# $CO_2$ Taxation versus Emissions Trading – An Analytical Representation for Switzerland

## Master's Thesis

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# Abstract

Climate policy is important to combat the effects of climate change caused by mankind. The goal of this Master's thesis is to contribute to the analysis of emissions trading as climate policy instrument. Thus, the regulations of the European Union emissions trading system (EU-ETS) are analysed and applied to the Swiss system. It is found that with the ETS as the only climate policy instrument the Swiss abatement target is not attainable. Therefore, the regulations of the EU-ETS must be changed slightly and further amendments of the policy design should be introduced. A new policy design to reduce Swiss carbon dioxide ($CO_2$) emissions by 20 per cent in the year 2020 compared to the level of 1990 is formulated. The proposed hybrid policy consists of an ETS linked with the EU and an additional $CO_2$ tax. With a computable general equilibrium model (CGE), the $CO_2$ tax to achieve the abatement target and the effects thereof are calculated. It is found that when introducing an ETS, the domestic production sectors not participating in the trading system have to carry a higher tax burden of 200 CHF per tonne of $CO_2$ when compared to the $CO_2$ tax policy. In contrast, the sectors participating in the ETS are benefited from the introduction of the trading system. As a consequence, sectors paying the $CO_2$ tax have to shoulder a part of the reduction of the sectors participating in the ETS. Notwithstanding these results, the hybrid policy is slightly more efficient due to the smaller welfare loss compared to the $CO_2$ tax policy.

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# List of Abbreviations

| | |
|---|---|
| CDM | Clean Development Mechanism |
| CES | Constant Elasticity of Substitution |
| CGE | Computable General Equilibrium |
| CHF | Swiss francs |
| CHU | Swiss emission allowance |
| $CO_2$ | Carbon Dioxide |
| EC | European Commission |
| ETS | Emissions Trading System |
| EU | European Union |
| EUA | European Union Allowance |
| EU-ETS | European Union Emissions Trading System |
| FOEN | Federal Office for the Environment |
| GAMS | General Algebraic Modelling System |
| GDP | Gross Domestic Product |
| GHG | Greenhouse Gas |
| IOT | Input Output Table |
| IPCC | Intergovernmental Panel on Climate Change |
| JI | Joint Implementation |
| MW | Megawatt |
| NAP | National Allocation Plan |
| NCCR | National Centre of Competence in Research |
| NOGA | General Classification of Economic Activities (Nomenclature Générale des Activités économiques) |
| TJ | Tera-joule |
| UNFCCC | United Nations Framework Convention on Climate Change |

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# 1 Introduction

Climate change is a global problem that people are faced with in this century. Nowadays scientists mostly agree on the fact that climate change really occurs. Every country in the world will be affected in some way by climate change. Even though the impact will not be as pronounced in Switzerland and other European countries as it will be in Africa or Asia, floods and heat waves are assumed to become more frequent in Switzerland (BAFU 2009b).

According to the fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC), it is a fact that mankind has mainly contributed to global warming, through the increase in anthropogenic greenhouse gas (GHG) concentrations. Scientists approve that an additional increase in harmful GHG emissions would further increase global warming and cause greater damage to the climate system than experienced so far. Carbon dioxide ($CO_2$), the most important GHG, is said to be responsible for a large part of the temperature increase. The primary source of $CO_2$ emissions is the use of fossil fuels (IPCC 2007).

It is crucial that a stabilisation of GHG concentration is achieved. Negotiating parties in the political climate discussions have agreed upon a threshold on the maximum temperature increase, which should not be exceeded. The maximum temperature increase of two degree Celsius is seen as an increase in temperature that does not harm the climate system in an unmanageable way. Any further increase above this threshold can lead to large damages in the climate system (BAFU 2009b).

Different policy instruments have been established in order not to cross this threshold. These eco-political instruments are the main political tools to achieve a lower level of $CO_2$ emissions. One policy instrument is the taxation of $CO_2$ emissions. Essentially, a tax on $CO_2$ emissions increases the price of emitting $CO_2$ emissions. An increased price leads to a decrease of the demand thereof, finally leading to a reduction of the $CO_2$ emission level. Another eco-political tool is an emissions trading system (ETS). The government sets an overall cap on $CO_2$ emissions. Total emissions allowed in a trading system will exactly equal the total number of emission allowances distributed by government. The allowance to emit $CO_2$ emissions are traded on the market, which establishes a market price for emission allowances.

In the Kyoto Protocol, Switzerland committed to reduce its GHG emissions by eight per cent in 2012 compared to the level of 1990. An expansion of this climate policy target is currently being negotiated in parliament. The current proposal is a reduction of GHG emissions by 20 per cent in 2020. Therefore, Switzerland has already introduced a $CO_2$ tax with a limited ETS for certain sectors. Currently, the $CO_2$ tax is 36 Swiss francs (CHF) per tonne of $CO_2$.

By contrast, the European Union's (EU) climate policy is principally based on the EU-wide ETS. Since emissions trading is a very young and not well known policy instrument, there is an urgent need for further research in order to analyse the effects of such an instrument.

## 1.1 Goal of this Master's Thesis

The goal of this Master's thesis is to contribute to the investigation of emissions trading as a climate policy instrument. Therefore, the effects of an ETS on the Swiss economy are evaluated and compared with the policy instrument of $CO_2$ taxation. The period from 2013 to 2020 with the corresponding climate policy target is analysed. For the purpose of this thesis, the 20 per cent reduction target of GHG emissions will be transformed in a 20 per cent reduction target of $CO_2$ emissions.

In a first step, the economic theory with respect to different environmental policies is elaborated. The advantages and drawbacks of the two instruments, $CO_2$ taxation and emissions trading, are compared. Further, the Swiss climate policy as well as the European climate policy are analysed and compared. The EU was chosen because the EU climate policy is essentially based on an ETS. In a further step, the regulations of the European Union emissions trading system (EU-ETS) are analysed and applied to the Swiss economy. The question is answered whether Switzerland, as a participant of the EU-ETS, would be able to reach its climate policy target with the regulations defined for the EU-ETS. As the Swiss climate policy target cannot be reached with the ETS as the only policy instrument, it will be examined how the policy design could be adjusted in order to attain the Swiss climate policy target. The numerical examination is performed with a data record of the Swiss economy.

Considering the modifications of the policy design made in the previous step, the thesis provides a second numerical analysis for Switzerland implemented with a computable general equilibrium (CGE) model. Two different Swiss climate policies are investigated and compared, using the General Algebraic Modelling System (GAMS), a system which was developed for modelling real world phenomena. The abatement target of both climate policies is identical, namely a reduction of $CO_2$ emission by 20 per cent in 2020. In the first model, the Swiss economy is analysed with a $CO_2$ tax as the only policy instrument (CO2-TAX model). The CO2-TAX model is a simplified version of the current prevailing system in Switzerland. GAMS will calculate the optimal $CO_2$ tax, which is necessary for reaching the abatement target. In the second model, the Swiss system is investigated when both instruments, $CO_2$ tax and emissions trading, are adopted (CO2-TAX&TRADING model). This policy design is referred to as hybrid policy. Finally, the results of these calculations are compared. The outcomes will show if the integration of the ETS is beneficial for Switzerland or not. At the end, the thesis will point out which of the two policies is more efficient for Switzerland, the $CO_2$ tax policy or the hybrid policy.

The remainder of this thesis is organised as follows. Chapter 1.2 discusses the literature related to this Master's thesis. Chapter 2 gives an overview of the economic arguments qualifying the price policy and the quantity policy. An overview of the Swiss and European climate policies is provided in Chapter 3 and 4. Chapter 5 answers the question whether the Swiss climate policy target would be reached with the regulations from the EU-ETS or if certain modifications are necessary. In Chapter 6 the results of the modelling work are discussed and finally the conclusions are presented in Chapter 7.

## 1.2 Related Literature

Numerous studies have already been made on the topic of climate economics. The models that have been developed try to grasp the economic impacts of different climate policies and to estimate their effects quantitatively. Even though the questions of different studies may be identical, results may differ due to a different model approach chosen.

The main difference between the studies is the discrepancy among the different model types used. On the one hand, CGE models assume that the economy is in equilibrium. Elasticities of substitution and returns to scale are assumed to be constant as well as that there is perfect competition and full employment in all production sectors. Additionally, CGE models are calibrated on a base year. Macro econometric models, on the other hand, do not have as many restrictions and are regarded to be more realistic. It is not assumed that full employment and perfect competition arises. The estimation of macro econometric models is completed on the basis of time series data (Pempetzoglou and Karagianni 2002).

In spite of the more realistic macro econometric models, a CGE model is used in this thesis. With a CGE model, the impact of a policy can be analysed in more detail because the production is split in several sectors. Thereby, CGE models require a smaller amount of data than macro econometric models. Additionally, CGE analysis was designed specifically for the investigation of policy analysis (Pempetzoglou and Karagianni 2002).

CGE models are divided into static and dynamic CGE models. In static CGE models two situations of an economy are compared; one state of the economy is before the introduction of a new policy and the other after the adoption of a new policy. In contrast, dynamic models also analyse the years between these two states, which allows examining the development of different economic variables. Static CGE models have a straightforward and easier structure than dynamic CGE models (Pempetzoglou and Karagianni 2002). This Master's thesis does not focus on the development of economic variables. Therefore, a static CGE model approach was chosen.

In the following, the relevant literature based on CGE models is shortly presented. Important contributions to this thesis are two papers written at the National Centre of Competence in Research (NCCR) climate research institute of the University of Berne. Bucher (2009) conducted a dynamic CGE analysis for Switzerland. The study computes $CO_2$ taxes and the resulting economic effects, when $CO_2$ emissions have to be reduced by 20 per cent until 2020. The study detects that the $CO_2$ tax has to be raised to 280 CHF per tonne of $CO_2$ emitted. Schneider and Stephan (2007) introduced a static CGE model for the Swiss economy. This model also investigates $CO_2$ taxation for a 20 per cent reduction target for $CO_2$ emissions by 2020. They found that $CO_2$ emissions can be reduced by 20 per cent if a tax of 400 CHF per tonne of $CO_2$ is levied. Both models assume that taxing $CO_2$ emissions is the only policy instrument introduced in Switzerland. The different findings of these models are attributed to the fact that Schneider and Stephan levy the tax only on production sectors while consumption goods are excluded from taxation.

A study by First Climate and Econability (2009) investigated questions similar to the ones in this thesis by examining the effects of emissions trading on the Swiss economy after 2012. The study was made at the behest of the Federal Office for the Environment and the State Secretariat for Economic Affairs. Four different data records and interrogations with affected companies were used for the analysis. Among other things the emission data from the exempted Swiss companies in 2008 were applied, which is the same data record used for this thesis. The simulations for the study were calculated with a dynamic CGE model. The study takes the EU emission allowances price as exogenously given and calculates the effects on the Swiss economy. The price for the $CO_2$ tax is adopted from a survey by Ecoplan and not calculated with the CGE model. In particular, two different scenarios were contrasted. In one scenario the Swiss ETS was linked with the EU-ETS and in the other scenario the Swiss ETS was not connected with the EU trading system. The study assumed an emission threshold of 10,000 tonnes of $CO_2$ for a mandatory participation in the EU-ETS and a threshold of 5,000 tonnes of $CO_2$ for a voluntary opt-in possibility. These thresholds are considerably lower than the current regulations of the EU-ETS.

The analysis reveals that only 43 companies would have to participate in the ETS. Moreover, an additional number of 52 companies would benefit from an opt-in option. Consequently, approximately 100 companies would be included in the EU-ETS compared to the 400 companies in the current Swiss ETS. Thus, with a smaller emission threshold than adopted by the EU, only a few companies would participate in the EU-ETS. The authors conclude that a larger number of participants would be desirable and therefore the emission threshold should not be applied. The study further reveals that companies beyond the ETS would have to take a larger share of the overall abatement of Switzerland. This can be explained through a lower abatement target of the EU-ETS. In contrast, companies paying the $CO_2$ tax are only slightly negatively affected through emissions trading. Finally, it is found that the welfare loss is smaller if the ETS is linked with the EU than compared to a stand-alone Swiss ETS. Consequently, a linking of the Swiss ETS with the EU-ETS would be beneficial (First Climate & Econability 2009).

So far, little information exists on the interaction of $CO_2$ taxation and emissions trading. The surveys written at the NCCR focus on the effect of $CO_2$ taxation, whereas the instrument of emissions trading is not implemented. The study by First Climate and Econability (2009) analyses the interdependences of the Swiss economy and the ETS. However, the $CO_2$ tax for the non-emissions trading area is fixed.

This thesis will build on the work from Schneider and Stephan (2007) by extending the scope of their model with the policy instrument of emissions trading.

# 2 Theoretical Background

Global warming is one type of a negative externality problem. An externality arises due to the production or the consumption of a specific good where the external effect of this good has no price and is not compensated by the causer. Two important conditions of an ideally working economy are violated in this case. First, prices of goods do not reflect the real costs. Second, the utility of a single individual is not independent of activities carried out by other individuals. In other words, the market fails to allocate resources in an efficient way (Brunetti 2006).

There exist negative external effects through which a third person is worse off and as well as positive external effects, through which a third person is better off. However, in environmental economics, the negative external effect predominates (Brunetti 2006).

The Coase theorem assumes that individuals can solve an externality problem by negotiating the efficient allocation of resources, without governmental intervention. The necessary condition for such an efficient outcome is that no transaction costs arise and that property rights of resources are clearly defined (Stephan and Ahlheim 1996).

However, in reality these assumptions are considered to be unrealistic. Therefore, government has to intervene as soon as a negative externality occurs as individuals are not able to solve the problem on their own (Stephan and Ahlheim 1996). A possible approach to correct such a negative externality is to implement the polluter pay principle by defining prices for the external effect of these goods[1].

## 2.1 Price Policy versus Quantity Policy

An example of a negative external effect is the consumption of fossil fuels. When fossil fuels are burned, $CO_2$ emissions are emitted. These emissions produce a negative externality because they cause damage to the environment, which is not compensated by

[1] There are also other instruments at the disposal of governments it implement an environmental policy, for example orders, prohibitions, standards and restrictions.

the consumer. Producers and consumers do not consider these costs and therefore an overproduction of emissions results. So, an emission level results which is not optimal. This emission level is shown in Figure 1 and labelled with ê. The government can for example introduce a price for emissions or a quantity limit on emissions. The price policy is typically formulated as an emission tax. In contrast, the quantity policy normally takes the form of a cap-and-trade system (Pizer 1999a).

**Figure 1**: Optimal Price p* versus Optimal Quantity e*

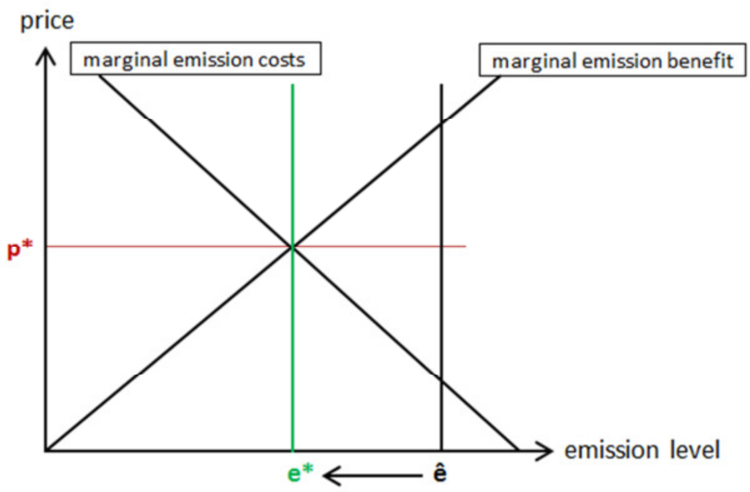



Figure 1 shows the different effects of the two instruments. The horizontal axis denotes the emission level; the vertical axis represents the price for emissions. Marginal emission costs are the costs incurred to reduce an additional unit of emissions. The negative slope of the marginal abatement costs curve shows the fact that when the emission level is high, the costs to reduce one unit of emissions are relatively low. In contrast, if the emission level is already low, the costs for a further reduction are higher (Mankiw 1999).

When a price policy is implemented, the government will set the optimal price at p*, where the marginal emission costs are equal to the marginal emission benefit. With the fixed price p*, the emission level will decrease from ê to e*. Contrariwise, the quantity policy will limit the emission level to e* and correspondingly the price p* will result. In sum, both policies will lead to the same emission level.

Consequently, no matter how the first policy instrument was fixed, there is always a corresponding way to set the other policy instrument in order to reach the same result. However, identity between the two policies is only true if complete knowledge about costs and perfect certainty about the future occurs (Weitzman 1974).

Though, in reality incomplete knowledge about costs and uncertainty about the future are present. Consequently, the marginal abatement costs of the policies are unclear. As a result, the two contrary policies lead to different outcomes and welfare effects. In the following sections the policy instruments are assessed in more detail on the basis of six evaluation criteria, which are presented in the subsequent chapter.

### 2.1.1 Criteria for the Evaluation of Environmental Policies

Following, six criteria for the evaluation of an environmental policy are cited and shortly explained.

The *ecological accuracy* is the criterion evaluating whether a certain emission level can be attained with the given policy or not. The criterion assesses the question whether a policy is able to reach a certain emission level or if the emission level cannot be fixed with a specific policy.

*Economic efficiency* refers to reaching a target with the smallest costs possible. It means that only the cheapest abatement reductions are undertaken. The emission level is reduced as long as the marginal abatement costs are below the marginal utility.

Furthermore, the criteria *incentive for innovation and investment* means that a given policy should give a strong incentive to improve technologies and to finance research on new technologies.

The *transaction costs* are the costs that emerge from the implementation of a new policy, i.e. the formulation of a specific target, transformation of the specified target into legal basis, realisation and surveillance of the implemented law. The government’s effort in these points should be as small as possible. Moreover, the criterion also evaluates the effort for consumers and producers for information procurement concerning the policy. A further point that is included in this criterion is the international aspect. This aspect is important for the questions answered in this thesis.

Another criterion is the *allocation effect,* implying that every governmental intervention has an effect on income. It is possible to cushion the allocation effect through redistribution of the tax revenue or other forms of compensation for the most negative affected individuals.

The last evaluation criterion is about the *acceptability of a policy*. It is important to distinguish between the type of agent when discussing this criterion. The two agents are differently affected through a policy. Consumers on the one hand usually oppose a new policy. On the other hand, the dismay of producers directly depends on the policy configuration. Acceptability of a policy by agents is important for political approval as well as the efficiency of a policy (Stephan and Ahlheim 1996).

### 2.1.2 Arguments for Price Policy

When implementing a price policy, a fixed price incentive is set. This leads to a price ceiling of the policy. Contrariwise, due to uncertainty about costs, no strict limit on the emission level is guaranteed. Uncertainty leads to a range of possible emission levels, the optimal emission level e* in Figure 1 will not be reached (Pizer 1997). When the price set by government is low, people will be willing to pay the price because the marginal abatement costs of $CO_2$ emissions are higher when compared to the emission price. Therefore, it is economical not to abate $CO_2$ emissions and pay the price. This will lead to a much higher emission level. The same argument applies for the reverse situation. If the price for $CO_2$ emissions is staggering, then abatement activities will be cost effective as opposed to the payment of the tax. This situation will lead to an undercut of a specified emission level. In sum, a price policy is economically efficient because only the cheapest reductions are undertaken, whereas ecological accuracy is not reached because the emission level is unclear (Pizer 1999a; Pizer 1999b).

A tax policy is generally opposed by consumers especially if the revenue flows to the government (Pizer 1999a). By contrast, producers always have to possibility of passing prices on the consumer such that their own costs not increase. Therefore, the criterion acceptability cannot be implicitly evaluated. A price policy gives a strong incentive for innovation and investment. A price signal governs innovation and investment because through the elevated price a permanent incentive is given to invest in new and more efficient technologies. The transaction costs of a tax policy cannot be clearly evaluated either. On the one hand, the governmental effort arising from a price policy is a constant monitoring of the emission level and the amount of fiscal charges. On the other hand, the effort of agents for information procurement is relatively low (Stephan and Ahlheim 1996).

Every policy intervention has an effect on the distribution of income; also the price policy. An emission tax has a regressive effect on income which means that individuals with a low income are charged heavier by the tax. This regressive effect can be mitigated through redistribution or compensation. This will lead to a reallocation of income by transferring money between different income categories (Stephan and Ahlheim 1996).

### 2.1.3 Arguments for Quantity Policy

The quantity policy is an efficient market-based mechanism, more often known as cap-and-trade system. The quantity policy asses what the price policy was not able to attain; it precisely limits the emission level. Total $CO_2$ emissions allowed will exactly equal total number of emission allowances under a cap-and-trade system. An emission allowance permits to emit a certain quantity of $CO_2$ emissions. However, in reality the costs to achieve the emission level are unclear. Prices will be built on the market depending on supply and demand of emission allowances. Therefore, prices are highly volatile. Individuals can freely buy and sell emission allowances in order to minimize the costs for themselves. If agents can reduce their $CO_2$ emissions at costs lower than the market price, they will do so and possibly sell their emission allowances. However, individuals who face high marginal abatement costs will more likely buy emission allowances than undertake the reduction effort by themselves. Summarised, the quantity policy achieves ecological accuracy but cannot give a fixed price incentive for abatement activities. Also the economic efficiency is given because the system is controlled through prices (Pizer 1999a; Pizer 1997).

Overall, the acceptability of a quantity policy depends on the allocation of emission allowances and therefore, cannot be generally evaluated. The allocation can be a free distribution or an auction of emission allowances. When emission allowances are auctioned, they are sold to the highest bidder. If total emission allowances were auctioned by government, the same revenue as with a tax policy would flow into governmental budget. However, producers hope that some, if not all, emission allowances will be distributed for free, which means that only for additional emission allowances a price must be paid (Pizer 1999a). The acceptability of consumers is again low because they do not approve if revenue flows into governmental budget, in the case of auctioning of emission allowances. In addition, when emission allowances are auctioned, producers again could pass prices on the consumer, making the consumer even worse off. This attitude could be different, depending on producers to roll over revenues from a free allocation. The acceptability could also change through redistribution of the revenue.

The emission allowances representing a clear price signal give a strong incentive to improve technologies and to finance research on new technologies. There are two aspects to consider when evaluating the transaction costs. Government face large transaction costs due to the organisation, the implementation and the monitoring of a cap-and-trade system (Stephan and Ahlheim 1996). However, these costs can be cut considerably when introducing a cap-and-trade system on the international level. Furthermore, a cap-and-trade system has a regressive allocation effect, depending on the behaviour of companies to roll over the costs of emission allowances on the consumer price (Pizer 1999a).

### 2.1.4 Comparison of Price Policy and Quantity Policy

The crucial difference between the two diverse policies lies in the emergence of the price and the quantity, respectively. Under uncertainty about marginal abatement costs, the difference between the two policies originates from the way the price is calculated (Weitzman 1974, p. 477).

In the case of the tax policy, government sets the price for each tonne of $CO_2$ emissions. Whereas in the case of the cap-and-trade system, the government defines the total amount of emission allowances being issued and the price will develop on the market. Regardless how prices and quantities are determined, both policies are cost efficient because only the cheapest reductions are undertaken (Stephan and Ahlheim 1996; Pizer 1999a). [2]

Table 1, shows the assessment of the six evaluation criteria for the price policy as well as for the quantity policy.

**Table 1:** Evaluation of Price Policy and Quantity Policy

| | Price Policy | Quantity Policy |
|---|---|---|
| **Ecological accuracy** | No | Yes |
| **Economic efficiency** | Yes | Yes |
| **Incentive for innovation and investment** | Price signal governs innovation | Price signal governs innovation |
| **Transaction costs** | Monitoring costs<br>Low costs for information procurement | Organisation, implementation and monitoring costs<br>International aspect |
| **Allocation effects** | Regressive effect can be cushioned through redistribution or compensation | Regressive effect if costs for emission allowances are rolled over on prices<br>Compensation possible |
| **Acceptability** | Political opposition by consumers<br>Producer can pass prices to consumer | Depends on allocation and redistribution of revenues |

Even though the qualitative evaluation does not clearly favour one or the other policy, quantitative analysis shows a clear result. Numerical simulations of these policies have shown that a price policy is preferable to a quantity policy because it generates much higher welfare benefits. The overall cost consequences of an implemented price policy show that the costs of a price policy are below one percentage of gross domestic product (GDP). In contrast, the costs of a quantity policy are assumed to be much higher (Pizer 1999a; Weitzman 1974).

[2] There exists also the possibility of a combination of the two policies in order to exploit the advantages of both polices. On the one hand the economic efficiency of the price policy is kept and on the other hand the political attractiveness of the quantity policy is considered. Such a combined price-quantity policy would be able to balance out uncertainties about marginal abatement costs and the environmental benefits. The benefit of a combined system is that the risk of high costs of emission reduction can be limited by setting a price ceiling. Moreover, a combined policy reflects environmental concerns as well as economic concerns. It is agreed that a mixed price-quantity is slightly more efficient than the price or the quantity policy on its own (Jacoby and Ellerman 2004; Stiglitz, Orszag and Aldy 2001).

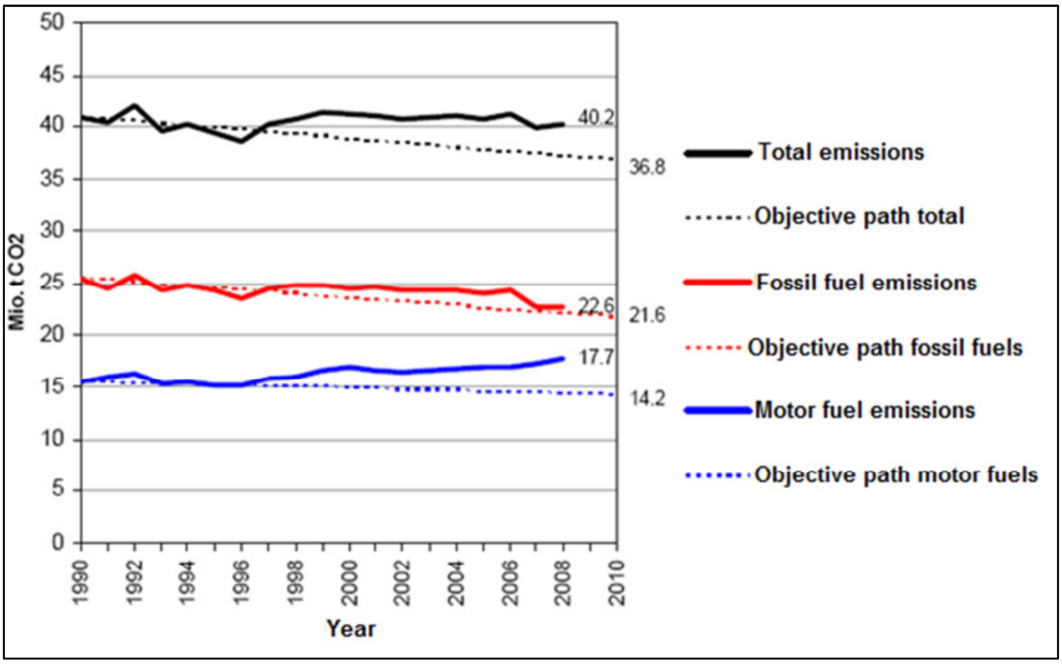
# 3 Swiss Climate Policy

With the ratification of the Kyoto Protocol, Switzerland has committed to contribute to the abatement of GHG emissions. Therefore, Swiss climate policy has been established. This chapter gives an overview of Swiss climate policy and the commitments of the Swiss confederation.

## 3.1 The Kyoto Protocol

The Kyoto Protocol is the first international agreement linked to the United Nations Framework Convention where the industrialised countries agreed to a binding limitation of GHG emissions. Switzerland ratified the Kyoto Protocol in 2003. The Swiss confederation made the commitment to reduce GHG emissions by eight per cent against 1990 levels until 2012 (UNFCCC 1998).

**Figure 2:** $CO_2$ Emissions in Switzerland 1990 – 2010




Source: BAFU 2010b

The $CO_2$ emissions of the Swiss economy are currently still above the Kyoto target. In Figure 2, the development of $CO_2$ emissions in Switzerland is reported for the period from 1990 to 2010. Total $CO_2$ emissions are still exceeding the target by about four million tonnes of $CO_2$. Fossil fuels show a decreasing trend. This is attributed to the fact that the Swiss climate policy only charges taxes on fossil fuels, leading to this decrease. In contrast, $CO_2$ emissions from motor fuels, which are tax free, still increase. Both effects lead to a stabilisation of the $CO_2$ emission level in Switzerland.

With the implementation of flexibility mechanisms, the Kyoto Protocol allows industrialised countries to meet their binding commitments by emissions reductions achieved in other countries. On the one hand, industrialised countries can invest into projects that reduce emissions either in other industrialised countries (joint implementation (JI)) or in developing countries (clean development mechanism (CDM)). On the other hand, industrialised countries can use the opportunity to trade with emission allowances (ETS). They can acquire emission allowances from other industrialized countries. However, the use of these flexibility mechanisms is supplementary to domestic effort in reducing emissions (UN 1998).

## 3.2 The $CO_2$ Law

The main eco-political instrument to achieve the abatement target in Switzerland is the $CO_2$ law. Swiss climate policy is primarily focused on the main GHG, namely $CO_2$. With a share of 85 per cent of all emissions, it is the most common GHG in Switzerland. The $CO_2$ law attempts to reduce $CO_2$ emissions by ten per cent. This target differs slightly from the Swiss target stated in the Kyoto Protocol (BAFU 2009e). This chapter covers the $CO_2$ law in more detail.

### 3.2.1 The $CO_2$ Tax

As mentioned before, the $CO_2$ law is the most important eco-political instrument in Switzerland to achieve the climate policy target. In 2010, $CO_2$ emissions from fossil fuels have to be reduced by ten per cent compared to the level of 1990. There is a differentiation between the abatement targets of heating and motor fuel. The $CO_2$ emissions of heating fuel must be reduced by 15 per cent, whereas $CO_2$ emissions of motor fuel must be reduced by eight per cent.[3] The reduction target should be achieved above all through voluntary measures. If it is not possible to achieve the target with voluntary measures, then a tax on $CO_2$ will be levied on heating fuels.[4]

In the decree of the $CO_2$ law, the levy of a tax on heating fuel, the amount of fiscal charges and their gradual introduction were specified as follows.[5] If the decrease of $CO_2$ emissions is insufficient in 2006, then a tax of 12 CHF per tonne of $CO_2$ will be introduced in 2008. The fiscal burden increases in the following two years to 24 CHF per tonne of $CO_2$ in 2009 and 36 CHF per tonne of $CO_2$ in 2010.[6] The tax on heating fuel was introduced in January 2008 because the voluntary emission reductions undertaken were insufficient. Nevertheless, the amount of fiscal charge remained for two years at 12 CHF per tonne of $CO_2$. In 2010 the $CO_2$ tax was raised to 36 CHF per tonne of $CO_2$, which is a tripling of the tax burden.

The tax on heating fuel paid by the population must be reallocated lump sum to the population. This will lead to a reallocation of income between different income classes and money will be transferred from the richest to the poorest part of the population. The share of the $CO_2$ tax paid by companies will be disbursed to the employer according to the wage bill. Such a refunding system benefits the wage intensive industry, whereas the energy intensive industry is encouraged to reduce their $CO_2$ emissions constantly. The reallocation of the taxes paid by the population is implemented through the health insurance; the taxes of the economy are repaid by the old age and survivors' insurance.[7]

[3] See $CO_2$ law article 2
[4] See $CO_2$ law article 3
[5] See enactment of the $CO_2$ law article 1
[6] See enactment of the $CO_2$ law article 3
[7] See $CO_2$ law article 10

### 3.2.2 Emissions Trading

The decree on the $CO_2$ law establishes a limited ETS for energy intensive companies. These companies have the possibility of being exempted from the $CO_2$ tax if they conclude a voluntary agreement with the federal government to reduce their $CO_2$ emissions to a specified level. These companies will be allocated emission allowances equal to their targets and free of charge. To achieve compliance they either have to reduce their $CO_2$ emissions or acquire emission allowances from other companies.[8] Participants in the Swiss ETS are, among others, producer of cement, glass, ceramic, synthetics and paper, as well as nutrition, touristic and chemical companies (BAFU 2009d).

The Swiss ETS is a baseline-and-credit system. In such a system each participant has the right to emit a certain baseline level of $CO_2$ emissions, where the baseline is computed individually for every participant. When participants fall below their baseline level, they earn emission reduction credits for the additional abatement of $CO_2$ emissions. These credits may be transferred to the next trading period or sold to participants who exceed their baseline emissions and need to purchase additional emission allowances. However, the Swiss ETS does not seem to have promoted the establishment of a market for credits, because companies do not trade among themselves. The only player and buyer of credits in the Swiss ETS is the foundation of the climate cent. The climate cent is a special fee on motor fuels based on the exclusion of motor fuels from the $CO_2$ tax.

### 3.2.3 The Climate Cent

As mentioned above, the $CO_2$ tax is only levied on heating fuels and not on motor fuels. Instead, the federal office has reached an agreement with a private foundation, called the foundation of the climate cent. This is a voluntary measure by the Swiss mineral oil industry that strives for a reduction of motor fuels. The foundation can charge a levy of 1.3 to 1.9 cents per litre of petrol. At present, the levy of 1.5 cents per litre is charged on all gasoline and diesel imports into Switzerland. The revenue of about 100

[8] See $CO_2$ law article 9 and enactment of the $CO_2$ law article 12

million CHF will be spent on domestic measures to reduce $CO_2$, as well as on purchases of emission allowances from projects abroad. The foundation is obliged by agreement to reduce $CO_2$ emissions by 12 million tonnes of $CO_2$ until 2012, whereof at least two million of the reduction must be undertaken domestically. A part of the national abatement is the purchase of $CO_2$ emission allowances from companies being exempted from the $CO_2$ tax which undercut their emission targets. The price of these national emission allowances is rather set by the foundation itself than built on the market. The foundation paid in a first round 70 CHF for one emission allowance equal to a reduction of one tonne of $CO_2$. In a second round they paid 100 CHF for an emission allowance from Swiss companies.[9]

When comparing the prices paid by the foundation of the climate cent with $CO_2$ spot prices built on the EU market (currently at 23 CHF) it is obvious that the price in the Swiss system is far above a market price.[10] Consequently, no real trade in the Swiss ETS is taking place. It is only a unilateral trade where companies sell their over allocations to the foundation of the climate cent.[11] No trade takes place among companies themselves because the foundation controls the price and the Swiss $CO_2$ market.

