Updated emissions scenarios without measures
1990-2035

Final report

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Executive Summary

The goal of this study is to estimate the net impact of all policies and measures implemented in the context of the Swiss energy and climate policies on CO_2 emissions from combustion processes between 1990 and 2035. The study provides a projection of CO_2 emissions until 2035 under the assumption of continuation of existing measures, optionally including the strengthening as adopted by the popular vote on the first package of measures of the Energy Strategy 2050 on 21 May 2017. It contrasts these emissions with a scenario excluding all policies and measures introduced after 1990. The study does not estimate the evolution of CO_2 emissions from non-combustion processes, other (non-CO_2) greenhouse gas emissions and the impact of measures on these emissions. Nor does it simulate a scenario with additional measures that are currently discussed/planned but not adopted yet or that may become necessary in the future if it appears that the emission targets cannot be met with existing measures alone.

This report updates an earlier report addressing the same questions (INFRAS and EPFL, 2016) by using the latest greenhouse gas inventory, the revised transportation forecasts and newer data whenever available. In addition, it incorporates the first package of measures of the Energy Strategy 2050 in a separate scenario.

Methodological approach

This study embeds detailed bottom-up assessments of individual mitigation measures within a computable general equilibrium (CGE) model of the economy (GEMINI-E3, Bernard and Vielle, 2008). The scenario of the Swiss economy with existing measures ("WEM scenario") is based on existing economic and emissions data from 1990 to 2015 or 2016, as available, and forecasts beyond, up to 2035, including the continued effects of climate and energy policy measures existing or adopted in 2016. After the positive vote of the population on 21 May 2017, the new Energy Act and revisions to other acts, in particular the second CO_2 Act, will extend and strengthen various measures starting in 2018. This is reflected in a second set of forecasts for the years to 2035 ("WEM+ scenario"). A counterfactual scenario of the Swiss economy called "without measures" ("WOM scenario") is derived from the WEM scenario by subtracting the estimated effects of Swiss energy and climate policies back to 1990.

GEMINI-E3 is a multi-country, multi-sector, recursive dynamic CGE model – similar to CGE models implemented and applied by other modelling teams and institutions (EPPA, OECD-Env-Linkage, etc.). It allows for a full set of supply, demand and price responses. The standard model is based on the assumption of total flexibility in all markets, both macroeconomic markets such as the capital and the exchange markets (with the associated prices being the real rate of interest and the real exchange rate, which are then endogenous), and microeconomic or sector markets (goods, factors of production). For more information on the model, we refer to the first report (INFRAS and EPFL, 2016).

Abatement measures simulated in this study and other changes relative to first report

The measures simulated in this updated report are essentially the same as in the first report (INFRAS and EPFL, 2016), with a few innovations:

- Measures that are supposed to continue beyond 2020 at the same level are now extended to 2035, our new calculation horizon
- An additional scenario is analysed that takes into account the first package of measures of the Energy Strategy 2050 adopted on 21 May 2017 (i.e. a higher budget for the national buildings refurbishment program, more ambitious targets for CO_2 emissions of new cars and more subsidies for renewable electricity generation)

In addition, the data were updated and some modelling changes applied, mainly:

- For transport, the way the increase in efficiency of vehicles can be attributed to energy and climate policy measures was revised
- Some assumptions and methods used in the bottom-up assessments were revised and updated, as detailed in Table 3.

Main results

In the WEM scenario, CO_2 emissions from energy combustion (source category 1A) decrease from 40.9 million tonnes in 1990 to 35.0 million tonnes in 2020. Taking into account that 50% of emissions from electricity generation using natural gas (gas-fired combined-cycle power plants) will be compensated through international compensation (in addition to the 50% domestic compensation already counted), total CO_2 emissions are projected to be equal to 34.8 million tonnes, which represents a reduction of 15% compared to 1990. CO_2 emissions from energy combustion further decline to 30.5 million tonnes (again including the domestic and international compensation of emissions from gas-fired combined-cycle power plants) in 2035, which amounts to a reduction of 25% relative to 1990. Over the time span 1990-2035, mitigation measures lead to cumulated reductions of CO_2 emissions from energy combustion of 215 million tonnes, or 9% of the cumulated emissions in the WOM scenario.

In the WEM+ scenario[1], the measures adopted with the first package of measures of the Energy Strategy 2050 (which are not included under the WEM scenario) lead to further decreases. CO_2 emissions (including international compensation of emissions from gas-fired combined cycle power plants) will reach 34.2 Mt in 2020 and 29.1 Mt in 2035. Over the whole time span, the cumulative CO_2 savings under the WEM+ scenario exceed the cumulative CO_2 savings under the WEM scenario by 20 Mt.

In both the WEM and the WEM+ scenario, the greatest CO_2 savings compared to the WOM scenario are obtained in industry and in residential and non-residential buildings (Table 1). In

[1] Given that the first package of measures of the Energy Strategy 2050 has passed the referendum, the WEM+ scenario corresponds to the “with existing measures scenario” as defined in the framework of the UNFCCC reporting requirements.

contrast, CO_2 emissions by energy industries (energy conversion, in particular electricity generation) remain close to their peak level of 2005 (3.8 Mt), about 50% above their 1990 level, due to the penetration of gas-fired combined-cycle power plants (GCCPP) that replace decommissioned nuclear power plants. Emissions from transport exceed the 1990 level until 2023. Nevertheless, energy combustion as a whole will emit much less CO_2 than in a scenario without measures.

Figure 1: CO_2 emissions from energy combustion in the WEM, WEM+ and WOM scenarios (1990-2035, without international compensation of emissions from gas-fired combined-cycle power plants)

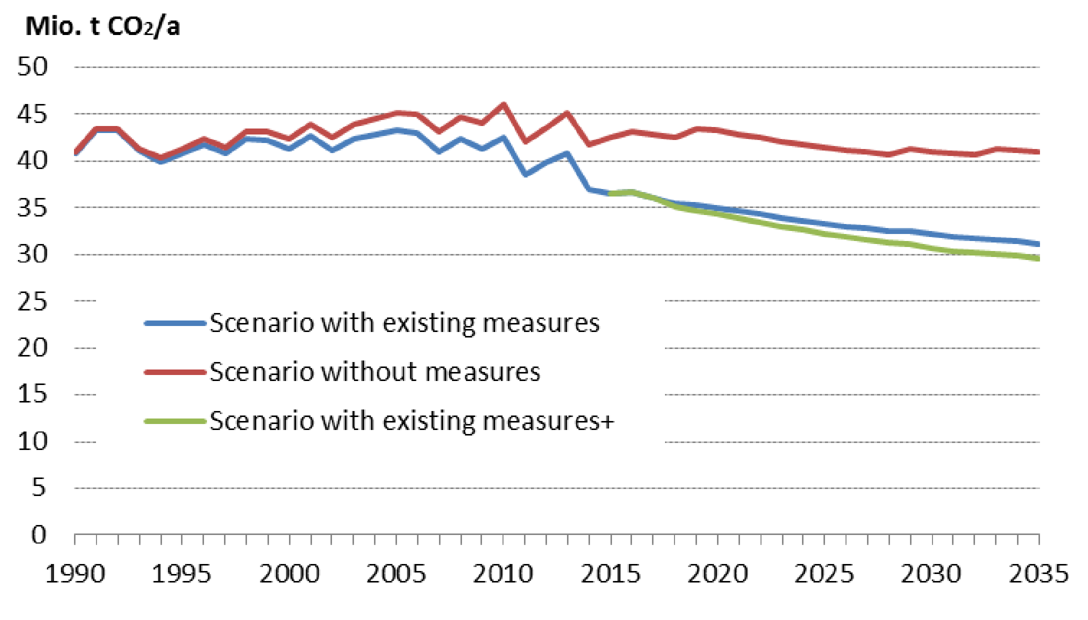


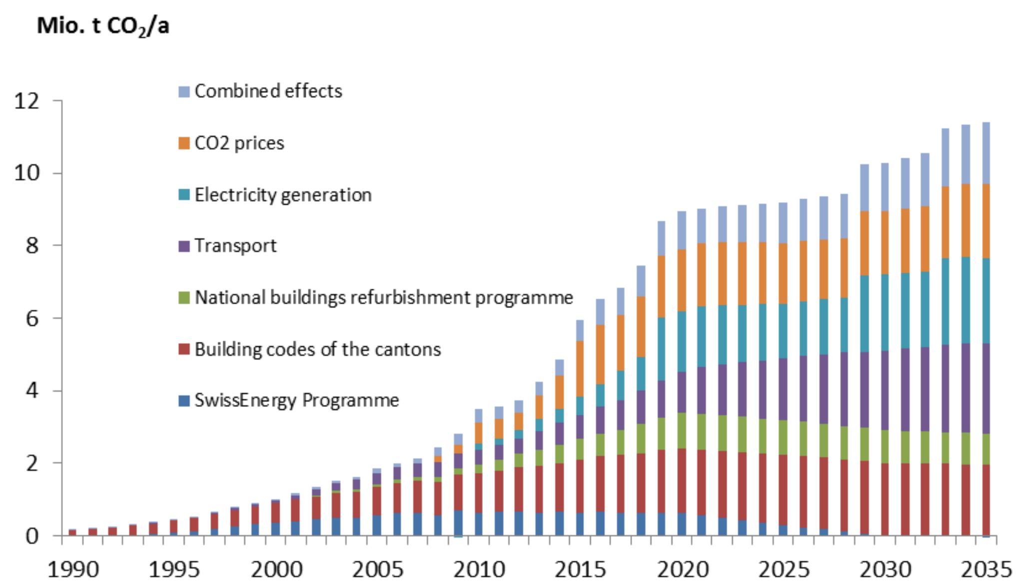
Table 1: CO_2 emissions from energy combustion in different sectors in the WEM, WEM+ and WOM scenarios (Mt)

