatements are nevertheless reinforced in the multi-gas scenario, where the abatement of High GWP gases reaches 40%, methane is reduced by 38% and nitrous oxide is reduced by 26%.

Table 2: GHG emissions abatement in 2020

| | *Kyoto2020* | *Kyoto2020GHG* |
|---|---|---|
| $CO_2$ | -31% | -27% |
| Methane | -7% | -38% |
| Nitrous Oxide | -3% | -26% |
| High GWP gases | -1% | -40% |
| Total GHG | -28% | -28% |

## 2.2 Scenario Kyoto2050GHG

This second scenario is similar to the previous one when is comes to the targets from 2006 to 2020, but it assumes strong reduction of 10% per decade after the year 2020 and until 2050. Table 3 compares from 2020 to 2050 the taxes and the welfare costs in the pure $CO_2$ abatement scenario with the multi-gas scenario. As expected the results are analogous to those of the scenario *Kyoto2020GHG*. In 2050, the tax would be reduced by 24% and the welfare cost would reduced by approximately 2,5 billion CHF. Nevertheless, when the abatement effort is increased, the benefits of a a multi-gas policy are decreasing in relative term. In 2020, a 28% abatement in GHG emission, using the multi-gas strategy, leads to a reduction of the welfare costs of to 42%. In 2050, for an abatement of 45%, the multi-gas policy only allows for saving 27% of the welfare costs. This highlights the fact that the abatement potential of non $CO_2$ GHG is limited and they take a relatively smaller part in the total effort when substantial emission reductions are required.

Table 3: Tax and Welfare Cost in Switzerland

| | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|
| Tax in $CHF_{2001}$ | | | | |
| $CO_2$ tax (*Kyoto2050*) | 790 | 1’061 | 1’568 | 2’429 |
| GHG tax in eq. $CO_2$ (*Kyoto2050GHG*) | 570 | 782 | 1’180 | 1’841 |
| | | | | |
| Welfare cost in millions CHF | | | | |
| *Kyoto2050* | -3’211 | -4’287 | -6’209 | -9’117 |
| *Kyoto2050GHG* | -1’850 | -2’699 | -4’238 | -6’599 |
| | | | | |
| Welfare cost as % of total households consumption | | | | |
| *Kyoto2050* | -1.01% | -1.22% | -1.56% | -2.00% |
| *Kyoto2050GHG* | -0.58% | -0.77% | -1.06% | -1.45% |

Table 4 provides the GHG emissions abatement for both 2050 scenarios. It shows that non $CO_2$ GHG emission are reduced even when they are not directly taxed due to the slowdown of key emitting sectors. Nevertheless, abatement is much stronger when those gases are also taxed.

Table 4: GHG emissions abatement in 2050

| | *Kyoto2050* | *Kyoto2050GHG* |
|---|---|---|
| $CO_2$ | -49% | -45% |
| Methane | -13% | -51% |
| Nitrous Oxide | -10% | -40% |
| High GWP gases | -1% | -43% |
| Total GHG | -45% | -45% |

# 3 Conclusion

These results are in line with existing studies on multi-gas mitigation (see [2] and [18]). The inclusion of non $CO_2$ GHG in the scenarios reduces significantly the carbon price and the welfare cost. Figure 1 shows the $CO_2$ tax in Switzerland for both *Kyoto2050* and *Kyoto2050GHG* scenarios. The multi-gas approach allows for a lower tax to reach similar targets and the difference between the two taxes is growing over time. In 2050, the welfare cost reduction due to the inclusion of other gases is estimated to about 27%. The importance of non $CO_2$ GHG abatement is nevertheless limited when substantial emission reductions are required due to the limited potential of reduction of those gases.

# References

[1] A. Bernard and M. Vielle. GEMINI-E3, a General Equilibrium Model of International National Interactions between Economy, Energy and the Environment. *Computational Management Science*, forthcoming.

[2] J.P. Weyant D. Van Vuuren and F. de la Chesnaye. Multi-gas Scenarios to Stabilize Radiative Forcing. *Energy Economics*, 28(1):102–120, January 2006.