## 3.3 Announcement of the $CO_2$ Law

The $CO_2$ law is harmonised with the Kyoto Protocol, which means that it is temporary, and will end with the commitment period of the Kyoto Protocol in 2012. Therefore, further reduction targets and measures need to be specified for the period after the Kyoto Protocol. For that reason, the $CO_2$ law was appealed in 2009. The target of the Swiss climate policy is to achieve a decrease of GHGs by 20 per cent in the year 2020 compared to the level of 1990, equal to a decline to a level of 35.6 million tonnes of $CO_2$

[9] www.klimarappen.ch
[10] www.pointcarbon.com
[11] The far above market price originates through the fact that the foundation has to reduce a certain amount of $CO_2$ emissions domestically. Moreover, the foundation disposes a defined sum for the domestic reduction. Consequently, the Swiss ETS prices depend on the willingness of exempted companies to sell their emission allowances. Therefore, it is not necessary that Swiss ETS prices are market-driven.

emissions in 2020. The current Swiss climate abatement target is only specified for $CO_2$ emissions and not for other GHGs. Hence, the scope of the revised $CO_2$ law is wider.

The announcement includes the established instrument of the tax on $CO_2$ emissions. The tax on heating fuel should be maintained. However, the idea of a tax on motor fuel continues to be abandoned by parliament. Nevertheless, a substantial decrease on motor fuels should be achieved with other measures for instance a $CO_2$ emission limit on passenger cars among other reduction measures. Another point introduced is the appropriation of a part of the tax revenues, which means that a part of the tax revenue is not reallocated. Two-thirds or a maximum of 200 million CHF per year are invested into the building department. A significant contribution to the Swiss abatement target can be achieved with this measure.

Another main point is the improvement of the established Swiss ETS and the coupling with the EU-ETS. Furthermore, other measures in different areas are taken to achieve the abatement target. In addition, the federal government can increase the abatement target to 30 per cent, depending on international negotiations. These reduction targets are consistent with the climate policy of the EU. At present, the consultation of the appealed $CO_2$ law is taking place in the National Council and the Council of States (BAFU 2009a).

## 3.4 Negotiation Mandate

The Federal Council conferred in December 2009 to gather negotiations with the EU about their ETS. The goal of these negotiations was to complete a bilateral agreement to link the Swiss ETS and the EU-ETS and to acknowledge each other's emission allowances. Currently, the EU as well as Switzerland both have a closed ETS. This means that for example a Swiss company cannot sell its emission allowances in the EU market and vice versa they cannot buy emission allowances from the EU market to achieve compliance (BAFU 2009c).

The EU-ETS is the biggest market for emission allowances in the world and is one of the most important instruments of international collaboration to combat climate change. The European Commission (EC) seeks the connection to other trading systems to create a global market in this area (BAFU 2010a).

Such a linking has several advantages for Switzerland. The emission market will grow and be more liquid when more participants take part. The costs for the abatement of one tonne of $CO_2$ are cheaper in the EU; therefore, Swiss companies can gain a lot through such a linking. A study, investigating the effects of a connection with the EU-ETS, concludes that a linking is positive from a macroeconomic perspective (BAFU 2009c).

Currently, the Federal Office for the Environment and the Federal Council are negotiating with the environmental ministers in the EU about the configuration of such a linking and the obligations Switzerland would have to bear.

# 4 EU Emissions Trading System

In 2007 the European Union (EU) has committed to reduce its $CO_2$ emissions to at least 20 per cent by 2020 compared to the level of 1990. This climate policy target is regardless of the action other countries undertake. However, the EU is eager to increase its abatement target to 30 per cent if other countries commit to comparable abatement targets. The EU-ETS is the corner stone of the European climate policy for reaching the reduction target and to attain compliance with the Kyoto Protocol (EC 2009b).

## 4.1 Development and History

The EU-ETS is the biggest market for emission allowances, making the EU the world leader in this market. It has been established through the Directive 2003/87/EC entering into force in October 2003. The first phase of the trading system started in January 2005. The three-year-phase from 2005 to 2007 was a start-up phase to gain experience with emissions trading. After the start-up period, a five-year-phase from 2008 to 2012 was launched. Approximately 11,500 installations[12] from all 25 EU countries[13] were included in this first phase. They accounted for 45 per cent of all European $CO_2$ emissions. Large emitters from the power and heat generation industry were included in the EU-ETS as well as energy-intensive industries for example combustion plants, oil refineries, coke ovens, iron and steel producers and the cement, lime, brick, ceramic, pulp and paper industry (EC 2005).

[12] In the European climate policy not companies but rather installations are subject to reduction measures. An installation is a stationary technical unit. A company normally consists of several installations. In the Swiss law it is the obligation of the entire company to achieve an emission reduction, regardless which installation is emission intensive and completing an activity under Annex I of the EU Directive. Therefore, the term *installations* will be used when talking about EU climate policy and *companies* when talking about Swiss climate policy. In chapter 5, where the directives are applied to Switzerland, the focus lies on companies because no data is available on emission output of every installation of a company.

[13] In 2005 the EU was constituted of 25 member states. Rumania and Bulgaria entered the EU in January 2007.

The installations comprised in the EU-ETS have to hold emission allowances equal to their emission output, where one emission allowance represents the right to emit one tonne of $CO_2$. The allocation of emission allowances is in the responsibility of each member state. The allocations are predominantly free of charge and only a small part of total emission allowances was auctioned. In the first trading period, at least 95 per cent of allowances had to be allocated free of charge. In fact, most member states did not auction the emission allowances but distributed all of the emission allowances for free. In the second trading period, the cost-free allocation had to be at least 90 per cent of total allowances. In reality, only four countries used auctions to sell a small part of emissions allowances (EC 2005, EC 2009a).

These allocations are recorded in a country's national allocation plan (NAP). A NAP should be consistent with a country's Kyoto target; therefore, the total amount of emission allowances allocated plays a key role. Table 2 gives an overview of the NAPs from the first and the second trading period for the countries participating in the EU-ETS. This overview shows the national Kyoto target, the total number of emission allowances allocated in each country and the number of installations covered in that country. For example, Austria has committed in the Kyoto Protocol to reduce its $CO_2$ emissions by 13 per cent. A total of 205 Austrian companies are included in the EU-ETS. In the first trading period, Austria had 33 million $CO_2$ emission allowances at disposal for the allocation. In the second trading period, the allocation was reduced to 32 million $CO_2$ emission allowances (EC 2005).

**Table 2:** NAP Overview for EU-ETS

| Member state | Kyoto target (%) | Number of insalllations covered | 2005 - 2007 Allocated $CO_2$ emission allowances (million tonnes per year) | 2008 - 2012 Allocated $CO_2$ emission allowances (million tonnes per year) |
|---|---|---|---|---|
| Austria | -13 | 205 | 33 | 32 |
| Belgium | -7.5 | 363 | 62 | 58 |
| Bulgaria | -8 | Only 2007 | 42 | 42 |
| Cyprus | - | 13 | 6 | 5 |
| Czech Republic | -8 | 435 | 98 | 87 |
| Denmark | -21 | 378 | 34 | 25 |
| Estonia | -8 | 43 | 19 | 12 |
| Finland | 0 | 535 | 46 | 38 |
| France | 0 | 1,172 | 157 | 132 |
| Germany | -21 | 1,849 | 499 | 452 |
| Greece | +25 | 141 | 74 | 68 |
| Hungary | -6 | 261 | 31 | 20 |
| Ireland | +13 | 143 | 22 | 22 |
| Italy | -6.5 | 1,240 | 223 | 202 |
| Latvia | -8 | 95 | 5 | 3 |
| Lithuania | -8 | 93 | 12 | 9 |
| Luxembourg | -28 | 19 | 3 | 3 |
| Malta | - | 2 | 3 | 2 |
| Netherlands | -6 | 333 | 95 | 86 |
| Poland | -6 | 1,166 | 239 | 206 |
| Portugal | +27 | 239 | 39 | 35 |
| Romania | -8 | Only 2007 | 75 | 73 |
| Slovakia | -8 | 209 | 31 | 33 |
| Slovenia | -8 | 98 | 9 | 8 |
| Spain | +15 | 819 | 174 | 152 |
| Sweden | +4 | 499 | 23 | 22 |
| UK | -12 | 1,078 | 245 | 246 |
| Liechtenstein | -8 | 2 | - | 0 |
| Norway | +1 | - | - | 15 |
| **Total** | **-** | **11,430** | **2,299** | **2,087** |

Source: EC 2005, EC 2009a

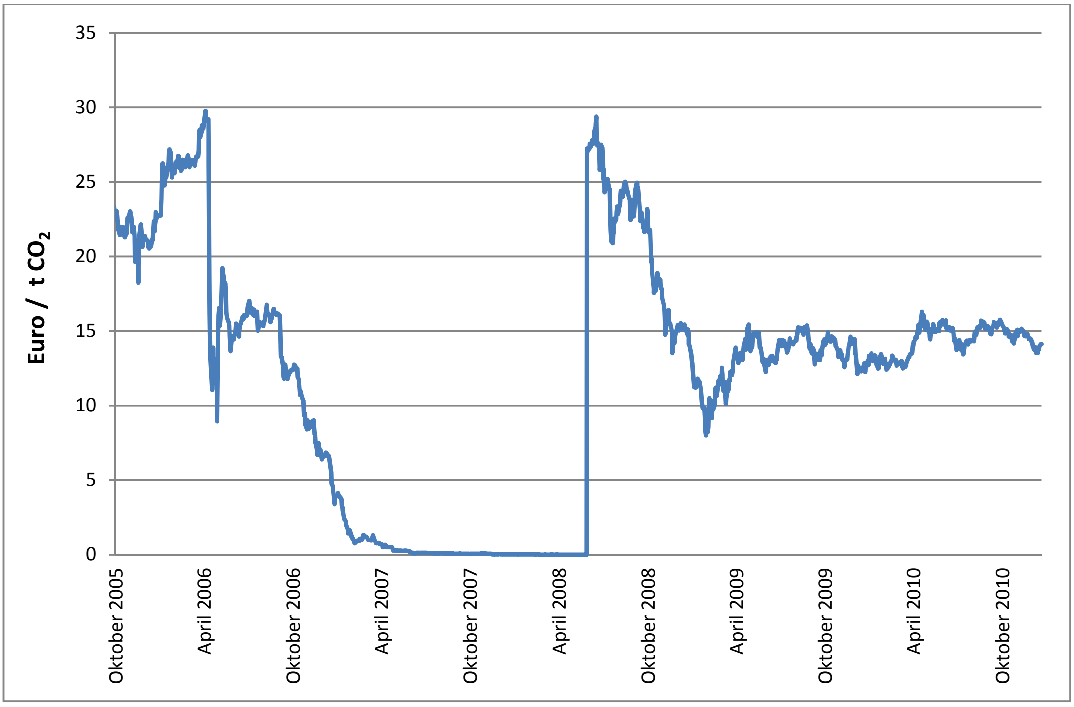
The EU-ETS is based on six fundamental principles. First of all, it is a pure cap-and-trade system. Second, the initial focus lies on $CO_2$ emissions from big industrial emitters. Third, the implementation of the trading system takes place in different phases. Due to this application the opportunity to change and improve the system is given. Fourth, the allocation plans of the EU countries are remade for each period. Fifth, compliance is monitored in a strong way and sanctions are hard. Sixth, the $CO_2$ emission allowance market is EU-wide and it is linked with the rest of the world through acknowledgment of emission reduction projects from abroad and possible linkages with compatible trading systems from other countries (EC 2005).

When the start-up phase was launched, the price for emission allowances increased rapidly. The power sector immediately started buying emission allowances for covering their emissions, whereas the other players did not yet sell their surplus allowances. This development created an artificial scarcity increasing the price of emission allowances to 30 Euros in March 2006. In April 2006, the European Commission released the information about the emission data from 2005 for all the installations included in the EU-ETS. The data record showed that a surplus of emission allowances was allocated and essentially no scarcity existed. National allocation plans were too close to the current emissions or in some cases above the actual emission level. Therefore, the price of emission allowances declined very fast and converged to zero by midyear 2007. This over-allocation of emission allowances is often referred to as the collapse of the EU-ETS (Convery, Ellerman and de Perthuis 2008).

After the start-up phase, a five-year period from 2008 to 2012 in compliance with the Kyoto period started. Due to the price collapse in the start-up period, the allowance prices of the first and the second trading period were totally disconnected. The allowance price of the second period was relatively steady reflecting a real abatement target and a stricter view of the European Commission when reviewing the NAPs for the second trading period (Convery, Ellerman and de Perthuis 2008).

In Figure 3, the price path of the EU emission allowances is plotted for the years since the EU-ETS was established. The peak in 2006 represents the price maximum in the first trading period. Then, the collapse is clearly visible where the price is zero. After the collapse, the steep increase in the allowance price shows the clear cut between the two trading periods. The fall in allowance prices at the end of 2008 can be ascribed to the reduced output as a result of the recession due to the financial crisis.

**Figure 3:** Price of EU Emission Allowances (Euro/t $CO_2$)




Source: Point Carbon

In the second trading period not only the volume of emission allowances changed, but also other improvements were made. The smaller volume of emission allowances has to ensure that a real reduction of emissions is undertaken. Furthermore, in addition to emissions from $CO_2$ also emissions of nitrous oxide are included in the EU-ETS. Moreover, the EU-ETS was extended to the new members of the EU, Rumania and Bulgaria, and also beyond the EU to include Iceland, Liechtenstein and Norway. Through the linking directive, also credits from CDM and JI projects, CER and ERU units respectively, were accepted in the EU-ETS. The credits were recognised as equivalent to the EU emission allowances. The acknowledgment of these credits improves the liquidity of the market and lowers the price of emission allowances (EC 2009a).

## 4.2 EU Directives

In this chapter the EU-ETS directives are analysed in more detail in order to be able to apply the regulations to Swiss companies as a member state of the EU in the next section. Of special interest are the criteria for the inclusion of a company in the EU-ETS. The goal of this analysis is to understand which rules apply for the companies included in the EU-ETS. On that account, the most important articles covering the inclusion criteria are treated in this section. Conveniently, the enclosure of aviation activities into the EU-ETS, which is treated in a further directive, will not be subject of this analysis.

### 4.2.1 Directive 2003/87/EC

The directive 2003/87/EC in force since 2003 is the underlying legal obligation of the EU-ETS. In this chapter the most important articles of the basic directive are described, with a special focus on the description of Annex I.

This directive establishes a system for GHG emissions trading within the European countries. The goal of the EU-ETS is the reduction of GHG emissions in a cost effective and economically efficient way.[14] The scope of the directive comprises the activities listed in Annex I and the GHGs listed in Annex II.[15]

Annex I covers activities from the production of energy, metal, cement, glass, ceramics, synthetics and paper. The *type of activity* builds the first criterion for the inclusion of an installation into the EU-ETS. The second criterion is the definition of a capacity threshold, representing the amount of a combustion unit for fossil fuels in an installation. Installations with a combustion capacity above the threshold are included in the EU-ETS regardless what type of activity they perform. The threshold is defined as total rated thermal input of 20 megawatt (MW).[16] [17] The output of emissions can only be derived from the combustion capacity because on the one hand it depends on the effectiveness of a combustion unit and on the other hand on the type of fossil fuel used. The capacity of 20 MW corresponds approximately to 20,000 to 40,000 tonnes of $CO_2$ emissions per year (First Climate & Econability 2009). This conversion is of great importance since Swiss companies only display their emission output in tonnes of $CO_2$

[14] See Directive 2003/87/EC article 1
[15] See Directive 2003/87/EC article 2
[16] Watt is a derived unit of power
[17] See Directive 2003/87/EC Annex I

and do not indicate the capacity of their combustion units. Therefore, a threshold in tonnes of $CO_2$ must be specified precisely. For that purpose, several assumptions and calculations are needed. This conversion will be made in chapter 5.2.1.

The GHGs listed in Annex II are the following: Carbon dioxide ($CO_2$), methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride.[18] Despite listing all GHGs, covered also by the Kyoto Protocol, the focus of the underlying directive lies on $CO_2$ emissions only.

Each member state of the EU has the obligation to develop a NAP where all installations with the corresponding number of emission allowances are listed. The European Commission has to verify the NAP of each country and in addition has the right to reject the plan or certain aspects thereof.[19] The total quantity of emission allowances to be allocated shall be consistent with a country's obligation under the Kyoto Protocol and national climate change programmes. Moreover, the NAP must be consistent with the technological potential of activities and shall not discriminate between companies and sectors.[20] The allocation will be free of charge for at least 95 per cent of emission allowances in the first trading period and for at least 90 per cent in the second trading period.[21]

The emission allowances are only valid for one particular trading period. Therefore, emission allowances issued for the first trading period from 2005 to 2007 are only valid in these three years. Consequently, emission allowances not used for covering emissions in the current trading period are cancelled; however, they are replaced by emission allowances valid for the subsequent trading period.[22] This procedure is also called banking of emission allowances. In the case that the emissions of an installation are not covered by emission allowances, an excess emissions penalty must be paid. The penalty for each tonne of excess emissions is 40 Euros in the start-up phase and 100 Euros for the

[18] See Directive 2003/87/EC Annex II
[19] See Directive 2003/87/EC article 9
[20] See Directive 2003/87/EC Annex III
[21] See Directive 2003/87/EC article 10
[22] See Directive 2003/87/EC article 13

following trading periods. However, the amount of excess emissions must be covered nonetheless with emission allowances.[23]

Under the directive, a unilateral inclusion or exclusion of installations is allowed. The type of activities and GHGs not listed in the annexes of this directive, or installations with an amount of emission output below the capacity limits can be included into the EU-ETS, if the European Commission approves this approach of a particular country.[24] In contrast to this procedure, certain installations can be temporarily excluded from the trading system. The possibility of such exclusion is only given for the start-up phase.[25] These procedures are also called opt-in and opt-out possibility.

Article 25 of the directive establishes the possibility of linking the EU-ETS with other GHG trading systems to provide mutual recognition of emission allowances between the systems. Such a linking would increase the cost effectiveness of the EU-ETS. However, such a connection can only be made with Annex B countries[26] having ratified the Kyoto Protocol.[27] Switzerland fulfils this requirement as Switzerland belongs to the list of Annex B countries.

A further important point of this directive concerning the climate policy of the EU is written in the preamble of the directive. The EU-ETS should only be a part of a package of policies and measures leading to a decrease of emissions. Thus, other policies should be implemented on the level of each country.[28] Moreover, it is explicitly stated that the instrument of taxation can be used to limit emissions from installations and production processes excluded from the EU-ETS.[29] This is a significant point for the following chapters, since, the goal of this thesis is to apply the EU directive to the Swiss system and if necessary make modifications of the trading system in order to achieve the Swiss climate policy target. A possible modification of the policy system is the introduction of the instrument of taxation. The preceding regulations of the EU-ETS directive show that

23 See Directive 2003/87/EC article 16
24 See Directive 2003/87/EC article 24
25 See Directive 2003/87/EC article 27
26 Annex B countries to the Kyoto Protocol are the countries ratifying the Kyoto Protocol and committing to a specific abatement target.
27 See Directive 2003/87/EC article 25
28 See Directive 2003/87/EC preamble cipher 23
29 See Directive 2003/87/EC preamble cipher 24

a diversification of domestic climate policy is desired and that the approach of extending the eco-political instrument of emissions trading is compatible with the regulations of the EU.

### 4.2.2 Directive 2009/29/EC

The directive 2009/29/EC, in force since June 2009, is an amendment of the directive 2003/87/EC, being applied with the start of the third trading period in January 2013. Many changes and improvements have been made due to the apparent inefficiencies of the EU-ETS in the start-up phase. The most significant changes will be named here. Again, especially, the inclusion criteria will be of importance since these criteria will be applied to the Swiss system.

A significant change was made with the inclusion of new sectors and new gases into the EU-ETS. The new sectors include the production of petrochemicals, ammonia and aluminium, as well as the inclusion of aviation. The inclusion of the aviation sector is not further analysed. Through the inclusion of these activities, other GHGs than $CO_2$ are covered in the EU-ETS, such as nitrous oxide and perfluorocarbons. Due to the enlarged scope in the third trading period, approximately 50 per cent of all European $CO_2$ emissions are covered in the EU-ETS. The emissions should be reduced by 21 per cent in 2020 compared to the level of 2005.[30] For this purpose, the emission allowances are reduced each year by the linear factor of 1.74 per cent compared to the average annual total quantity of emission allowances for the period from 2008 to 2012.[31]

Compared to the preceding periods, the allocation of emission allowances will be auctioned for the most part.[32] There are some exceptions and special cases. Full auctioning is the rule for the power and electricity sector, whereas the energy intensive sectors, which are at a high risk of relocating their production to countries with looser environmental policies (carbon leakage), will obtain their emission allowances predominantly for free. This distribution method is based on the definition of benchmarks.

[30] See Directive 2009/29/EC, preamble cipher 14
[31] See Directive 2009/29/EC article 9
[32] See Directive 2009/29/EC article 10

If an installation is below the specified benchmark it will receive all its emission allowances gratuitous.[33]

The opening clause for the linkage with other GHG trading systems is stricter in the amending directive. A further requirement for a possible connection is an absolute cap on overall emissions in the other trading system.[34] Again, it is crucial to ask whether the Swiss system is specified with an absolute cap. The eight per cent reduction target of Switzerland is clearly an absolute emission cap. Consequently, the Swiss system is still qualified for a potential connection with the EU-ETS.

Furthermore, the opt-out criteria became more stringent; the opportunity for exclusion is no longer given for large installations but only for small installations. However, the excluded installations must also contribute to reducing emissions with an equivalent contingent. Any installation that was excluded and then reintroduced into the EU-ETS must stay in the trading system for the rest of the trading period. Further shifts are no longer possible.[35]

In Table 3, the activities listed in Annex I of the EU directive are named. In a further step these activities are connected to the corresponding industrial sector (first column). Therefore, the NOGA classification, which is the general classification of economic activities applied in Switzerland, was used. With this classification, companies can be categorised according to their economic activity and arranged in coherent groups.[36] This transformation of the criteria will be necessary for the inclusion of Swiss companies into the EU-ETS. Conveniently, the industrial sector will be used as an inclusion criteria rather than the type of activities listed in Annex I.

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[33] See Directive 2009/29/EC article 10a
[34] See Directive 2009/29/EC article 25
[35] See Directive 2009/29/EC article 27
[36] http://www.bfs.admin.ch/bfs/portal/en/index/infothek/nomenklaturen/blank/blank/noga0/vue_d_ensemble.html

**Table 3:** Industrial Sectors to be included in the EU-ETS (Determined with the Activities listed in Annex I)

| Industrial Sector | Type of Activities (Annex I) |
|---|---|
| Mining and production of stones | • Production of primary aluminium<br>• Production of secondary aluminium where combustion units with a total rated thermal input exceeding 20 MW are operated<br>• Metal ore (including sulphide ore) roasting or sintering, including pelletisation |
| Paper production, publishing and printing industry | • Production of pulp from timber or other fibrous materials<br>• Production of paper and cardboard with a production capacity exceeding 20 tonne per day |
| Chemical industry, mineral oil processing, production of plastic goods | • Refining of mineral oil<br>• Production of coke<br>• Production of nitric acid<br>• Production of adipic acid<br>• Production of ammonia<br>• Production of glyoxal and glyoxylic acid<br>• Production of hydrogen and synthesis gas by reforming or partial oxidation with a production capacity exceeding 25 tonne per day<br>• Production of soda ash and sodium bicarbonate<br>• Production of bulk organic chemicals by cracking, reforming, partial or full oxidation or by similar processes, with a production capacity exceeding 100 tonne per day |
| Manufacturing of non-metallic minerals | • Manufacturing of glass including glass fibre with melting capacity exceeding 20 tonnes per day<br>• Production of cement clinker in rotary kilns with a production capacity exceeding 500 tonnes per day or in other furnaces with a production capacity exceeding 50 tonnes per day<br>• Production of lime or calcinations of dolomite or magnesite in rotary kilns or in other furnaces with a production capacity exceeding 50 tonnes per day<br>• Manufacturing of ceramic products by firing, in particular roofing tiles, bricks, refractory bricks, tiles, stoneware or porcelain, with production capacity exceeding 75 tonnes per day<br>• Drying or calcinations of gypsum or production of plaster boards and other gypsum products where combustion units with a total rated thermal input exceeding 20MW are operated<br>• Manufacturing of mineral wool insulation material using glass, rock or slag with a melting capacity exceeding 20 tonnes per day |
| Manufacturing and processing of metals and products thereof | • Production or processing of ferrous metals (including ferro-alloys) where combustion units with a total rated thermal input exceeding 20 MW are operated. Processing includes, inter alia, rolling mills, re-heaters, annealing furnaces, smitheries, foundries, coating and pickling<br>• Production or processing of non-ferrous metals, including production of alloys, refining, foundry casting, etc., where combustion units with a total rated thermal input (including fuels used as reducing agents) exceeding 20 MW are operated<br>• Production of pig iron or steel (primary or secondary fusion) including continuous casting, with a capacity exceeding 2,5 tonne per hour |
| Energy and water supply | • Combustion of fuels in installations with a total rated thermal input exceeding 20MW (except installations for the incineration of hazardous or municipal waste) |
| *Activities where a classification is not possible* | • Production of carbon black involving the carbonisation of organic substances such as oils, tars, cracker and distillation residues, where combustion units with a total rated thermal input exceeding 20MW are operated<br>• Capture GHGs from installations covered by this Directive for the purpose of transport and geological storage in a storage site permitted under Directive 2009/31/EC<br>• Transport of GHGs by pipelines for geological storage in a storage site permitted under Directive 2009/31/EC<br>• Geological storage of GHGs in a storage site permitted under Directive 2009/31/EC |

In addition to the list of the activities listed in Annex I, the amount of the combustion unit of a certain company is relevant for the inclusion. The type of activity referred to in Annex I is *combustion of fuels in installations with a total rated thermal input exceeding 20 megawatt* and will be further referred to as the amount of emission output. This type of activity cannot be assigned to a certain sector like the association for the other activities listed in Annex I. However, the criterion will also be used as inclusion criterion for Swiss companies. In sum, the assigned sectors and the amount of emission output will be the relevant criteria to acquire the list of Swiss companies being included in the EU-ETS.

## 4.3 Comparison of the Swiss Emissions Trading System and the EU Emissions Trading System

This chapter provides a system comparison of the Swiss ETS and the EU-ETS. An overview of the similarities and the distinctions of the two systems is acquired. The systems are compared on the basis of the current regulations. However, if the new legislations from 2013 onwards differ greatly from the current system, these changes will be referenced.

The criteria for this assessment are categorised in three groups. The set *system design* is about the specification of the ETS, the participants, the emission units and the GHGs covered with the trading system. The second block of criteria, *target and allocation*, specifies the system in more detail; the allocation of the emission allowances, the emission targets itself and the overall transparency of the system. The last criteria set *compliance* specifies the elements of the compliance mechanism. The key results of the comparison are summarised in Table 4.

**Table 4:** System Comparison of EU-ETS and CH-ETS

| | **EU-ETS** | **CH-ETS** |
|---|---|---|
| **System Design** | | |
| Trading system | Cap-and-trade system | Baseline-and-credit system |
| Participation principle | Mandatory | Voluntary |
| Participants | Power and heat generation, combustion plants, oil refineries, coke ovens, iron and steel producers and the cement, lime, brick, ceramic, pulp and paper industry (Annex I)<br><br>Approx. 11'500 participants | No conclusive list.<br>Inter alia cement, glass, ceramic, synthetic, paper industry as well as nutrition, touristic and chemical companies<br><br>Approx. 400 participants |
| GHG covered | $CO_2$ and other GHGs | $CO_2$ |
| Emission unit | EU emission allowance (EUA) | Swiss emission allowance (CHU) |
| Trading periods | Phase 1: 2005 - 2007<br>Phase 2: 2008 - 2012 | 2008 - 2012 |
| Other Kyoto units | CER (CDM) and ERU (JI)[37] | CER (CDM) and ERU (JI)[38] |
| **Target and Allocation** | | |
| Emission target | Absolute emission target | Relative emission target |
| Allocation | Free of charge, only a portion of 5 per cent will be auctioned[39] | Free of charge |
| Transparency | Information about allocation of emission allowances and compliance of every installation is public[40] | Limited publication |
| **Compliance** | | |
| Monitoring | Assignment of every member state and independent verification[41] | Assignment of the energy agency of the economy and no independent verification |
| Banking[42] | Allowed (from 2008)[43] | Allowed[44] |

[37] See Directive 2004/101/EC
[38] See enactment about the deduction of foreign emission reduction article 5
[39] The allocation in the 3rd trading period will be based on auctioning. See Directive 2009/29/EC, Art. 10
[40] See Directive 2003/87/EC article 16 (2) and article 17
[41] See Directive 2003/87/EC article 14 and 15
[42] The Kyoto Protocol allows unlimited banking and borrowing within commitment periods, but only banking between periods (Jacoby p. 486)
[43] See Directive 2003/87/EC article. 13
[44] UVEK 2005

| | | |
|---|---|---|
| Borrowing | Always prohibited in accordance with the Kyoto Protocol | Always prohibited in accordance with the Kyoto Protocol |
| Sanctions | 100 Euro per tonne $CO_2$ for the missing emission allowances plus missing emission allowances in the following year | 36 CHF per tonne $CO_2$ for the entire $CO_2$ emission output |
| Market price per EUA/CHU | 23 CHF | 100 CHF |

The main distinction is the trading system. The EU trading system is specified as a cap-and-trade system whereas the Swiss trading system is defined as a baseline-and-credit system. Under a cap-and-trade system, an aggregate cap is placed on emissions. The regulatory authority sets the cap and then it is divided into a number of tradable emission allowances. These emission allowances are distributed to the participants trading the emission allowances and establishing a market price. The participants of the cap-and-trade system must submit an allowance for every unit of emission output. The baseline-and-credit system is a different approach, where participants earn emission reduction credits for emissions below their baselines. There is no explicit cap on aggregate emissions. Instead, each participant has the right to emit a certain baseline level of emissions. Participants receive credits for their baseline level. The credits are used for covering the level of actual emissions. If the credits are not entirely used they may be transferred to the next trading period or sold to participants who exceed their baseline emissions and need to purchase additional credits. Theoretically, if the implicit cap of the baseline-and-credit were fixed and numerically equal to the aggregated cap in the cap-and-trade system, the two trading systems would be equivalent. In many cases, however, the baseline is computed individually for every participant without fixing an overall implicit cap (Buckley, Mestelman and Muller 2005).

Another key difference lies in the participation principle of the system. The EU system is a mandatory system, whereas the Swiss system is on a voluntary basis. This configuration also has an effect on the set of participants. Fundamentally, the groups are similar, but not identical. The Swiss system contains a wider circle of members. With the new regulations in the Swiss system after 2012 also companies of certain sectors will be obliged to participate in the ETS; hence, a voluntary participation will no longer exist (BAFU 2009a). This adaptation implies that the circle of participants will be fixed.

Both systems particularly cover $CO_2$ emissions. The EU-ETS is slightly wider and covers also the other GHGs. However, with the revision of the $CO_2$ law all GHGs will be subject to reduction measures in Switzerland. Concerning the emission unit, the EU established its own unit, called EUA, because the EU-ETS was launched before the Kyoto period started. Moreover, with an own unit, the EU can prevent that other Kyoto allowances directly enter the system. Similarly, Switzerland created an own emission unit, called CHU. It is convenient that Switzerland has its own emission unit when considering a linking with the EU-ETS.

A further fundamental dissimilarity concerns the definition of the emission targets. The EU has an absolute emission target. This implies that the target is fixed at the beginning of a trading period and not altered during the period. By contrast, the target of the Swiss system is defined as a relative target, implying that the target can be changed during the trading period. However, the adaptation of the emission target during the period is not pursued in the trading period after 2012 (BAFU 2009a).

Another key difference of the two systems is the market-based price of an emission allowance. In the EU-ETS participants trade their emission allowances in a free market and thus a market-based price is established at approximately 23 CHF per allowance. Whereas in the Swiss system the market is lame and does not work sound. The only buyer of emission allowances is the foundation of the climate cent, setting the price above the market price at 100 CHF per emission allowance.

Summarised, the comparison shows that similarities as well as large differences exist in the two systems. The main difference between the Swiss ETS and the EU-ETS is the trading systems. However, due to the announcement of the $CO_2$ law, these differences should be fathomed in such a way that a linking of the Swiss ETS with the EU-ETS is achievable.

# 5 Switzerland in the EU Emissions Trading System

The inclusion criteria for the EU-ETS are based on the amount of emission output and the type of activity of a company. In this chapter, these regulations are adopted for the Swiss system. A detailed analysis of the effects for Switzerland is made. Further, it is studied how many companies and how much $CO_2$ emissions would be covered in Switzerland. The reduction potential of Swiss companies in the EU-ETS is analysed. Finally, it is examined if the Swiss climate policy target of a 20 per cent reduction of $CO_2$ emissions in 2020 can be reached with these regulations.

## 5.1 Data Basis

The data basis used for the analysis consists of three data sets. The first one is the Swiss NAP with information on emission allocation of today's Swiss ETS companies for the period from 2008 to 2012.[45] The second one is a data record from 2008 consisting of the actual emission data for all companies listed in the NAP.[46] The third data set is an assignment of these companies to the corresponding industrial sector. This assignment was completed with the NOGA classification. For the purpose of this analysis, the companies included in the NAP were classified at the second level of the NOGA classification. This assignment is central for the implementation of the inclusion criteria activities listed in Annex I of the EU directive.

The three data sets were merged to one single data record containing all required information for further analysing the Swiss system; company name, emission allocation, actual emission output and the corresponding NOGA sector. This *extended Swiss NAP* is listed in Table A-1 Appendix A.

The extended Swiss NAP includes data from 396 companies. 46 companies do not display an actual emission output in 2008, since they joined the Swiss ETS only in 2009

[45] https://www.national-registry.ch/ListePnaq.aspx?Period=01&menu=yes

[46] https://www.national-registry.ch/WebFormEtat.aspx?ETAT=SyntheseEV&TYPE=EV&ANNEE=2008&IDAUTO=-1

or 2010. Regardless of the missing data, these companies are included to increase the data record of the extended Swiss NAP. Thus, the difference in the year of participation will be abandoned. For these companies the emission output is equal to the emission allocation.

## 5.2 Implementation and Application of Inclusion Criteria

For implementing and applying the inclusion criteria of the EU directive, the extended Swiss NAP is analysed in detail. The two inclusion criteria cannot be directly applied to the extended Swiss NAP. Therefore, the criteria must be modified such that they can be applied. After all, the EU directive sets a capacity threshold on the production output of activities listed in Annex I. Data on production capacity are not available for Swiss companies. Therefore, this production capacity criterion will be neglected for the further analysis.

The focus for the inclusion of a company in the Swiss economy will lie on the two criteria amount of emission output and affiliation to a specific sector, which is used as an approximation of the criterion activities listed Annex I.