Sector	1990	2010		2020			2035		
		WEM	WOM	WEM+	WEM	WOM	WEM+	WEM	WOM
Energy industries (1A1)	2.5	3.8	4.0	3.2	3.6	5.1	4.1	4.3	7.6
Manufacturing industries and construction (1A2)	6.4	5.8	6.0	4.4	4.4	5.6	3.7	3.7	5.0
Transport (1A3)	14.4	16.2	16.9	14.7	14.9	15.7	12.0	13.1	14.0
Other sectors (1A4)	17.4	16.6	19.1	11.8	12.0	16.8	9.7	9.9	14.2
Commercial/institutional (1A4a)	*5.2*	*5.2*	*6.1*	*4.0*	*4.1*	*6.1*	*3.9*	*4.0*	*5.8*
Residential (1A4b)	*11.6*	*11.0*	*12.5*	*7.4*	*7.6*	*10.3*	*5.5*	*5.6*	*8.1*
Agriculture/forestry/fishing (1A4c)	*0.5*	*0.5*	*0.5*	*0.4*	*0.4*	*0.4*	*0.3*	*0.3*	*0.4*
Military (1A5)	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total domestic[1] (1A)	**40.9**	**42.6**	**46.1**	**34.3**	**35.0**	**43.3**	**29.6**	**31.1**	**41.0**
International compensation GCCPP				0.1	0.3		0.5	0.5	
Total with international compensation				**34.2**	**34.8**		**29.1**	**30.5**	

[1] Domestic compensation is taken into account in this total and the corresponding totals in all following tables. When a source category must compensate part of its emissions domestically, this may also translate into lower emissions by other source categories that provide the compensation.

Regarding the effectiveness of measures, the greatest CO_2 savings relative to the WOM scenario are obtained with the CO_2 levy, including its exemption mechanisms (both included in “CO_2 prices” in the figure below), the building codes of the cantons and the measures in electricity generation (Figure 2).

Figure 2: Total CO_2 savings by cluster of measures relative to the WOM scenario in the WEM+ scenario



1. Introduction

Goals and key questions

The goals and key questions for this update to the first report (INFRAS and EPFL, 2016) are essentially the same and will not be repeated here. What is new is the extension from 2030 to 2035, the use of more recent data and the WEM+ scenario, which incorporates the measures adopted by the population on 21 May 2017 (first package of the Energy strategy 2050).

Scenarios

- The scenario “with existing measures” (WEM) corresponds to observed economic activity and CO_2 emissions for the time span 1990 until 2015, to a simulation of economic development and emissions until 2020 with the existing set of legislation that is relevant for CO_2 emissions (in particular the second CO_2 Act of 2011 which defines measures until 2020), and to a simulation of economic development and emissions from 2020 until 2035 based on the continuation of the measures that will exist in 2020.
- The scenario “with existing measures plus” (WEM+) adds to the WEM scenario the first package of measures of the Energy Strategy 2050 adopted on 21 May 2017. This concerns the transport sector, the national buildings refurbishment programme and the feed-in-tariff used to promote renewable electricity generation.
- The scenario “without measures” (WOM) depicts a hypothetical situation in which the economic and environmental effects of greenhouse gas abatement measures implemented since 1990 are excluded for both the past and the future. The counterfactual past emissions without measures are estimated by back casting under the exclusion of the impact of existing measures. Projections to 2035 are simulated as in the WEM scenario, except that all measures that lead to CO_2 savings are removed.

Emissions covered by the model simulations

As previously, the simulations performed in the present study cover only CO_2 emissions from combustion processes (source category 1A). Process-related CO_2 emissions of companies within the ETS are considered for the simulations of the ETS market (see section 4.2.1), but not included in the totals presented in the figures and tables of this study. Other emissions from all other source categories and sectors (1B, 2, 3, 4, 5, and 6) are not considered. For the sake of simplicity, in the following we use the expression "CO_2 savings" for the reduction of the CO_2 emissions in source category 1A considered here.

Time span

The time span of interest is 1990 to 2035. The WEM and WEM+ scenarios of the Swiss economy are based on statistical data from 1990 to 2015 and forecasts for 2016 to 2035. The WOM scenario is derived from the WEM scenario by subtracting the estimated effects of Swiss energy and climate policies. The WEM+ scenario is derived from the WEM scenario by factoring in the additional effects of the first package of measures of the Energy Strategy 2050.

Outline of the report

After this introduction comes an overview of the main changes in the key variables for our simulations (chap. 2), a summary of the bottom-up impact assessment for selected abatement measures including a documentation of the underlying data sources and assumptions (chap. 3) and corresponding full impact assessments obtained with the GEMINI-E3 model simulations (chap. 4). The report concludes with a discussion and an outlook (chap. 5).

2. Methodological approach and changes relative to first report

The core methodological approach, with our computable general equilibrium model GEMINI-E3, is described in chapter 2 of the first report (INFRAS and EPFL, 2016). Please refer to that chapter for a description of the model, of how energy efficiency improvements are represented, of how the WOM scenario is derived from the WEM scenario, and of the contribution of bottom-up impact assessments.

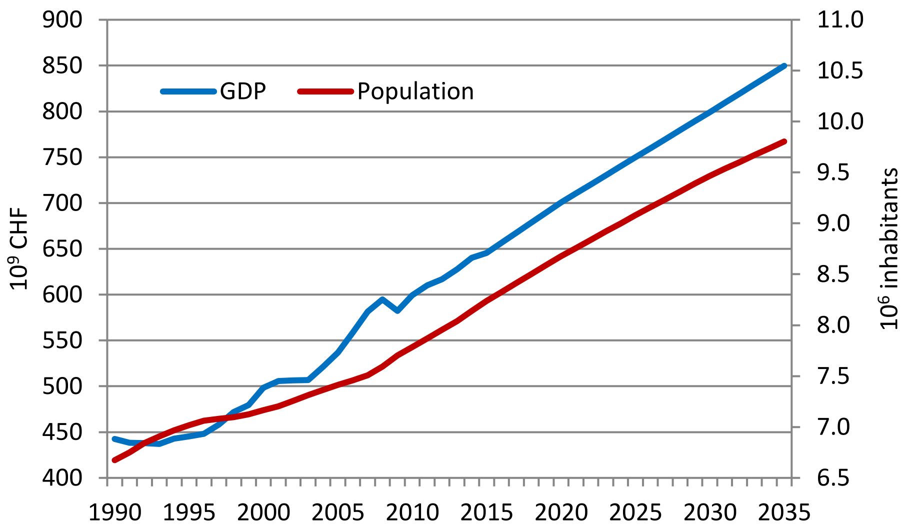
For this report, the key variables for the WEM, WEM+ and WOM scenarios were updated with the newest statistics and extended to 2035. The WEM, WEM+ and WOM scenarios use a common set of demographic and macroeconomic assumptions (Table 2). Population assumptions follow the Swiss demographic scenario A-00-2015 (OFS 2015). GDP growth is forecasted by the State Secretariat for Economic Affairs SECO by multiplying the labour force (coming from the demographic scenario) with a labour productivity increase of 0.9% per year. Historical heating degree days (HDD) are from the Swiss Federal Office of Energy SFOE (BfE 2015); the forecasted HDD are the same as in Switzerland's Sixth National Communication under the UNFCCC (Swiss Confederation 2013, table 29). Energy prices are based on the *current policies scenario* of the World Energy Outlook 2016 (IEA 2016). Variables specific for the various sectors analysed will be presented in the respective sections.