[3] B. J. DeAngelo, F. C. de la Chesnaye, R. H. Beach, A. Sommer, and B. C. Murray. Methane and Nitrous Oxide Mitigation in Agriculture. *Energy*

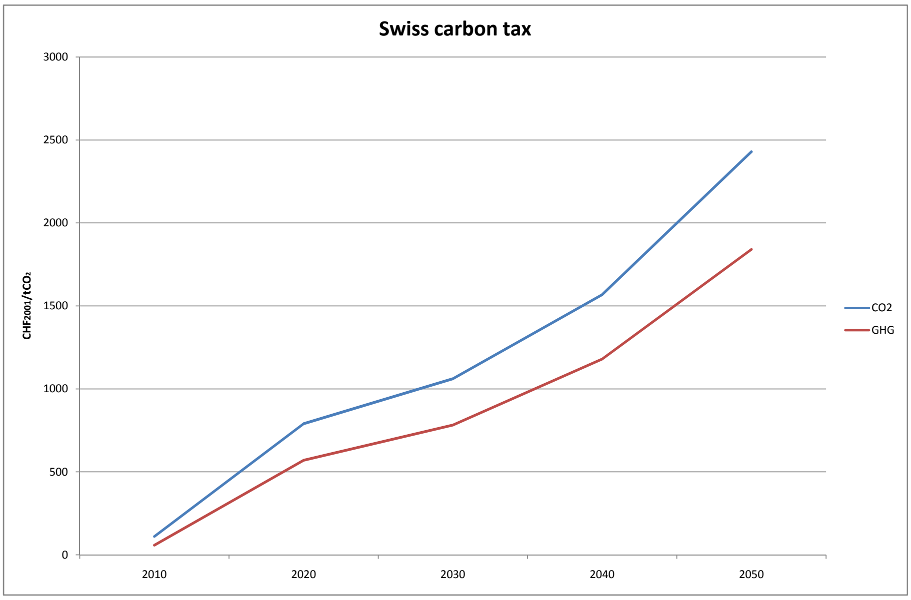


Figure 1: Comparison of the evolution of the $CO_2$ tax in Switzerland ($CO_2$ only and multi-gas).

*Journal*, Multi-Greenhouse Gas Mitigation and Climate Policy, Special Issue #3:89–108, 2006.

[4] K. C. Delhotal, F. C. de la Chesnaye, A. Gardiner, J. Bates, and A. Sankovski. Mitigation of Methane and Nitrous Oxide Emissions from Waste, Energy and Industry. *Energy Journal*, Multi-Greenhouse Gas Mitigation and Climate Policy, Special Issue #3:45–62, 2006.

[5] L. Drouet, A .Sceia, P. Thalmann, and M. Vielle. Evaluation of a swiss carbon tax with the computable general equilibrium model gemini-e3. working paper, EPFL-REME, Lausanne, December 2006.

[6] European Commission. *Economic Evaluation of Sectoral Emission Reduction Objectives for Climate Change*. Brussels, 2001.

[7] J.T. Houghton, L.G. Meira Filho, B. Lim, K. Treanton, I. Mamaty, and Y. Bonduki. *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*. Intergovernmental Panel on Climate Change, Organization for Economic Co-Operation and Development, International Energy Agency. UK Meteorological Office, Bracknell, 1997.

[8] International Energy Agency. *Abatement of Emissions of Other Greenhouse Gases - Nitrous Oxide. International Greenhouse Gas R&D Programme*. OECD/IEA, Washington D.C., 2000.

[9] D. O. Schaefer, D. Godwin, and J. Harnisch. Estimating Future Emissions and Potential Reductions of HFCs, PFCs, and SF6. *Energy Journal*, Multi-Greenhouse Gas Mitigation and Climate Policy, Special Issue #3:63–88, 2006.

[10] E. A. Scheehle and D. Kruger. Global Anthropogenic Methane and Nitrous Oxide Emissions. *Energy Journal*, Multi-Greenhouse Gas Mitigation and Climate Policy, Special Issue #3:33–44, 2006.

[11] United Nations Framework Convention on Climate Change. *National greenhouse gas inventory data for the period 1990-2004 and status of reporting*. FCCC/SBI/2006/26. United Nations, 2005.

[12] United Nations Framework Convention on Climate Change. *Sixth compilation and synthesis of initial national communications from Parties not included in Annex I to the Convention*. FCCC/SBI/2005/18/Add.2. United Nations, 2005.

[13] United States Environmental Protection Agency. *U.S. Methane Emissions 19902020: Inventories, Projections, and Opportunities for Reductions*. Washington, DC 20460, September 1999.

[14] United States Environmental Protection Agency. *Addendum Update to U.S. Methane Emissions 1990-2020: Inventories, Projections, and Opportunities for Reductions*. Office of Air and Radiation, Washington, DC 20460, 2001.

[15] United States Environmental Protection Agency. *U.S. Adipic Acid and Nitric Acid Nitrous Oxide Emissions 1990-2020: Inventories, Projections and Opportunities for Reductions*. Office of Air and Radiation, Washington, DC 20460, 2001.

[16] United States Environmental Protection Agency. *Global Anthropogenic Non-CO2Greenhouse Gas Emissions: 1990-2020*. Office of Atmospheric Programs EPA Report 430-R-06-003, Washington, DC 20460, June 2006.