### 5.2.1 Modification of the Inclusion Criteria

In the Swiss system companies indicate their emissions output in tonnes of $CO_2$, whereas in the EU regulations the criterion of the amount of emission output is specified as a capacity expressed in megawatts. For the purpose of adopting the inclusion criterion amount of emission output, a transformation of the criterion must be made in order to apply the rule to the extended Swiss NAP. Therefore, the capacity measured in megawatt must be transformed in a threshold quantified in tonnes of $CO_2$. On that account, several assumptions are necessary.

Watt is the notation for a capacity over a certain time period. For the threshold expressed in tonnes of $CO_2$, the watt-hour must be first calculated and for that reason the declaration of the occupancy rate must be known. The occupancy rate is assumed to be

6,989 hours per year. The assumption is based on an 80 per cent occupancy rate, which is a standard assumption and as well presumable for the Swiss economy (First Climate & Econability 2009).

The definition of the capacity in the EU directive is expressed as an input capacity, which means that the output of emissions depends heavily on the efficiency factor. The input capacity of 20 MW corresponds, depending on the efficiency factor, to 10 to 15 MW of output capacity (First Climate & Econability 2009). For the calculation of the threshold in tonnes of $CO_2$, the upper boundary of this range is taken.

Further, an assumption about the emission factor is made. The emission factor is the indicator of the emission output per unit of energy emitted. Diesel oil emits 73 tonnes of $CO_2$ per tera-joule (TJ), petrol 73.9 tonnes, heavy oil 77 tonnes, light oil 73.7 tonnes, gas 55 tonnes and coal 94 tonnes per TJ. Since the most part of fossil fuels used in Switzerland is light oil, diesel oil and petrol, it is assumed that the average emission factor is 74 tonnes of $CO_2$ per TJ (Bucher 2009). This value is used for the calculation of the emission threshold.

**Table 5:** Assumptions for the Calculation of the Emission Threshold

| | |
|---|---|
| **Occupancy rate** | 6,989 hours per year (80%) |
| **Output capacity** | 15 MW |
| **Emission factor** | 74 tonnes of $CO_2$ per TJ |

Moreover, the definition of a kilowatt-hour expressed in mega-joule per second is used. Therefore, the following equivalence is used for calculating the $CO_2$ emissions threshold:

$$1 \text{ kilowatt-hour} \equiv 3.6 \text{ mega-joule per second}$$

Finally, the calculation of the threshold is completed with the following formula:

$$\text{Threshold in t } CO_2 = \frac{\left((6{,}989 * 15) * 1{,}000\right) * 3.6}{10^6} * 74$$

With these assumptions, a threshold of **27,930 tonnes of $CO_2$** is calculated. This threshold means that all companies emitting more than 27,930 tonnes of $CO_2$ per year are included in the EU-ETS.

In addition, the inclusion criterion type of activities listed in Annex I had to be modified in order to implement the criterion to the extended Swiss NAP. This adjustment was already prepared in chapter 4.2.2, where the activities listed in Annex I of the EU directive are connected to the NOGA sectors. In Table 6, NOGA sectors which have to join the EU-ETS are listed.

**Table 6:** NOGA Sectors Participating in the EU-ETS

| | |
|---|---|
| Mining and production of stones | Production of plastic ware |
| Paper production | Manufacturing of non-metallic minerals |
| Publishing and printing industry | Manufacturing and processing of metals and products thereof |
| Chemical industry | Energy and water supply |
| Mineral oil processing | |

### 5.2.2 The Reduction Potential of Swiss Companies in the EU Emissions Trading System

When applying, the modified inclusion criteria to the extended Swiss NAP, one can see that 167 companies are included in the EU-ETS. Contrariwise, the current Swiss ETS comprises 396 companies. Thus, a share of 42 per cent of current Swiss ETS companies would participate in the EU-ETS, whereas 58 per cent would no longer be able to participate in the emissions trading.

The 167 companies have a total $CO_2$ emission output of 2,384,170 tonnes. The emission output of the 25 largest companies constitutes a share of 75 per cent of these $CO_2$ emissions. Consequently, the other 142 companies are by tendency smaller. Approximately 80 per cent of $CO_2$ emissions from today's exempted companies would be covered with the EU-ETS. When considering only the amount of emission output, no more than five companies are included in the EU-ETS. The rest of the 167 companies was included because of the affiliation to a specific NOGA sector. Thus, the criteria type of activity was decisive in the most cases which reflects the purpose of the EU-ETS to include the energy intensive sectors in the emissions trading.

The largest share of companies fulfilling the criteria is located in the sectors chemical industry, mineral oil processing, production of plastic goods and manufacturing of non-metallic minerals (99 companies). This is equal to a portion of 60 per cent of all companies included in the EU-ETS. Thus, these sectors embody many activities listed in Annex I of the EU directive because the production processes thereof are very $CO_2$ intensive.

In a subsequent step, the reduction potential of the companies fulfilling the inclusion criteria is calculated. The emission allowances shall be reduced each year by a linear factor of 1.74 per cent relative to the average annual quantity of emission allowances for the period from 2008 to 2012.[47] To simplify, the value for the average annual quantity of emission allowances from 2008 to 2012 will be approximated with the allocation in the year 2012.

Total $CO_2$ emissions of Swiss companies potentially participating in the EU-ETS will be reduced every year by 1.74 per cent of the total allocation of emission allowances in 2012. This leads to a yearly reduction of $CO_2$ emissions by 45,738 tonnes. An aggregated decrease of 365,901 tonnes of $CO_2$ results over the entire trading period of eight years. This is equal to a decline of $CO_2$ emissions by 15.3 per cent. Though, the reduction is not measured compared to the level of 1990 but only compared to the emission level in 2008. However, the $CO_2$ emission levels of 1990 and 2008 in Switzerland (BAFU 2010c) are only marginally different and can be neglected.

Apparently, the emission reduction is distant from the 20 per cent abatement target of the Swiss climate policy. The target of the EU-ETS is an emission reduction by 21 per cent in 2020 compared to the level of 2005.[48] Whereas the Swiss abatement target is a 20 per cent emissions reduction in 2020 compared to the level of 1990. Due to the fact that the emission level in 2005 was higher than in 1990, the EU-ETS reduction target is relatively less ambitious than the Swiss climate policy reduction target. The Swiss abatement target cannot be achieved because of the lower reduction potential of the EU-

[47] See Directive 2009/29/EC article 9

[48] See Directive 2009/29/EC preamble cipher 5

ETS. As a result, Swiss companies in the EU-ETS are not able to achieve a 20 per cent reduction of their $CO_2$ emissions with the EU-ETS.

For the targets of Swiss climate policy, the decrease of $CO_2$ emissions by Swiss companies in the EU-ETS should be measured in comparison to the overall Swiss climate policy abatement target. It is clear from the outset that such a comparison is disproportionate. The potential of companies participating in the EU-ETS is very small compared to the Swiss overall abatement target. It is not possible that such a small group of Swiss companies can undertake the entire reduction target of Switzerland. The following numbers show the disproportionate comparison.

Based on the Swiss $CO_2$ statistic, it is assumed that the Swiss economy, in contrast to Swiss households, has to reduce a fraction of 50.1 per cent of the Swiss reduction target, since this fraction of emissions was caused by the economy (BAFU 2010b). Consequently, Swiss companies have to contribute to the abatement target with a share of 4.46 million tonnes of $CO_2$. By contrast, total $CO_2$ emissions of Swiss companies included in the EU-ETS are 2.38 million tonnes. The reduction potential of Swiss ETS companies equals to eight per cent of the required decrease of the Swiss economy.

Accordingly, it is not possible to reach the overall abatement target of Switzerland with the EU-ETS as the only eco-political instrument. Therefore, it is necessary to further extend the Swiss policy design. Based on the fact that the EU-ETS has a lower reduction potential than the Swiss abatement target, it is necessary to modify the regulations from the EU-ETS for the Swiss needs. Several possibilities of modifying the EU-ETS and extending the policy design are discussed in more detail in the following chapters.

### 5.2.3 Sensitivity Analysis

For the modification of the inclusion criterion amount of emission output, several assumptions were necessary. A crucial point was the assumption of the occupancy rate. As standard assumption an occupancy rate of 80 per cent was chosen for the analysis of the extended Swiss NAP. This guess resulted in an emission threshold of 27’930 tonnes of $CO_2$. In order to identify the effect of this assumption, significantly different occupancy rates of 50 per cent and 95 per cent were chosen. The results of the sensitivity analysis are listed in Table 7. An occupancy rate of 50 per cent leads to an additional inclusion of five companies with an aggregated emission output of 87,172 tonnes of $CO_2$, which is not a significant change. The inclusion of these five companies will lead to a further decrease in $CO_2$ emissions by 6,713 tonnes over the entire period, which is an increase of the overall reduction potential by 1.8 per cent.

**Table 7:** Sensitivity Analysis for Different Assumptions of the Occupancy Rate

| Occupancy rate | Threshold in t $CO_2$ | Number of companies in the EU-ETS | Quantity of emissions in the EU-ETS in t $CO_2$ | Overall reduction of emissions in t $CO_2$ |
|---|---|---|---|---|
| **50%** | 17,455 | + 5 | + 87,172 | + 6,713 |
| **80%** (standard assumption) | 27,930 | 167 | 2,384,170 | 365,901 |
| **95%** | 33,166 | - 3 | - 77,428 | - 9,825 |

When choosing an occupancy rate of 95 per cent, the results do not change significantly as well. Only three companies would not be part of the EU-ETS anymore because of the higher threshold for the inclusion criterion. These three companies have an aggregated emission output of 77,428 tonnes of $CO_2$, which leads to a smaller reduction potential of $CO_2$ emissions in the entire period by 9,825 tonnes (-2.6%). In sum, the assumption about the occupancy rate is not very sensitive as the analysis with different occupancy rates shows.

Another significant assumption for the calculation of the emission threshold was the presumption about the efficiency factor. Therefore, the assumption of the efficiency factor is tested with a sensitivity analysis as well. Table 8 shows the results for an output capacity of 10 MW instead of the 15 MW assumed.

The results show that the smaller efficiency factor in combination with a lower occupancy rate leads to a large decrease of the $CO_2$ emission threshold. However, the lower threshold only leads to an additional inclusion of ten companies (5.6%). This in turn leads to an additional inclusion of 145,614 tonnes of $CO_2$, which results in a larger reduction potential of $CO_2$ emissions by 32,700 tonnes over the entire period (+8.9%).

**Table 8:** Sensitivity Analysis for an Efficiency Factor of 10 MW

| Occupancy rate | Threshold in t $CO_2$ | Number of companies in the EU-ETS | Quantity of emissions in the EU-ETS in t $CO_2$ | Overall reduction of emissions in t $CO_2$ |
|---|---|---|---|---|
| **80%** (standard assumption with 15 MW) | 27,930 | 167 | 2,384,170 | 365,901 |
| **50%** | 11,638 | + 10 | + 145,614 | + 32,700 |
| **80%** | 18,618 | + 5 | +116,082 | + 20,691 |
| **95%** | 22,109 | + 4 | + 94,931 | + 13,539 |

The sensitivity analysis also shows that the $CO_2$ emission threshold decreases when calculated with the standard assumption of an occupancy rate of 80 per cent. The number of Swiss companies in the EU-ETS increases by five companies. This results in an additional inclusion of $CO_2$ emissions in the EU-ETS by 4.8 per cent.

Concerning the sensitivity of the efficiency factor, it can be concluded that the $CO_2$ emission thresholds are much smaller than compared to the standard assumption. However, the effect on the quantity of companies in the EU-ETS is not significant. Only the combination of a low occupancy rate and a low efficiency would change the results slightly.

### 5.2.4 Comparing Principal Numbers of the Swiss Emissions Trading System and the EU Emissions Trading System

In order to acquire an evaluation of Swiss companies in the EU-ETS, some principal numbers of the Swiss ETS and the EU-ETS are compared. This comparison is comprised of the number of companies participating in the trading system and the quantity of $CO_2$ emissions covered with the EU-ETS. Table 9 shows all statistics discussed in this chapter.

The analysis of the extended Swiss NAP showed that a total number of 167 companies with an aggregated $CO_2$ emission output of 2,384,170 are included in the EU-ETS. Altogether, approximately 450,000 companies are operating in Switzerland.[49] Consequently, the companies participating in the EU-ETS are less than one per cent (0.037%) of all Swiss companies.

[49] http://www.bfs.admin.ch/bfs/portal/de/index/news/medienmitteilungen.Document.125350.pdf

By contrast, 11,428 companies participate in the EU-ETS in the second trading period. In the EU, a total number of 12 million companies are operative.[50] Accordingly, the fraction of European companies in the EU-ETS is also smaller than one per cent (0.095%).

Swiss companies would represent a share of 1.5 per cent of all companies in the EU-ETS. However, it is important to remember that the EU consists of 27 countries and that most of them are larger than Switzerland. The coverage of the Swiss ETS would not be different than for other small members; for instance Austria is participating with 205 companies in the EU-ETS. The portion of Austrian companies in the EU-ETS is a share of 1.6 per cent, which would be equal to the share of Switzerland.

**Table 9:** Comparison of Principal Numbers of CH-ETS and EU-ETS

| | CH | EU |
|---|---|---|
| **Number of companies in the EU-ETS** | 167 | 11,428 |
| **Total number of companies** | ~ 450,000 | ~ 12 million |
| **Share of companies participating** | 0.037% | 0.095% |
| **$CO_2$ emissions contained in the EU-ETS** | 2.38 million t $CO_2$ | 2,086.5 million t $CO_2$ |
| **Overall $CO_2$ emissions** | 45.06 million t $CO_2$ | 4,636.67 million t $CO_2$ |
| **Share of $CO_2$ emissions in the EU-ETS** | 5% | 45% |

Besides the number of companies participating in the EU-ETS, also the total amount of $CO_2$ emissions covered through the EU-ETS is relevant. The 11,428 European companies participating in the EU-ETS accounted for 45 per cent of all $CO_2$ emissions in the EU (2,086.5 million t $CO_2$). In contrast, the Swiss ETS companies accounted for a small part of $CO_2$ emissions of five per cent. Thus, in the EU, almost half of all $CO_2$ emissions are included in the ETS, whereas only one-twentieth of total Swiss $CO_2$ emissions are.

The large difference in $CO_2$ emissions covered can be explained through the average company size. Basically, Swiss companies are smaller than companies from the EU. There are only three Swiss companies included in the EU-ETS with a yearly emission output above 100,000 tonnes of $CO_2$. Other participating EU countries have many

[50] http://www.statistik.at/web_de/services/wirtschaftsatlas_oesterreich/branchendaten_im_eu_vergleich/index.html

companies with a yearly emission output above 100,000 tonnes of $CO_2$. Some of the companies even have an emission output larger than one million tonnes of $CO_2$ per year, for example the German power generation plant E.ON and the ThyssenKrupp Stahl AG.[51] Nevertheless, the difference between the $CO_2$ emissions coverage in the EU in comparison with Switzerland is substantial. Consequently, the reduction potential of Swiss companies participating in the EU-ETS is far below the potential of European companies in the EU-ETS.

Summarised, the number of Swiss companies participating in the EU-ETS is comparable with a small European country as for instance Austria. However, European companies are basically larger and therefore have a higher emission output than Swiss companies. This fact explains the large difference of $CO_2$ emission coverage in the EU-ETS in Switzerland and the EU. Consequently, for reaching a similar coverage of $CO_2$ emissions in Switzerland a larger number of companies should be included in the EU-ETS.

## 5.3 Defining a New Policy Design for Swiss Climate Policy

The previous chapters confirmed the result that with the regulations of the EU-ETS and the emissions trading as the only eco-political instrument the Swiss abatement target cannot be reached. Therefore, the regulations of the EU-ETS must be modified and extended for the targets of Swiss climate policy. The amendments must include measures for the sectors and companies not covered by the EU-ETS. The EU regulations specify that the ETS should be part of a comprehensive and coherent package of policies and measures implemented at the national level; as for example fiscal or regulatory policies.[52] Therefore, the amendments of the Swiss climate policy design are within the set of rules of the EU directive. Hence, the configuration for an efficient policy design is done, which considers the Swiss climate policy target.

[51] http://ec.europa.eu/environment/climat/pdf/list_installations_germany.pdf
[52] See Directive 2003/87/EC preamble cipher 23

When applied to Switzerland, the EU-ETS must achieve a larger decrease of $CO_2$ emissions, which means that the main parameters for the EU-ETS must be changed. One possibility is opening the trading system to a larger share of companies. This can be achieved by lowering the emission threshold. Another option is to introduce a higher abatement target for the companies in the EU-ETS. For an intended linking with the EU-ETS, these amendments must be consistent with the EU directive and the EU commission must approve the modifications. Since a larger decrease of $CO_2$ emissions and a larger group of participants are a tightening and an expansion of the EU-ETS, the EU commission should have no opposition.

The threshold for the emission output will be set to a lower level in order to take into account the average company size in Switzerland, which is fairly smaller than the average size of companies in Europe. For that reason, three further values for the emission threshold are considered. In a first scenario, the threshold is set to a level of 10,000 tonnes of $CO_2$, such as the announcement of the $CO_2$ law suggested. In a second scenario, the threshold is fixed at 5,000 tonnes of $CO_2$. And finally, in the third scenario the criterion of the amount of emission output was not applied. Nevertheless, repeating the calculations with different $CO_2$ emission thresholds shows that this amendment has not the desired effect. The modifications increase the reduced $CO_2$ emissions by 30,000 tonnes for a threshold of 10,000 tonnes to 100,000 tonnes if no threshold is applied. The achieved increase of 0.3 per cent points negligible. These results are summarised in Table 10.

**Table 10:** Comparison of Different Emission Thresholds

| Threshold in t $CO_2$ | Number of companies in the EU-ETS | Attained reduction in $CO_2$ emissions | Attained reduction in per cent (compared to the $CO_2$ emissions in 2008) |
|---|---|---|---|
| 27,930 | 167 | 365,900 t $CO_2$ | 15.3% |
| 10,000 | 178 | 393,053 t $CO_2$ | 15.3% |
| 5,000 | 193 | 413,383 t $CO_2$ | 15.5% |
| No (all exempted companies included) | 396 | 462,491 t $CO_2$ | 15.6% |

Thus, an adjustment of the emission threshold is not sufficient for reaching an abatement target of a 20 per cent reduction of $CO_2$ emissions. Another possibility is to adjust the abatement target for the ETS. For that reason, the linear reduction factor is analysed in detail. The EU-ETS prescribes a reduction factor of 1.74 per cent compared to the total average annual quantity of emission allowances in the period from 2008 to 2012.

Even though the national abatement target is compared to the emissions in 1990, the following analysis is done in comparison to the year 2008. This difference has two reasons. First, the latest emission data from the exempted companies are from the year 2008. And second, Swiss $CO_2$ emissions in 1990 and 2008 differ by 0.5 million tonnes (BAFU 2010c), which is a difference of 1.12 per cent and will be neglected here. Therefore, $CO_2$ emissions are reduced by 20 per cent compared to the level of 2008.

The computation for the accurate reduction rate for an efficient policy design is made for all four cases of the $CO_2$ threshold analysed before. For the emission threshold in accordance with the EU directive, a yearly reduction factor of 2.27 per cent is necessary to achieve the 20 per cent abatement target (see Table 11). The required reduction factor does change slightly with a lower emission threshold.

**Table 11:** Comparison of Reduction Factors for Different Cases

| Threshold in t $CO_2$ | Reduction factor (to achieve a 20 per cent reduction) | Attained $CO_2$ reduction 2013-2020 |
|---|---|---|
| 27,930 | 2.27% | 477,354 t $CO_2$ |
| 10,000 | 2.27% | 512,776 t $CO_2$ |
| 5,000 | 2.26% | 536,923 t $CO_2$ |
| No (all exempted companies included) | 2.24% | 595,391 t $CO_2$ |

The analysis shows that an increase in the reduction factor is the only way to enlarge the reduction of $CO_2$ emissions in the EU-ETS. Consequently, Switzerland would have to change the linear reduction factor to achieve the climate policy target when participating in the EU-ETS. An increase of the reduction factor implies an adaptation of the Swiss NAP. The total quantity of emission allowances are calculated with the reduction factor. The NAP is calculated from the total average annual quantity of emission allowances in the period from 2008 to 2012 minus the yearly reduction factor and then added over the entire trading period.

In addition to the trading system, a tax on $CO_2$ emissions is implemented for companies not participating in the EU-ETS and for households. This adaption possibility is in accordance with the EU directive which states that along with the ETS, further measures should be implemented. The directive suggests the instrument of taxation to limit emissions from companies and households excluded from the ETS. [53] The calculations for the necessary tax level for Switzerland are done in Chapter 6.

## 5.4 Key Findings

There are two criteria for the inclusion of a company in the EU-ETS. These criteria had to be reformulated in order to be able to apply them to the extended Swiss NAP. The first criterion, the capacity of the combustion unit, is referred to as *the amount of emission output* of a company. This criterion was converted into a $CO_2$ threshold value. The second criterion is specified as *activities listed in Annex I of the EU directive*. These type of activities were simplified with the assignment of the NOGA code, which is a generalization of the criterion.

When applying the regulations of the EU-ETS to Switzerland, 167 companies from the Swiss economy with a total $CO_2$ emissions output of 2,384,170 tonnes are included in the EU-ETS. The coverage of $CO_2$ emissions with the EU-ETS compared with total Swiss $CO_2$ emissions constitutes a fraction of five per cent. In contrast, in the EU, 45 per cent of overall $CO_2$ emissions are covered.

With a yearly reduction factor of 1.74 per cent, specified in the EU directive, a potential reduction of 365,901 tonnes of $CO_2$ could be realised; this equals a decline of $CO_2$ emissions from participating companies by 15.3 per cent. When compared to the total abatement target of the Swiss economy of 4.46 million tonnes of $CO_2$, the abatement of the ETS accounts only to eight per cent of the required abatement. Thus, there is a relatively large discrepancy between the Swiss climate policy target and the reduction

[53] See Directive 2003/87/EC preamble cipher 24

potential of the companies participating in the emissions trading. Consequently, with the emissions trading as the only instrument for reducing $CO_2$ emissions, the Swiss climate policy target would be unattainable.

Therefore, the regulations of the EU-ETS must be modified and the climate policy design must be extended with a further instrument for decreasing $CO_2$ emissions. The alteration of the $CO_2$ threshold has no significant effect on the reduction potential of the ETS companies, even if the threshold would be completely neglected. The modification of the yearly reduction factor is the only way to increase the reduction potential of the ETS. The yearly reduction factor has to be raise to 2.27 per cent in order to ensure that the companies participating in the EU-ETS will achieve a 20 per cent reduction of their $CO_2$ emissions. A modification of the reduction rate is equal to an adjustment of the Swiss NAP.

Furthermore, the Swiss climate policy design must be extended with an additional $CO_2$ tax for companies not participating in the EU-ETS as well as for households. The configuration of such a policy design is a mixture of a price policy and a quantity policy. The mixed price-quantity policy defined here is a policy design adapted for the Swiss situation. It takes into account the retention of the $CO_2$ tax as policy instrument and the intention to link the Swiss ETS with EU-ETS. In the following chapters this policy design will be referred to as hybrid policy.

The results of the analyses are different to the results of the study by First Climate & Econability (2009). They found that 100 companies of the Swiss economy will participate in the EU-ETS. This disparity can be explained with the simplifications of the criteria made in this thesis. On the one hand, the production capacity criterion was neglected and on the other hand the activities listed in Annex I were approximated with the NOGA sector. The study concluded that if the emission threshold was not applied, the number of participants would increase. This analysis showed that when the emission threshold is not applied, the number of participants would double but the reduction potential does not increase.

# 6 Modelling the Hybrid Policy for Switzerland

As seen in Chapter 5, Switzerland cannot achieve its climate policy target with the emissions trading as the only eco-political instrument. Instead, a hybrid policy, consisting of both an ETS for a specified group of companies and a $CO_2$ tax for the rest of the economy as well as the Swiss households, was formulated. In this chapter, a model of this hybrid policy is introduced and compared to a model of a policy based solely on a $CO_2$ tax.

The configuration of the policy design for Switzerland was formulated in Chapter 5.3. The group of participants of the ETS was defined according to the EU-ETS regulations. Their abatement target as well as the required yearly reduction factor were calculated in previous chapters. In order to be consistent with the 20 per cent abatement target of the Swiss climate policy, companies in the ETS have to reduce their $CO_2$ emissions by 2.24 per cent per year in the period from 2012 to 2020. As Switzerland as a small country has no influence on the price of emission allowances, the price is assumed to be 50 CHF per $CO_2$ emission allowance, which is a moderate forecasting for the third trading period of the EU-ETS.[54] While, the parameters for the ETS are specified with these assumptions, the $CO_2$ tax is still unknown. On that account, a CGE model of Switzerland is used, which will calculate the optimal $CO_2$ tax for the hybrid policy.

Two different models for the two different policy designs are made. The first model, called the CO2-TAX model, implements only a $CO_2$ tax. The second model represents the hybrid policy. This model is referred to as the CO2-TAX&TRADING model. The results from the two models are compared at the end of this chapter.

## 6.1 Data

The main data source for the models is the Swiss input output table (IOT) which was compiled by the ETH for the year 2001. This table was extended with data on fossil fuel

[54] http://www.pointcarbon.com/news/1.1453768

inputs, which is necessary for calculating $CO_2$ taxes. The Swiss IOT is displayed in Table A-2 Appendix A. The IOT shows the flows of economic transactions taking place within an economy; production of goods as well as the demand thereof, capital supply and demand, labour supply and demand. The Swiss IOT consists of 22 production sectors and 14 consumption goods (Schneider and Stephan 2007).

The 22 production sectors are divided into 19 domestic production sectors and three foreign productions sectors. The foreign production includes the electricity sector, the fossil fuel sector and an artificial sector called ROW, which represents the rest of the world (Schneider and Stephan 2007).

The detailed record of different household income types was aggregated for the purpose of this thesis. The initial data set distinguished five different income categories to make a detailed analysis of the effect of a $CO_2$ tax on different household groups. However, this thesis does not analyse these effects; therefore, the five household categories were summed up to one household only.

For the calculations of the hybrid policy, a clear assignment of the sectors is necessary. However, the 19 domestic production sectors in the Swiss IOT are not consistent with the NOGA structure used for the classification of the EU-ETS sectors. Consequently, a new assignment of the ETS sectors was necessary. Therefore, an alignment of the sector structure of the IOT with Table 6, where the NOGA sectors participating in the EU-ETS are listed, is done. This grouping for the data structure of the IOT is shown in Table 12.

**Table 12:** Classification of the ETS and non ETS Sectors

| ETS Sectors | Non ETS Sectors | | | |
|---|---|---|---|---|
| Paper | Food production | Construction | Hospitality service | Education |
| Mineral oil | Agriculture | Textiles | Credit | Other services |
| Cement | Machinery | Trade | Administration | Transport |
| Metal | Equipment | Other industry | Health | |

Accordingly, four of the 19 domestic production sectors will not pay a $CO_2$ tax but rather participate in the ETS, namely paper, mineral oil, cement and metal production. The other 15 domestic production sectors will pay the $CO_2$ tax. The three foreign sectors, fossil fuel, electricity and ROW, are not grouped into these classes.

## 6.2 Models

An existing model developed at the University of Berne is used. The model developed by Schneider and Stephan (2007) was established for a research project on behalf of the Federal Office for the Environment. The Swiss economy is modelled as a static, small and open economy. The purpose of the study was to compute the impacts of reducing $CO_2$ emissions by 20 per cent and to calculate the corresponding $CO_2$ tax for such an abatement target.

Consumer preferences in the model are expressed as a nested constant elasticity of substitution (CES) utility function. The top level elasticity of substitution characterises how the consumer will divide the income between consumption and savings. The production sectors each produce an output which can be used as an input into another production sector or as consumption good. A further input into production is the capital-labour aggregate, which is supplied by the consumer. Additionally, the production functions are represented as nested CES production functions (Schneider and Stephan 2007).

### 6.2.1 CO2-TAX Model

The model designed by Schneider and Stephan (2007) used several sets which arranged the input variables of the model in coherent groups. For example, a set for the production sectors as well as a set for the domestic production sectors was introduced. As a result, the different sets have a complex interdependency. The definition of the sets had to be improved in order to simplify the structure of the model and to be able to include the ETS in the model. Therefore, the entire model had to be redefined with no dependence of the sets. The adjusted model consists of two sets only; one set for the consumption goods and one set for the domestic production sectors.

Furthermore, a shortcoming of the existent model is the fact that only fossil fuels used in the production sectors were taxed while fossil fuels used by consumers were not burdened. This leads to an overestimation of the $CO_2$ tax computed by the model. The CO2-TAX model takes this into account and levies a $CO_2$ tax on the consumption goods.

A constraint is used for calculating the level of the $CO_2$ tax. The constraint limits the fossil fuel use of the domestic production and the consumption goods to 80 per cent of the baseline level. This stands for a 20 per cent reduction of $CO_2$ emissions.

### 6.2.2 CO2-TAX&TRADING Model

In a further step, the CO2-TAX model was extended to introduce the emissions trading as policy instrument (CO2-TAX&TRADING model). Therefore, domestic production is divided into sectors paying the $CO_2$ tax, also called the NONETS sectors, and sectors buying emission allowances for their excess emissions, labelled ETS sectors. The classification of these sectors was described Table 12.

Moreover, the reduction factor for the ETS sectors and the price of emission allowances had to be incorporated. These parameters are introduced as fixed variables. The unknown variable in the model remains the $CO_2$ tax. A yearly reduction factor of 2.24 per cent was calculated in Chapter 5.3 (see Table 11). However, a reduction factor for the entire period of eight years is used in the CO2-TAX&TRADING model. As a result, the ETS sectors have to reduce their $CO_2$ emissions by 18 per cent only. This is not in accordance with the 20 per cent reduction target, even though the reduction factor was calculated under the assumption of the 20 per cent abatement target. This is explained due to the fact that the reduction factor is calculated from the allocation of emission allowances and not from the actual $CO_2$ emissions. The allocation of emission allowances was higher than the actual $CO_2$ emission. Nonetheless, a reduction factor of 18 per cent is used in the model.

A further adjustment in the definition of the production functions was necessary. The fossil fuel sector had to be divided into a fossil fuel sector used for the production of ETS sectors (Y_F_ETS) and a fossil fuel sector where the output is used for the production of NONETS sectors (Y_F_NONETS). Consequently, prices for these two different outputs of fossil fuel are different as well. This adjustment was necessary to include separate constraints for the two groups of sectors.

The constraint associated with the NONETS sectors defines the level of the $CO_2$ tax. The constraint is similar to the one in the CO2-TAX model.

The constraint linked to the emissions trading, leads to a price increase of fossil fuels in the ETS sectors (Y_F_ETS). This price increase reflects the costs for purchasing emission allowances for the excess consumption of fossil fuels. If the activity level of fossil fuel production for ETS sectors undercuts the necessary reduction of ETS sectors, the price will increase by the shortcoming of the reduction multiplied by the emission allowance price. The model assumes a free allocation of emission allowances in the range of the allowed consumption of fossil fuel.

## 6.3 Results

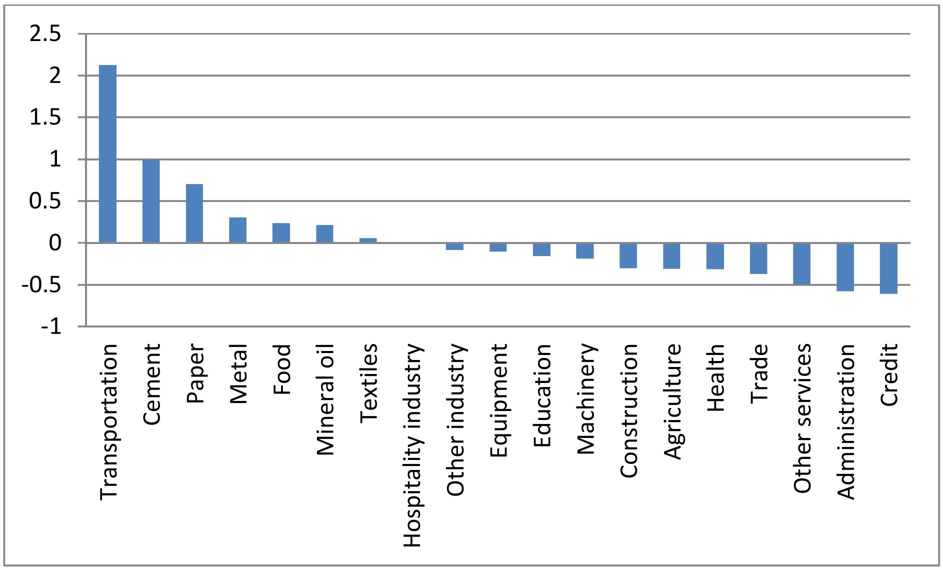
This section provides an overview of the results obtained for the two models, the CO2-TAX model and CO2-TAX&TRADING. The results in a static model are derived from the counter-factional analysis, where the baseline scenario is compared to the scenario with the policy intervention.

### 6.3.1 Results of the CO2-TAX Model

Under the assumptions used in the CO2-TAX model, $CO_2$ emissions can be reduced in 2020 by 20 per cent compared to the level of 1990 if a tax of 188 CHF per tonne of $CO_2$ is imposed. The $CO_2$ tax will be levied on the Swiss economy as well as on the use of consumption goods. This generates revenues in the order of 5.46 billion CHF, which is completely reallocated to the households. The $CO_2$ tax calculated in this model is half as high as the resulting $CO_2$ tax in the model by Schneider and Stephan (2007). This large difference can be explained with the additional taxation of consumption goods. Approximately, half of fossil fuels used in Switzerland go into the consumption goods housing and transport. Therefore, an expansion of the tax burden to the consumption goods halves the $CO_2$ tax.

The introduction of the tax has an effect on the output and the prices of the production sectors as well as on prices and quantities of consumption goods. As shown in Figure 4, not all prices of production goods increase due to the introduction of the $CO_2$ tax. The service industries, where the fossil fuel input is negligible, do not experience a price increase. In contrast, prices of these production goods decrease because they are not heavily burdened through the $CO_2$ tax and in relative terms gain competitiveness. The highest price increase is shown for the sectors transportation (2.1%), cement (0.99%) and paper (0.7%). These sectors are correspondingly the production sectors with the largest fossil fuel share as input factor.

**Figure 4:** Percentage Change of Prices of Production Goods (CO2-TAX Model)




In general, the domestic production sectors reduce their output of production due to the price increase of the $CO_2$ tax. The percentage change of activity levels of domestic production sectors are depicted in Figure 5. Sectors with a large input of fossil fuels are most affected and thus reduce their production output strongest, for example transportation, mineral oil, cement and paper production. The transportation sector decreases its output by seven per cent. In contrast, the service intensive sectors such as the credit industry are able to increase their output because the production is relatively inexpensive.