Table 2: Key variables in the WEM, WEM+ and WOM scenarios

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035
Population (million, 1st Jan.)	6.67	7.02	7.16	7.42	7.79	8.24	8.68	9.08	9.47	9.80
GDP (billion CHF_{2015})	443	445	499	537	599	646	701	751	799	850
Heating degree days	3203	3397	3081	3518	3586	3075	3244	3154	3064	2974
Energy reference area for housing (100 in 1990)[1]	100	111	126	136	147	158	170	178	186	191
IEA crude oil price (USD_{2015}/barrel)	37	25	38	61	85	51	82	105	127	137
Natural gas import price for EU (USD_{2015}/Mbtu)	4.1	2.8	4.2	6.7	7.9	7.0	7.3	9.2	11.1	12.1

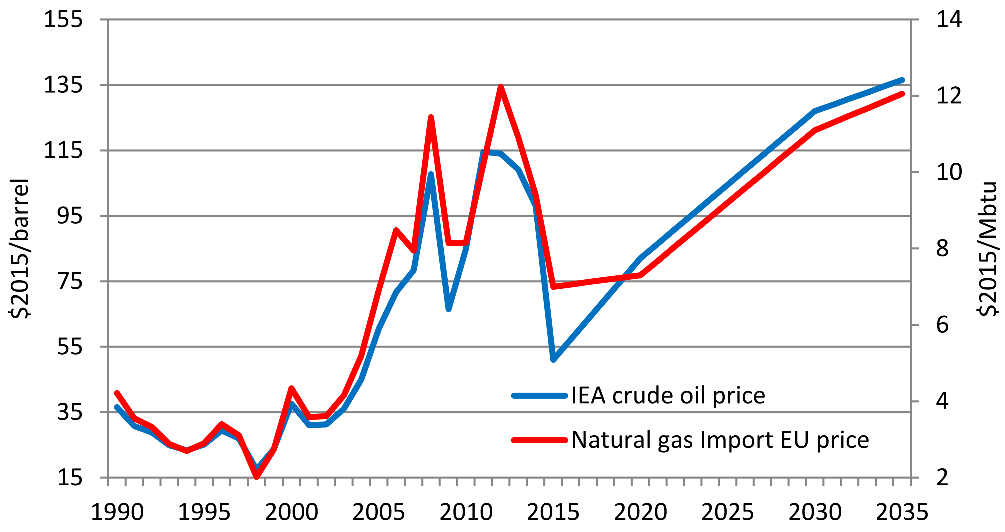
[1] Proxy based on household consumption in housing, relative to 1990.

Figure 3: GDP and population in the WEM, WEM+ and WOM scenarios



GDP on left axis, population on right axis

Figure 4: Energy prices in the WEM, WEM+ and WOM scenarios



Crude oil price left axis, natural gas price right axis.

The many revisions and improvements made for this report compared to the first report are detailed in Table 3.

Table 3: Main changes between the first report and this one

	Scenario impacted[1]	Years impacted	Significance[2]
Statistical revisions			
Integration of the update of GHG inventories done by FOEN (1990-2014)	WEM & WOM	1990-2014	low
Revision of year 2015 taking into account release of GHG inventories by FOEN for this year	WEM & WOM	2015-2030	medium
Shutdown of one of the two Swiss refineries in 2015	WEM & WOM	2015-2030	low
Update of heating degree days, year 2015 and 2016 based on statistical release by Meteo Swiss	WEM & WOM	2015, 2016	low
Update of GDP growth year 2014 and 2015 based on FSO statistical figures	WEM & WOM	2014-2030	low
Revision of the figures related to the CO_2 compensation for transport fuels	WOM	2013-2030	low
Revision of electricity generation in 2015 and 2016 taking account release of new statistical information by SFOE (e.g. decrease of hydro generation in 2016 and decrease of nuclear generation in 2015 and 2016)	WEM & WOM	2015,2016	medium
Update of international energy prices year 2015 and 2016	WEM & WOM	2015 2016	medium
Integration of new projections of energy prices done by IEA in its World Energy Outlook	WEM & WOM	2017-2030	medium

Methodological improvements			
Integration of recent changes in tank tourism following the end of Swiss Franc to Euro pegging	WEM & WOM	2015-2030	medium
Revision of the methodology used to assess the feed-in tariff instruments	WEM & WOM	2015-2030	low
Integration of CO_2 process-related emissions in the simulations of the ETS market (in particular geogenic emissions of the cement industry)	WEM & WOM	2013-2030	low
Revision of the financial data (investment estimates) related to the heavy vehicle charge	WOM	1990-2030	medium
Revision of the assumptions on the fuel efficiency for light vehicles regarding the part that can be attributed to Swiss energy and climate policies	WOM	1990-2030	high
Revision of transport modal shift based on Transport Outlook 2040 by Fed. Off. of Spatial Development	WEM & WOM	2015-2030	high

[1] If WEM is impacted, WEM+ is obviously also affected.
[2] Low: impact related to few years or to a specific sector and whose CO_2 emissions change is estimated to be less than 0.3 Mt CO_2 per year / Medium: impact related to several years and/or impact that is estimated to be more than 0.3 Mt CO_2 but less than 0.7 Mt per year. / High: impact related to several years or several sectors and whose CO_2 emissions change is estimated to be more 0.7 Mt CO_2 per year.

3. Bottom-up impact assessment

The bottom-up impact assessment is mainly based on the work presented in INFRAS and EPFL (2016). However, these figures have to be extended for the time span 2031-2035 and some of them have been updated taking into consideration new available statistics and new assumptions about the impacts of the measures. That is for example the case for the CO_2 emission regulations for new passenger cars, where we now assume that 15% (instead of 50%) of total emission savings can be attributed to efficiency measures and the remaining 85% (instead of 50%) are due to autonomous energy efficiency improvement.

In the following sections, we do not detail the data sources and the assumptions used in each sector, as this information was already available in INFRAS and EPFL (2016). We only present the figures used and explain briefly the difference with the previous assessment.

3.1. Energy in buildings

Within the cluster *energy in buildings*, CO_2 savings and total investments due to existing building codes of the cantons and their revisions as well as CO_2 reductions attributed to the national buildings refurbishment programme (parts A and B), since 2010, and cantonal programmes since 2000 are considered.

Figure 5 and Figure 6 show the CO_2 savings and financial data that are used respectively in the WEM and WEM+ scenarios. The same assumptions as in INFRAS and EPFL (2016) have been used in the WEM scenario. After 2019, no additional impact of the national buildings refurbishment programme is considered. Concerning the building codes of the cantons, beyond 2020, it is assumed that the annual incremental CO_2 savings decrease by 2% per year due to “erosion of the attributable impact” of technical progress.

In the WEM+ scenario, we assume that the amount of subsidies earmarked for the national buildings refurbishment programme is raised from 300 million CHF to 450 million CHF starting in 2018 (see Figure 6). This triggers a proportional increase in investments. The amount of subsidies is stable from 2018 to 2020 (i.e. three years). After 2020, no additional investments are triggered by the national buildings refurbishment programme. Indeed, Parliament has not made a final decision to extend the programme beyond 2020. However, energy and CO_2 savings made possible by earlier investments are maintained, with a small decay rate. The assumptions regarding the building codes of the cantons are the same as in the WEM scenario.

Figure 5: Bottom-up assessment of annual CO_2 savings and investments attributable to the cluster *energy in buildings* in the WEM scenario