[17] United States Environmental Protection Agency. *Global Mitigation of Non-CO2 Greenhouse Gases*. Office of Atmospheric Programs (6207J) EPA 430-R-06-005, Washington, DC 20460, June 2006.

[18] J. Weyant, F. de la Chesnaye, and G. Blanford. Overview of EMF-21: Multi-gas Mitigation and Climate Policy. *Energy Journal*, Multi-Greenhouse Gas Mitigation and Climate Policy, Special Issue #3:1–32, 2006.

# A Modeling non carbon GHG

## A.1 Emission of non carbon GHG

We take into account all the direct GHGs covered by the United Nations Framework Convention on Climate Change (UNFCC) : Methane, nitrous oxide, perfluorocarbons (PFCs), hydrofluorocarbons (HFCs) and sulphur hexafluoride ($SF_6$) (the last three gases are called the high global warming potential gases). Emissions of non carbon greenhouse gas emissions are converted to a $CO_2$-equivalent based on the 100-year Global Warming Potentials (GWPs) defined by the Intergovernmental Panel on Climate Change [7]. Historical estimates are reported for 1990, 1995 and 2000 and projections of emissions are provided for 2005, 2010, 2015 and 2020 (see [16, 10][1]). Historical and projected emissions are mainly based on national inventory compiled by each nation and submitted to UNFCC Secretariat [12, 11], but national reports are also used. When no emissions data are available or data are insufficient, EPA estimates emissions or projections using the methodologies presented in the IPCC Guidelines[2]. The EPA projections represent the business as usual scenario where currently achieved reductions are incorporated and future mitigation actions are included only if either a well established program or an international sector agreement is in place.

### A.1.1 Methane

The model takes into account 13 sources of $CH_4$ emissions. The emissions of each source are linked to an activity level (or an economic driver) the coefficient of which is calibrated on the baseline scenario:

$$NCO2_{lr} = \frac{\upsilon_{lr}}{{\theta_{lr}}^{t}} \cdot ED_{lr} \tag{1}$$

where $ED_{lr}$ is the economic driver, $\upsilon_{lr}$ a coefficient representing the amount of source $l$ emitted by the economic driver and $\theta_{lr}$ an exogenous technical progress on the coefficient $\upsilon_{lr}$ .

[1]The data compiled by Environmental Protection Agency can be found on U.S. EPA's webpage at http://www.epa.gov/nonco2/econ-inv/international.html.

[2]This is often the case for high GWP gases.

Table 5: Methane and GEMINI-E3 activities

| Source | Index $(l)^a$ | Economic Drivers | MAC |
|---|---|---|---|
| Landfilling of Solid Waste | LAN | Total Household Consumption | Yes |
| Biomass Combustion | BIC | Total Household Consumption | |
| Fugitives from Coal Mining Activities | COA | Agriculture Production | Yes |
| Enteric Fermentation | ENT | Agriculture Production | Yes |
| Stationary and Mobile Combustion | FUE | Total Demand of Refined Petroleum | |
| Other Industrial Non-Agricultural Sources | IND | Chemical Production | |
| Oil | OIL | Crude Oil Production | Yes |
| Manure Management | MAN | Agriculture Production | Yes |
| Rice Cultivation | RIC | Agriculture Production | Yes |
| Other Agricultural Sources | OAG | Agriculture Production | Yes |
| Wastewater | WAS | Total Household Consumption | |
| Other Non-Agricultural Sources (Waste & Other) | OTH | Total Household Consumption | |
| Natural gas | GAS | Total Demand of Natural Gas | Yes |

[a] for example the index in the case of emissions coming from coal mining is noted $CH4^{Coa}$

Table 6: Nitrous oxide and GEMINI-E3 activities

| Source | Index $(l)^a$ | Economic Drivers | MAC |
|---|---|---|---|
| Agricultural Soils | AGS | Agriculture Production | Yes |
| Other Agricultural Sources | OAG | Agriculture Production | Yes |
| Biomass Combustion | BIC | Total Household Consumption | |
| Stationary and Mobile Combustion | FUE | Total Demand of Refined Petroleum | |
| Manure Management | MAN | Agriculture Production | Yes |
| Other Non-Agricultural Sources (Waste & Other) | OTH | Total Household Consumption | |
| Other Industrial Non-Agricultural Sources | OIN | Metal and Metal Goods Production | |
| Adipic Acid Production | ADI | Chemical Production | Yes |
| Nitric Acid Production | NIT | Chemical Production | Yes |
| Human Sewage | HUM | Total Household Consumption | |

[a] for example the index in the case of emissions coming from adipic acid production is noted $N20^{Adi}$

The table 5 shows the correspondence between the sources and the sectors/products in GEMINI-E3, the variable of the model representing the economic driver, and whether an abatement curve (MAC) is available for this source.