**Figure 5:** Percentage Change of Activity Levels in the Domestic Production Sectors (CO2-TAX Model)

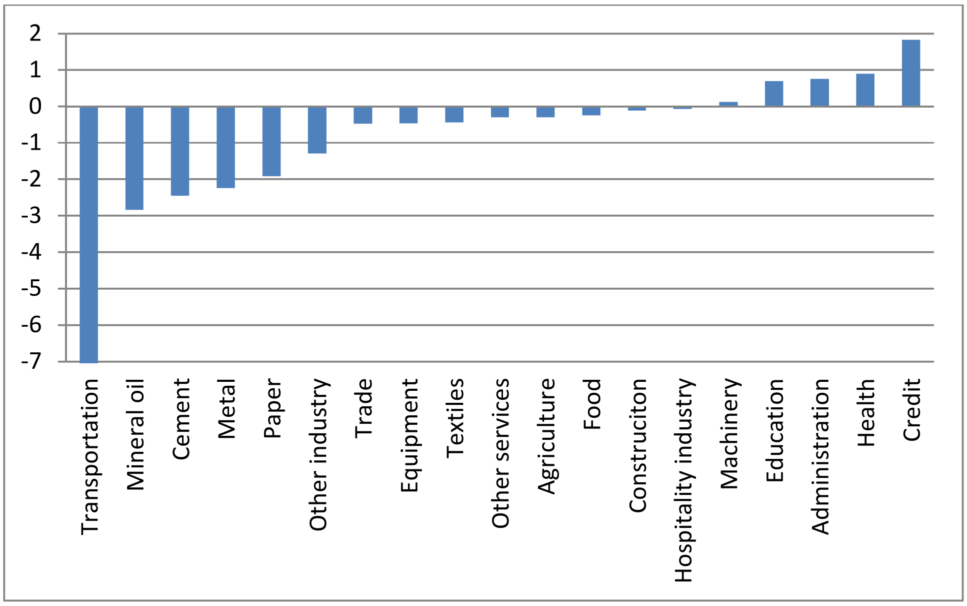



Figure 6 reports the percentage change of $CO_2$ emissions per sector. $CO_2$ emissions are cut due to the price increase in fossil fuels. The largest $CO_2$ reduction is observed in the transportation sector. The sector's $CO_2$ emissions are decreased by 34 per cent. Other energy intensive sectors follow with an over-average decrease of their $CO_2$ emissions, for instance paper production (27.4%) and mineral oil production (26.3%). On average, domestic production sectors decrease their emissions by 25 per cent. Due to better substitution possibilities in the production sectors compared to the consumption goods, the reduction of $CO_2$ emissions is larger than the compulsory 20 per cent decrease. Therefore, the domestic production sectors undertake a higher reduction of $CO_2$ emissions. Consequently, the fossil fuel input into consumption goods is cut by less than 20 per cent.

**Figure 6:** Percentage Change of $CO_2$ Emissions per Sector (CO2-TAX Model)

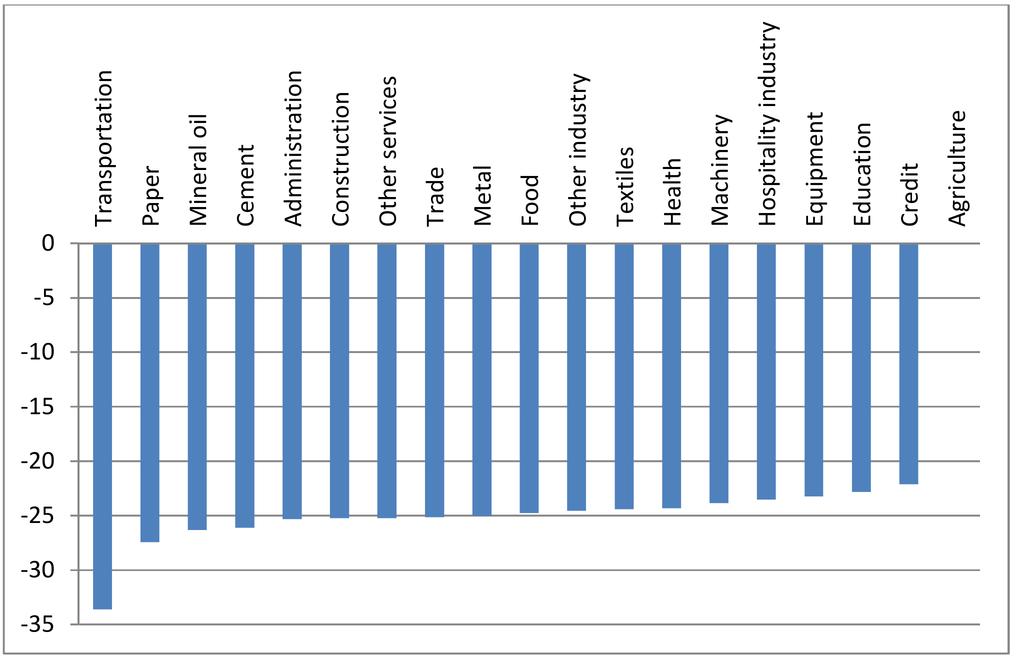



**Figure 7:** Percentage Change of Prices of Consumption Goods (CO2-TAX Model)

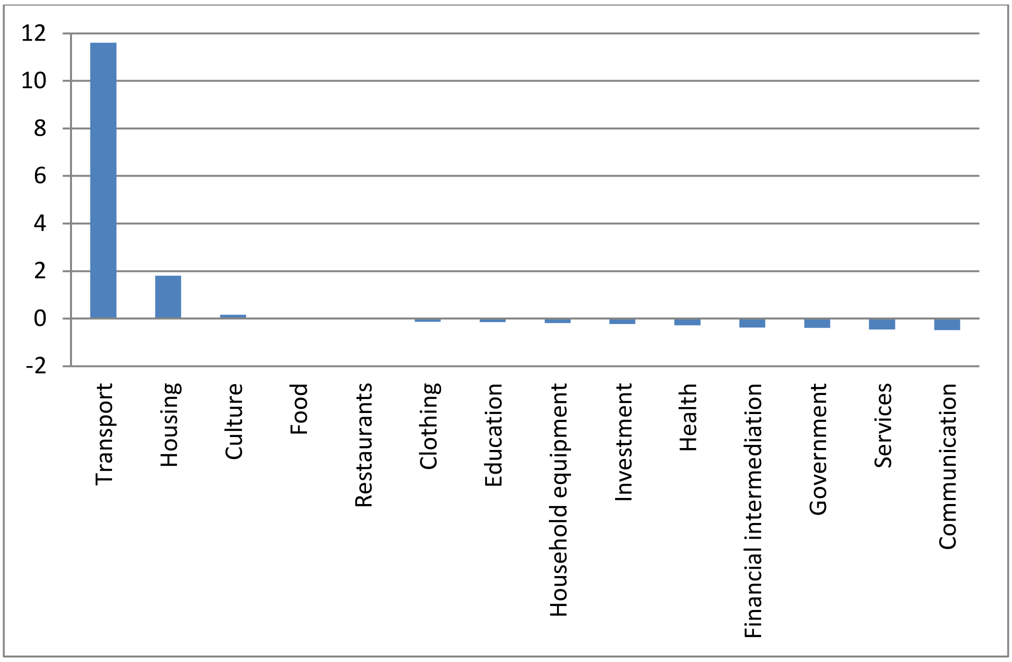



Figure 7 shows the increase in the prices of consumption goods in percentages. Prices of the consumption goods transport (11.6%), housing (1.8%), culture (0.15%) and food

(0.02%) increase due to the $CO_2$ taxation of fossil fuels. Prices of the other consumption goods decrease slightly. The highest price increase results where fossil fuel is a central input factor into the production of the consumption goods. In accordance to these price changes, the demanded quantity of consumption goods alters as well. The demand of transport decreases by 10 per cent due to the price increase of 11.6 per cent. The consumption goods with a slight prices increase show a small rise in demand.

Due to the policy intervention the welfare[55] of households declines by 0.132 per cent. This welfare effect is relatively small due to the redistribution of the tax revenue. The lump sum reallocation of the revenue from the $CO_2$ tax diminishes the negative effect of the tax on households almost completely. This compensation can explain the small negative welfare effect on households.

### 6.3.2 Results of the CO2-TAX&TRADING Model

In order to reduce $CO_2$ emissions from NONETS sectors and from consumption goods by 20 per cent in 2020, a tax of 200 CHF per tonne of $CO_2$ must be levied. The $CO_2$ tax calculated must be paid for the entire consumption of fossil fuels. The tax burden leads to revenues of 5.21 billion CHF, which is again completely reallocated to households. In contrast, the ETS sectors have to buy emission allowances for their excess consumption of fossil fuels. The price for the excess use amounts to 50 CHF per tonne of $CO_2$.

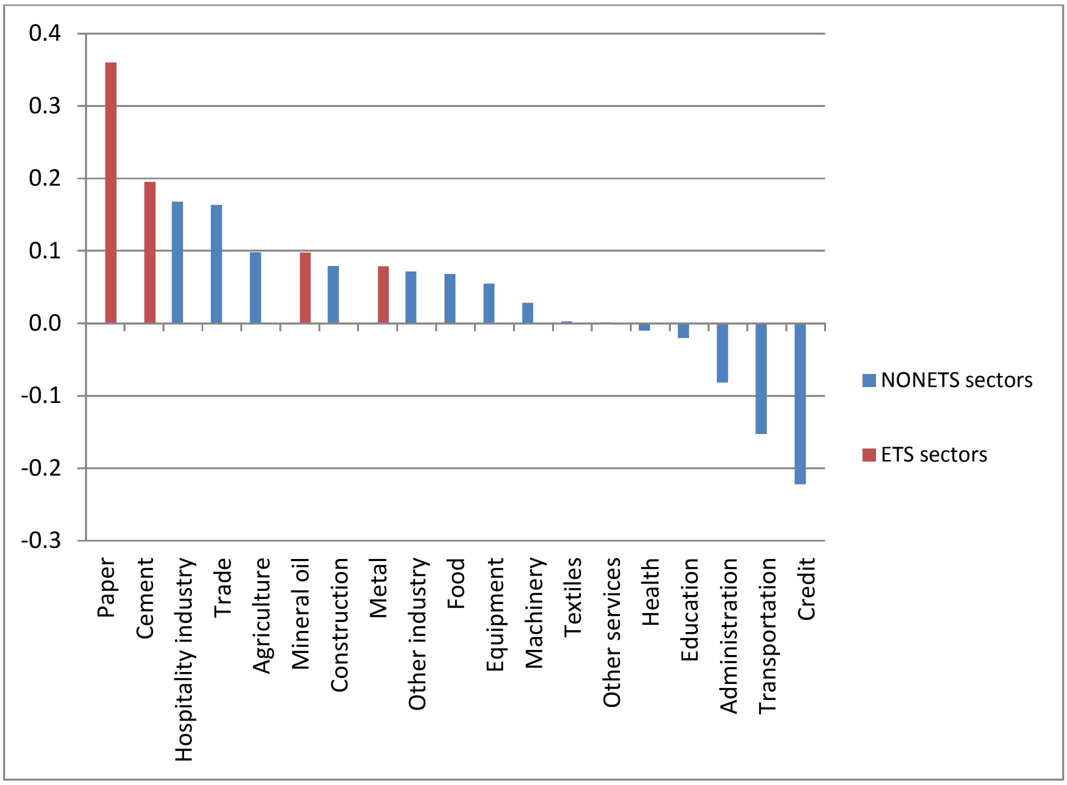
In summary, NONETS sectors have to pay 200 CHF for every tonne of $CO_2$ emitted, whereas ETS sectors must pay 50 CHF for at most 20 per cent of their $CO_2$ emissions. Consequently, the NONETS sectors have to carry the higher tax burden.

In contrast to the $CO_2$ tax, the price increase due to the obligation to hold emission allowances for the excess consumption of fossil fuel in the ETS sectors does not lead to a sufficient decrease of $CO_2$ emissions. The costs for emission allowances lead to an undersized price incentive. Therefore, the ETS sectors have to buy additional emission allowances. The sectors participating in the ETS spend a total of 17 million CHF for the

[55] The welfare measure used here is calculated through Hicksian equivalent variation, which is based on the discounted consumption (Schneider and Stephan 2007).

purchase of emission allowances, leading to an additional price increase in these sectors. The price increase is reflected in the rise of the price of intermediate goods from the ETS sectors. On average, these prices increase by 0.2 per cent. In contrast, prices of intermediate products from NONETS sectors do not show a clear trend (see Figure 8). Some of these prices increase and some prices show a diminution.

**Figure 8:** Percentage Change of Prices from Intermediate Production (CO2-TAX&TRADING Model)




However, when displaying price changes for final products, the price increase due to the $CO_2$ taxation is clearly noticeable (see Figure 9). A small price decrease of production goods from ETS sectors is determined. Figure 9 also demonstrates the higher tax burden of NONETS sectors in contrast to the ETS sectors.

**Figure 9:** Percentage Change of Prices from Production Sectors (CO2-TAX&TRADING Model)

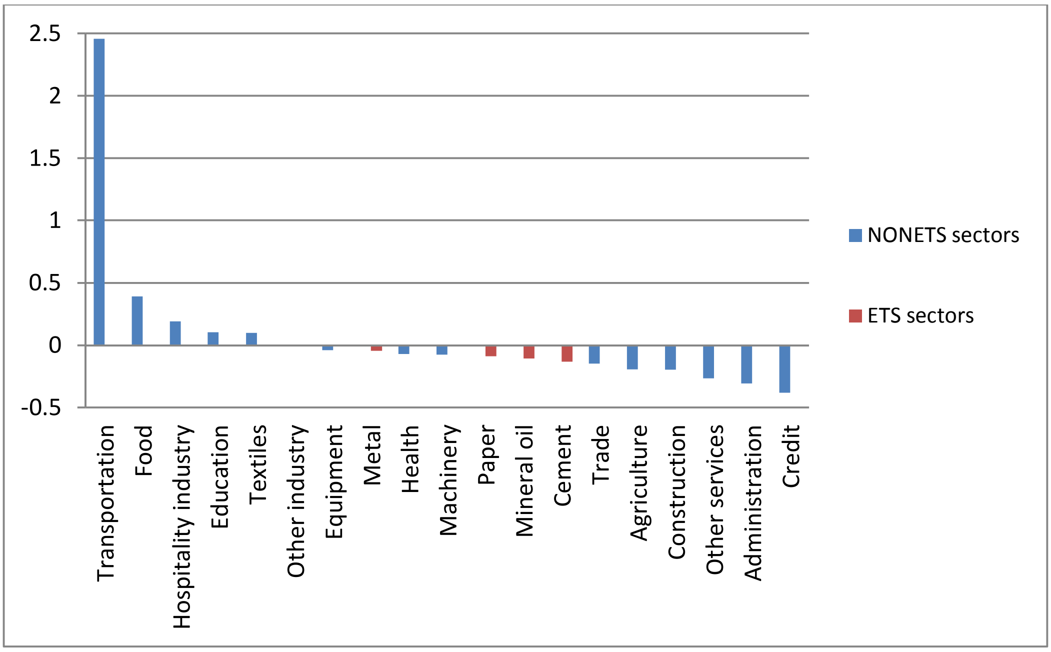
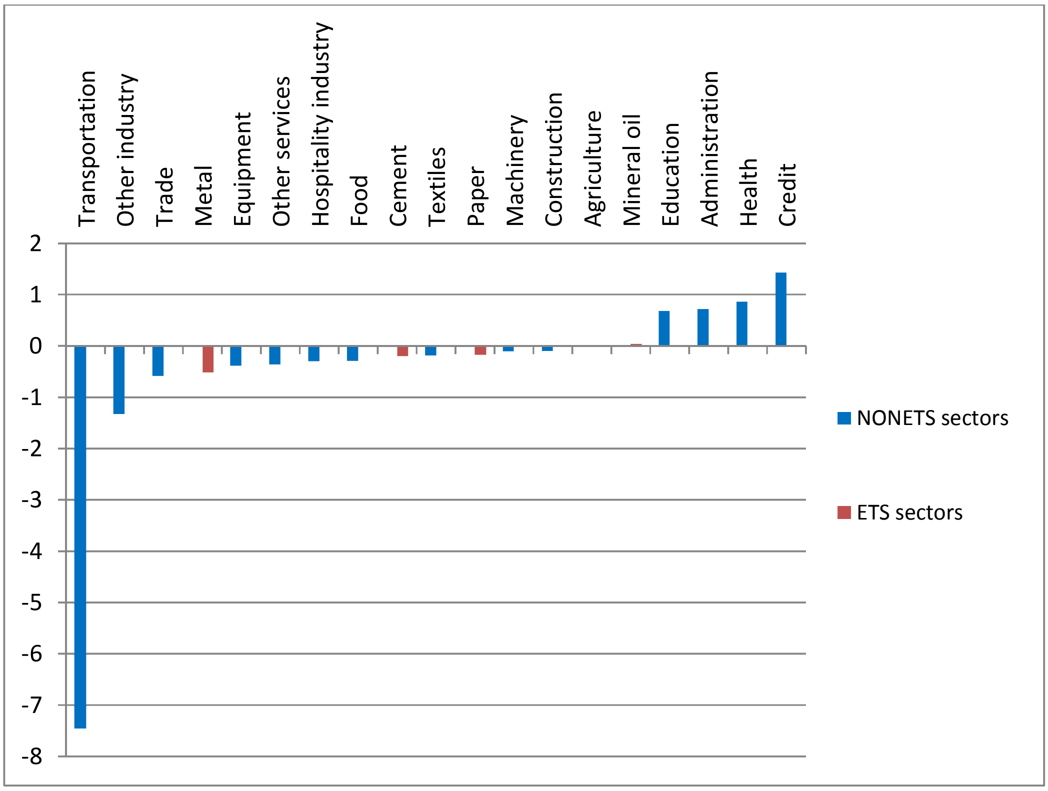
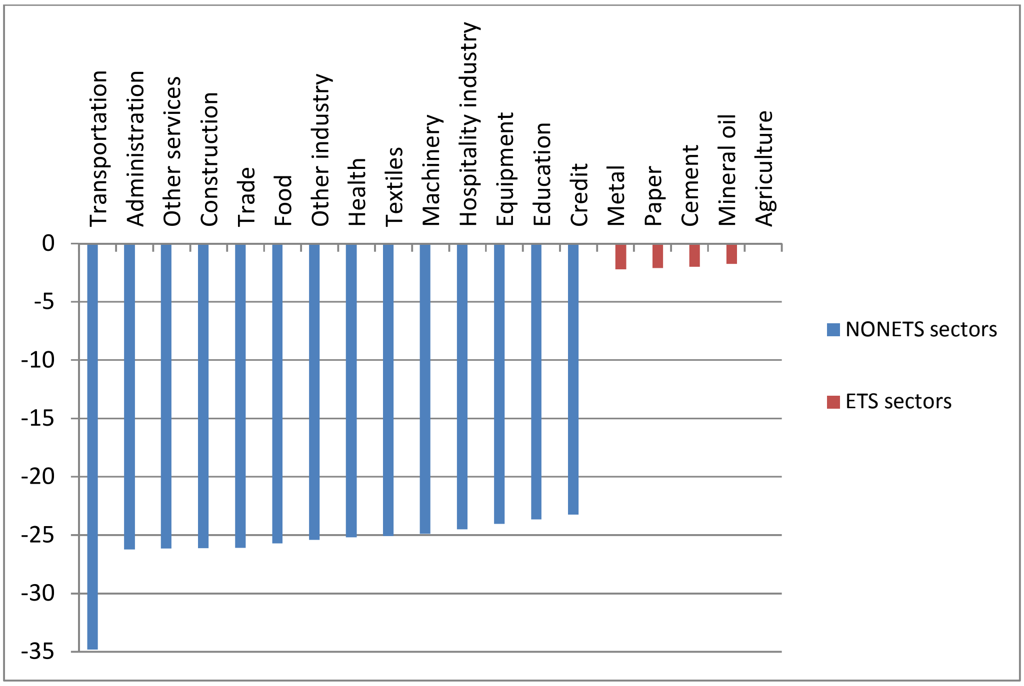



**Figure 10:** Percentage Change of Activity Levels in the Domestic Production Sectors (CO2-TAX&TRADING Model)



Likewise in the hybrid policy system, domestic production sectors reduce predominantly their output due to the price increase. The change of activity levels in domestic production sectors is depicted in Figure 10. It is shown that the fossil fuel intensive sectors exhibit an output loss, for example the transportation sector decreases its output level by 7.4 per cent. Conversely, the service intensive sectors increase their output level. Moreover, it is distinct that the production output of ETS sectors is only slightly affected. These results reflect as well the fact that the sectors paying the $CO_2$ tax are more affected through the hybrid policy.

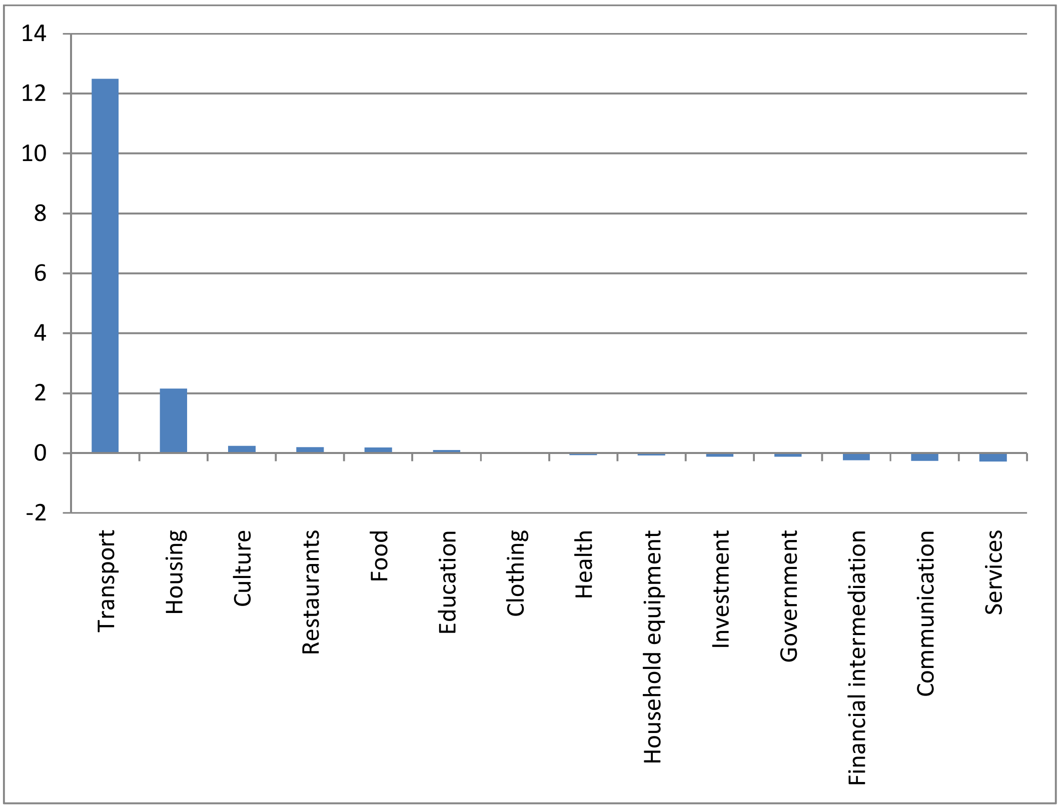
**Figure 11:** Percentage Change of $CO_2$ Emissions per Sector (CO2-TAX&TRADING Model)




In addition to the changes in the output level of production sectors, also the $CO_2$ emission output alters. In Figure 11, the percentage change of $CO_2$ emissions per sector is reported. One can see that tax paying sectors reduce their $CO_2$ emissions by far more than the sectors participating in the emissions trading. On average, ETS sectors reduce their $CO_2$ emissions by two per cent only, whereas NONETS sectors reduce their $CO_2$ emissions by 26 per cent on average. The marginal reduction of ETS sectors occurs because of the choice between the reduction of $CO_2$ emissions and the purchase of emission allowances. The purchase of emission allowances is the cheaper option. Therefore, the abatement target is mainly achieved with the purchase of emission allowances rather than the actual decrease $CO_2$ emissions. Figure 11 shows through the hybrid policy the production sectors paying the $CO_2$ tax are more negatively affected than the sectors participating in the ETS. Through the higher price incease of fossil fuels in the NONETS sectors, they diminish the production output and consequently reduce $CO_2$ emissions by far more.

Furthermore, the hybrid policy has an effect on consumption good prices and the quantity of consumption goods demanded by households. The percentage change of prices of consumption goods is reported in Figure 12. Consumption goods with fossil fuel as important input factor exhibit a price increase. The highest price rise is recorded for transport and housing. Prices of these consumption goods increase by 12.5 and 2.1 per cent, respectively.

**Figure 12:** Percentage Change of Prices of Consumption Goods (CO2-TAX&TRADING Model)



In accordance to the price changes of consumption goods, also the demanded quantity by households varies. The demand of the consumption goods transport (-10.4%) and housing (-1.3%) regresses mostly. The consumption goods with a slight price increase show a small growth in demand.

Even though prices of consumption goods increase, the welfare of households is only slightly affected. Welfare decreases by 0.125 per cent. The small welfare effect can be explained with the lump sum reallocation of the $CO_2$ tax revenue to households. Also the revenue of the sale from emission allowances is redistributed to households. The reallocation of the revenues to households reduces the negative effect of the hybrid policy almost completely.

## 6.4 Sensitivity Analysis

In order to determine the robustness of the results and the conclusions, a sensitivity analysis was conducted. This analysis can help to get a better understanding of how much the results are influenced by certain assumptions. The assumption of the price of emission allowances (EUA price) plays a crucial role, since this price directly influences the choice of ETS sectors. Sensitivity analysis about the price of emission allowances shows by how much the results of the CO2-TAX&TRADING model change, when the price of emission allowances is altered. In the CO2-TAX&TRADING model, the standard assumption of the price of emission allowances is 50 CHF per emission allowance.

For the purpose of the sensitivity analysis, other price assumptions are chosen. The assumptions are listed in Table 13. One price assumption is below the standard assumption of 50 CHF ($EUA_{ST}$). The presumption of 23 CHF per EUA ($EUA_1$) is based on the average price of EUAs in the second trading period. The other price assumptions are higher than the standard assumption. These higher prices are chosen because it is expected that the price of emission allowances will increase in the near future. A tenfold increase of the price is forecasted to be very likely in the future.[56] The highest price

[56] http://www.pointcarbon.com/news/1.1453768

assumption for the sensitivity analysis, $EUA_4$, was chosen because the $CO_2$ tax is as high. In this way, the two types of sectors have an equivalent burden. To see the differences between an elevated and a moderate price increase, two other prices above the standard assumption are analysed ($EUA_2$, $EUA_3$).

**Table 13:** $CO_2$ Emission Allowance Prices for the Sensitivity Analysis

| | $EUA_1$ | $EUA_{ST}$ | $EUA_2$ | $EUA_3$ | $EUA_4$ |
|---|---|---|---|---|---|
| EUA price (CHF/ EUA) | 23 | 50 | 100 | 150 | 200 |

For each of these values listed in Table 13 the CO2-TAX&TRADING model is rerun. The simulations show that the results of the NONETS sectors change only marginally. This result is attributed to the fact that the emission allowance price is a parameter of the ETS and does not concern the NONETS sectors directly.

Contrariwise, an alteration of the $CO_2$ emission allowance price has an effect on the results of the ETS sectors. Depending on the $CO_2$ emission allowance price, the decrease of $CO_2$ emissions is lower or higher when compared to the standard assumption. The results of the sensitivity analysis concerning $CO_2$ emission levels are depicted in Figure 13. With an emission allowance price of 23 CHF, $CO_2$ emissions in the paper production decrease by 1.1 per cent compared to 2.1 per cent with an emission allowance price of 50 CHF. However, when the $CO_2$ emission allowance price is 100 CHF, $CO_2$ emissions in the paper production are reduced by 3.6 per cent. Moreover, the reduction of $CO_2$ emissions in the paper production sector increases to 5.81 per cent when the emission allowance price is 200 CHF. The results for the other ETS sectors show similar results.

These results demonstrate that the model works as expected. If the price of emission allowances is below the standard assumption, $CO_2$ emissions are reduced to a smaller extent because the purchase of emission allowances is cheaper than the reduction of $CO_2$ emissions. In contrast, with an emission allowance price of 200 CHF per tonne of $CO_2$, sectors attain a much higher decrease of $CO_2$ emissions due to the fact that the reduction of $CO_2$ emissions becomes relatively inexpensive in contrast to the purchase of emission allowances. The average $CO_2$ emission reduction in the ETS sectors with an emission allowance price of 200 CHF is 5.5 per cent. It is further noticeable that NONETS sectors decrease their reduction of $CO_2$ emissions due to the increased emission reduction of ETS sectors.

**Figure 13:** Percentage Change of $CO_2$ Emissions in ETS Sectors Depending on Different $CO_2$ Emission Allowance Prices

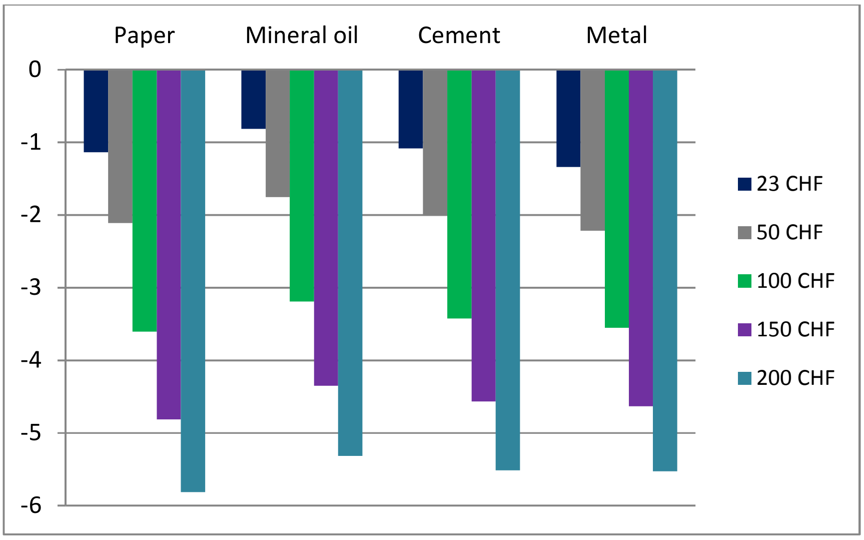
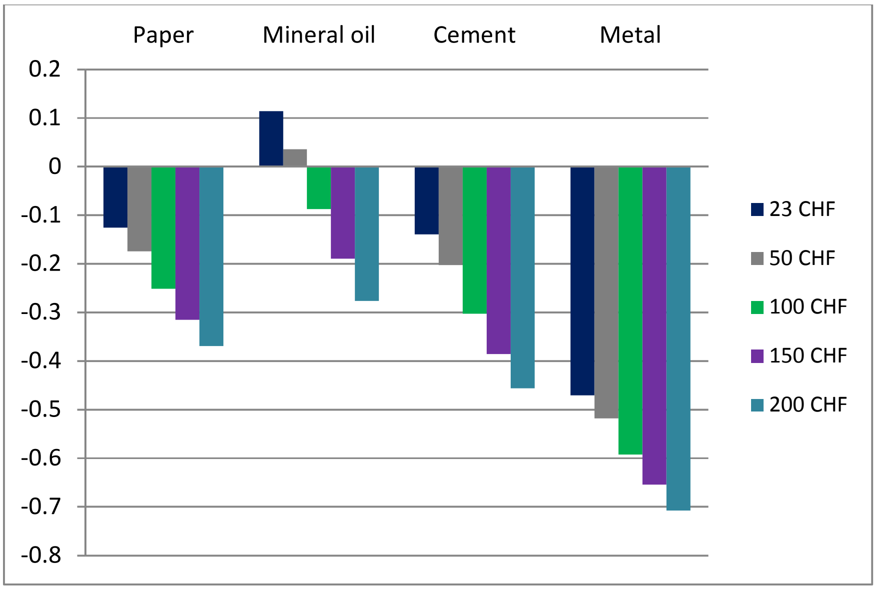



**Figure 14:** Percentage Change of Activity Levels in ETS Sectors Depending on Different $CO_2$ Emission Allowance Prices




Moreover, the activity level of ETS sectors changes. In comparison with the standard assumption of 50 CHF per emission allowance, the production output decreases by 0.45

per cent on average in the highest price scenario. The effects on the single sectors are depicted in Figure 14.

Even though the alteration of the $CO_2$ emission allowance prices is substantial, these modifications have no significant effect on the results regarding the consumption goods. A higher emission allowance price has no effect on the prices of consumption goods and the quantity demanded by households. This outcome is explained by the fact that prices of final goods from domestic production, from NONETS sectors as well as from ETS sectors, do not change significantly.

## 6.5 Comparison between the $CO_2$ Tax Policy and the Hybrid Policy

Only a small part of Swiss $CO_2$ emissions are comprised in the sectors included in the ETS. Nearly 3.7 million $CO_2$ emissions, equal to ten per cent of total Swiss $CO_2$ emissions, are included in the ETS. The remaining share of 90 per cent of $CO_2$ emissions will be burdened with the $CO_2$ tax.

In the CO2-TAX&TRADING model, the $CO_2$ tax has increased by 12 CHF per tonne of $CO_2$ in contrast to the CO2-TAX model. The tax rise is attributed to the fact that the energy intensive sectors are participating in the ETS such that the $CO_2$ tax cannot be levied on these sectors. Therefore, the NONETS sectors do not benefit from the integration of the emissions trading. In contrast, the ETS sectors are less burdened and they benefit from the change of climate policy.

In the CO2-TAX model, ETS sectors were, among others, the sectors with the largest price increase, the highest output loss and the largest reduction of $CO_2$ emissions. Consequently these sectors were strongest affected through the $CO_2$ tax policy. Though, the change to a hybrid policy system alters the effect on domestic production sectors.