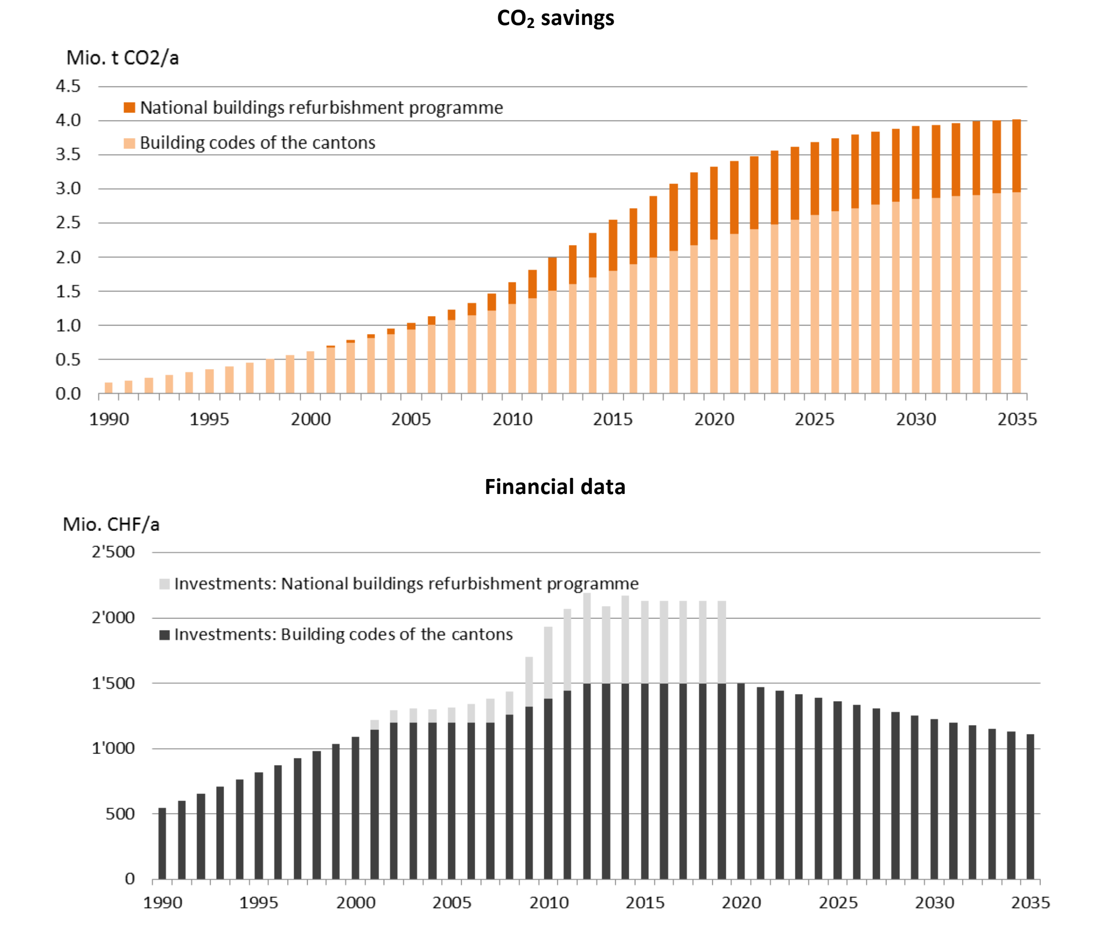
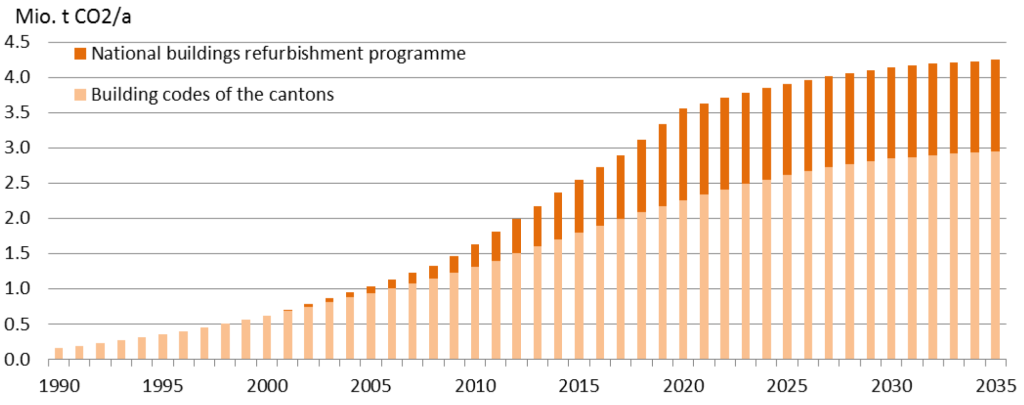
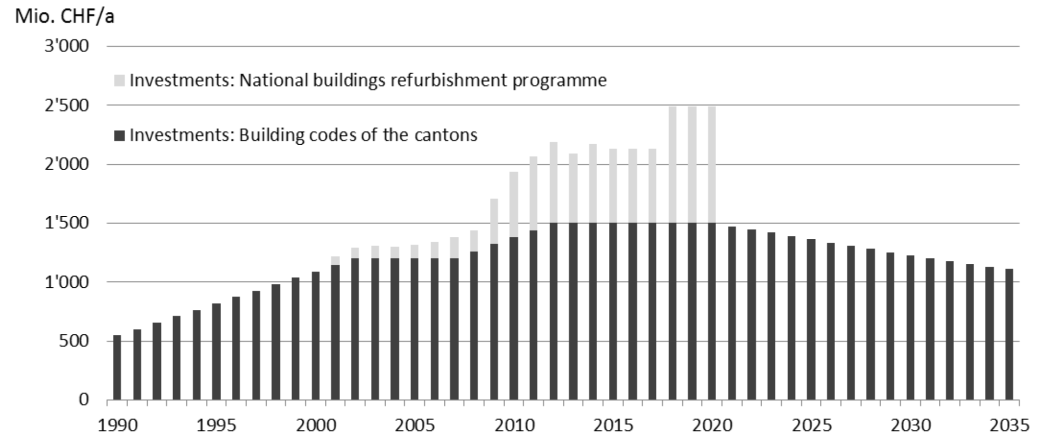


Figure 6: Bottom-up assessment of annual CO_2 savings and investments attributable to the cluster *energy in buildings* in the WEM+ scenario

CO_2 savings



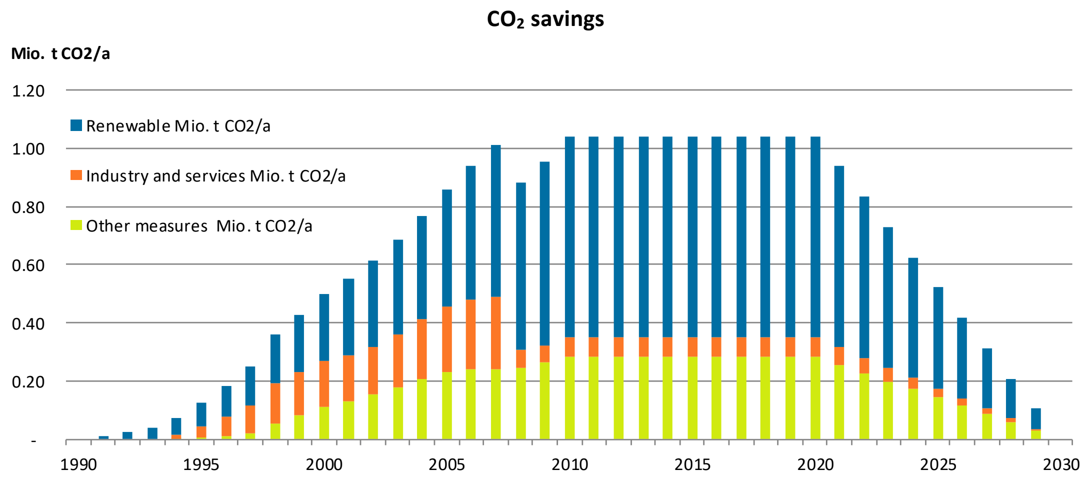
Financial data

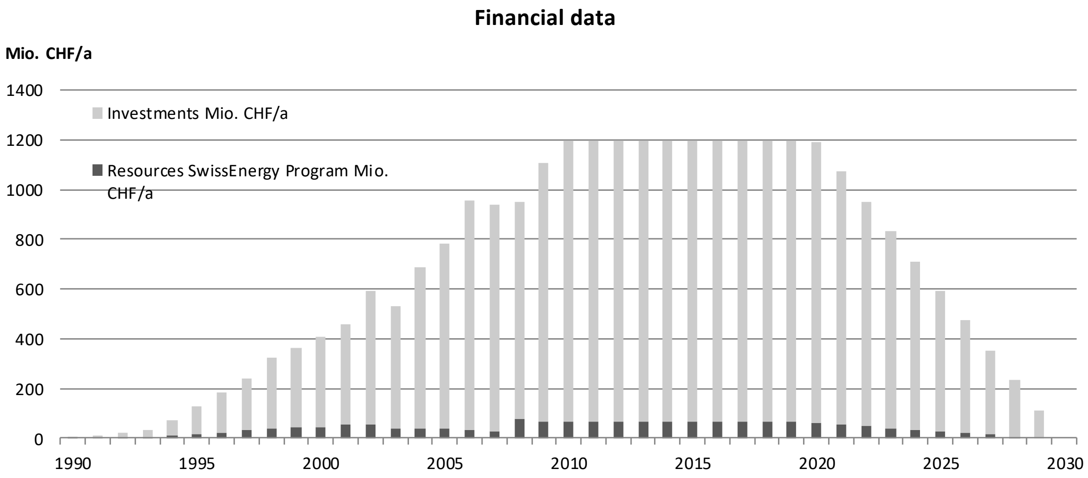


3.2. SwissEnergy programme

The CO_2 savings and financial data are unchanged with respect to INFRAS and EPFL (2016). Figure 7 describes these assumptions (no differences between the WEM and WEM+ scenarios).

Figure 7: Bottom-up assessment of annual CO_2 savings and investments attributable to the SwissEnergy programme





Time series of historical and projected total impact in terms of CO_2 savings from various measures in the cluster *SwissEnergy programme* 1990-2030 (upper part). Other measures comprise SwissEnergy for communities, energy in infrastructure and energy efficiency in buildings (energho). Related financial data are shown in the lower part. After 2007, 75% of the total savings from voluntary measures are accounted for under nonETS price measures. In order to avoid double counting, these CO_2 savings are not included in the cluster *SwissEnergy programme* after 2007. This leads to a significant decrease of emission savings attributed to the cluster *SwissEnergy programme* between 2007 and 2008.

3.3. Transport

The cluster *transport* includes three measures:

1. EcoDrive (as part of the SwissEnergy programme but accounted for in this cluster),
2. The distance-related heavy vehicle charge,
3. Fuel efficiency for light vehicles (CO_2 emission regulations for newly registered vehicles, energy label for new motor vehicles, target agreements with Swiss car importers).