### A.1.2 Nitrous oxide

For $N_2O$ emissions we adopt the same formulation and the table 6 gives the economic driver for the 10 sources of emission.

### A.1.3 High global warming potential gases

High global warming potential gas emissions result from the use of substitutes for ozone-depleting substances, from the production of magnesium, aluminum, semiconductors, flat panel display, HCFC-22, electrical equipment and from the

Table 7: High global warming potential gases and GEMINI-E3 activities

| Source | Index ($l$) | Economic Drivers | MAC |
|---|---|---|---|
| ODS Substitutes Aerosols (Non-MDI) | PFC_AEN | Total Household Consumption | Yes |
| ODS Substitutes Fire Extinguishing | PFC_FIR | Total Household Consumption | Yes |
| ODS Substitutes Foams | PFC_FOA | Total Household Consumption | Yes |
| ODS Substitutes Solvents | PFC_SOL | Total Household Consumption | Yes |
| ODS Substitutes Aerosols (MDI) | PFC_AEM | Total Household Consumption | Yes |
| ODS Substitutes Refrigeration/Air Conditioning | PFC_REF | Total Household Consumption | Yes |
| HFC-23 Emissions from HCFC-22 Production | HFC_22 | Total Household Consumption | Yes |
| SF6 Emissions from Electric Power Systems | SF6_EPS | Metal and Metal Goods Production | Yes |
| PFC Emissions from Primary Aluminum Production | PFC_PAP | Metal and Metal Goods Production | Yes |
| HFC, PFC, SF6 from Semiconductor Manufacturing | PFC_SEM | Equipment Goods Production | Yes |
| SF6 Emissions from Magnesium Manufacturing | SF6_MAM | Metal and Metal Goods Production | Yes |

use of electrical equipment. GEMINI-E3 distinguishes 11 types of fluorinated gases, they are presented in table 7.

## A.2 Abatement cost

Concerning the mitigation option analysis [17] the methodologies are based mainly on [4, 9, 3]. The first part of their analysis is to establish a list of mitigation options for each gas by source category from existing engineering and/or economic studies. Extensive information is available concerning USA and European countries and the major developed regions (see [6, 8, 13, 14, 15]). Each abatement option is then characterized in terms of its costs and benefits per abated ton, the costs include capital and operation & maintenance costs. The cost of abatement are adjusted across regions and take into account mainly the difference in labor costs. The benefits include the abated gas multiplied by the carbon tax and sometimes revenues coming from the sale of a byproduct linked to the abated gas or from the sale of the gas itself (for example sales of methane as an energy input). A present value analysis of each option is then used to determine break-even abatement costs for each option. The result of the analysis is marginal abatement costs (MACs) indicating the potential reduction in non-carbon gas emissions for a given break-even price. These curves have the generic form described in figure 2.

We can then compute the level of emissions on the basis of a $CO_2$ tax:

$$NCO2_{lr} = \frac{\upsilon_{lr}}{{\theta_{lr}}^{t}} \cdot [1 - f_{lr}(TCO2_r)] \cdot ED_{lr} \tag{2}$$

where $f_{lr}(TCO2_r)$ is a linear approximation of the abatement curve given by [17].

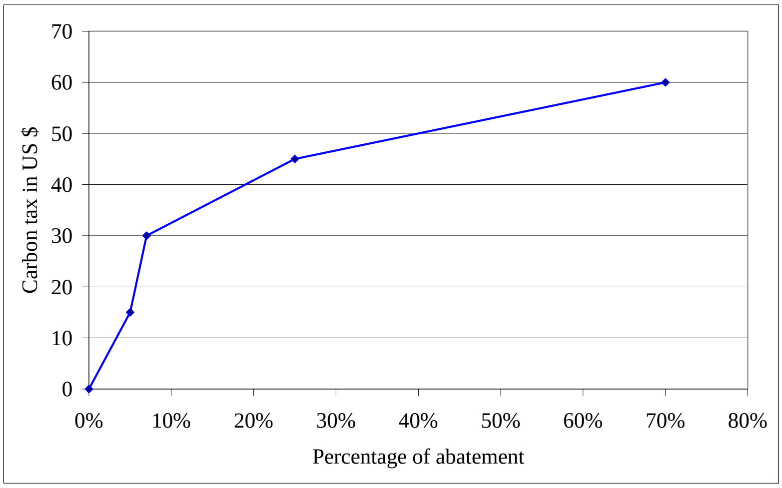


Figure 2: Curve of marginal abatement costs.