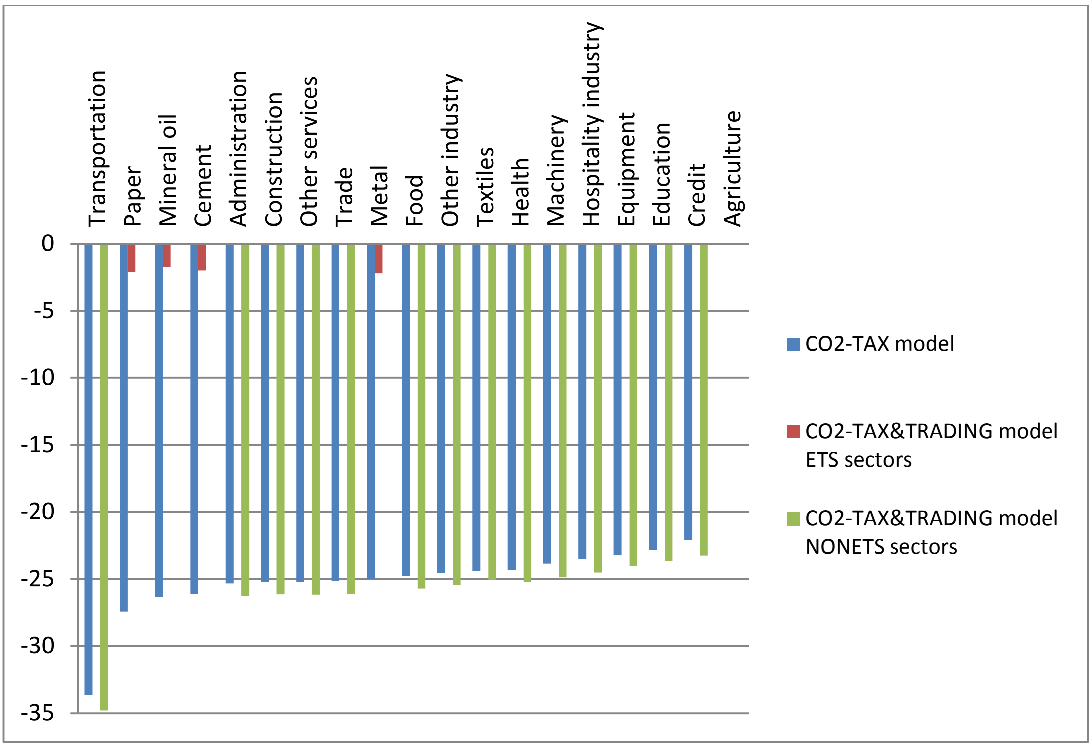
Both policy instruments have an effect on the prices of domestic production sectors. In Table 14, the percentage price changes of final products for both policies and the difference between them are listed. Sectors participating in the ETS are green coloured in the first column. Due to the fact that ETS sectors have a lower burden than NONETS sectors, the prices for final products from ETS sectors decrease. The comparison shows that with the introduction of the emissions trading, prices of final products from the ETS sectors decline, whereas all prices from NONETS sectors increase. For example, the cement sector exhibited a price increase of 0.99 per cent with the $CO_2$ tax policy. In contrast, prices from the cement production decrease by 0.13 per cent with the hybrid policy.

**Table 14:** Comparison of Percentage Change of Prices from Production Sectors between the CO2-TAX Model and the CO2-TAX&TRADING Model: Green coloured are the ETS sectors, red coloured are the prices exhibiting a price decrease with the change to the hybrid policy

| Production Sectors | CO2-TAX Model | CO2-TAX& TRADING Model | Difference |
|---|---|---|---|
| Administration | -0.5774 | -0.3079 | 0.2695 |
| Agriculture | -0.3107 | -0.1935 | 0.1172 |
| Cement | 0.9937 | -0.1339 | -1.1276 |
| Construction | -0.3024 | -0.1961 | 0.1063 |
| Credit | -0.6067 | -0.3801 | 0.2266 |
| Education | -0.1590 | 0.1050 | 0.2640 |
| Equipment | -0.1017 | -0.0405 | 0.0612 |
| Food | 0.2362 | 0.3908 | 0.1546 |
| Health | -0.3157 | -0.0709 | 0.2448 |
| Hospitality industry | -0.0038 | 0.1930 | 0.1968 |
| Machinery | -0.1879 | -0.0741 | 0.1138 |
| Metal | 0.3068 | -0.0462 | -0.3530 |
| Mineral oil | 0.2145 | -0.1056 | -0.3201 |
| Other industry | -0.0837 | 0.0016 | 0.0853 |
| Other services | -0.4930 | -0.2652 | 0.2278 |
| Paper | 0.7059 | -0.0873 | -0.7932 |
| Textiles | 0.0569 | 0.1000 | 0.0431 |
| Trade | -0.3688 | -0.1468 | 0.2220 |
| Transportation | 2.1256 | 2.4553 | 0.3297 |

These price effects have an impact on $CO_2$ emission outputs generated with the two policies; a difference is noticeable when displaying the $CO_2$ emission levels. Figure 15 shows the change of $CO_2$ emissions for both policy scenarios. One can see that ETS sectors cut their $CO_2$ emissions by substantially less when compared to the $CO_2$ tax policy. The largest difference is shown for the paper sector (-25.32%). In contrast, all NONETS sectors cut their $CO_2$ emissions even more when compared with the $CO_2$ tax policy. This result can be explained through the configuration of the hybrid policy, especially the ETS. Sectors participating in the ETS have the choice between reducing $CO_2$ emissions and buying emission allowances for their excess consumption of fossil fuels. Because the purchase of emission allowances is the cheaper option, $CO_2$ emissions are reduced only marginally and a big difference between the two policy scenarios occurs.

**Figure 15:** Comparison of Percentage Change of $CO_2$ Emissions per Sector between the CO2-TAX Model and the CO2-TAX&TRADING Model




When analysing the effect of the integration of the emissions trading on the production output, a similar results as for the $CO_2$ emission output are observable. The results are depicted in Figure 16. Again, the ETS sectors show an over-average decrease of the output in the CO2-TAX model. By contrast, in the CO2-TAX&TRADING model these sectors reduce their output only slightly or are able to raise the output such as the mineral oil sector, whereas the NONETS sectors show a higher output loss compared to the CO2-TAX model or a lower output gain. For example the transportation sector reduces its output by 7.4 per cent and the credit sector is not able to raise its output as much as in the CO2-TAX model.

**Figure 16:** Comparison of Percentage Change of Activity Levels in the Domestic Production Sectors between the CO2-TAX Model and the CO2-TAX&TRADING Model

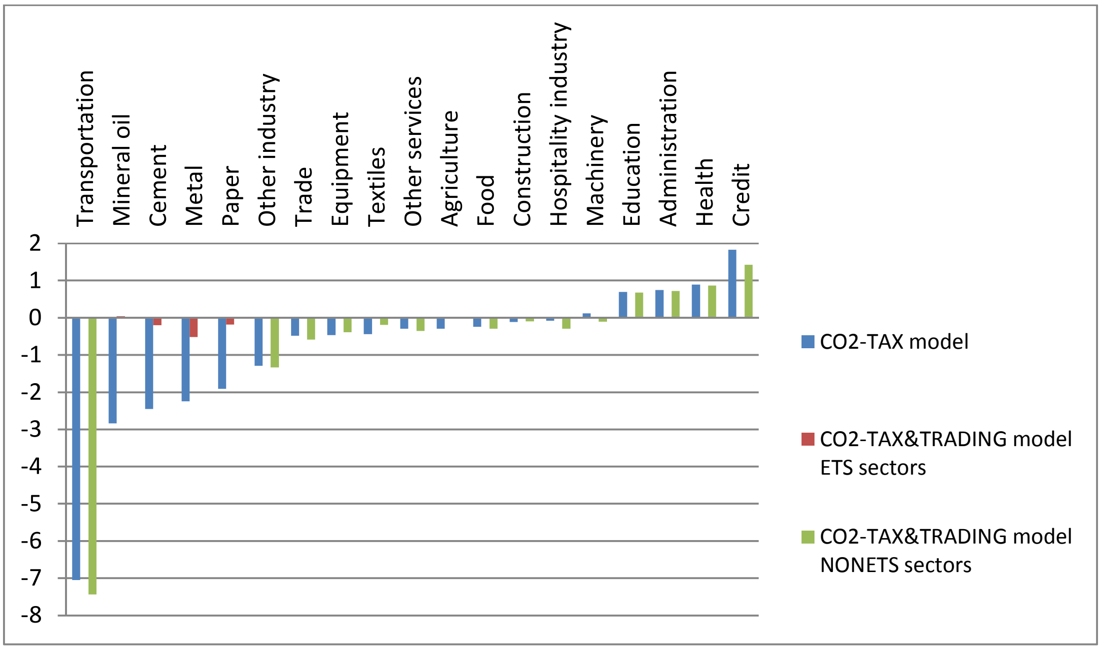
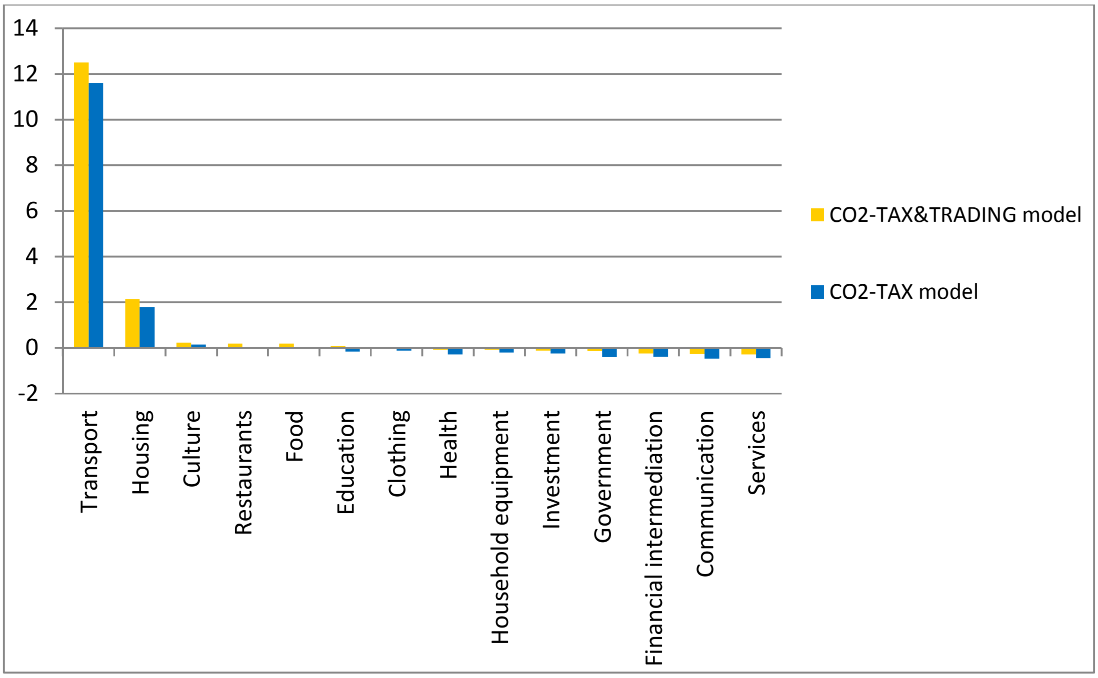
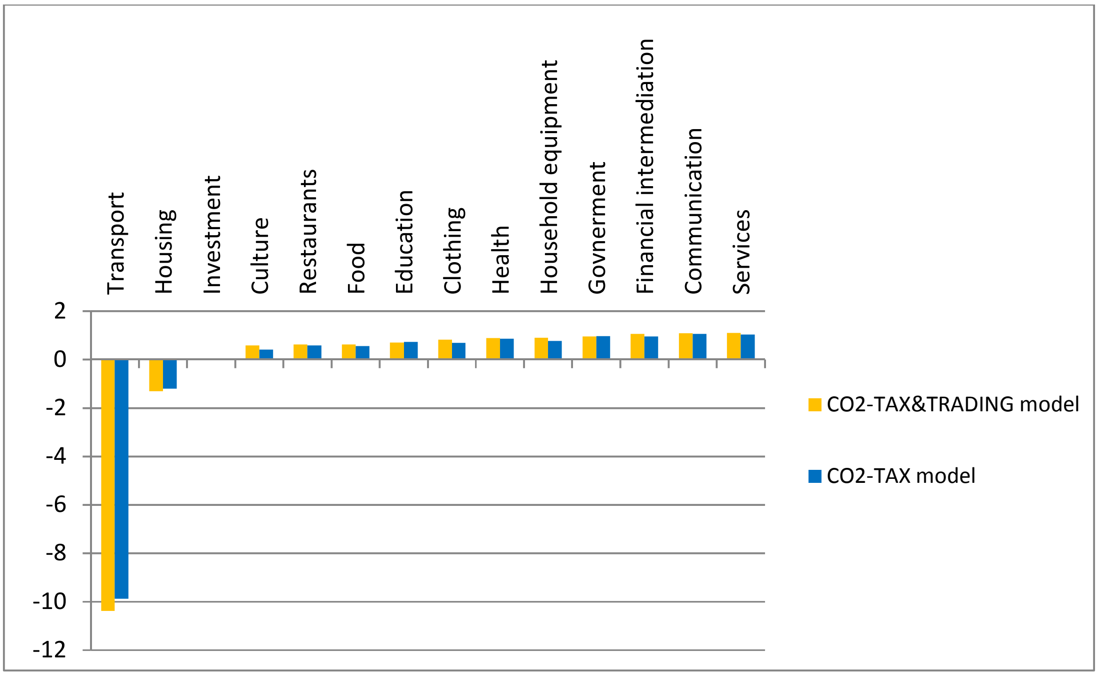



**Figure 17:** Comparison of Percentage Change of Prices of Consumption Goods between the CO2-TAX Model and the CO2-TAX&TRADING Model



Additionally, consumption good prices differ between the two policy scenarios. Figure 17 shows the prices of consumption goods for both policy scenarios. Due to the higher $CO_2$ tax of 200 CHF in the CO2-TAX&TRADING model in comparison with the CO2-TAX model, consumption good prices increase. It is observable that all prices have increased due to the hybrid policy. A relative price increase may also mean that the price in the hybrid policy did not decrease as much as in the $CO_2$ tax policy. For example, the price of the consumption good transport is one per cent higher, whereas the price of services decreased from a price reduction of -0.45 per cent to -0.28 per cent.

**Figure 18:** Comparison of Percentage Change of Quantities Demanded of Consumption Goods between the CO2-TAX Model and the CO2-TAX&TRADING Model




Even though all prices increase in the hybrid policy compared to the $CO_2$ tax policy, the demand of particular consumption goods increases. The comparison of the percentage change in quantities demanded of consumption goods is shown in Figure 18. Although the increase is only very small, it is observable that the demand of most consumption goods has increased. This growth in demand can be explained with the absolute price decrease of these consumption goods and the relative large decrease in demand of the consumption good transport.

Even though sectors paying the $CO_2$ tax are negatively affected through the change to the hybrid policy, it is found that the welfare of households is slightly higher in the hybrid policy than in the $CO_2$ tax policy. The welfare increase of 0.007 per cent can be explained with the substantial lower emission reduction costs of ETS sectors compared to NONETS sectors. The smaller abatement costs of ETS sectors leads to lower prices of products from these sectors. This price decrease in the production for ETS sectors will lead to the slightly higher welfare of households.

## 6.6 Key Findings

This section gives a brief summary on the impacts of the integration of emissions trading in the CO2-TAX model. The key findings of the hybrid policy are discussed in comparison to the $CO_2$ tax policy, not compared to the situation without a policy intervention. The key results are presented in Table 15. For analysing the effects correctly, it is necessary to split the results of the CO2-TAX model into ETS and NONETS sectors. The results from the two models are comparable through this division.

The $CO_2$ tax increases due to the fact that the most energy intensive sectors are excluded from $CO_2$ taxation. Through the exclusion from the $CO_2$ tax and the participation in the ETS these sectors have lower emission reduction costs. Consequently, these products are relatively more favourable and the demand of these products increases. Therefore, the $CO_2$ tax has to rise in order to achieve the 20 per cent reduction target. The tax rises from 188 CHF to 200 CHF per tonne of $CO_2$. Due to the higher tax burden, the NONETS sectors are negatively affected through the change to the hybrid policy.

The percentage price change of final goods from NONETS sectors increases on average by 0.11 per cent. The price increase of final goods of NONETS sectors is larger in the hybrid policy scenario than in the $CO_2$ tax policy. Due to this additional price increase, the NONETS sectors decrease their $CO_2$ emission levels even more. The reduction of $CO_2$ emissions in the $CO_2$ tax policy is 24.9 per cent, whereas in the hybrid policy $CO_2$ emissions are reduced by 25.8 per cent.

**Table 15:** Key Results CO2-TAX Model and CO2-TAX&TRADING Model

| | **CO2-TAX Model** | **CO2-TAX&TRADING Model** | |
|---|---|---|---|
| | **All domestic sectors** | **NONETS sectors** | **ETS sectors** |
| **$CO_2$ tax (per tonne of $CO_2$)** | 188 CHF | 200 CHF | - |
| **EUA price (per tonne of $CO_2$)** | - | - | 50 CHF |
| **Percentage change of prices of intermediate goods** (average value) | -0.01%<br>NONETS: -0.04%<br>ETS:-+0.07% | +0.02% | +0.19% |
| **Percentage change of prices of final goods** (average value) | +0.06%<br>NONETS: -0.07%<br>ETS:+0.6% | +0.11% | -0.09% |
| **Percentage change of $CO_2$ emission level** (average value) | -25.2%<br>NONETS: -24.9%<br>ETS:-26.2% | -25.8% | -2% |
| **Percentage change of activity level** (average value) | -0.84%<br>NONETS: -0.43%<br>ETS:-2.36% | -0.49% | -0.22% |
| **Percentage change of consumption good prices** (average value) | +0.78% | +1.01% | |
| **Percentage change of quantities demanded by households** (average value) | -0.17% | -0.16% | |
| **Welfare effect** | -0.132% | -0.125% | |

In contrast, ETS sectors gain through the change of the policy due to the lower emission reduction costs. The sectors participating in the emissions trading have to pay only for a share of their fossil fuel consumption. In contrast, NONETS sectors pay for the entire consumption of fossil fuel. In addition the prices for the consumption of fossil fuel are not identical for the ETS and NONETS sectors. Hence, different marginal abatement costs result. It has been shown that with an emission allowances price equal to the $CO_2$ tax, marginal abatement costs are not equalised.

With the emissions trading the participating sectors have the choice to either decrease their $CO_2$ emissions or to buy emission allowances for their abatement target. Because the purchase option is the cheaper way to attain the abatement target, only an insignificant part of $CO_2$ emissions is reduced, namely two per cent on average. In comparison, the same sectors reduced their $CO_2$ emissions on average by 26.2 per cent with the $CO_2$ tax policy.

The lower tax burden is also observable in the percentage change of activity levels. It is evident that NONETS sectors have further reduced their production output in contrast to the $CO_2$ tax policy. Contrariwise, ETS sectors were able to increase their production output by 2.2 per cent.

Another key result of the policy change concerns the consumption good prices. The prices for consumption goods increase overall due to the higher $CO_2$ tax. On average prices increase by 0.2 per cent in contrast to the $CO_2$ tax policy.

Although the hybrid policy leads to a higher tax burden for the NONETS sectors a higher welfare compared to the $CO_2$ tax policy results. The welfare of households increases very slightly by 0.007 per cent. The lower emission reduction costs in ETS sectors result in a positive effect. In contrast, the different marginal abatement costs of ETS and NONETS sectors lead to a negative effect. Altogether, the positive effect outweighs the negative effect leading to an increased welfare.

Hence, the results presented are similar to the results of the study by First Climate & Econability (2009). They also concluded that sectors not participating in the EU-ETS have to increase their emission reduction effort. Moreover, they found that the welfare is slightly higher in the scenario with the EU-ETS.

# 7 Conclusions

The goal of this Master's thesis was to analyse the regulations of the EU-ETS for an implementation in the Swiss system. Moreover, its aim was to evaluate the effects of the emissions trading on the Swiss economy. The thesis answers the question whether Switzerland can reach its climate policy target of reducing $CO_2$ emissions by 20 per cent in 2020 compared to the level of 1990 with the instrument of the EU-ETS. Moreover, the thesis demonstrates how the EU-ETS regulations should be modified for the targets of Swiss climate policy. At present, the climate policy of Switzerland consists of a $CO_2$ tax for fossil fuel consumption and a limited ETS for certain companies exempted from the $CO_2$ tax.

The analysis of the EU-ETS regulations has shown that two criteria for the inclusion of a company in the EU-ETS were defined. The first criterion is specified as the amount of emission output of a company. The second criterion is a specification of the type of activities listed in Annex I of the EU directive. These criteria have been applied to the extended Swiss NAP. The results indicate that the emissions trading as the only climate policy instrument is not appropriate to reach the Swiss climate policy target. This conclusion can be explained with the lower reduction target of the EU-ETS in comparison to the target of the Swiss climate policy.

Due to the results gained, the policy design for Switzerland is further developed. Based on the analyses, the EU-ETS regulations are slightly modified in order to reach the targets of Swiss climate policy. It has been shown that the EU-ETS has an abatement target that is too low for Switzerland. Therefore, the yearly reduction factor for participating Swiss companies must be increased. Moreover, the policy design must be further enlarged with a tax on $CO_2$ emissions to involve companies and households in the climate policy which were excluded from the EU-ETS. This enlargement is in accordance with the EU directive. The established hybrid policy is a mixture of a price and a quantity policy.

Finally, the hybrid policy is evaluated with a CGE model of Switzerland, called the CO2-TAX&TRADING model. For the purpose of analysing the effect of the integration of the ETS, the hybrid policy model is compared with a policy model consisting only of a $CO_2$ tax. It has been shown that the $CO_2$ tax increases due to the integration of the emissions trading to 200 CHF per tonne of $CO_2$. The tax rise can be explained through the participation of the energy intensive sectors in the ETS. Accordingly, the $CO_2$ tax of 200 CHF per tonne is levied on the entire consumption of fossil fuel from tax paying sectors and households. In contrast, the sectors participating in the ETS have to buy emission allowances for their excess consumption of fossil fuels. The price per $CO_2$ emission allowance amounts to 50 CHF. Thus, it can be concluded that the sectors participating in the ETS are benefited through the change to a hybrid policy through the lower emission reduction costs. In contrast, the sectors which have to pay the $CO_2$ tax lose through the integration of the emissions trading.

It has been shown that this outcome is strongest reflected in the $CO_2$ emission levels. Sectors paying the $CO_2$ tax have to reduce their emission levels and have no other option. However, the sectors participating in the ETS have a choice between the reduction of $CO_2$ emissions and the purchase of the necessary quantity of emission allowances. Because the purchase of emission allowances is relatively inexpensive compared to the decrease of $CO_2$ emissions, only a small part of the necessary emission reduction is really undertaken. For the remainder of the required abatement, emission allowances are bought. The results imply that the sectors paying the $CO_2$ tax have to shoulder a part of the reduction of the sectors participating in the ETS.

Even though the results indicate that the NONETS sectors lose through the policy transformation, the hybrid policy is slightly more efficient than the $CO_2$ tax policy. The welfare effect of households is by 0.007 per cent higher for the hybrid policy. The positive effect of lower emission reduction costs outweighs the negative effect of different marginal abatement costs leading to the smaller welfare loss with the hybrid policy.

A drawback of the two models applied in this thesis is their static nature and the comparison of only two states at different points in time. In a further step it would be a desirable extension to move from a static to a dynamic model. Through this extension the development of central variables over time could be investigated.

Moreover, a further weakness of the models used is the fact that the results of the modelling work are based on a single country perspective. The rest of the world is introduced in the model as artificial sector, but no trade between countries takes place. This modification was made for convenience. As an extension of the model, further countries could be added and the trade of emission allowances between those countries could be modelled. As a result, supply and demand of emission allowances must be equal and no excess demand would be possible. In the hybrid policy model, this principal economic rule is not obeyed. It is assumed that the demand of sectors participating in the ETS is covered in any case. Through this improvement the emission allowance price could be endogenously calculated. This implies that through the mentioned modifications results might shift completely.

In addition to these enhancements in the CGE model, it would be interesting to analyse certain European countries participating in the EU-ETS in more detail. What is the additional policy instrument introduced to support the reduction of the sectors in the emissions trading? How is the ETS implemented in these countries? Furthermore, other ETS could be analysed. It is expected that these analyses would considerably increase the appreciation and the knowledge of the impacts of emissions trading as a policy instrument.

Summing up, there is a central need for the continuing research on ETS. Especially, the development of accurate CGE models should be advanced. The contribution of this Master’s thesis showed that the introduction of an ETS has a great effect especially on the domestic economy. Notwithstanding its limitations, this thesis offers insight into the evaluation of the emissions trading as a climate policy instrument.

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# Appendix A – Data

## **Table A-1:** Extended Swiss NAP

| Asset number | Company name | Effective emissions 2008 | Allocation 2008-2012 (per year) | NOGA code | |
|---|---|---|---|---|---|
| 10801509 | Aarepapier AG | 4152 | 4444 | 21 | |
| 10401418 | Acima AG für Chemische Industrie | 1263 | 1485 | 24 | |
| 10201040 | AEK Energie AG | 246 | 538 | 40 | |
| 10203101 | AEK Pellet AG | 1641 | 2592 | 40 | |
| 12401715 | AG Cilander | 11921 | 12375 | 17 | |
| 9301163 | AG Ziegelwerke Horw-Gettnau | 13945 | 14768 | 26 | |
| 17802144 | Albert Spiess AG | 1143 | 2208 | 15 | |
| 15401828 | Alcan Airex AG | 1612 | 1919 | 25 | |
| 15203174 | Alcan Aluminium Valais SA | 32605 | 37485 | 27 | |
| 13902581 | Alcan Packaging Kreuzlingen AG | 4653 | 5680 | 25 | |
| 13902241 | Alcan Packaging Rorschach AG | 9372 | 14556 | 25 | |
| 15602686 | ALSTOM Technologie AG | 39694 | 36146 | 73 | |
| 15401059 | Alu Menziken Extrusion AG | 5168 | 4902 | 27 | |
| 15401829 | Aluminium Laufen AG Liesberg | 7130 | 8168 | 27 | |
| 15502633 | Aluwag AG | 4793 | 6731 | 27 | |
| 13902242 | Amcor Flexibles Schüpbach AG | 2307 | 2668 | 25 | |
| 15501873 | AMG-Alu Metall Guss AG | 4082 | 3879 | 27 | |
| 18902186 | Amrein Futtermühle AG | 139 | 139 | 15 | * |
| 11001577 | ARA Rhein AG | 1118 | 6227 | 90 | |
| 20503326 | Argobit AG | 740 | 740 | 26 | * |
| 20603318 | Associés Poste Enrobage en Commun (APE | 781 | 781 | 51 | * |
| 11301005 | Bäckerei Wallisellen | 2013 | 2514 | 15 | |
| 9201124 | Bad Seedamm AG | 3892 | 3675 | 92 | |
| 17902125 | BAER AG | 1473 | 3066 | 15 | |
| 18502626 | Bardusch AG Basel | 1234 | 923 | 93 | |
| 18503344 | Bardusch AG Zentrale Schweiz | 1315 | 1315 | 93 | * |
| 11001528 | BASF Kaisten AG | 27159 | 27683 | 24 | |
| 11101581 | BASF-Orgamol Pharma Solutions SA | 5723 | 5482 | 24 | |
| 15401831 | Baumann Federn AG | 1748 | 2589 | 28 | |
| 13602630 | BAXTER Bioscience Manufacturing SARL | 2069 | 1954 | 24 | |
| 14902151 | Beerstecher AG | 639 | 735 | 1 | |
| 20503327 | Belag + Beton AG | 1479 | 1479 | 26 | * |
| 20503330 | Belagswerk Boningen AG | 1878 | 1878 | 26 | * |
| 20503329 | Belagswerk Rinau AG | 1631 | 1631 | 26 | * |
| 11501596 | Bell AG Charcuterie | 1649 | 2571 | 15 | |
| 11501552 | Bell AG Frischfleisch Oensingen | 965 | 1151 | 15 | |
| 11501555 | Bell AG, Geflügel Zell | 1885 | 1724 | 15 | |
| 11501595 | Bell SA, Romandie Cheseaux | 1214 | 1127 | 15 | |
| 20503331 | Belreba AG | 1441 | 1441 | 26 | * |
| 20503341 | BERAG Belagslieferwerk Rubigen AG | 2605 | 2605 | 26 | * |
| 17101884 | Betriebsgesellschaft Kongresshaus Zürich A | 257 | 325 | 55 | |
| 20503333 | BHZ Baustoff Holding Zürich AG | 4650 | 4650 | 26 | * |
| 17802145 | Bigler Holding AG | 948 | 1018 | 15 | |
| 17702100 | bio-familia AG | 730 | 730 | 15 | * |
| 14902775 | Bioleguma Etter und Frey | 922 | 800 | 1 | |
| 20503334 | Bipp Asphalt AG | 1463 | 1463 | 26 | * |
| 14002235 | Biral AG | 652 | 573 | 45 | |
| 14101029 | Bischofszell Nahrungsmittel AG | 17464 | 15481 | 15 | |
| 20503335 | Biturit AG | 989 | 989 | 26 | * |
| 9501171 | Blattmann Schweiz AG | 3002 | 3390 | 24 | |
| 20501442 | BLH Belagswerk Hasle AG | 1399 | 1399 | 26 | * |
| 19302609 | Blondin Frères BMB Productions | 867 | 1061 | 1 | |
| 14902772 | Blumen Berger AG | 1369 | 1621 | 1 | |
| 10801036 | Borregaard Schweiz AG | 44274 | 43444 | 21 | |
| 14902152 | Bösiger Gemüsekulturen AG | 3730 | 3269 | 1 | |
| 13602631 | Bourquin SA | 2001 | 2144 | 21 | |
| 15701649 | Boxal (Suisse) SA | 4477 | 5186 | 27 | |
| 9301159 | Brauchli Ziegelei AG | 3816 | 3231 | 26 | |
| 12701863 | Brauerei Falken AG | 747 | 589 | 15 | |
| 12701867 | Brauerei H. Müller AG | 470 | 506 | 15 | |
| 12701866 | Brauerei Locher AG | 1151 | 951 | 15 | |
| 12701871 | Brauerei Schützengarten AG | 896 | 881 | 51 | |
| 13603154 | British American Tobacco Switzerland SA | 3927 | 6413 | 16 | |
| 10202389 | Brönnimann AG, Industrielackierwerk | 558 | 595 | 28 | |
| 11901665 | Brugg Kabel AG | 2716 | 1763 | 31 | |
| 13103175 | Camandona SA | 2274 | 2407 | 45 | |
| 16601925 | Carbagas | 1535 | 1863 | 24 | |
| 10903171 | Cartaseta-Friedrich + Co | 8138 | 8138 | 21 | * |
| 20503336 | Catram AG | 3081 | 3081 | 26 | * |
| 11301019 | CD Aclens | 1392 | 3028 | 51 | |
| 11301020 | CD Castione | 570 | 706 | 51 | |
| 11301015 | CD Givisiez | 72 | 49 | 51 | |
| 11301014 | CD La Chaux-de-Fonds | 636 | 363 | 51 | |

| Asset number | Company name | Effective emissions 2008 | Allocation 2008-2012 (per year) | NOGA code | |
|---|---|---|---|---|---|
| 19302613 | Légufrais | 825 | 648 | 1 | |
| 10201405 | Lindt und Sprüngli (Schweiz) AG, Olten | 1622 | 1086 | 15 | |
| 9401144 | Lista AG | 1966 | 2348 | 28 | |
| 9403099 | Lista Office AG | 1635 | 1594 | 36 | |
| 11301540 | LNA Gwatt | 591 | 591 | 51 | * |
| 11401022 | LNA Pratteln | 665 | 1266 | 51 | |
| 11301541 | LNA Wangen | 1234 | 1234 | 51 | * |
| 12602670 | Lonstroff AG | 2271 | 2821 | 25 | |
| 11001926 | Lonza AG | 100846 | 81357 | 24 | |
| 13202471 | LRG Groupe SA (site PLO) | 2949 | 2445 | 15 | |
| 19802785 | Luxit Isolations SA | 3299 | 2130 | 45 | |
| 19802786 | Mapei Suisse SA | 5617 | 8180 | 26 | |
| 14903188 | Markus Schildknecht Gemüskulturen | 828 | 1017 | 1 | |
| 17802147 | Meinen AG | 2055 | 1949 | 15 | |
| 11901664 | Messer Schweiz AG | 300 | 713 | 24 | |
| 13103185 | Metalcolor S.A. | 2680 | 2427 | 28 | |
| 14902184 | Meyer Pflanzenkulturen AG | 1532 | 1776 | 1 | |
| 14101032 | Micarna SA | 4446 | 2871 | 15 | |
| 14101033 | Micarna SA, Division volaille, Courtepin | 3378 | 3135 | 1 | |
| 14101849 | Midor AG | 3010 | 3452 | 15 | |
| 14101850 | Mifa AG Frenkendorf | 3049 | 4394 | 25 | |
| 14101855 | Mifroma SA | 665 | 1076 | 15 | |
| 19301068 | Millo und Cie | 497 | 1051 | 1 | |
| 12401720 | Mitloedi Textildruck AG | 1593 | 3023 | 17 | |
| 17902137 | Mittelland Molkerei AG | 7081 | 14299 | 15 | |
| 20503339 | MOAG Baustoffe Holding AG | 2104 | 2104 | 26 | * |
| 20603320 | MOBIVAL | 1257 | 1257 | 26 | * |
| 17902136 | Molkerei Biedermann AG | 350 | 373 | 15 | |
| 9301167 | Morandi Frères SA | 13979 | 15268 | 26 | |
| 12703160 | Mosterei Möhl AG | 1321 | 1706 | 15 | |
| 17101886 | Mövenpick Hotel Zürich Airport | 477 | 447 | 55 | |
| 17101887 | Mövenpick Hotel Zürich-Regensdorf | 405 | 664 | 55 | |
| 9401135 | MOWAG GmbH | 1339 | 1113 | 29 | |
| 18902200 | Mühle Burgholz AG | 294 | 291 | 15 | |
| 13403199 | Nestec S.A., Centre de Recherche Nestl | 1649 | 1904 | 73 | |
| 13403203 | Nestec S.A., PTC Konolfingen | 1167 | 931 | 15 | |
| 13403206 | Nestlé Nespresso S.A. | 3376 | 5469 | 15 | |
| 13403200 | Nestlé Suisse S.A. - Fabrik Basel | 2666 | 2265 | 15 | |
| 13403198 | Nestlé Suisse S.A. - Fabrik Konolfingen | 13612 | 16739 | 15 | |
| 13403202 | Nestlé Suisse S.A. - Fabrik Rorschach G | 1188 | 1475 | 15 | |
| 13403201 | Nestlé Suisse S.A. - Fabrik Rorschach T | 723 | 976 | 15 | |
| 13403205 | Nestlé Suisse S.A. - Fabrik Wangen | 248 | 354 | 15 | |
| 13403204 | Nestlé Suisse S.A. - Fabrique de Broc | 3751 | 4149 | 15 | |
| 13403197 | Nestlé Suisse S.A. - Fabrique d'Orbe | 21151 | 31429 | 15 | |
| 13103281 | Nestlé Waters (Suisse) SA | 2636 | 2030 | 15 | |
| 17101881 | Neue Hotel Atlantis AG | 341 | 546 | 55 | |
| 13302585 | Nexans Suisse SA | 2863 | 2586 | 25 | |
| 15701654 | Nexis Fibers AG | 8262 | 7800 | 24 | |
| 15702726 | Nitrochemie Wimmis AG | 10537 | 12255 | 24 | |
| 15501025 | Nottaris AG | 2320 | 1971 | 27 | |
| 15203173 | Novelis Sierre | 12846 | 44977 | 27 | |
| 17101888 | Novotel Zürich Airport Messe | 233 | 230 | 55 | |
| 11401559 | Nutrex | 116 | 160 | 15 | |
| 13902245 | NYCO flexible packaging GmbH | 1487 | 2278 | 25 | |
| 13902244 | O. Kleiner AG | 368 | 472 | 25 | |
| 12703161 | Obipektin AG | 10482 | 10408 | 15 | |
| 14702234 | Oerlikon Stationär-Batterien AG Aesch B | 797 | 1204 | 31 | |
| 17703164 | Oleificio SABO | 2967 | 3481 | 15 | |
| 15501878 | Osterwalder AG | 1271 | 1094 | 27 | |
| 10901521 | Papierfabrik Netstal AG | 7617 | 7617 | 21 | * |
| 10801038 | Papierfabrik Utzenstorf AG | 49140 | 54539 | 21 | |
| 17101883 | Park Plaza Hotel AG | 848 | 798 | 55 | |
| 11401021 | Pasta Gala | 1080 | 1199 | 15 | |
| 17702178 | Pasta Premium AG | 899 | 3088 | 15 | |
| 14903189 | Paul und Ruedi Meier Gemüsebau | 2183 | 2472 | 1 | |
| 15701653 | Pavatex SA | 14325 | 14619 | 21 | |
| 10801511 | Perlen Papier AG | 56280 | 44035 | 21 | |
| 20603321 | Perrin Groupe | 677 | 677 | 26 | * |
| 13901043 | Petroplast AG | 5496 | 4925 | 25 | |
| 14502153 | Pflanzenkulturen Emil Huber AG | 611 | 919 | 1 | |
| 13302590 | Philip Morris Products SA | 5775 | 13079 | 16 | |
| 15801826 | Precicast SA | 2893 | 2183 | 27 | |
| 18502623 | Prohotel Wäscherei AG | 1211 | 1716 | 93 | |