For the two first measures, the assumptions regarding CO_2 savings have not be revised and are supposed identical between the WEM and WEM+ scenarios. INFRAS extended the impacts of Ecodrive and the heavy vehicle charge to 2035 (see Figure 8 and Figure 9).

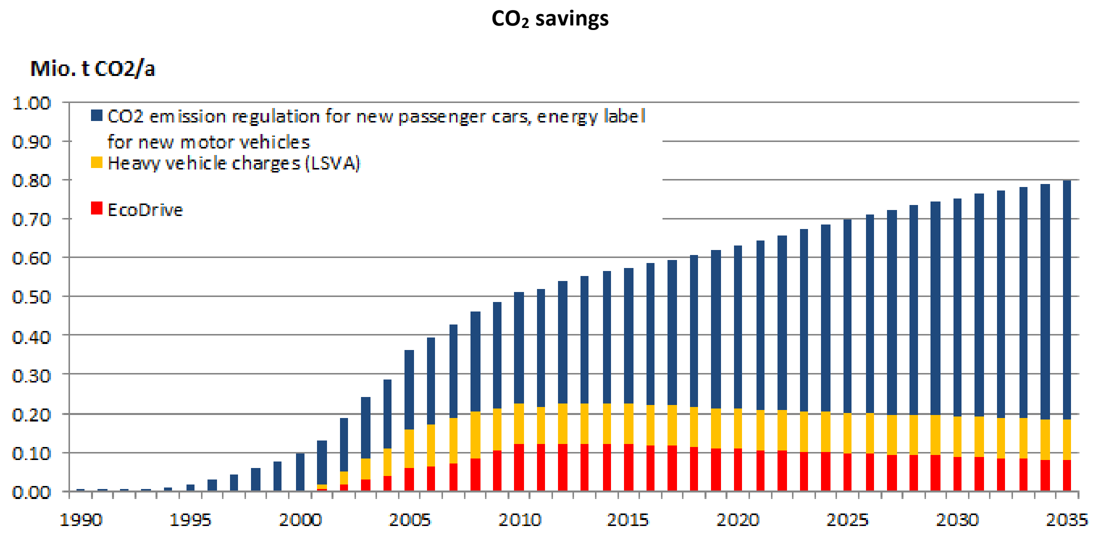
We revised the investment estimates related to the heavy vehicle charge, i.e. the costs of adopting more fuel-efficient trucks and of upgrading trucks. The distribution of trucks between the seven emissions standards (from "Euro 0" to Euro VI) is based on INFRAS data and projections of transportation activity (tonnes x kilometres) by emission standard. We assume that the distribution of vehicles by emission standard is equal to the distribution of transportation activity, i.e. that the average truck of each emission standard contributes the same activity as the average truck of the other emission standards. Combining this description of the stock of vehicles and its evolution with data on new vehicles allows describing a scenario of truck replacement and upgrading. Next, we assume that the average extra cost of an emission standard compared to the emission standard below is 2000 CHF for Euro I, 4000 CHF for Euro II, etc. This implies that a Euro VI truck is assumed to cost 42,000 CHF more than a "Euro 0" truck. The same guestimates are applied for the conversion of trucks from a lower to a higher emission standard. Electric trucks are assumed to cost 20,000 CHF more than Euro VI trucks. The WOM scenarios assumes that all trucks remain at the "Euro 0" standard.

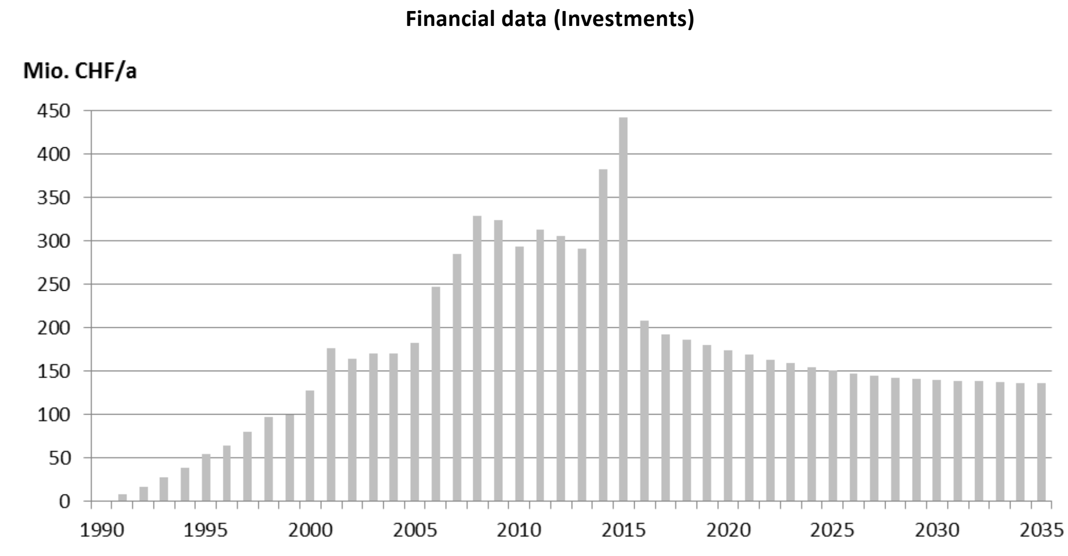
The sub-cluster *Fuel efficiency for light vehicles* was more profoundly revised. In the previous evaluation, we had assumed that 50% of total emission savings can be attributed to efficiency measures and the other 50% to autonomous energy efficiency improvement (INFRAS and EPFL, 2016). INFRAS reconsidered this in the context of updating the transport perspectives and found, in agreement with the FOEN, that only 15% of the emission savings should be attributed to Swiss measures (i.e. representing the difference between WEM and WOM scenarios). Indeed, based on new expert judgment, it is more likely that 85% of the energy efficiency improvement is due to the general trend and to measures taken abroad. This results in smaller CO_2 savings attributable to Swiss measures, as can be seen in Figure 8.

The WEM+ scenario has the more ambitious targets for CO_2 emissions of new cars adopted with the new Energy Act. The limit is lowered to 95 g CO_2/km in 2020 and decreases further to

78 g CO_2/km in 2030 due to technological progress. In the WEM scenario, the 95 g CO_2/km limit is reached in 2030. Figure 9 shows the resulting CO_2 saving and financial data.

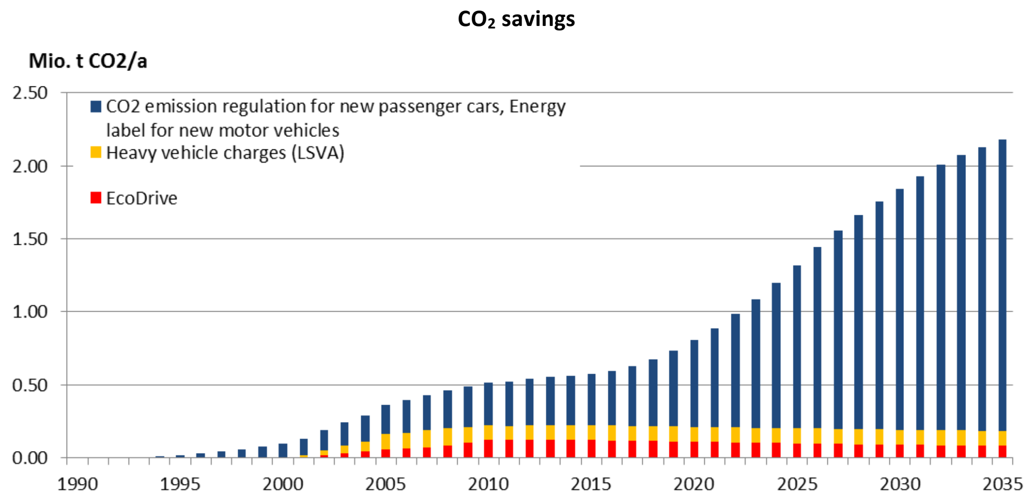
Figure 8: Bottom-up assessment of annual CO_2 savings and investments attributable to the cluster transport in the WEM scenario

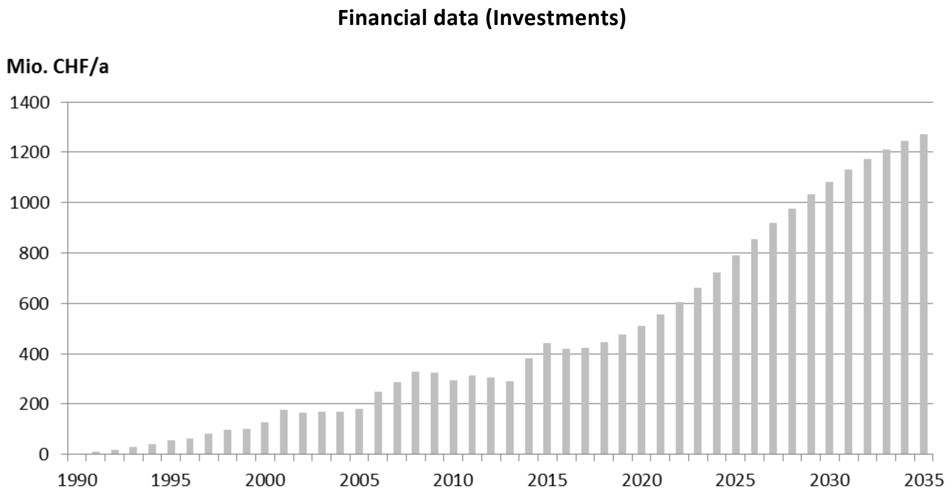




Time series of total impact in terms of CO_2 savings from various measures attributed to the cluster *transport* since 1990 as well as future projection (upper part). Related financial data are shown in the lower part.

Figure 9: Bottom-up assessment of annual CO_2 savings and investments attributable to the cluster transport in the WEM+ scenario





Time series of total impact in terms of CO_2 savings from various measures attributed to the cluster *transport* since 1990 as well as future projection (upper part). Related financial data are shown in the lower part.

3.4. Renewable electricity production

The feed-in tariff was implemented in 2009 for promoting electricity generation from renewable energy sources. It covers the difference between the cost of production and the market price. The feed-in tariff supports small-scale generation of electricity such as hydropower plants (<10MW), photovoltaics (>10kW), wind energy, geothermal energy, biomass and biological waste. Small photovoltaic plants are eligible for a one-time investment subsidy.

The amount of subsidised electricity production continuously increased since 2009. Electricity produced from renewable energy sources is subsidized by several instruments:

1. Feed-in remuneration at cost (FIT),
2. Financing of additional costs (FAC),
3. One-off investment grants (OOI).

Table 4 shows the electricity generated from these mechanisms and the allocated funds from 2009 to 2016.

Table 4: Historical subsidized renewable electricity generation and financial data (FIT annual reports)

	Electricity generated in GWh			Grants in million CHF		
	FIT	FAC	OOI	FIT	FAC	OOI
2009	391	555		77	50	
2010	505	413		103	28	
2011	722	311		145	26	
2012	1123	388		229	29	
2013	1389	398		284	27	
2014	1669	392		344	31	
2015	2018	332	96	419	31	105
2016	2595	332	213	503	31	107

These funds are fed by a surcharge on final electricity consumption equal in 2016 to 0.013 CHF per kWh. The surcharge will be equal in 2017 to 0.015 CHF and will remain constant thereafter. In the scenario WEM+, with the new Energy Act of 2017, the surcharge is raised to 0.023 CHF/kWh, of which 0.021 CHF will feed the funds. We ignore the fact that the subsidies are limited in time, i.e., we assume that the surcharge stays at the same level until 2035. This is not very important for the FIT as the total funds available are hardly sufficient to cover earlier commitments, so very little extra capacity is added under this scheme after 2022. The OOI will be continued until 2030 under the new Energy Act.

The assumptions used to forecast the subsidized renewable electricity production after 2016 are the following:

1. The total funds available every year are computed by multiplying the surcharge with the final electricity consumption computed from GEMINI-E3,
2. The fund used for financing additional cost (FAC) is assumed to be constant after 2016 and equal to 31 million CHF,
3. The volume of one-off investment grants is assumed to increase by 4% per year, except if the residual fund (i.e. the FIT fund) cannot stay at least constant, as it must cover earlier commitments; in that case, it is computed from the difference between the total funds available and the funds used by the FAC and the FIT (staying constant with respect to the previous year),
4. If the fund dedicated to the FIT is not constant, it is computed as the difference between the total funds available and the sum of the two other funds.

The resulting electricity generated thanks to these three funds is computed from the following assumptions:

1. Electricity generation subsidized by the FAC fund is constant after 2016 and equal to 332 GWh,
2. One CHF invested from the OOI fund generates 1 kWh,
3. The FIT paid to producers decreases by 2% per year, reflecting decreasing production costs, down to a floor of 18 ct./kWh in 2020. Electricity prices are assumed to reach a floor of 7 ct./kWh. This implies a subsidy of 11 ct./kWh from 2020 on. Dividing the funds available by the subsidy rate determines the production level that can be subsidized.

Figure 10 and Figure 11 show the subsidised renewable electricity production in the scenarios WEM and WEM+ respectively.

Figure 10: Bottom-up assessment of electricity production and subsidies attributable to the cluster *renewable electricity production* in the WEM scenario

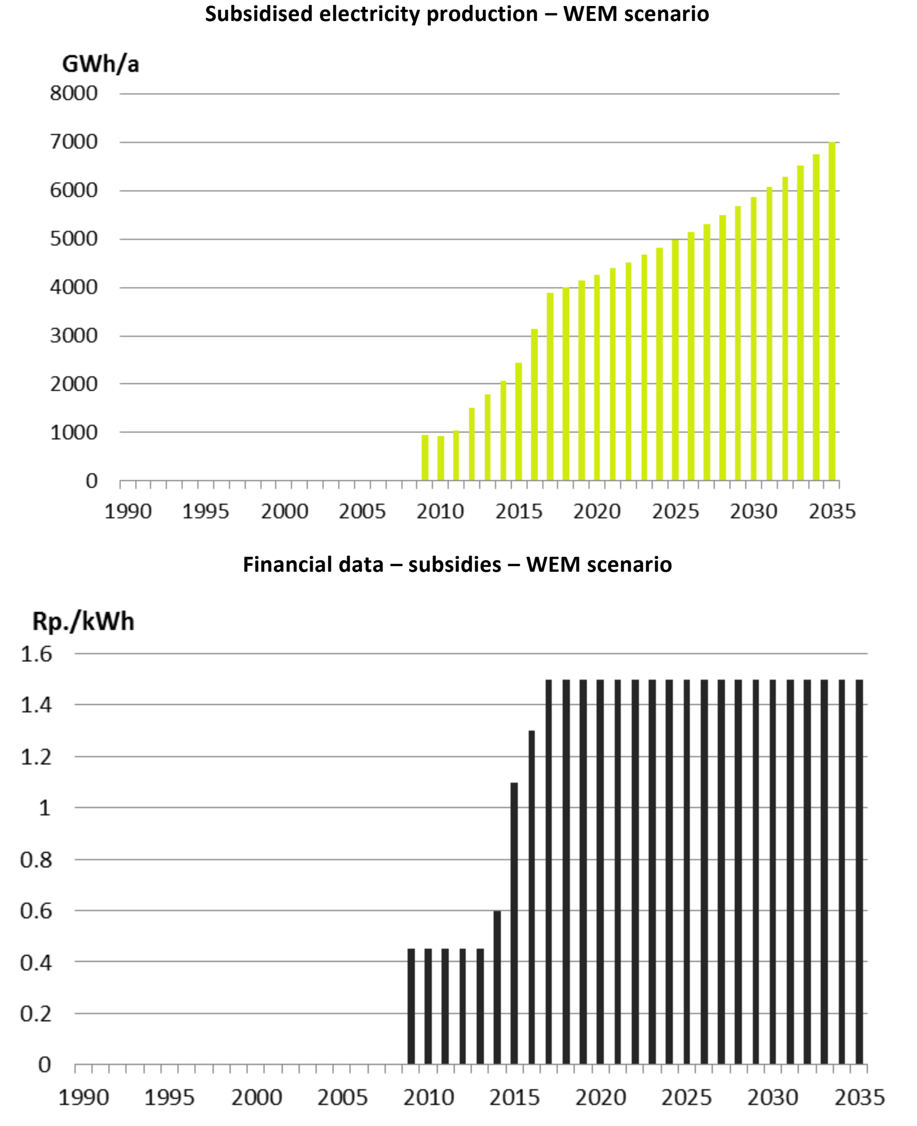
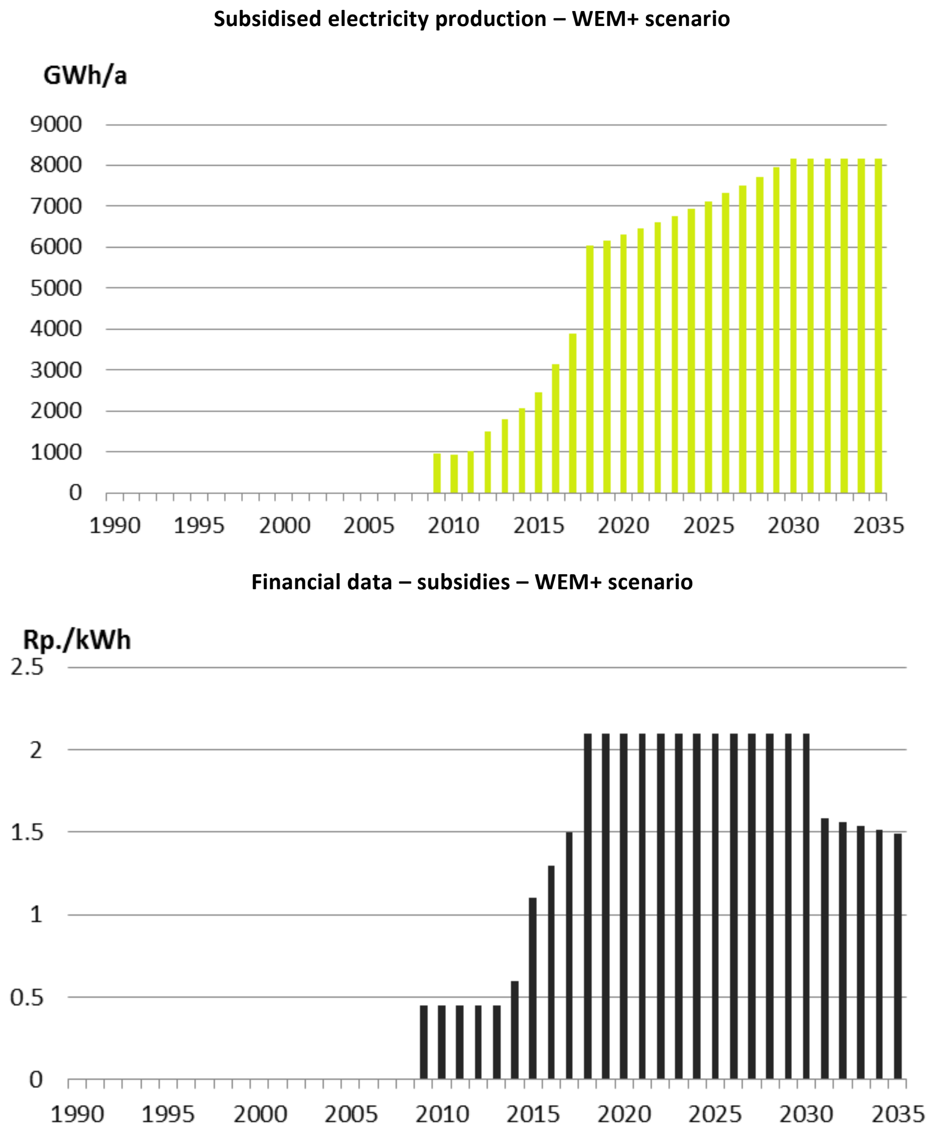