| | | | | | |
|---|---|---|---|---|---|
| 19120191 | cemsuisse Verband der Schweizerischen Ce | 609586 | 643663 | 26 | |
| 16702092 | Centravo AG | 3643 | 10646 | 51 | |
| 13102480 | Cevins SA | 191 | 259 | 51 | |
| 10901522 | Cham Paper Group Schweiz AG | 34737 | 46728 | 21 | |
| 9501175 | Chocoladenfabriken Lindt und Sprüngli (Schw | 2312 | 2837 | 15 | |
| 11401558 | Chocolats Halba, Division der Coop | 775 | 866 | 15 | |
| 12401716 | Christian Eschler AG | 1921 | 1813 | 17 | |
| 12801736 | Cilag AG | 8194 | 10052 | 24 | |
| 11001578 | CIMO, Compaigne industrielle de Monthey S | 106826 | 109387 | 40 | |
| 13203182 | Colas Suisse SA | 1914 | 1858 | 26 | |
| 20503337 | Comibit SA | 2121 | 2121 | 26 | * |
| 13303196 | Commune de Lausanne | 23390 | 24319 | | |
| 10501432 | Creabeton Matériaux SA | 4175 | 3599 | 26 | |
| 12501727 | Creation Baumann Weberei und Färberei AG | 1634 | 2474 | 17 | |
| 18603152 | Cremo SA | 28324 | 14633 | 15 | |
| 19302634 | Crousaz Fleurs | 1492 | 2325 | 1 | |
| 18902187 | Dambach AG | 614 | 664 | 15 | |
| 14101846 | Delica AG | 1521 | 1722 | 15 | |
| 15503346 | DGS Druckguss Systeme AG | 2944 | 2944 | 27 | * |
| 19302611 | Domaine des Loveresses | 950 | 893 | 1 | |
| 11101537 | Dottikon Exclusive Synthesis AG | 2054 | 9326 | 24 | |
| 11101536 | Dr. Kolb AG | 2624 | 3298 | 51 | |
| 11101533 | Drug'On Pharma Switzerland AG | 2477 | 2806 | 24 | |
| 11001003 | DSM Nutritional Products AG | 65194 | 94377 | 24 | |
| 12501728 | E. Schellenberg Textildruck AG | 2119 | 5303 | 17 | |
| 18902188 | Egli Mühlen AG | 474 | 769 | 15 | |
| 17101882 | Elba I Swiss GmbH | 579 | 755 | 55 | |
| 13302589 | EM Microelectronic-Marin SA | 2558 | 1782 | 32 | |
| 13603352 | Emile EGGER & Cie SA | 408 | 408 | 29 | * |
| 17902119 | Emmi Fondue AG | 1859 | 1966 | 15 | |
| 17902134 | Emmi Frischprodukte AG | 6633 | 5982 | 15 | |
| 17902174 | Emmi Frischprodukte AG, Betrieb Bern | 8573 | 8046 | 15 | |
| 17902121 | Emmi Käse AG | 4512 | 4756 | 15 | |
| 17902128 | Emmi Milch AG | 11758 | 11924 | 15 | |
| 15701650 | EMS-Chemie AG | 3363 | 29498 | 24 | |
| 14101843 | Estavayer Lait SA | 17259 | 24316 | 15 | |
| 11001529 | F. Hoffmann-La Roche AG | 40263 | 47667 | 24 | |
| 20603319 | Famobit SA | 2108 | 2108 | 26 | * |
| 17002096 | FBB Frischbeton + Baustoffe AG Hinwil (Asp | 4584 | 4913 | 26 | |
| 17002098 | FBB Frischbeton + Baustoffe AG Hinwil (Kal | 2780 | 2326 | 26 | |
| 20603325 | FEBEX S.A | 3053 | 3053 | 24 | * |
| 12701825 | Feldschlösschen Getränke AG | 10968 | 14657 | 51 | |
| 18012600 | fenaco Stammhaus ML | 1082 | 454 | 52 | |
| 18012601 | fenaco Stammhaus Ostschweiz | 1023 | 2701 | 52 | |
| 18012602 | fenaco Stammhaus Westschweiz | 1558 | 1475 | 52 | |
| 18012603 | fenaco Stammhaus Zentralschweiz | 2197 | 315 | 52 | |
| 17802179 | FF Frischfleisch AG | 710 | 1805 | 15 | |
| 10402341 | Filtrox AG | 1968 | 1968 | 29 | * |
| 11101580 | Firmenich SA | 19443 | 19850 | 24 | |
| 15701651 | Fixit AG | 5427 | 6395 | 26 | |
| 12202515 | Flims Waldhaus Mountain Resort AG | 1806 | 2034 | 55 | |
| 17702101 | Florin AG | 9395 | 10808 | 15 | |
| 15701652 | Flumroc AG | 30783 | 27632 | 26 | |
| 13102483 | Fondation Caux Initiatives et Changement | 283 | 254 | 91 | |
| 12602671 | Forbo Siegling Schweiz | 549 | 574 | 29 | |
| 10201402 | Fortisa AG | 475 | 571 | 15 | |
| 12703159 | Fremo Interdrink AG | 287 | 606 | 15 | |
| 18012594 | frigemo ag Produktion Mellingen | 685 | 659 | 15 | |
| 18012593 | frigemo production Cressier + frigemo AG Cr | 8168 | 8006 | 51 | |
| 18012595 | frigemo Produktion Weinfelden + frigemo AG | 87 | 1916 | 15 | |
| 12401725 | Fritz + Caspar Jenny AG | 1978 | 2002 | 17 | |
| 18602180 | Fromalp AG | 1281 | 1516 | 15 | |
| 9501172 | Frutarom Switzerland Ltd | 4053 | 3088 | 24 | |
| 9403100 | Galvaswiss AG Wellhausen | 5746 | 7152 | 28 | |
| 19303179 | Garden Centre Schilliger SA | 1415 | 1299 | 1 | |
| 18012596 | Gattiker Ernst Sutter AG | 1720 | 1150 | 51 | |
| 19802778 | Geberit Fabrication SA | 625 | 1085 | 27 | |
| 9301133 | Gebr. Rössler AG | 647 | 993 | 26 | |
| 14903191 | Gebr. V. & O. Isenegger | 1310 | 1549 | 1 | |
| 18602138 | Gefu Oberle AG | 2678 | 2991 | 51 | |
| 17802159 | Gehrig AG | 889 | 918 | 15 | |
| 17802160 | Geistlich Pharma AG Zweigniederlassung Ac | 18 | 496 | 24 | |
| 14902156 | Gerber Bio Greens AG | 1034 | 1929 | 1 | |
| 15501876 | Giesserei Erzenberg AG | 2531 | 2995 | 27 | |
| 11101579 | Givaudan Suisse SA | 14940 | 23977 | 24 | |
| 19802783 | Grisoni-Zaugg SA | 2599 | 2529 | 45 | |
| 14903194 | Grob Gemüse + Landbau | 3536 | 3497 | 1 | |
| 13103186 | Groupe Schenk | 858 | 1001 | 51 | |

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|---|---|---|---|---|---|
| 11001576 | ProRheno AG | 6358 | 13989 | 90 | |
| 18902196 | Provimi Kliba SA | 4115 | 4417 | 15 | |
| 11901658 | Quadrant Plastic Composites AG | 874 | 1816 | 24 | |
| 10201407 | R. Nussbaum AG | 853 | 1039 | 29 | |
| 14903192 | Ralph Bötsch Gemüsebau | 937 | 1045 | 1 | |
| 10203309 | Ramseier Rubigen AG | 1998 | 1998 | 28 | * |
| 18012592 | Ramseier Suisse AG | 5411 | 8803 | 51 | |
| 15801824 | Rapelli SA | 2990 | 2538 | 15 | |
| 14902158 | Rathgeb BioLog AG | 2085 | 1776 | 51 | |
| 12703187 | Rauch Trading AG | 8778 | 8778 | 51 | * |
| 18012598 | Reber Ernst Sutter AG | 1241 | 1929 | 51 | |
| 17602132 | Ricola AG | 3246 | 2053 | 15 | |
| 14002238 | Ricoter Erdaufbereitung AG | 324 | 751 | 90 | |
| 15701655 | Rigips AG | 13877 | 16282 | 26 | |
| 17201707 | Ringier Print Zofingen AG | 5701 | 5233 | 22 | |
| 10202390 | Rino Weder AG | 404 | 631 | 25 | |
| 12701869 | Rivella AG | 3654 | 6291 | 15 | |
| 11903151 | Rothrist Rohr (Schweiz) AG | 5594 | 7037 | 27 | |
| 20603323 | S.E.P. Société Enrobés et Pose | 723 | 723 | | * |
| 17703165 | Sabo Specialities AG | 3105 | 5128 | 15 | |
| 11902199 | Sager AG | 4195 | 5610 | 26 | |
| 13101657 | Saint-Gobain Isover SA | 7847 | 5465 | 24 | |
| 10901515 | Sappi Schweiz AG | 97398 | 102511 | 21 | |
| 11501553 | SBA Schlachtbetrieb Basel AG | 1193 | 1089 | 15 | |
| 17802148 | SBZ Schlachtbetrieb Zürich | 879 | 908 | 15 | |
| 10401427 | Scapa (Schweiz) AG | 3578 | 2575 | 21 | |
| 14902773 | Schäfle Rosen AG | 279 | 264 | 1 | |
| 10203310 | Schenker Storen AG | 861 | 861 | 25 | * |
| 15703261 | Schifffahrtsgesellschaft des Vierwaldstätt | 4574 | 3815 | 61 | |
| 17802149 | Schlachtbetrieb St. Gallen AG | 980 | 3265 | 15 | |
| 18802166 | Schmiedewerk Stooss AG | 8134 | 7541 | 28 | |
| 12401741 | Schoeller Textil AG | 3667 | 3565 | 17 | |
| 9501176 | Schweizer Getränke AG | 638 | 1178 | 15 | |
| 18902195 | Schweizerische Schälmühle E. Zwicky A | 652 | 1310 | 15 | |
| 14101853 | Seba Aproz SA | 1381 | 2869 | 15 | |
| 10401428 | Sefar AG | 3579 | 3574 | 22 | |
| 18802169 | Senn Chemicals AG | 490 | 490 | 24 | * |
| 20603324 | Seval | 974 | 974 | 26 | * |
| 11001532 | SI Group-Switzerland GmbH | 14366 | 21405 | 24 | |
| 9401146 | sia Abrasives Industries AG | 5067 | 6306 | 26 | |
| 11901659 | Siegfried Ltd | 7124 | 12053 | 24 | |
| 21103343 | SIG | 9407 | 9407 | 40 | * |
| 12603313 | Sihl AG | 1980 | 1980 | 21 | * |
| 12601570 | Sika Schweiz AG | 6503 | 6544 | 24 | |
| 13603155 | Sintetica-Bioren S.A. | 765 | 1389 | 24 | |
| 11902198 | Smurfit Kappa Swisswell AG | 1855 | 2300 | 21 | |
| 11101538 | Solvay (Schweiz) AG | 1289 | 1682 | 24 | |
| 15203158 | Stahl Gerlafingen AG | 76614 | 85679 | 27 | |
| 12602674 | Stamoid AG | 3358 | 5926 | 17 | |
| 12202516 | Steigenberger Hotels AG | 1316 | 1439 | 55 | |
| 13901044 | Stewo International AG | 1579 | 5316 | 21 | |
| 19302614 | Stoll Freres | 5925 | 10789 | 51 | |
| 18602139 | Strähl Käse AG | 960 | 953 | 15 | |
| 10202391 | Stucortec AG | 798 | 798 | 28 | * |
| 13902246 | Südpack Bioggio SA | 1856 | 1531 | 25 | |
| 10901517 | Swiss Quality Paper Horgen Balsthal AG | 14730 | 14966 | 21 | |
| 15203157 | Swiss Steel AG | 49601 | 47363 | 27 | |
| 13302635 | Swissmetal Industries Ltd | 6527 | 5839 | 27 | |
| 11401023 | Swissmill Division der Coop | 946 | 917 | 15 | |
| 12401719 | swisstulle, Münchwilen | 2287 | 3246 | 17 | |
| 18502621 | Textil-Service Frei AG | 1205 | 978 | 93 | |
| 14903193 | Theo Ellenbroek Gemüsekulturen | 712 | 736 | 1 | |
| 12703283 | Thurella Produktion AG | 6719 | 9011 | 15 | |
| 10801037 | Thurpapier Model AG | 7067 | 11165 | 21 | |
| 12401723 | Tiara Teppichboden AG | 1188 | 1436 | 17 | |
| 9301158 | Tonwerke Keller AG | 7553 | 8291 | 26 | |
| 17802150 | Traitafina AG | 655 | 1114 | 15 | |
| 18602140 | Translait SA | 943 | 414 | 51 | |
| 20503332 | Turbag AG | 1759 | 1759 | 29 | * |
| 10202388 | Tyco Electronics Logistics AG | 1106 | 823 | 72 | |
| 19803350 | UCB Farchim SA | 5018 | 5018 | 24 | * |
| 18011065 | UFA AG | 7677 | 9007 | 15 | |
| 18012599 | UFA SA (ex Rivalor) | 1164 | 874 | 15 | |
| 19302615 | Uniagro SA | 631 | 1091 | 1 | |
| 12703282 | Unipektin AG | 1358 | 1232 | 15 | |
| 18602130 | Vallait SA | 1315 | 1019 | 15 | |
| 11101534 | van Baerle AG | 1611 | 2167 | 24 | |
| 19803351 | Vaparoid AG | 2259 | 2259 | 24 | * |

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|---|---|---|---|---|---|
| 14902776 | Gutknecht Gemüse | 1178 | 1791 | 1 | |
| 12802445 | Gutta Werke AG | 5670 | 5585 | 21 | |
| 14002236 | Haco AG | 9863 | 13006 | 15 | |
| 18012597 | Haefliger AG | 681 | 1146 | 15 | |
| 20503338 | Hans Weibel AG | 4725 | 4725 | 45 | * |
| 18803147 | Hard AG | 1160 | 2391 | 14 | |
| 10201404 | Härterei Gerster AG | 823 | 620 | 28 | |
| 17702175 | Hefe Schweiz AG | 592 | 363 | 15 | |
| 12501732 | Heimbach Switzerland AG | 1380 | 1791 | 17 | |
| 12701865 | Heineken Switzerland AG, Chur | 3660 | 4778 | 15 | |
| 12701868 | Heineken Switzerland AG, Luzern | 2303 | 2081 | 15 | |
| 14902155 | Heinz Eymann Gemüse und CO | 239 | 337 | 1 | |
| 15703260 | Hergiswiler Glas AG | 3179 | 3179 | 26 | * |
| 12401717 | Hermann Koller AG | 1010 | 1386 | 17 | |
| 17702176 | Hero | 3868 | 5374 | 15 | |
| 17603262 | HiCoPain AG | 1620 | 1620 | 15 | * |
| 18803210 | HKS Hunziker Kalksandstein AG | 2584 | 2584 | 14 | * |
| 17702177 | HOCHDORF Nutritec AG | 22906 | 24424 | 15 | |
| 14001001 | Hoffmann Neopac AG | 3135 | 4260 | 25 | |
| 17101891 | Hotel Continental Zürich | 252 | 236 | 55 | |
| 17102342 | Hotel Dolder Waldhaus | 584 | 913 | 55 | |
| 18802163 | IMBACH + CIE. AG | 2497 | 2832 | 28 | |
| 14902777 | Imhof-Bioprodukte | 1412 | 1428 | 24 | |
| 13902243 | ISCO Jacques Schindler und Co AG | 538 | 883 | 21 | |
| 10401424 | Jansen AG, Stahlröhrenwerk, Kunststoffwerk | 4003 | 6233 | 25 | |
| 19302610 | Jaquenoud Edouard et Ernest | 3742 | 4738 | 1 | |
| 18802167 | JOSEF AMSTUTZ AG | 510 | 610 | 28 | |
| 14101031 | Jowa AG | 16833 | 17462 | 15 | |
| 19802784 | JPF Holding SA, Bulle | 1658 | 1308 | 45 | |
| 9401168 | Kalkfabrik Netstal AG | 25223 | 25564 | 14 | |
| 17602112 | Kambly SA, Specialites de Biscuits Suisses | 1346 | 1726 | 15 | |
| 10801506 | Karton Deisswil AG | 83292 | 77245 | 21 | |
| 9301131 | Keller AG Ziegeleien | 5416 | 5817 | 26 | |
| 14902182 | kellermann.ch ag | 2525 | 5334 | 51 | |
| 14002237 | Kentaur GmbH | 2598 | 2499 | 15 | |
| 9301026 | Keramik Laufen AG | 5753 | 6684 | 26 | |
| 10801520 | Kimberly-Clark GmbH | 5626 | 8600 | 21 | |
| 12401718 | Kopp AG - Textilveredlung | 2156 | 2337 | 17 | |
| 17602113 | Kraft Foods Schweiz AG | 2283 | 3493 | 15 | |
| 15701060 | Kronospan Schweiz AG | 39277 | 73139 | 20 | |
| 13203312 | Kugler Bimetal SA | 797 | 797 | 27 | * |
| 12501730 | Kuny AG | 817 | 1099 | 17 | |
| 18902191 | Kunz Kunath Fors AG | 794 | 1068 | 51 | |
| 14902183 | Lamprecht Pflanzen AG | 1140 | 2144 | 1 | |
| 18012591 | LANDI Zola AG | 1683 | 1535 | 51 | |
| 12501731 | Lantal Textiles | 2154 | 1895 | 17 | |
| 17902117 | Lataria Engiadinaisa SA (LESA) | 367 | 485 | 15 | |

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|---|---|---|---|---|---|
| 19301067 | Verdonnet-Bouchet | 250 | 921 | 1 | |
| 11101535 | Vereinigte Schweizerische Rheinsalinen | 4457 | 2771 | 14 | |
| 15701656 | Vetropack AG | 38809 | 41599 | 26 | |
| 13901045 | Vinora AG | 2820 | 4339 | 24 | |
| 18012605 | VOLG Weinkellereien AG | 618 | 657 | 15 | |
| 15501875 | vonRoll casting (emmenbrücke) ag | 495 | 1157 | 27 | |
| 15501874 | vonRoll casting (pipesystems) sa | 13199 | 17466 | 27 | |
| 15501879 | vonRoll casting (rondez) sa | 5500 | 4266 | 27 | |
| 11301006 | VZ Basel | 1736 | 1126 | 51 | |
| 11301007 | VZ Bern | 1640 | 2020 | 51 | |
| 11301008 | VZ Chur | 667 | 490 | 51 | |
| 11303207 | VZ Dietikon | 69 | 69 | 51 | * |
| 11301009 | VZ Gossau | 1674 | 1487 | 51 | |
| 11301545 | VZ Hinwil | 312 | 194 | 51 | |
| 11301011 | VZ Langenthal | 199 | 176 | 51 | |
| 11301012 | VZ Schafisheim | 669 | 258 | 51 | |
| 14002239 | Wander AG | 6533 | 6686 | 15 | |
| 18502624 | Wäsche-Perle AG | 595 | 825 | 93 | |
| 18502622 | Wäscherei Mariano AG | 571 | 493 | 93 | |
| 18502625 | Wäscheria Textil Service AG | 1518 | 1629 | 93 | |
| 15702727 | Weidmann Infra AG | 7063 | 5762 | 74 | |
| 17602114 | Wernli AG | 495 | 495 | 15 | * |
| 12401724 | Willy Koller + Co. | 1064 | 861 | 17 | |
| 13902247 | Wipf AG | 1238 | 3298 | 25 | |
| 12501734 | Wollspinnerei Huttwil AG | 665 | 750 | 17 | |
| 14902774 | Wyss Samen und Pflanzen AG | 793 | 1255 | 51 | |
| 11901662 | Zehnder Group Produktion Gränichen AG | 1185 | 1406 | 51 | |
| 18502620 | Zentralwäscherei Chur | 543 | 582 | 93 | |
| 9501179 | Zeochem AG | 6171 | 7349 | 24 | |
| 17003145 | Ziegelei Fisibach AG | 5768 | 5506 | 26 | |
| 9301156 | Ziegelei Hochdorf AG | 6440 | 6490 | 26 | |
| 17003144 | Ziegelei Ineichen AG | 1645 | 4408 | 26 | |
| 9301027 | Ziegelei Landquart AG | 4564 | 5589 | 26 | |
| 9301162 | Ziegelei Rapperswil, L. Gasser AG | 8718 | 9893 | 26 | |
| 9301028 | Ziegelei Schumacher | 9281 | 4926 | 26 | |
| 9301161 | Ziegelei Schüpfen AG | 1152 | 2098 | 26 | |
| 9301165 | Ziegeleien Freiburg und Lausanne AG | 7525 | 6399 | 26 | |
| 17003146 | Ziegelwerke Lauper AG | 4610 | 5081 | 26 | |
| 9301164 | Ziegelwerke Roggwil AG | 4876 | 3835 | 26 | |
| 10901518 | Ziegler Papier AG | 30559 | 29184 | 21 | |
| 18602142 | Zingg Transporte AG | 431 | 364 | 60 | |
| 9401147 | Zuckerfabriken Aarberg und Frauenfeld A | 23412 | 22953 | 15 | |
| 9401155 | Zuckerfabriken Aarberg und Frauenfeld A | 27953 | 24521 | 15 | |
| 18602143 | Züger Frischkäse AG | 1521 | 1002 | 15 | |
| 17101885 | Zürich Marriott Hotel | 762 | 933 | 55 | |
| 17702107 | Zweifel Pomy Chips AG | 3638 | 3126 | 15 | |
| 9301157 | ZZ Wancor | 29391 | 41853 | 26 | |

* Effective emissions are zero in the year 2008

**Table A-2:** Swiss IOT

| | NAHRUNG | TEXTIL | PAPIER | MINERALOEL | ZEMENT | METALL | GERAETE | MASCHINEN | ANDEREIND | BAU | HANDEL | GASTGEW | KREDIT | VERWALTUN | UNTERRICHT | GESUNDHEIT | ANDEREDL | TRANSPORT | ELE | LANDW | FOSSIL | ROW |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NAHRUNG | 30954 | -19 | -23 | -677 | 0 | 0 | -2 | -4 | -3 | -9 | -85 | -3714 | -2 | -74 | -378 | -1028 | -112 | -4 | -1 | -955 | 0 | -4335 |
| TEXTIL | -48 | 13431 | -77 | -544 | -5 | -11 | -77 | -77 | -403 | -266 | -281 | -92 | -15 | -9 | -108 | -112 | -195 | -5 | -1 | -31 | 0 | -3877 |
| PAPIER | -351 | -86 | 20126 | -749 | -83 | -5 | -475 | -268 | -507 | -180 | -3148 | -131 | -708 | -188 | -233 | -222 | -5039 | -173 | -48 | -69 | 0 | -3964 |
| MINERALOEL | -14 | -419 | -489 | 56380 | -106 | -17 | -987 | -309 | -2767 | -1079 | -389 | -220 | -19 | -40 | -203 | -1006 | 0 | -58 | -234 | -755 | 0 | -41979 |
| ZEMENT | -365 | -22 | -3 | -345 | 6466 | -41 | -458 | -56 | -361 | -3000 | -50 | -68 | 0 | -11 | -19 | -24 | -48 | -84 | -12 | -42 | 0 | -1182 |
| METALL | -39 | -1 | -1 | -264 | -72 | 16142 | -4871 | -1465 | -1798 | -735 | -21 | 0 | 0 | -5 | -16 | 0 | -8 | -8 | -42 | -6 | 0 | -6368 |
| GERAETE | -228 | -28 | -26 | -1128 | -68 | -400 | 51407 | -6020 | -4487 | -3759 | -1181 | -145 | -141 | -176 | -323 | -493 | -2596 | -453 | -132 | -166 | 0 | -16398 |
| MASCHINEN | -113 | -51 | -63 | -224 | -39 | -41 | -407 | 39996 | -594 | -745 | -565 | -36 | -3 | -93 | -51 | -33 | -301 | -25 | -151 | -298 | 0 | -23571 |
| ANDEREIND | -448 | -65 | -701 | -1122 | -96 | -372 | -1258 | -1550 | 74802 | -3005 | -1857 | -80 | -55 | -95 | -224 | -1712 | -1250 | -1230 | -49 | -103 | 0 | -32796 |
| BAU | -39 | -20 | -88 | -91 | -31 | -1 | -104 | -50 | -181 | 42823 | -244 | -426 | -451 | -154 | -593 | -472 | -3345 | -515 | -288 | -236 | 0 | -289 |
| HANDEL | -2488 | -217 | -1158 | -1600 | -269 | -259 | -2116 | -2168 | -2203 | -2180 | 74278 | -1318 | -146 | -206 | -385 | -1174 | -2490 | -1615 | -170 | -919 | 0 | -8908 |
| GASTGEW | -27 | -6 | -89 | -37 | -20 | 0 | -136 | -127 | -116 | -82 | -288 | 27551 | -170 | -61 | -127 | -35 | -537 | -635 | -25 | -14 | 0 | -5665 |
| KREDIT | -254 | -13 | -59 | -449 | -58 | -96 | -559 | -260 | -646 | -174 | -1150 | -223 | 69117 | -99 | -72 | -171 | -1785 | -469 | -107 | -73 | 0 | -20152 |
| VERWALTUNG | 0 | -6 | -1 | 0 | 0 | 0 | -15 | -9 | -27 | -12 | -27 | -6 | -64 | 24390 | -8 | -609 | -681 | -255 | -58 | -17 | 0 | -206 |
| UNTERRICHT | 0 | -2 | -8 | -292 | 0 | 0 | -19 | -29 | -6 | -14 | -49 | -2 | -46 | -28 | 21939 | -32 | -58 | -3 | -5 | -7 | 0 | -453 |
| GESUNDHEIT | -9 | 0 | -2 | 0 | -1 | 0 | -9 | -5 | -8 | 0 | -6 | -3 | 0 | 0 | -21 | 39457 | -4 | 0 | -3 | -257 | 0 | -1146 |
| ANDEREDL | -908 | -265 | -1694 | -4450 | -274 | -94 | -2621 | -1764 | -3769 | -1881 | -8157 | -1928 | -14357 | -1298 | -1574 | -3021 | 138312 | -2880 | -438 | -626 | 0 | -5444 |
| TRANSPORT | -1339 | -76 | -1132 | -1368 | -226 | -115 | -1021 | -674 | -1489 | -1406 | -2537 | -468 | -138 | -93 | -171 | -392 | -965 | 30153 | -253 | -249 | 0 | -7774 |
| ELE | -518 | -101 | -370 | -998 | -276 | -369 | -572 | -207 | -669 | -119 | -639 | -701 | -342 | -135 | -846 | -452 | -1047 | -484 | 16767 | -223 | 0 | -3011 |
| LANDW | -7788 | -100 | -143 | -2151 | -331 | -160 | -65 | -1 | -103 | -1383 | -30 | -545 | -50 | -78 | -68 | -140 | -197 | -26 | -1013 | 19256 | 0 | -1027 |
| FOSSIL | -145 | -21 | -191 | -232 | -80 | -63 | -53 | -37 | -100 | -36 | -168 | -103 | -44 | -53 | -112 | -130 | -296 | -779 | 0 | 0 | 5508 | 0 |
| ROW | -7635 | -10146 | -6498 | -26303 | -2309 | -12387 | -21534 | -12370 | -34465 | -94 | -322 | -5556 | -7391 | -8 | -184 | -642 | -3964 | -5477 | -1897 | -7652 | -5508 | 188547 |
| C_FOOD | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C_CLOTH | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C_HOUSING | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C_HHEQUIP | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C_HEALTH | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C_TRANSP | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C_COMM | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C_CULTURE | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C_EDU | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C_REST | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C_SERVICES | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| INVEST | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| GOV | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| FISIM | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| VA | -8199 | -1768 | -7308 | -13355 | -2120 | -1711 | -14047 | -12548 | -20100 | -22663 | -53081 | -11782 | -44975 | -21486 | -16223 | -27555 | -113393 | -14976 | -11840 | -6557 | 0 | 0 |

| | C_FOOD | C_CLOTH | C_HOUSING | C_HHEQUIP | C_HEALTH | C_TRANSP | C_COMM | C_CULTURE | C_EDU | C_REST | C_SERVICES | INVEST | GOV | FISIM | HH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NAHRUNG | -18958 | 0 | 0 | 0 | 0 | 0 | 0 | -409 | 0 | 0 | 0 | -162 | 0 | 0 | 0 |
| TEXTIL | 0 | -5433 | 0 | -948 | 0 | 0 | 0 | -313 | 0 | 0 | -276 | -171 | -55 | 0 | 0 |
| PAPIER | -31 | 0 | -26 | -56 | 0 | 0 | 0 | -2239 | 0 | 0 | -484 | -663 | 0 | 0 | 0 |
| MINERALOEL | 0 | 0 | 0 | -437 | -1789 | -288 | 0 | -504 | 0 | 0 | -1173 | -1098 | 0 | 0 | 0 |
| ZEMENT | 0 | 0 | -29 | -177 | 0 | 0 | 0 | -89 | 0 | 0 | 0 | 19 | 0 | 0 | 0 |
| METALL | 0 | 0 | 0 | -35 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -387 | 0 | 0 | 0 |
| GERAETE | 0 | -45 | -26 | -443 | 0 | -70 | -144 | -1025 | 0 | 0 | 0 | -11306 | 0 | 0 | 0 |
| MASCHINEN | 0 | 0 | -76 | -1254 | 0 | 0 | 0 | -21 | 0 | 0 | -61 | -11180 | 0 | 0 | 0 |
| ANDEREIND | 0 | -100 | -190 | -2065 | -302 | -6135 | 0 | -1175 | 0 | 0 | -1099 | -15669 | 0 | 0 | 0 |
| BAU | 0 | 0 | -1332 | -46 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -33824 | 0 | 0 | 0 |
| HANDEL | -11139 | -4243 | -578 | -3729 | -1898 | -4884 | -73 | -4046 | 0 | 0 | -2424 | -9274 | 0 | 0 | 0 |
| GASTGEW | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -734 | 0 | -18603 | 0 | 0 | -16 | 0 | 0 |
| KREDIT | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -15288 | -351 | 0 | -26609 | 0 |
| VERWALTUNG | 0 | 0 | 0 | 0 | 0 | -253 | 0 | 0 | 0 | 0 | -121 | 0 | -22013 | 0 | 0 |
| UNTERRICHT | 0 | 0 | 0 | 0 | 0 | -296 | 0 | -1281 | -1152 | 0 | 0 | 0 | -18156 | 0 | 0 |
| GESUNDHEIT | 0 | 0 | 0 | 0 | -30377 | 0 | 0 | -159 | 0 | 0 | -425 | 0 | -7020 | 0 | 0 |
| ANDEREDL | 0 | -37 | -46186 | -1608 | 0 | -1084 | -4841 | -4771 | 0 | 0 | -3245 | -11680 | -7418 | 0 | 0 |
| TRANSPORT | -445 | -35 | -34 | -66 | -36 | -4529 | 0 | -2703 | 0 | 0 | -42 | -268 | -108 | 0 | 0 |
| ELE | 0 | 0 | -4687 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| LANDW | -2935 | 0 | -147 | -32 | 0 | 0 | 0 | -401 | 0 | 0 | 0 | -343 | 0 | 0 | 0 |
| FOSSIL | 0 | 0 | -1112 | 0 | 0 | -1753 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ROW | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -16204 | 0 |
| C_FOOD | 33507 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -33508 |
| C_CLOTH | 0 | 9893 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -9893 |
| C_HOUSING | 0 | 0 | 54422 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -54422 |
| C_HHEQUIP | 0 | 0 | 0 | 10896 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -10896 |
| C_HEALTH | 0 | 0 | 0 | 0 | 34402 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -34402 |
| C_TRANSP | 0 | 0 | 0 | 0 | 0 | 19292 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -19292 |
| C_COMM | 0 | 0 | 0 | 0 | 0 | 0 | 5058 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -5057 |
| C_CULTURE | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 19871 | 0 | 0 | 0 | 0 | 0 | 0 | -19871 |
| C_EDU | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1152 | 0 | 0 | 0 | 0 | 0 | -1152 |
| C_REST | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 18603 | 0 | 0 | 0 | 0 | -18603 |
| C_SERVICES | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 24636 | 0 | 0 | 0 | -24635 |
| INVEST | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 96356 | 0 | 0 | -96356 |
| GOV | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 54787 | 0 | -54788 |
| FISIM | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 42813 | -42813 |
| VA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 425689 |

# Appendix B – Results

**Figure B-1:** Percentage change in quantities demanded by households (CO2-TAX Model)

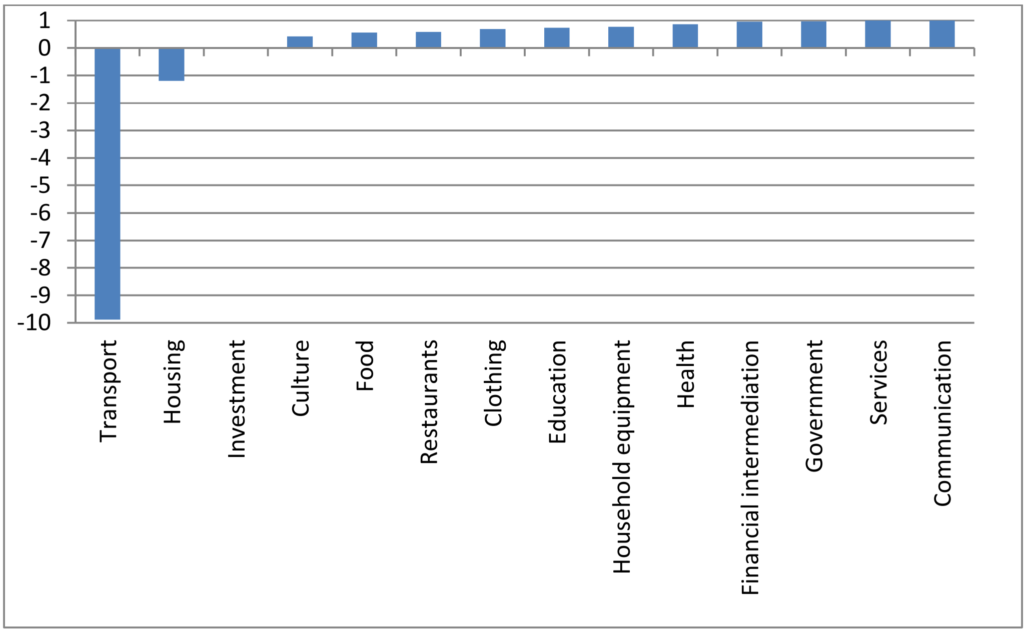


**Figure B-2:** Percentage Change in Quantities Demanded by Households (CO2-TAX&TRADING Model)

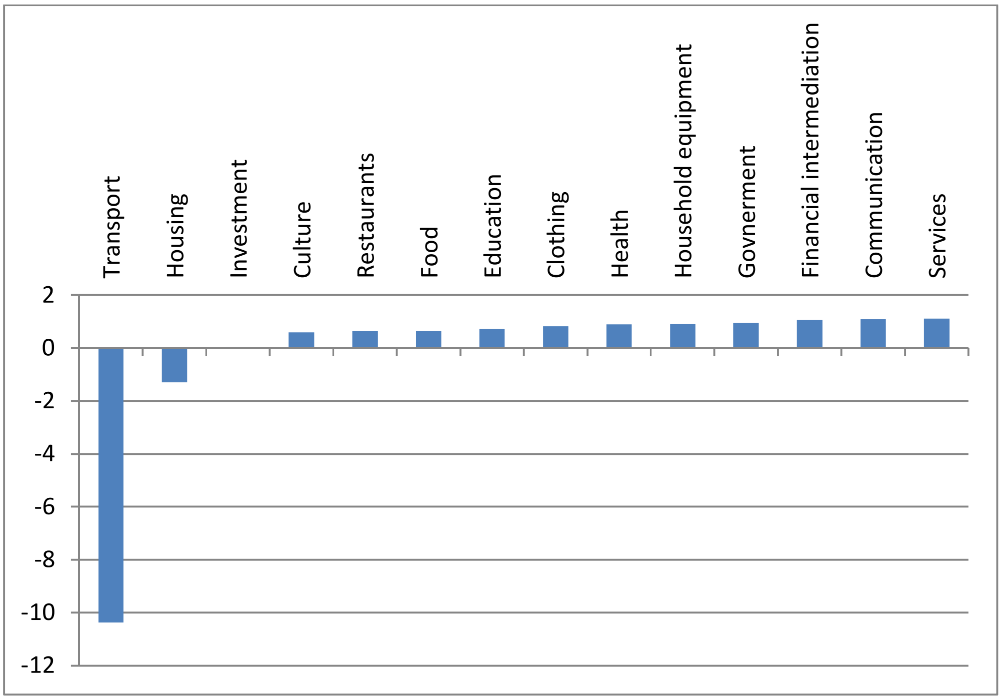

**Table B-1:** Results of the Sensitivity Analysis for NONETS Sectors

| **Percentage Change of $CO_2$ Emissions** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **23** | **50** | **100** | **150** | **200** | **Diff-23** | **Diff-100** | **Diff-150** | **Diff-200** |
| **Food** | -25.708 | -25.707 | -25.707 | -25.706 | -25.706 | 0.0003 | -0.0006 | -0.0011 | -0.0016 |
| **Textiles** | -25.086 | -25.091 | -25.099 | -25.105 | -25.111 | -0.0051 | 0.0080 | 0.0146 | 0.0202 |
| **Equipment** | -24.022 | -24.024 | -24.027 | -24.029 | -24.031 | -0.0019 | 0.0031 | 0.0056 | 0.0076 |
| **Machinery** | -24.895 | -24.891 | -24.884 | -24.879 | -24.875 | 0.0039 | -0.0062 | -0.0115 | -0.016 |
| **Other industry** | -25.432 | -25.433 | -25.434 | -25.435 | -25.435 | -0.0007 | 0.0011 | 0.0020 | 0.0027 |
| **Construction** | -26.133 | -26.134 | -26.135 | -26.136 | -26.136 | -0.0006 | 0.0010 | 0.0018 | 0.0024 |
| **Trade** | -26.111 | -26.111 | -26.11 | -26.109 | -26.108 | 0.0006 | -0.0010 | -0.0019 | -0.0026 |
| **Hospitality industry** | -24.52 | -24.517 | -24.511 | -24.507 | -24.503 | 0.0036 | -0.0056 | -0.0103 | -0.0143 |
| **Credit** | -23.253 | -23.245 | -23.231 | -23.22 | -23.211 | 0.0085 | -0.0134 | -0.0246 | -0.0341 |
| **Administration** | -26.248 | -26.248 | -26.247 | -26.247 | -26.247 | 0.0004 | -0.0005 | -0.0010 | -0.0014 |
| **Education** | -23.649 | -23.649 | -23.649 | -23.649 | -23.649 | 0.0001 | -0.0002 | -0.0004 | -0.0005 |
| **Health** | -25.215 | -25.214 | -25.214 | -25.213 | -25.212 | 0.0005 | -0.0008 | -0.0014 | -0.002 |
| **Other services** | -26.155 | -26.155 | -26.155 | -26.155 | -26.156 | -0.0002 | 0.0003 | 0.0005 | 0.0007 |
| **Transportation** | -34.807 | -34.807 | -34.807 | -34.807 | -34.807 | 0.0001 | -0.0002 | -0.0004 | -0.0007 |
| **Agriculture** | 0 | 0 | 0 | 0 | 0 | 0.0000 | 0.0000 | 0.0000 | 0 |

| **Percentage Change of Prices in NONETS Sectors** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **23** | **50** | **100** | **150** | **200** | **Diff-23** | **Diff-100** | **Diff-150** | **Diff-200** |
| **Food** | 0.3944 | 0.3908 | 0.385 | 0.3803 | 0.3762 | -0.0036 | 0.0058 | 0.0105 | 0.0146 |
| **Textiles** | 0.101 | 0.1 | 0.0983 | 0.097 | 0.0958 | -0.0010 | 0.0017 | 0.0030 | 0.0042 |
| **Equipment** | -0.0388 | -0.0405 | -0.0433 | -0.0455 | -0.0474 | -0.0017 | 0.0028 | 0.0050 | 0.0069 |
| **Machinery** | -0.0709 | -0.0741 | -0.0791 | -0.0833 | -0.0869 | -0.0032 | 0.0050 | 0.0092 | 0.0128 |
| **Other industry** | 0.0039 | 0.0016 | -0.002 | -0.0051 | -0.0076 | -0.0023 | 0.0036 | 0.0067 | 0.0092 |
| **Construction** | -0.1929 | -0.1961 | -0.2011 | -0.2052 | -0.2088 | -0.0032 | 0.0050 | 0.0091 | 0.0127 |
| **Trade** | -0.1407 | -0.1468 | -0.1566 | -0.1647 | -0.1716 | -0.0061 | 0.0098 | 0.0179 | 0.0248 |
| **Hospitality industry** | 0.198 | 0.193 | 0.1851 | 0.1785 | 0.1729 | -0.0050 | 0.0079 | 0.0145 | 0.0201 |
| **Credit** | -0.3734 | -0.3801 | -0.3905 | -0.3992 | -0.4065 | -0.0067 | 0.0104 | 0.0191 | 0.0264 |
| **Administration** | -0.3002 | -0.3079 | -0.32 | -0.3301 | -0.3386 | -0.0077 | 0.0121 | 0.0222 | 0.0307 |
| **Education** | 0.1119 | 0.105 | 0.094 | 0.0849 | 0.0771 | -0.0069 | 0.0110 | 0.0201 | 0.0279 |
| **Health** | -0.0643 | -0.0709 | -0.0815 | -0.0902 | -0.0977 | -0.0066 | 0.0106 | 0.0193 | 0.0268 |
| **Other services** | -0.2587 | -0.2652 | -0.2754 | -0.2839 | -0.2912 | -0.0065 | 0.0102 | 0.0187 | 0.026 |
| **Transportation** | 2.4609 | 2.4553 | 2.4465 | 2.4391 | 2.4328 | -0.0056 | 0.0088 | 0.0162 | 0.0225 |
| **Agriculture** | -0.1901 | -0.1935 | -0.1989 | -0.2034 | -0.2072 | -0.0034 | 0.0054 | 0.0099 | 0.0137 |

| Percentage Change of Intermediate Prices in NONETS Sectors | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 23 | 50 | 100 | 150 | 200 | Diff-23 | Diff-100 | Diff-150 | Diff-200 |
| Food | 0.0706 | 0.0678 | 0.0634 | 0.0597 | 0.0565 | -0.0028 | 0.0044 | 0.0081 | 0.0113 |
| Textiles | 0.0016 | 0.0026 | 0.0042 | 0.0056 | 0.0068 | 0.0010 | -0.0016 | -0.0030 | -0.0042 |
| Equipment | 0.0524 | 0.0544 | 0.0576 | 0.0604 | 0.0627 | 0.0020 | -0.0032 | -0.0060 | -0.0083 |
| Machinery | 0.0299 | 0.0284 | 0.026 | 0.0241 | 0.0224 | -0.0015 | 0.0024 | 0.0043 | 0.006 |
| Other industry | 0.0717 | 0.0716 | 0.0715 | 0.0713 | 0.0713 | -0.0001 | 0.0001 | 0.0003 | 0.0003 |
| Construction | 0.0765 | 0.0791 | 0.0832 | 0.0867 | 0.0896 | 0.0026 | -0.0041 | -0.0076 | -0.0105 |
| Trade | 0.1642 | 0.1634 | 0.1622 | 0.1612 | 0.1604 | -0.0008 | 0.0012 | 0.0022 | 0.003 |
| Hospitality industry | 0.1715 | 0.1677 | 0.1617 | 0.1567 | 0.1525 | -0.0038 | 0.0060 | 0.0110 | 0.0152 |
| Credit | -0.2172 | -0.2223 | -0.2303 | -0.237 | -0.2427 | -0.0051 | 0.0080 | 0.0147 | 0.0204 |
| Administration | -0.0783 | -0.0815 | -0.0865 | -0.0906 | -0.0942 | -0.0032 | 0.0050 | 0.0091 | 0.0127 |
| Education | -0.0177 | -0.0204 | -0.0247 | -0.0282 | -0.0313 | -0.0027 | 0.0043 | 0.0078 | 0.0109 |
| Health | -0.0071 | -0.0102 | -0.0149 | -0.0189 | -0.0223 | -0.0031 | 0.0047 | 0.0087 | 0.0121 |
| Other services | -0.0012 | 0.0011 | 0.0049 | 0.008 | 0.0106 | 0.0023 | -0.0038 | -0.0069 | -0.0095 |
| Transportation | -0.1486 | -0.1528 | -0.1595 | -0.1651 | -0.1698 | -0.0042 | 0.0067 | 0.0123 | 0.017 |
| Agriculture | 0.1001 | 0.0979 | 0.0946 | 0.0918 | 0.0894 | -0.0022 | 0.0033 | 0.0061 | 0.0085 |

| Output Loss of NONETS Sectors in Percentage | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 23 | 50 | 100 | 150 | 200 | Diff-23 | Diff-100 | Diff-150 | Diff-200 |
| Food | -0.2928 | -0.2918 | -0.2902 | -0.2889 | -0.2878 | 0.0010 | -0.0016 | -0.0029 | -0.004 |
| Textiles | -0.181 | -0.1881 | -0.1992 | -0.2084 | -0.2163 | -0.0071 | 0.0111 | 0.0203 | 0.0282 |
| Equipment | -0.3868 | -0.3895 | -0.3937 | -0.3972 | -0.4002 | -0.0027 | 0.0042 | 0.0077 | 0.0107 |
| Machinery | -0.1065 | -0.101 | -0.0922 | -0.0848 | -0.0784 | 0.0055 | -0.0088 | -0.0162 | -0.0226 |
| Other industry | -1.331 | -1.3319 | -1.3332 | -1.3343 | -1.3352 | -0.0009 | 0.0013 | 0.0024 | 0.0033 |
| Construction | -0.0948 | -0.0951 | -0.0958 | -0.0963 | -0.0968 | -0.0003 | 0.0007 | 0.0012 | 0.0017 |
| Trade | -0.5863 | -0.5841 | -0.5807 | -0.5779 | -0.5755 | 0.0022 | -0.0034 | -0.0062 | -0.0086 |
| Hospitality industry | -0.305 | -0.2995 | -0.2907 | -0.2834 | -0.2772 | 0.0055 | -0.0088 | -0.0161 | -0.0223 |
| Credit | 1.4146 | 1.4271 | 1.447 | 1.4636 | 1.4777 | 0.0125 | -0.0199 | -0.0365 | -0.0506 |
| Administration | 0.7136 | 0.7159 | 0.7195 | 0.7225 | 0.725 | 0.0023 | -0.0036 | -0.0066 | -0.0091 |
| Education | 0.6774 | 0.679 | 0.6816 | 0.6836 | 0.6854 | 0.0016 | -0.0026 | -0.0046 | -0.0064 |
| Health | 0.8628 | 0.865 | 0.8684 | 0.8712 | 0.8735 | 0.0022 | -0.0034 | -0.0062 | -0.0085 |
| Other services | -0.357 | -0.3558 | -0.354 | -0.3525 | -0.3512 | 0.0012 | -0.0018 | -0.0033 | -0.0046 |
| Transportation | -7.4431 | -7.4417 | -7.4396 | -7.4378 | -7.4362 | 0.0014 | -0.0021 | -0.0039 | -0.0055 |
| Agriculture | -0.005 | -0.0127 | -0.0249 | -0.035 | -0.0436 | -0.0077 | 0.0122 | 0.0223 | 0.0309 |

**Table B-2:** Results of the Sensitivity Analysis for ETS Sectors

| Percentage Change of CO2 Emissions | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 23 | 50 | 100 | 150 | 200 | Diff-23 | Diff-100 | Diff-150 | Diff-200 |
| Paper | -1.1334 | -2.1108 | -3.6079 | -4.8139 | -5.814 | -0.9774 | 1.4971 | 2.7031 | 3.7032 |
| Mineraloil | -0.8156 | -1.7536 | -3.1915 | -4.3509 | -5.3129 | -0.9380 | 1.4379 | 2.5973 | 3.5593 |
| Cement | -1.0814 | -2.007 | -3.4252 | -4.5682 | -5.5163 | -0.9256 | 1.4182 | 2.5612 | 3.5093 |
| Metal | -1.3398 | -2.2137 | -3.5527 | -4.6321 | -5.5274 | -0.8739 | 1.3390 | 2.4184 | 3.3137 |

| Percentage Change of Prices in ETS Sectors | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 23 | 50 | 100 | 150 | 200 | Diff-23 | Diff-100 | Diff-150 | Diff-200 |
| Paper | -0.1084 | -0.0873 | -0.0541 | -0.0264 | -0.0028 | 0.0211 | -0.0332 | -0.0609 | -0.0845 |
| Mineraloil | -0.1139 | -0.1056 | -0.0926 | -0.0817 | -0.0724 | 0.0083 | -0.0130 | -0.0239 | -0.0332 |
| Cement | -0.1635 | -0.1339 | -0.0873 | -0.0483 | -0.0151 | 0.0296 | -0.0466 | -0.0856 | -0.1188 |
| Metal | -0.0553 | -0.0462 | -0.0317 | -0.0196 | -0.0093 | 0.0091 | -0.0145 | -0.0266 | -0.0369 |

| Percentage Change of Intermediate Prices in ETS Sectors | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 23 | 50 | 100 | 150 | 200 | Diff-23 | Diff-100 | Diff-150 | Diff-200 |
| Paper | 0.3638 | 0.3596 | 0.353 | 0.3476 | 0.3429 | -0.0042 | 0.0066 | 0.0120 | 0.0167 |
| Mineraloil | 0.1001 | 0.0976 | 0.0936 | 0.0903 | 0.0875 | -0.0025 | 0.0040 | 0.0073 | 0.0101 |
| Cement | 0.1973 | 0.1951 | 0.1917 | 0.1889 | 0.1865 | -0.0022 | 0.0034 | 0.0062 | 0.0086 |
| Metal | 0.0811 | 0.0785 | 0.0743 | 0.0708 | 0.0679 | -0.0026 | 0.0042 | 0.0077 | 0.0106 |

| Output Loss of ETS Sectors in Percentage | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 23 | 50 | 100 | 150 | 200 | Diff-23 | Diff-100 | Diff-150 | Diff-200 |
| Paper | -0.1255 | -0.1743 | -0.2512 | -0.315 | -0.3692 | -0.0488 | 0.0769 | 0.1407 | 0.1949 |
| Mineraloil | 0.1138 | 0.0359 | -0.0869 | -0.1891 | -0.2761 | -0.0779 | 0.1228 | 0.2250 | 0.3120 |
| Cement | -0.139 | -0.2025 | -0.3026 | -0.3856 | -0.4562 | -0.0635 | 0.1001 | 0.1831 | 0.2537 |
| Metal | -0.4701 | -0.5175 | -0.5921 | -0.6543 | -0.7072 | -0.0474 | 0.0746 | 0.1368 | 0.1897 |

**Table B-3:** Results of the Sensitivity Analysis for Consumption Goods

| Percentage Change of Prices of Consumption Goods | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **23** | **50** | **100** | **150** | **200** | **Diff-23** | **Diff-100** | **Diff-150** | **Diff-200** |
| **Food** | 0.1953 | 0.1908 | 0.1838 | 0.1779 | 0.173 | -0.0045 | 0.007 | 0.0129 | 0.0178 |
| **Clothing** | 0.0027 | -0.0005 | -0.0057 | -0.0101 | -0.0137 | -0.0032 | 0.0052 | 0.0096 | 0.0132 |
| **Housing** | 2.1535 | 2.1472 | 2.1371 | 2.1287 | 2.1216 | -0.0063 | 0.0101 | 0.0185 | 0.0256 |
| **Household equipment** | -0.0809 | -0.0841 | -0.089 | -0.0932 | -0.0967 | -0.0032 | 0.0049 | 0.0091 | 0.0126 |
| **Health** | -0.0678 | -0.0736 | -0.0828 | -0.0905 | -0.097 | -0.0058 | 0.0092 | 0.0169 | 0.0234 |
| **Transport** | 12.5067 | 12.5019 | 12.4943 | 12.4879 | 12.4824 | -0.0048 | 0.0076 | 0.014 | 0.0195 |
| **Communication** | -0.2507 | -0.2571 | -0.2671 | -0.2754 | -0.2825 | -0.0064 | 0.01 | 0.0183 | 0.0254 |
| **Culture** | 0.2412 | 0.2392 | 0.2362 | 0.2336 | 0.2315 | -0.002 | 0.003 | 0.0056 | 0.0077 |
| **Education** | 0.1119 | 0.105 | 0.094 | 0.0849 | 0.0771 | -0.0069 | 0.011 | 0.0201 | 0.0279 |
| **Restaurants** | 0.198 | 0.193 | 0.1851 | 0.1785 | 0.1729 | -0.005 | 0.0079 | 0.0145 | 0.0201 |
| **Services** | -0.2763 | -0.2814 | -0.2893 | -0.296 | -0.3016 | -0.0051 | 0.0079 | 0.0146 | 0.0202 |
| **Government** | -0.1236 | -0.1307 | -0.142 | -0.1514 | -0.1593 | -0.0071 | 0.0113 | 0.0207 | 0.0286 |
| **Financial intermediation** | -0.2321 | -0.2362 | -0.2427 | -0.2481 | -0.2527 | -0.0041 | 0.0065 | 0.0119 | 0.0165 |

| Percentage Change of Quantities Demanded of Consumption Goods | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **23** | **50** | **100** | **150** | **200** | **Diff-23** | **Diff-100** | **Diff-150** | **Diff-200** |
| **Food** | 0.634 | 0.6334 | 0.6322 | 0.6312 | 0.6303 | -0.0006 | 0.0012 | 0.0031 | 0.0031 |
| **Clothing** | 0.8278 | 0.826 | 0.823 | 0.8204 | 0.8182 | -0.0018 | 0.003 | 0.0078 | 0.0078 |
| **Housing** | -1.295 | -1.294 | -1.2923 | -1.291 | -1.2899 | 0.001 | -0.0017 | -0.0041 | -0.0041 |
| **Household equipment** | 0.9123 | 0.9103 | 0.907 | 0.9043 | 0.9019 | -0.002 | 0.0033 | 0.0084 | 0.0084 |
| **Health** | 0.899 | 0.8997 | 0.9008 | 0.9016 | 0.9022 | 0.0007 | -0.0011 | -0.0025 | -0.0025 |
| **Transport** | -10.3782 | -10.3789 | -10.3802 | -10.3812 | -10.3821 | -0.0007 | 0.0013 | 0.0032 | 0.0032 |
| **Communication** | 1.084 | 1.0853 | 1.0872 | 1.0887 | 1.0899 | 0.0013 | -0.0019 | -0.0046 | -0.0046 |
| **Culture** | 0.588 | 0.5848 | 0.5796 | 0.5753 | 0.5715 | -0.0032 | 0.0052 | 0.0133 | 0.0133 |
| **Education** | 0.7178 | 0.7197 | 0.7225 | 0.7248 | 0.7267 | 0.0019 | -0.0028 | -0.007 | -0.007 |
| **Restaurants** | 0.6313 | 0.6312 | 0.6309 | 0.6306 | 0.6303 | -1E-04 | 0.0003 | 0.0009 | 0.0009 |
| **Services** | 1.11 | 1.1099 | 1.1097 | 1.1095 | 1.1093 | -1E-04 | 0.0002 | 0.0006 | 0.0006 |
| **Government** | 0.9554 | 0.9574 | 0.9605 | 0.9631 | 0.9652 | 0.002 | -0.0031 | -0.0078 | -0.0078 |
| **Financial intermediation** | 1.0652 | 1.0641 | 1.0624 | 1.061 | 1.0597 | -0.0011 | 0.0017 | 0.0044 | 0.0044 |

# Appendix C – GAMS Code

## **C–1:** Programme Code CO2-TAX Model

```
$TITLE CO2TAX model
$Ontext

Base Economy

$Offtext

FILE result /CO2results_Romina.dat/;

$INCLUDE Romi/bench_hh.dat

SETS
      CONS CONSUMPTION GOODS
 /    C_FOOD, C_CLOTH, C_HOUSING, C_HHEQUIP, C_HEALTH, C_TRANSP, C_COMM, C_CULTURE, C_EDU, C_REST, C_SERVICES, GOV, FISIM /,

      PS   PRODUCTION SECTORS
 /    NAHRUNG, TEXTIL, PAPIER, MINERALOEL, ZEMENT, METALL, GERAETE, MASCHINEN, ANDEREIND, BAU, HANDEL, GASTGEW, KREDIT,
      VERWALTUNG, UNTERRICHT, GESUNDHEIT, ANDEREDL, TRANSPORT, LANDW /;

ALIAS (CONS, CCONS);
ALIAS (PS,PSS);

PARAMETER
       INPUTS(PS,PSS)              Inputs into production,
       INPUT_FOSSIL_PS(PS)         Inputs into production,
       INPUT_ELE_PS(PS)            Inputs into production,
       INPUT_ROW_PS(PS)            Inputs into production,
       INPUT_VA_PS(PS)             Inputs into production,
       INPUT_VAE_PS(PS)            Inputs into production,

       INPUT_PS_ELE(PS)          Inputs of production sectors into ELE,
       INPUT_ROW_ELE             Inputs of ROW into ELE ,
       INPUT_VA_ELE              Inputs of endowment into ELE,
       INPUT_PS_ROW(PS)          Inputs of production factors into ROW,
       INPUT_ELE_ROW             Inputs of ELE into ROW,
       INPUT_ROW_FOSSI           Inputs of ROW into FOSSIL,

       INPUT_PS_CONS(PS,CONS)       Inputs into production of the consumption good,
       INPUT_PS_INVEST(PS)          Inputs Investment into production the production of the consumption good,
       INPUT_ELE_CONS(CONS)         Inputs of ELE into consumption goods,
       INPUT_FOSSIL_CONS(CONS)   Inputs of FOSSIL into consumption goods,
       INPUT_ROW_CONS(CONS)         Inputs of ROW into consumption goods,

       OUTPUTS(PS)               Output of production,
       OUTPUT_ELE                Output of ELE,
       OUTPUT_FOSSIL             Output of FOSSIL,
       OUTPUT_ROW                Output of ROW,
       OUTPUT_CONS(CONS)   Output of consumption good,
       OUTPUT_INVEST             Output of Investment,

       IMED_DEMAND(PS)       Intermediate goods demand per sector,
       QIMEDELE              Intermediate goods demand of sector ELE,

       HDEMAND(CONS)             Demand of households,
       HDEMAND_INVEST            Demand of households for investment,
       ENDOWMENT_VA              Factor endowment of households;

INPUTS(PS,PSS)   = -BENCH(PS,PSS);
INPUTS(PS,PS)    = 0;
INPUT_FOSSIL_PS(PS)= -BENCH("FOSSIL",PS);
INPUT_ELE_PS(PS)= -BENCH("ELE",PS);
INPUT_ROW_PS(PS)= -BENCH("ROW",PS);
INPUT_VA_PS(PS) = -BENCH("VA",PS);
INPUT_VAE_PS(PS) =   INPUT_VA_PS(PS)+INPUT_FOSSIL_PS(PS)+INPUT_ELE_PS(PS);

INPUT_PS_ELE(PS)   = -BENCH(PS,"ELE");
INPUT_ROW_ELE     = -BENCH("ROW","ELE");
INPUT_VA_ELE      = -BENCH("VA","ELE");
INPUT_PS_ROW(PS)  = -BENCH(PS,"ROW");
INPUT_ELE_ROW     = -BENCH("ELE","ROW");
INPUT_ROW_FOSSIL  = -BENCH("ROW","FOSSIL");

INPUT_PS_CONS(PS,CONS) = -BENCH(PS,CONS);
INPUT_PS_INVEST(PS) = -BENCH(PS,"INVEST");
INPUT_ELE_CONS(CONS)  = -BENCH("ELE",CONS);
INPUT_FOSSIL_CONS(CONS)  = -BENCH("FOSSIL",CONS);
INPUT_ROW_CONS(CONS)    = -BENCH("ROW",CONS);

OUTPUTS(PS)     = BENCH(PS,PS);
OUTPUT_ELE      = BENCH("ELE","ELE");
OUTPUT_FOSSIL   = BENCH("FOSSIL","FOSSIL");
OUTPUT_ROW      = BENCH("ROW","ROW");
OUTPUT_CONS(CONS)  = BENCH(CONS,CONS);
OUTPUT_INVEST      = BENCH("INVEST","INVEST");

IMED_DEMAND(PS) = SUM(PSS, INPUTS(PSS,PS));
QIMEDELE = SUM(PS, INPUT_PS_ELE(PS));
```

```
HDEMAND(CONS)   = -BENCH(CONS,"HH");
HDEMAND_INVEST  = -BENCH("INVEST","HH");
ENDOWMENT_VA = BENCH("VA","HH");

DISPLAY ENDOWMENT_VA, OUTPUTS, INPUTS, IMED_DEMAND;

PARAMETER
      TAXONCO2          Exogenous tax on fossil fuel (set equal to zero for Benchmark),
      REDUXCO2          C02 reduction target,
      Q_TO_tCO2         Factor which translates Output of fossil fuel by the Model to tonnes CO2 in the real world,
      CO2_BENCH         Benchmark quantity of CO2;

* SET TAXONCO2=0 FOR BENCHMARK AND TAXON>0 FOR TAXSCENARIO
REDUXCO2       = 0;
TAXONCO2       = 0;
Q_TO_tCO2      = 89*74;
CO2_BENCH      = OUTPUT_FOSSIL*Q_TO_tCO2;

* Foreign country prices:
SCALAR
         PEY    Export price of good Y / 0.999/
         PMX    Import price of good X / 1.001/
         PEX    Export price of good X / 1   /
         PMY    Import price of good Y / 1   /;

$INCLUDE ROMI/ELASTICITIES.DAT

$ONTEXT

$MODEL:CO2TAX

$SECTORS:
      Y(PS)
      Y_ELE
      Y_FOSSIL
      Y_ROW
      Y_C_GOOD(CONS)
      Y_INVEST
      INTERMED(PS)
      INTERMED_ELE
      VAE(PS)
      EX                ! Foreign country Export Import sectors
      MY                ! Foreign country Export Import sectors
      EY                ! Foreign country Export Import sectors
      MX                ! Foreign country Export Import sectors
      X_F               ! Foreign production sector for good X
      Y_F               ! Foreign production sector for good Y

$COMMODITIES:
      P(PS)
      P_ELE
      P_FOSSIL
      P_ROW
      P_VA
      P_CONS(CONS)
      P_INVEST
      PIMED(PS)
      PIMEDELE
      P_VAE(PS)
      P_ROWEXP         ! Export aggregate from Switzerland to foreign
      PXF              ! Good X produced by foreign country
      PYF              ! Good Y produced by foreign country
      PVAF             ! VA of foreign household

$CONSUMERS:
      RA
      CONS_F       ! Foreign household

$AUXILIARY:
      ENDTAX

$REPORT:
      V:CONSDEMAND(CONS)        D:P_CONS(CONS)       DEMAND:RA
      V:CONSDEMAND_INVEST       D:P_INVEST           DEMAND:RA
      V:IMPDEMAND(PS)           I:P_ROW              PROD:Y(PS)
      V:IMPDEMAND_FOSSIL        I:P_ROW              PROD:Y_FOSSIL
      V:IMPDEMAND_ELE           I:P_ROW              PROD:Y_ELE
      V:PRODOUTPUT(PS)          O:P(PS)              PROD:Y(PS)
      V:VAINPUT(PS)             I:P_VA               PROD:VAE(PS)
      V:FOSS_VAE(PS)            I:P_FOSSIL           PROD:VAE(PS)
      V:FOSSILOUTPUT            O:P_FOSSIL           PROD:Y_FOSSIL
      V:FOSSILINPUT             I:P_ROW              PROD:Y_FOSSIL
      V:FOSSIL_CONS(CONS)       I:P_FOSSIL           PROD:Y_C_GOOD(CONS)
      V:WLF                     W:RA
      V:WLF_FOREIGN             W:CONS_F

$PROD:X_F  s:1
     O:PXF        Q:600000
     I:PVAF       Q:600000

$PROD:Y_F  s:1
     O:PYF        Q:1
     I:PVAF       Q:1
```

```
$PROD:EX
      O:P_ROW              Q:(PEX*188547)
      I:PXF                Q:188547

$PROD:MY
      O:PYF                Q:188547
      I:P_ROWEXP           Q:(PMY*188547)

*      The following trade activities are not operated in the benchmark
*      period:

$PROD:EY
      O:P_ROWEXP           Q:PEY
      I:PYF                Q:1

$PROD:MX
      O:PXF                Q:1
      I:P_ROW              Q:PMX


$DEMAND:CONS_F
       D:PXF               Q:411453
       D:PYF               Q:188547
       E:PVAF              Q:600000

$PROD:Y_FOSSIL s:0
       O:P_FOSSIL          Q:OUTPUT_FOSSIL
       I:P_ROW             Q:INPUT_ROW_FOSSIL

$PROD:INTERMED_ELE  s:0
       O:PIMEDELE          Q:QIMEDELE
       I:P(PS)             Q:INPUT_PS_ELE(PS)

$PROD:Y_ELE s:0  a:EL_ARM
       O:P_ELE             Q:OUTPUT_ELE
       I:PIMEDELE          Q:QIMEDELE          a:
       I:P_ROW             Q:INPUT_ROW_ELE       a:
       I:P_VA              Q:INPUT_VA_ELE

$PROD:INTERMED(PS) s:0
       O:PIMED(PS)         Q:IMED_DEMAND(PS)
       I:P(PSS)            Q:INPUTS(PSS,PS)

$PROD:VAE(PS)  s:EL_VAE  a:EL_FE
       O:P_VAE(PS)         Q:INPUT_VAE_PS(PS)
       I:P_VA              Q:INPUT_VA_PS(PS)
       I:P_FOSSIL          Q:INPUT_FOSSIL_PS(PS)        A:RA N:ENDTAX a:
       I:P_ELE             Q:INPUT_ELE_PS(PS)           a:

$PROD:Y(PS) s:EL_SUB a:EL_ARM
       O:P(PS)             Q:OUTPUTS(PS)
       I:P_VAE(PS)         Q:INPUT_VAE_PS(PS)
       I:PIMED(PS)         Q:IMED_DEMAND(PS)         a:
       I:P_ROW             Q:INPUT_ROW_PS(PS)        a:

$PROD:Y_ROW   s:EL_ROW
       O:P_ROWEXP          Q:OUTPUT_ROW
       I:P(PS)             Q:INPUT_PS_ROW(PS)
       I:P_ELE             Q:INPUT_ELE_ROW

$PROD:Y_C_GOOD(CONS)  s:0    a:EL_FE
       O:P_CONS(CONS)      Q:OUTPUT_CONS(CONS)
       I:P(PS)             Q:INPUT_PS_CONS(PS,CONS)
       I:P_ROW             Q:INPUT_ROW_CONS(CONS)
       I:P_FOSSIL          Q:INPUT_FOSSIL_CONS(CONS)     A:RA N:ENDTAX  a:
       I:P_ELE             Q:INPUT_ELE_CONS(CONS)        a:

$PROD:Y_INVEST s:0
       O:P_INVEST          Q:OUTPUT_INVEST
       I:P(PS)             Q:INPUT_PS_INVEST(PS)

$DEMAND:RA  s:EL_CS   a:1
       D:P_INVEST          Q:HDEMAND_INVEST
       D:P_CONS(CONS)      Q:HDEMAND(CONS)       a:
       E:P_VA              Q:ENDOWMENT_VA

$CONSTRAINT:ENDTAX
       (1-REDUXCO2)*OUTPUT_FOSSIL =E= Y_FOSSIL*OUTPUT_FOSSIL;

$OFFTEXT

*      READ THE HEADER:
$SYSINCLUDE mpsgeset CO2Tax

*      GENERATE AND SOLVE THE MODEL:

* REPLICATE BENCHMARK
CO2Tax.ITERLIM = 0;
$INCLUDE CO2Tax.GEN

*SOLVE CO2Tax USING MCP;
*ABORT$(ABS(CarbonTax.OBJVAL) GT 1.E-3)
*"*** CO2Tax benchmark does not calibrate.";
CO2Tax.ITERLIM = 1000;
SOLVE CO2Tax USING MCP;
```

```
* Impose a reduction target of 20% to benchmark emission
REDUXCO2 = 0.2;
SOLVE CO2Tax USING MCP;

PARAMETER TAX_STAR Quantity tax in CHF per tCO2 on fossil fuel required to achieve target emission reduction;

TAX_STAR = ENDTAX.L * P_FOSSIL.L / Q_TO_tCO2 * 1000000;

DISPLAY "Tax rate (CHF/tCO2) = ", TAX_STAR;

TAX_STAR = ENDTAX.L * P_FOSSIL.L;

PARAMETER TAXREV Revenue of CO2 tax in mio CHF;
TAXREV = TAX_STAR * ( SUM(PS, FOSS_VAE.L(PS))+SUM(CONS, FOSSIL_CONS.L(CONS)) );
DISPLAY TAXREV

PARAMETER
        DELTAPER_QFOSS(PS)              Percentage change of CO2 equivalent emissions,
        DELTAPER_QFOSS_HOUSING     Percentage change of CO2 equivalent emissions in the HOUSING SECTOR,
        DELTAPER_QFOSS_MOB            Percentage change of CO2 equivalent emissions in the MOBILITY SECTOR,
        DELTA_QFOSS(PS)                  Change in emissions in tonnes of CO2 equivalents,
        DELTA_QFOSS_HOUSING         Change in emissions in tonnes of CO2 equivalents in HOUSING SECTOR,
        DELTA_QFOSS_MOB                Change in emissions in tonnes of CO2 equivalents in MOBILITY SECTOR;

DELTAPER_QFOSS(PS)=0;
DELTAPER_QFOSS_HOUSING=0;
DELTAPER_QFOSS_MOB=0;

DELTAPER_QFOSS(PS)$(INPUT_FOSSIL_PS(PS) ne 0) = 100* (FOSS_VAE.L(PS) - INPUT_FOSSIL_PS(PS)) / INPUT_FOSSIL_PS(PS);
*DELTAPER_QFOSS_HOUSING$(INPUTS("FOSSIL","HOUSING") ne 0) = 100* (FOSS_HOUSING.L - INPUTS("FOSSIL","HOUSING")) /
                INPUTS("FOSSIL","HOUSING");
*DELTAPER_QFOSS_MOB$(INPUTS("FOSSIL","MOBILITY") ne 0) = 100* (FOSS_MOB.L - INPUTS("FOSSIL","MOBILITY")) / INPUTS("FOSSIL","MOBILITY");

DELTA_QFOSS(PS) = Q_TO_tCO2 * (FOSS_VAE.L(PS) - INPUT_FOSSIL_PS(PS));
*DELTA_QFOSS_HOUSING = Q_TO_tCO2 * (FOSS_HOUSING.L - INPUTS("FOSSIL","HOUSING"));
*DELTA_QFOSS_MOB = Q_TO_tCO2 * (FOSS_MOB.L - INPUTS("FOSSIL","MOBILITY"));

put result; result.pc=5; result.nd = 4;
put 'Prozentuale Veränderung des CO2-Ausstosses' /;
loop(PS,  put PS.tl; );
put /;
loop(PS,  put DELTAPER_QFOSS(PS); );
put // 'Absolute Veränderung des CO2-Ausstosses in t CO2' /;
loop(PS,  put PS.tl; );
put /;
loop(PS,  put DELTA_QFOSS(PS); );

put // 'Aktivitätsniveaus nach Einführung der CO2-Steuer' /;
loop(PS, put PS.tl; );
put /;
loop(PS, put Y.L(PS); );
put // 'Preise nach Einführung der CO2-Steuer' /;
loop(PS, put PS.tl; );
put /;
loop(PS, put P.L(PS); );
put // 'Prozentuale Veränderung der Preise' /;
loop(PS, put PS.tl; );
put /;
loop (PS, put (100*(P.L(PS)-1)); );
*put // 'Prozentuale Veränderung des CO2-Ausstosses im Sektor HOUSING:' / DELTAPER_QFOSS_HOUSING;
*put // 'Absolute Veränderung des CO2-Ausstosses in t CO2 im Sektor HOUSING:' / DELTA_QFOSS_HOUSING;
*put // 'Prozentuale Veränderung des CO2-Ausstosses im Sektor MOBILITY:' / DELTAPER_QFOSS_MOB;
*put // 'Absolute Veränderung des CO2-Ausstosses in t CO2 im Sektor MOBILITY:' / DELTA_QFOSS_MOB;

put // 'Preise Konsumgüter: ' /;
loop(CONS, put CONS.tl; );
put /;
loop(CONS, put P_CONS.L(CONS); );
put /;
put // 'Prozentuale Veränderung der Preise der Konsumgüter:' /;
loop(CONS, put CONS.tl; );
put /;
loop(CONS, put (100*(P_CONS.L(CONS)-1)); );
put /;

put // 'Percentage change in quantities demanded by households' /;
loop(CONS, put CONS.tl; );
put /;
loop(CONS, put (100*(CONSDEMAND.L(CONS)-HDEMAND(CONS))/HDEMAND(CONS)););
put /;

put // 'Output loss in percentage' /;
loop (PS, put PS.tl;);
put /;
loop (PS, put(100*(Y.L(PS)-1)););
put /;
option WLF:8;
display WLF.L;
```