Figure 11: Bottom-up assessment of electricity production and subsidies attributable to the cluster *renewable electricity production* in the WEM+ scenario



4. Top-down impact assessment

The bottom-up estimations of the previous chapter provide the CO_2 savings attributed to non-price measures. Thus, they account for part of the wedge between the CO_2 emissions in the WEM and WOM scenarios and between the CO_2 emissions in the WEM and the WEM+ scenarios. The WOM scenario is derived from the WEM scenario by factoring out the CO_2 savings and investments computed by the bottom-up assessment for non-price measures as well as the simulated effects of the price measures. The WEM+ scenario is also derived from the WEM scenario by factoring in the CO_2 savings and investments computed by the bottom-up assessment for the first package of measures of the Energy Strategy 2050. This is done with the help of the macroeconomic simulation model GEMINI-E3. The price measures and their implementation in the model are described in section 4.2. The results of the respective simulations are presented in section 4.3.

4.1. Estimated energy efficiency improvements in the WEM scenario and GEMINI-E3 model

The total energy efficiency improvements (TEEI) are calculated with the same methodology as explained in INFRAS and EPFL (2016) and extended up to 2035. Therefore, we do not repeat this methodological section. The model is also unchanged; see its description in INFRAS and EPFL (2016).

4.2. Implementation of measures

The CO_2 savings from the non-price policy measures (energy in buildings, SwissEnergy programme and transport) have been estimated bottom-up (chap. 3). They are introduced into the GEMINI-E3 model in the following way. For each measure, the impacts on the Swiss energy mix (oil, gas, wood, and electricity in *toe*) are defined, together with the sectors in which these changes in energy consumption are obtained. These *ex-ante* changes in the energy mix are introduced into the model through a modification of the rates of energy efficiency improvement, i.e. these rates are adjusted until the CO_2 reductions calculated in the bottom-up assessment are obtained. The model also takes into account the costs of these CO_2 savings expressed in the bottom-up assessment in the form of additional investments, which are triggered through a reduction in the productivity of the capital stock.

Several measures can be implemented directly in the GEMINI-E3 model without intermediate bottom-up estimation. They include CO_2 prices such as the CO_2 levy and the price of emission certificates in the Swiss emissions trading scheme (ETS).

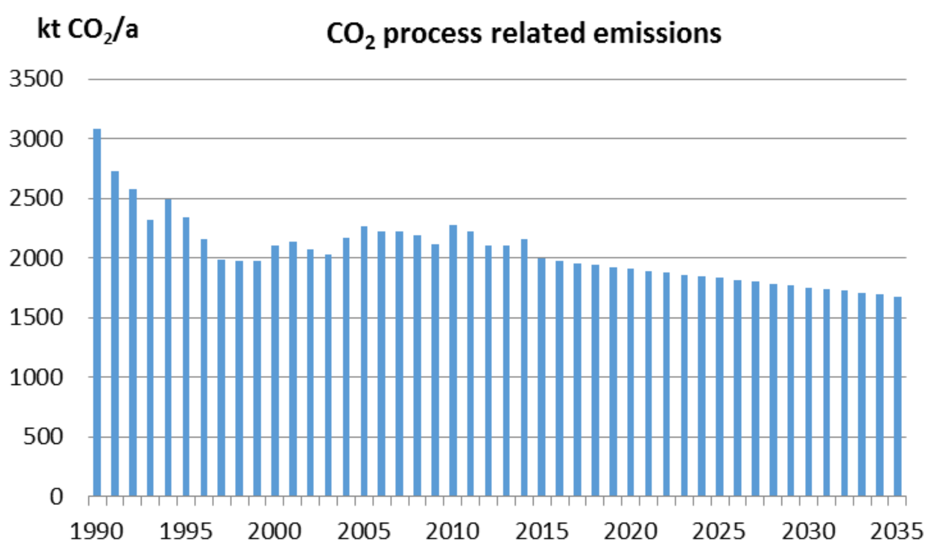
4.2.1. CO_2 levy and ETS price

A CO_2 levy is imposed on fossil combustible fuels since 2008. Over time, it was raised depending on the achievement of predefined reduction targets (Figure 14). In 2014 and 2015, the CO_2 levy was equal to 60 CHF/t CO_2. It was raised to 84 CHF/t CO_2 at the beginning of 2016. Future increases are determined by applying the adjustment rules of the CO_2 Ordinance to the emissions paths simulated for the WEM and the WEM+ scenarios (sect. 4.3.1).

The Swiss ETS market was also created in 2008. Participating firms are exempted from the CO_2 levy. Since 2013, participation in the Swiss ETS is mandatory for greenhouse gas intensive firms. The cap is reduced by 1.74% annually. For the WEM and the WEM+ scenario, the resulting ETS price for the time span 2013-2020 is a result of model simulations (sect. 4.3.1). Beyond 2020, the ETS price is assumed to remain constant. Nevertheless, total ETS emissions continue to decrease after 2020 due to technical progress and the energy price increase. They do so at a lower annual percentage rate of 0.85%. For the WOM scenario, it is assumed that no ETS is established.

In addition to the previous report (INFRAS and EPFL, 2016), our simulations of the ETS integrate now the process-related CO_2 emissions (in particular geogenic emissions of the cement industry) of sector 2. These emissions are integrated exogenously in the model and the emission level is given by the FOEN. The emissions are integrated in the ETS market, which now covers CO_2 emissions from both fuel combustion and industrial processes (in the previous report, processes emissions within the ETS were not considered, i.e. they were also excluded from the cap). Figure 12 shows the process related emissions within the ETS; they are supposed to be the same in the three scenarios (WEM, WEM+ and WOM).

Figure 12: CO_2 process related emissions within the ETS



Greenhouse gas-intensive firms can be exempted from the CO_2 levy if they commit to an emission reduction target (*nonETS* regime). The abatement they commit to is implemented in the simulation model through a shadow price on emissions (*PriceNonETS*), sufficient to induce them to fulfil their commitment. This shadow price is assumed to be equal to the Swiss CO_2 levy, which amounts to the optimistic assumption that the firms commit to the same emission reductions they would undertake if they were subject to the CO_2 levy.

In each sector, there could be firms subject to any of these regimes. As the simulation model aggregates firms at the sectoral level, an average CO_2 price is estimated for each sector by multiplying the share of emissions in that sector covered by a specific regime with the respective carbon price:

$$CO_2price = (1 - \alpha_i - \beta_i) \times CO_2levy + \alpha_i \times PriceETS + \beta_i \times PriceNonETS \quad (1)$$

α_i, β_i being the shares of emissions that are covered by the ETS or by the nonETS shadow price respectively.