## **C–2:** Programme Code CO2-TAX&TRADING Model

```
$TITLE CO2TAX&TRADING model
$Ontext

Base Economy

$Offtext

FILE result /CO2results_Romina.dat/;

$INCLUDE Romi/bench_hh.dat

SETS
     CONS CONSUMPTION GOODS
    / C_FOOD, C_CLOTH, C_HOUSING, C_HHEQUIP, C_HEALTH, C_TRANSP, C_COMM, C_CULTURE, C_EDU, C_REST, C_SERVICES, GOV, FISIM /,

     ETS    SECTORS IN THE ETS
    / PAPIER, MINERALOEL, ZEMENT, METALL /,

     NONETS  SECTORS PAYING THE CO2 TAX
    / NAHRUNG, TEXTIL, GERAETE, MASCHINEN, ANDEREIND, BAU, HANDEL, GASTGEW, KREDIT, VERWALTUNG, UNTERRICHT, GESUNDHEIT,
      ANDEREDL, TRANSPORT, LANDW /;

ALIAS (CONS, CCONS);
ALIAS (ETS,ETSS);
ALIAS (NONETS,NONETSS);

PARAMETER
      INPUTS_ETS(ETS,ETSS)                Inputs into ETS production,
      INPUTS_NONETS_ETS(NONETS,ETS)       Inputs NONETS into ETS production,
      INPUTS_NONETS(NONETS,NONETSS)       Inputs into NONETS production,
      INPUTS_ETS_NONETS(ETS,NONETS)       Inputs ETS into NONETSproduction,

      INPUT_FOSSIL_ETS(ETS)               Inputs FOSSIL into ETS production,
      INPUT_FOSSIL_ETS_SUM                Inputs FOSSIL into ETS production,
      INPUT_FOSSIL_NONETS(NONETS)         Inputs FOSSIL into NONETS production,
      INPUT_FOSSIL_NONETS_SUM             Inputs FOSSIL into NONETS production,
      INPUT_ELE_ETS(ETS)                  Inputs ELE into ETS production,
      INPUT_ELE_NONETS(NONETS)            Inputs ELE into NONETS production,
      INPUT_ROW_ETS(ETS)                  Inputs ROW into ETS production,
      INPUT_ROW_NONETS(NONETS)            Inputs ROW into NONETS production,
      INPUT_VA_ETS(ETS)                   Inputs VA into ETSproduction,
      INPUT_VA_NONETS(NONETS)             Inputs VA into NONETS production,
      INPUT_VAE_ETS(ETS)                  Inputs value added energy composite into ETS production,
      INPUT_VAE_NONETS(NONETS)            Inputs value added energy composite into NONETS production,

      INPUT_ETS_ELE(ETS)                  Inputs of ETS production sectors into ELE,
      INPUT_NONETS_ELE(NONETS)            Inputs of NONETS production sectors into ELE,
      INPUT_ROW_ELE                       Inputs of ROW into ELE ,
      INPUT_VA_ELE                        Inputs of endowment into ELE,
      INPUT_ETS_ROW(ETS)                  Inputs of ETS production into ROW,
      INPUT_NONETS_ROW(NONETS)            Inputs of NONETS production into ROW,
      INPUT_ELE_ROW                       Inputs of ELE into ROW,
      INPUT_ROW_FOSSIL                    Inputs of ROW into FOSSIL,

      INPUT_ETS_CONS(ETS,CONS)            Inputs ETS into production of the consumption good,
      INPUT_NONETS_CONS(NONETS,CONS)      Inputs NONETS into production of the consumption good,
      INPUT_ETS_INVEST(ETS)               Inputs ETS into the production of the consumption good Investment,
      INPUT_NONETS_INVEST(NONETS)         Inputs NONETS into the production of the consumption good Investment,
      INPUT_ELE_CONS(CONS)                Inputs of ELE into consumption goods,
      INPUT_FOSSIL_CONS(CONS)             Inputs of FOSSIL into consumption goods,
      INPUT_FOSSIL_CONS_SUM               Inputs of FOSSIL into consumption goods summarised,
      INPUT_ROW_CONS(CONS)                Inputs of ROW into consumption goods,

      OUTPUTS_ETS(ETS)                    Output of ETS production,
      OUTPUTS_NONETS(NONETS)              Output of NONETS production,
      OUTPUT_ELE                          Output of ELE,
      OUTPUT_FOSSIL                       Output of FOSSIL,
      OUTPUT_FOSSIL_NONETS                Output of FOSSIL NONETS,
      OUTPUT_FOSSIL_ETS                   Output FOSSIL ETS,
      OUTPUT_ROW                          Output of ROW,
      OUTPUT_CONS(CONS)                   Output of consumption goods,
      OUTPUT_INVEST                       Output of Investment,

      IMED_DEMAND_ETS(ETS)                Intermediate goods demand per ETS sector,
      IMED_DEMAND_NONETS(NONETS)          Intermediate goods demand per NONETS sector,
      QIMEDELE                            Intermediate goods demand of sector ELE,

      HDEMAND(CONS)          Demand of households,
      HDEMAND_INVEST         Demand of households for investment,
      ENDOWMENT_VA           Factor endowment of households;

INPUTS_ETS(ETS,ETSS) = -BENCH(ETS,ETSS);
INPUTS_ETS(ETS,ETS) = 0;
INPUTS_NONETS_ETS(NONETS,ETS) = -BENCH(NONETS,ETS);
INPUTS_NONETS(NONETS,NONETSS) = -BENCH(NONETS,NONETSS);
INPUTS_NONETS(NONETS,NONETS) = 0;
INPUTS_ETS_NONETS(ETS,NONETS) = -BENCH(ETS,NONETS);

INPUT_FOSSIL_ETS(ETS)          = -BENCH("FOSSIL",ETS);
```

```
INPUT_FOSSIL_ETS_SUM          = SUM(ETS, -BENCH("FOSSIL",ETS));
INPUT_FOSSIL_NONETS(NONETS)    = -BENCH("FOSSIL",NONETS);
INPUT_FOSSIL_NONETS_SUM        = SUM(NONETS, -BENCH("FOSSIL",NONETS));
INPUT_ELE_ETS(ETS)            = -BENCH("ELE",ETS);
INPUT_ELE_NONETS(NONETS)       = -BENCH("ELE",NONETS);
INPUT_ROW_ETS(ETS)            = -BENCH("ROW",ETS);
INPUT_ROW_NONETS(NONETS)       = -BENCH("ROW",NONETS);
INPUT_VA_ETS(ETS)             = -BENCH("VA",ETS);
INPUT_VA_NONETS(NONETS)        = -BENCH("VA",NONETS);
INPUT_VAE_ETS(ETS)            = INPUT_VA_ETS(ETS)+INPUT_ELE_ETS(ETS)+INPUT_FOSSIL_ETS(ETS);
INPUT_VAE_NONETS(NONETS)       = INPUT_VA_NONETS(NONETS)+INPUT_ELE_NONETS(NONETS)+INPUT_FOSSIL_NONETS(NONETS);

INPUT_ETS_ELE(ETS)            = -BENCH(ETS,"ELE");
INPUT_NONETS_ELE(NONETS)       = -BENCH(NONETS,"ELE");
INPUT_ROW_ELE                 = -BENCH("ROW","ELE");
INPUT_VA_ELE                  = -BENCH("VA","ELE");
INPUT_ETS_ROW(ETS)            = -BENCH(ETS,"ROW");
INPUT_NONETS_ROW(NONETS)       = -BENCH(NONETS,"ROW");
INPUT_ELE_ROW                 = -BENCH("ELE","ROW");
INPUT_ROW_FOSSIL              = -BENCH("ROW","FOSSIL");

INPUT_ETS_CONS(ETS,CONS)       = -BENCH(ETS,CONS);
INPUT_NONETS_CONS(NONETS,CONS)  = -BENCH(NONETS,CONS);
INPUT_ETS_INVEST(ETS)          = -BENCH(ETS,"INVEST");
INPUT_NONETS_INVEST(NONETS)     = -BENCH(NONETS,"INVEST");
INPUT_ELE_CONS(CONS)           = -BENCH("ELE",CONS);
INPUT_FOSSIL_CONS(CONS)        = -BENCH("FOSSIL",CONS);
INPUT_FOSSIL_CONS_SUM          = SUM(CONS, -BENCH("FOSSIL",CONS));
INPUT_ROW_CONS(CONS)           = -BENCH("ROW",CONS);

OUTPUTS_ETS(ETS)          = BENCH(ETS,ETS);
OUTPUTS_NONETS(NONETS)     = BENCH(NONETS,NONETS);
OUTPUT_ELE                = BENCH("ELE","ELE");
OUTPUT_FOSSIL             = BENCH("FOSSIL","FOSSIL");
OUTPUT_FOSSIL_NONETS      = INPUT_FOSSIL_NONETS_SUM + INPUT_FOSSIL_CONS_SUM;
OUTPUT_FOSSIL_ETS         = SUM(ETS, -BENCH("FOSSIL",ETS));
OUTPUT_ROW                = BENCH("ROW","ROW");
OUTPUT_CONS(CONS)         = BENCH(CONS,CONS);
OUTPUT_INVEST             = BENCH("INVEST","INVEST");

IMED_DEMAND_ETS(ETS) = SUM(ETSS, INPUTS_ETS(ETSS,ETS)) + SUM(NONETS, INPUTS_NONETS_ETS(NONETS,ETS)) ;
IMED_DEMAND_NONETS(NONETS) = SUM(NONETSS, INPUTS_NONETS(NONETSS,NONETS)) + SUM(ETS, INPUTS_ETS_NONETS(ETS,NONETS)) ;

QIMEDELE = SUM(ETS, INPUT_ETS_ELE(ETS)) + SUM(NONETS, INPUT_NONETS_ELE(NONETS));

HDEMAND(CONS)   = -BENCH(CONS,"HH");
HDEMAND_INVEST  = -BENCH("INVEST","HH");
ENDOWMENT_VA = BENCH("VA","HH");

DISPLAY ENDOWMENT_VA, INPUTS_ETS, INPUTS_NONETS_ETS, INPUTS_NONETS, INPUTS_ETS_NONETS,IMED_DEMAND_ETS, IMED_DEMAND_NONETS,
        INPUT_FOSSIL_NONETS_SUM, INPUT_FOSSIL_ETS_SUM ;
DISPLAY OUTPUT_FOSSIL, INPUT_ROW_FOSSIL, OUTPUT_FOSSIL_NONETS, INPUT_FOSSIL_NONETS_SUM, INPUT_FOSSIL_CONS_SUM;

PARAMETER
    TAXONCO2        Exogenous tax on fossil fuel (set equal to zero for Benchmark),
    REDUXCO2        C02 reduction target,
    REDUXETS        CO2 reduction target of ETS sectors,
    Q_TO_tCO2       Factor which translates Output of fossil fuel by the Model to tonnes CO2 in the real world,
    CO2_BENCH       Benchmark quantity of CO2;

* SET TAXONCO2=0 FOR BENCHMARK AND TAXON>0 FOR TAXSCENARIO
REDUXCO2       = 0;
TAXONCO2       = 0;
REDUXETS       = 0;
Q_TO_tCO2      = 89*74;
CO2_BENCH      = OUTPUT_FOSSIL*Q_TO_tCO2;

* Foreign country prices:
SCALAR     PEY    Export price of good Y / 0.999/
           PMX    Import price of good X / 1.001/
           PEX    Export price of good X / 1   /
           PMY    Import price of good Y / 1   /;

$INCLUDE ROMI/ELASTICITIES.DAT

$ONTEXT

$MODEL:CO2TAX&TRADING

$SECTORS:
    Y_ETS(ETS)
    Y_NONETS(NONETS)
    Y_ELE
    Y_F_ETS
    Y_F_NONETS
    Y_ROW
    Y_C_GOOD(CONS)
    Y_INVEST
    IMED_ETS(ETS)
    IMED_NONETS(NONETS)
    INTERMED_ELE
    VAE_ETS(ETS)
    VAE_NONETS(NONETS)
    EX          ! Foreign country Export Import sectors
    MY          ! Foreign country Export Import sectors
```

```
       EY           ! Foreign country Export Import sectors
       MX           ! Foreign country Export Import sectors
       X_F          ! Foreign production sector for good X
       Y_F          ! Foreign production sector for good Y

$COMMODITIES:
       P_ETS(ETS)
       P_NONETS(NONETS)
       P_ELE
       P_F_ETS
       P_F_NONETS
       P_ROW
       P_VA
       P_CONS(CONS)
       P_INVEST
       PIM_ETS(ETS)
       PIM_NONETS(NONETS)
       PIMEDELE
       P_VAE_ETS(ETS)
       P_VAE_NONETS(NONETS)
       P_ROWEXP       ! Export aggregate from Switzerland to foreign
       PXF          ! Good X produced by foreign country
       PYF          ! Good Y produced by foreign country
       PVAF          ! VA of foreign household

$CONSUMERS:
       RA
       CONS_F         ! Foreign household

$AUXILIARY:
       ENDTAX
       ETSREDUCTION

$REPORT:
       V:CONSDEMAND(CONS)                 D:P_CONS(CONS)       DEMAND:RA
       V:CONSDEMAND_INVEST                D:P_INVEST           DEMAND:RA
       V:IMPDEMAND_NONETS(NONETS)         I:P_ROW              PROD:Y_NONETS(NONETS)
       V:IMPDEMAND_ELE                    I:P_ROW              PROD:Y_ELE
       V:VAINPUT_ETS(ETS)                 I:P_VA               PROD:VAE_ETS(ETS)
       V:ROWINPUT_ETS(ETS)                I:P_ROW              PROD:Y_ETS(ETS)
       V:ELEINPUT_ETS(ETS)                I:P_ELE              PROD:VAE_ETS(ETS)
       V:IMPDEMAND_ETS(ETS)               I:PIM_ETS(ETS)       PROD:Y_ETS(ETS)
       V:VAEINPUT_ETS(ETS)                I:P_VAE_ETS(ETS)     PROD:Y_ETS(ETS)
       V:ETS_OUTPUT(ETS)                  O:P_ETS(ETS)         PROD:Y_ETS(ETS)
       V:FOSSILINPUT_ETS(ETS)             I:P_F_ETS            PROD:VAE_ETS(ETS)
       V:FOSSILOUTPUT_ETS                 O:P_F_ETS            PROD:Y_F_ETS
       V:VAINPUT_NONETS(NONETS)           I:P_VA               PROD:VAE_NONETS(NONETS)
       V:FOSSILINPUT_NONETS(NONETS)       I:P_F_NONETS         PROD:VAE_NONETS(NONETS)
       V:FOSSIL_CONS(CONS)                I:P_F_NONETS         PROD:Y_C_GOOD(CONS)
       V:FOSSILOUTPUT_NONETS              O:P_F_NONETS         PROD:Y_F_NONETS
       V:WLF                              W:RA
       V:WLF_FOREIGN                      W:CONS_F

****************************
* Export and Import production *
****************************
$PROD:X_F  s:1
      O:PXF          Q:600000
      I:PVAF         Q:600000

$PROD:Y_F  s:1
      O:PYF          Q:1
      I:PVAF         Q:1

$PROD:EX
      O:P_ROW               Q:(PEX*188547)
      I:PXF                 Q:188547

$PROD:MY
      O:PYF                   Q:188547
      I:P_ROWEXP              Q:(PMY*188547)

*      The following trade activities are not operated in the benchmark
*      period:

$PROD:EY
      O:P_ROWEXP             Q:PEY
      I:PYF                  Q:1

$PROD:MX
      O:PXF                Q:1
      I:P_ROW              Q:PMX

$DEMAND:CONS_F
       D:PXF               Q:411453
       D:PYF               Q:188547
       E:PVAF              Q:600000
*********************
* Production of FOSSIL *
*********************
$PROD:Y_F_ETS  s:0
       O:P_F_ETS          Q:OUTPUT_FOSSIL_ETS
       I:P_ROW            Q:INPUT_FOSSIL_ETS_SUM

$PROD:Y_F_NONETS  s:0
```

```
       O:P_F_NONETS        Q:OUTPUT_FOSSIL_NONETS
       I:P_ROW             Q:INPUT_FOSSIL_NONETS_SUM
       I:P_ROW             Q:INPUT_FOSSIL_CONS_SUM

********************
* Production of ROW *
********************
$PROD:Y_ROW   s:EL_ROW
       O:P_ROWEXP              Q:OUTPUT_ROW
       I:P_ETS(ETS)            Q:INPUT_ETS_ROW(ETS)
       I:P_NONETS(NONETS)      Q:INPUT_NONETS_ROW(NONETS)
       I:P_ELE                 Q:INPUT_ELE_ROW

*******************
* Production of ELE *
*******************
$PROD:INTERMED_ELE  s:0
       O:PIMEDELE              Q:QIMEDELE
       I:P_ETS(ETS)            Q:INPUT_ETS_ELE(ETS)
       I:P_NONETS(NONETS)      Q:INPUT_NONETS_ELE(NONETS)

$PROD:Y_ELE s:0  a:EL_ARM
       O:P_ELE             Q:OUTPUT_ELE
       I:PIMEDELE          Q:QIMEDELE            a:
       I:P_ROW             Q:INPUT_ROW_ELE       a:
       I:P_VA              Q:INPUT_VA_ELE

*********************
* Production block ETS *
*********************
$PROD:IMED_ETS(ETS) s:0
       O:PIM_ETS(ETS)          Q:IMED_DEMAND_ETS(ETS)
       I:P_ETS(ETSS)           Q:INPUTS_ETS(ETSS,ETS)
       I:P_NONETS(NONETS)      Q:INPUTS_NONETS_ETS(NONETS,ETS)

$PROD:VAE_ETS(ETS)  s:EL_VAE  a:EL_FE
       O:P_VAE_ETS(ETS)      Q:INPUT_VAE_ETS(ETS)
       I:P_VA                Q:INPUT_VA_ETS(ETS)
       I:P_F_ETS             Q:INPUT_FOSSIL_ETS(ETS)       A:RA  N:ETSREDUCTION  a:
       I:P_ELE               Q:INPUT_ELE_ETS(ETS)          a:

$PROD:Y_ETS(ETS) s:EL_SUB a:EL_ARM
       O:P_ETS(ETS)          Q:OUTPUTS_ETS(ETS)
       I:P_VAE_ETS(ETS)      Q:INPUT_VAE_ETS(ETS)
       I:PIM_ETS(ETS)        Q:IMED_DEMAND_ETS(ETS)      a:
       I:P_ROW               Q:INPUT_ROW_ETS(ETS)        a:

*************************
* Production block NONETS *
*************************
$PROD:IMED_NONETS(NONETS) s:0
       O:PIM_NONETS(NONETS)    Q:IMED_DEMAND_NONETS(NONETS)
       I:P_NONETS(NONETSS)     Q:INPUTS_NONETS(NONETSS,NONETS)
       I:P_ETS(ETS)            Q:INPUTS_ETS_NONETS(ETS,NONETS)

$PROD:VAE_NONETS(NONETS)  s:EL_VAE  a:EL_FE
       O:P_VAE_NONETS(NONETS)          Q:INPUT_VAE_NONETS(NONETS)
       I:P_VA                          Q:INPUT_VA_NONETS(NONETS)
       I:P_F_NONETS                    Q:INPUT_FOSSIL_NONETS(NONETS)      A:RA  N:ENDTAX a:
       I:P_ELE                         Q:INPUT_ELE_NONETS(NONETS)         a:

$PROD:Y_NONETS(NONETS) s:EL_SUB  a:EL_ARM
       O:P_NONETS(NONETS)              Q:OUTPUTS_NONETS(NONETS)
       I:P_VAE_NONETS(NONETS)          Q:INPUT_VAE_NONETS(NONETS)
       I:PIM_NONETS(NONETS)            Q:IMED_DEMAND_NONETS(NONETS)      a:
       I:P_ROW                         Q:INPUT_ROW_NONETS(NONETS)        a:

*******************************
* Production of the consumption good *
*******************************
$PROD:Y_C_GOOD(CONS)  s:0    a:EL_FE
       O:P_CONS(CONS)          Q:OUTPUT_CONS(CONS)
       I:P_ETS(ETS)            Q:INPUT_ETS_CONS(ETS,CONS)
       I:P_NONETS(NONETS)      Q:INPUT_NONETS_CONS(NONETS,CONS)
       I:P_ROW                 Q:INPUT_ROW_CONS(CONS)
       I:P_F_NONETS            Q:INPUT_FOSSIL_CONS(CONS)      A:RA N:ENDTAX  a:
       I:P_ELE                 Q:INPUT_ELE_CONS(CONS)         a:

$PROD:Y_INVEST s:0
       O:P_INVEST              Q:OUTPUT_INVEST
       I:P_ETS(ETS)            Q:INPUT_ETS_INVEST(ETS)
       I:P_NONETS(NONETS)      Q:INPUT_NONETS_INVEST(NONETS)

******************
* Budget constraint *
******************
$DEMAND:RA  s:EL_CS   a:1
       D:P_INVEST            Q:HDEMAND_INVEST
       D:P_CONS(CONS)        Q:HDEMAND(CONS)          a:
       E:P_VA                Q:ENDOWMENT_VA

*************
* Constraints *
*************
$CONSTRAINT:ENDTAX
```

```
        (1-REDUXCO2)*(INPUT_FOSSIL_NONETS_SUM + INPUT_FOSSIL_CONS_SUM) =E= Y_F_NONETS * (INPUT_FOSSIL_NONETS_SUM +
                INPUT_FOSSIL_CONS_SUM)   ;
$CONSTRAINT:ETSREDUCTION
        P_F_ETS + ETSREDUCTION =E= P_F_ETS + ((((Y_F_ETS - (1-REDUXETS)) * INPUT_FOSSIL_ETS_SUM) * Q_TO_tCO2) *50) / (INPUT_FOSSIL_ETS_SUM *
                1000000)  ;

$OFFTEXT

*       READ THE HEADER:

$SYSINCLUDE mpsgeset CO2TaxTrading

*       GENERATE AND SOLVE THE MODEL:

* REPLICATE BENCHMARK
CO2TaxTrading.ITERLIM = 0;
$INCLUDE CO2TaxTrading.GEN

*SOLVE CO2TaxTrading USING MCP;
*ABORT$(ABS(CarbonTaxTrading.OBJVAL) GT 1.E-3)
*"*** CO2TaxTrading benchmark does not calibrate.";
CO2TaxTrading.ITERLIM = 1000;
SOLVE CO2TaxTrading USING MCP;

* Impose a reduction target of 20% to benchmark emission
REDUXCO2 = 0.2;
REDUXETS = 0.18;
SOLVE CO2TaxTrading USING MCP;

PARAMETER TAX_STAR   Quantity tax in CHF per tCO2 on fossil fuel required to achieve target emission reduction;
TAX_STAR = ENDTAX.L * P_F_NONETS.L / Q_TO_tCO2 * 1000000;
DISPLAY "Tax rate (CHF/tCO2) = ", TAX_STAR;

TAX_STAR = ENDTAX.L * P_F_NONETS.L;

PARAMETER TAXREV Revenue of CO2 tax in mio CHF;
TAXREV = TAX_STAR * ( SUM(NONETS, FOSSILINPUT_NONETS.L(NONETS))+SUM(CONS, FOSSIL_CONS.L(CONS)) );
DISPLAY TAXREV;

PARAMETER
        DELTAPER_QFOSS_ETS(ETS)                 Percentage change of CO2 equivalent emissions in ETS sectors,
        DELTAPER_QFOSS_NONETS(NONETS)   Percentage change of CO2 emissions in NONETS sectors;

DELTAPER_QFOSS_ETS(ETS)=0;
DELTAPER_QFOSS_NONETS(NONETS)=0;

DELTAPER_QFOSS_ETS(ETS)$(INPUT_FOSSIL_ETS(ETS) ne 0) = 100* (FOSSILINPUT_ETS.L(ETS) - INPUT_FOSSIL_ETS(ETS)) / INPUT_FOSSIL_ETS(ETS);
*DELTAPER_QFOSS_HOUSING$(INPUTS("FOSSIL","HOUSING") ne 0) = 100* (FOSS_HOUSING.L - INPUTS("FOSSIL","HOUSING")) /
                INPUTS("FOSSIL","HOUSING");
*DELTAPER_QFOSS_MOB$(INPUTS("FOSSIL","MOBILITY") ne 0) = 100* (FOSS_MOB.L - INPUTS("FOSSIL","MOBILITY")) / INPUTS("FOSSIL","MOBILITY");
DELTAPER_QFOSS_NONETS(NONETS)$(INPUT_FOSSIL_NONETS(NONETS) ne 0) = 100* (FOSSILINPUT_NONETS.L(NONETS) -
                INPUT_FOSSIL_NONETS(NONETS)) / INPUT_FOSSIL_NONETS(NONETS);

put result; result.pc=5; result.nd = 4;
put 'Prozentuale Veränderung des CO2-Ausstosses in ETS Sektoren' /;
loop(ETS,  put ETS.tl; );
put /;
loop(ETS,  put DELTAPER_QFOSS_ETS(ETS); );
put //'Prozentuale Veränderung des CO2-Ausstosses in NONETS Sektoren' /;
loop(NONETS,  put NONETS.tl; );
put /;
loop(NONETS,  put DELTAPER_QFOSS_NONETS(NONETS); );
put // 'Aktivitätsniveaus der ETS Sektoren nach Einführung der CO2-Steuer ' /;
loop(ETS, put ETS.tl; );
put /;
loop(ETS, put Y_ETS.L(ETS); );
put // 'Aktivitätsniveaus der NONETS Sektoren nach Einführung der CO2-Steuer ' /;
loop(NONETS, put NONETS.tl; );
put /;
loop(NONETS, put Y_NONETS.L(NONETS); );
put // 'Preise in ETS Sektoren nach Einführung der CO2-Steuer' /;
loop(ETS, put ETS.tl; );
put /;
loop(ETS, put P_ETS.L(ETS); );
put // 'Preise in NONETS Sektoren nach Einführung der CO2-Steuer' /;
loop(NONETS, put NONETS.tl; );
put /;
loop(NONETS, put P_NONETS.L(NONETS); );
put // 'Prozentuale Veränderung der Preise in ETS Sektoren' /;
loop(ETS, put ETS.tl; );
put /;
loop (ETS, put (100*(P_ETS.L(ETS)-1)); );
put // 'Prozentuale Veränderung der Preise in NONETS Sektoren' /;
loop(NONETS, put NONETS.tl; );
put /;
loop (NONETS, put (100*(P_NONETS.L(NONETS)-1)); );
put // 'Prozentuale Veränderung der PIM in ETS Sektoren' /;
loop(ETS, put ETS.tl; );
put /;
loop (ETS, put (100*(PIM_ETS.L(ETS)-1)); )
put // 'Prozentuale Veränderung der PIM in NONETS Sektoren' /;
loop(NONETS, put NONETS.tl; );
put /;
loop (NONETS, put (100*(PIM_NONETS.L(NONETS)-1)); );
```

```
put // 'Preise Konsumgüter: ' /;
loop(CONS, put CONS.tl; );
put /;
loop(CONS, put P_CONS.L(CONS); );
put /;
put // 'Prozentuale Veränderung der Preise der Konsumgüter:' /;
loop(CONS, put CONS.tl; );
put /;
loop(CONS, put (100*(P_CONS.L(CONS)-1)); );
put /;

put // 'Percentage change in quantities demanded by households' /;
loop(CONS, put CONS.tl; );
put /;
loop(CONS, put (100*(CONSDEMAND.L(CONS)-HDEMAND(CONS))/HDEMAND(CONS)););
put /;

put // 'Output loss of ETS sectors in percentage' /;
loop (ETS, put ETS.tl;);
put /;
loop (ETS, put(100*(Y_ETS.L(ETS)-1)););
put /;
put // 'Output loss of NONETS sectors in percentage' /;
loop (NONETS, put NONETS.tl;);
put /;
loop (NONETS, put(100*(Y_NONETS.L(NONETS)-1)););
put /;

option WLF:8;
display WLF.L;
```

# Declaration

under Art. 28 Para. 2 RSL 05

Last, first name: Schürch, Romina

Matriculation number: 05-122-031

Programme: Master in Climate Sciences
Master's Thesis

Thesis title: $CO_2$ Taxation versus Emissions Trading –
An Analytical Representation for Switzerland

Thesis supervisor: Prof. Dr. Gunter Stephan
Prof. Dr. Ralph Winkler
Advisor: Raphael Bucher

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person, except where due acknowledgement has been made in the text. In accordance with academic rules and ethical conduct, I have fully cited and referenced all material and results that are not original to this work. I am well aware of the fact that, on the basis of Article 36 Paragraph 1 Letter o of the University Law of 5 September 1996, the Senate is entitled to deny the title awarded on the basis of this work if proven otherwise.

Berne, 16 January 2011

Romina Schürch