Implementation of these measures in GEMINI-E3 is thus based on input data on the shares of emissions and corresponding prices. Regarding future projections, several assumptions about the continuation of these measures are necessary. It is assumed, that all of these measures are continued after 2020 in a similar form. The carbon prices (CO_2 levy, Swiss ETS price and shadow price in the *nonETS* sectors) are maintained at their levels of the year 2020 for the time span 2021 to 2030. Since the linking of the Swiss and the European ETS is not adopted yet, the current Swiss ETS is extended until 2035 The shares of the three possible regimes (CO_2 levy, ETS price, nonETS shadow price) in the different industrial sectors are assumed to remain constant at the levels of 2020.

Emissions from GCCPP refer to another regime that is described in section 4.2.3.

4.2.2. CO_2 compensation for transport fuels

Compensation requirements

The CO_2 emissions that result from the use of transport fuels must be compensated in the following proportions (CO_2 Ordinance of 30.11.2012, art. 89):

2013 and before: 0%
2014-2015: 2%
2016-2017: 5%
2018-2019: 8%
2020: 10%

For the WEM scenario, we shall assume that the 10% compensation is maintained from 2021 to 2035. This compensation requirement applies to gasoline, diesel, natural gas and kerosene used by the transport sector. There are a few exceptions of minor importance, mainly fuels used in public transportation and agriculture, but we will ignore this for the sake of simplicity.

Table 5 indicates the quantities of transport fuels, resulting CO_2 emissions and ensuing compensation requirements for 2014-2035 as projected by the macroeconomic model with our assumptions about demographic and economic growth, fuel prices and fuel efficiency.

Table 5: Expected transport fuel consumption, CO_2 emissions and required offsets (Mt CO_2)

				2013	**2014**	**2015**	**2016**	**2017**	**2018**
CO_2 emissions transport fuels (WEM)				16.05	15.94	15.21	15.08	15.11	15.06
Percentage of compensation				0%	2%	2%	5%	5%	8%
CO_2 emissions to offset				0.00	0.32	0.30	0.75	0.76	1.20
2019	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**
15.01	14.98	14.83	14.68	14.53	14.40	14.26	14.19	14.11	14.02
8%	10%	10%	10%	10%	10%	10%	10%	10%	10%
1.20	1.50	1.48	1.47	1.45	1.44	1.43	1.42	1.41	1.40
2029	**2030**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	
13.93	13.84	13.73	13.63	13.52	13.40	13.29	13.93	13.84	
10%	10%	10%	10%	10%	10%	10%	10%	10%	
1.39	1.38	1.37	1.36	1.35	1.34	1.33	1.39	1.38	

Total compensation requirements amount to 6.0 Mt CO_2 for 2014-2020 and 21.0 Mt CO_2 for 2021-2035, which must be compensated within Switzerland. The admissible options are detailed in FOEN (2015). Offsets can be in the form of all greenhouse gases of the inventory, not only CO_2, but they are converted in CO_2 equivalent quantities when estimating their contribution to meeting the compensation requirements (see below).

KliK Foundation

The Swiss Petroleum Association, the association of mineral oil importers, created the Foundation for Climate Protection and Carbon Offset KliK to fulfil this compensation obligation. It estimates that it will have to offset 6.5 million tonnes CO_2 over 2013-2020, with a peak of 1.5 million tonnes in 2020, which will cost up to 1 billion CHF or between 1 and 2 cents per litre of transport fuel (KliK Short Profile[2]). The second CO_2 Act sets a cap of 5 cents per litre (art. 26).

[2] http://www.klik.ch/resources/KliK_Leporello_D_Web.pdf.

Despite its estimation of needed offset of 6.5 Mt CO_2, KliK displays plans to obtain certificates for 9.07 million tonnes in its annual report for 2015 (Figure 13).

Figure 13: Planned offsets (KliK Annual report 2015, German version)

Modelling the CO_2 compensation for transport fuels

Our modelling of the compensation by KliK uses as much as possible the plans of the Foundation as described in Figure 13 and updated on the webpages of KliK, in particular on the pages of the different platforms (access on 10.05.2017). We deviate from them to the extent that the Foundation estimates higher compensation requirements for 2013-2020 than we derive from our simulations of transport fuel consumption (6.5 Mt vs 6.04 Mt CO_2) and it has plans to contract for even more (9.07 Mt CO_2). Moreover, we extend the compensation requirements and offset options beyond 2020. To some extent, they will be met by lasting effects of offset options implemented between 2013 and 2020. For the rest, they will have to be obtained through additional efforts.

Some of the offsets are already present in our data prior to 2013 and some take the form of reductions of greenhouse gas emissions other than energy related CO_2, hence they do not impact our measure of CO_2 emissions (Table 6). These offsets simply reduce the compensation requirements (Table 7). The remaining compensation requirements must be offset through additional savings in emissions from fossil combustible fuels (Table 8). How this is implemented in the model is explained at the end of this section. First, we show how each offset option contributes to the compensation requirements, in decreasing order of importance.

Table 6: Treatment of KliK compensations

	Contribution to compensation requirement	Impact on emissions after 2012	Modelling in GEMINI-E3
Measures implemented before 2013	full	contribution through their lasting effects, no additional reductions	improved energy efficiency prior to 2013
Measures affecting non-CO_2 greenhouse gas emissions	full	no impact on CO_2 emissions from combustion processes	none
Measures affecting CO_2 emissions	full	full	shadow price leading to additional mitigation

Emission rights ("Emissionsrechte")

Under the first CO_2 Act, from 2008 to 2012, firms could be exempted from the CO_2 levy in exchange for pledges to reduce their emissions. They were granted emission rights for their allowed emissions, which they had to forfeit in proportion of their actual emissions. Overall, they did not use all these rights. The remaining rights were converted into certificates in 2014 and KliK bought them at a price of 50 CHF/t CO_2.

These reductions (3.05 Mt CO_2) are already part of the differential between WOM and WEM in 2012. In other words, statistical emissions in 2012 reflect these additional efforts made by firms. It is just assumed that they will stay effective until 2020. As a result, this part of offsets does not contribute to further reducing CO_2 emissions beyond 2012.

In our simulations, these offsets are represented as permanent increases in energy efficiency for the firms that were exempted from the CO_2 levy under the first CO_2 Act. They do not lead to additional reductions in CO_2 emissions but they reduce the total compensation requirement for the time span 2013-2035 by 3.05 Mt CO_2.

Climate Cent projects ("Projekte Klimarappen")

Under the first CO_2 Act, from 2008 to 2012, the Climate Cent Foundation funded emission mitigation projects in Switzerland. KliK purchases these emission reductions deemed to remain constant at the same level until 2020 at a price between 60 and 135 CHF/t CO_2. KliK expects these (past and continued) compensations to add up to 1.61 Mt CO_2 for the time span 2013-2020 (Figure 13). In fact, the FOEN accepted that 0.29 Mt CO_2 can be counted in 2013 (towards the offset requirement of 2014) and 0.24 Mt CO_2 in 2014. These compensations and the lasting effects of projects realised within the buildings refurbishment programme of the Climate Cent Foundation – 0.042 Mt CO_2/year according to the KliK Annual report 2015 – would lead to cumulated effects of 0.78 Mt CO_2 for the time span 2014-2020. We retain these lasting effects of 0.042 Mt CO_2/year and count them for 2021-2035 too, *pro rata temporis*.

In our simulations, these offsets are represented as increases in energy efficiency under the first CO_2 Act. They do not lead to additional reductions in CO_2 emissions but they reduce the total compensation requirement for the time span 2013-2035 by 1.41 Mt CO_2 (0.78 Mt over 2013-2020 plus 0.63 Mt over 2021-2035)

Additional efforts ("Mehrleistungen")

Under the second CO_2 Act, greenhouse gas-intensive firms can again be exempted from the CO_2 levy in exchange for a commitment to reduce their emissions. When they exceed this commitment by more than 5%, they get attestations for the additional emission reductions (the 5% not included), which they can sell to KliK. KliK offers to buy them at a price of 100 CHF/t CO_2.

In the absence of better information, we assume that this offset option will deliver all of the reduction amount published in Figure 13 in the form of CO_2 emissions from combustion processes, which amounts to 1.29 Mt CO_2 cumulated over 2013-2020 and, with their lasting effects, to 4.30 Mt CO_2 cumulated over 2021-2035[3]. In our simulations, we represent this as a shadow carbon price designed to induce additional abatement by firms, the costs of these additional efforts being covered by KliK. We detail in the next subsection how we specifically do this.

Platforms – programmes and new projects

The four KliK platforms each group several programmes that make it possible to handle smaller greenhouse gas abatement projects with reasonable administrative costs. In addition, they host "new projects", which are projects created after 2013 that will each lead to cumulative emission reductions until 2020 of at least 1,000 tonnes of CO_{2eq}. Each project must be negotiated with KliK (district heating projects will be supported at a constant rate of 100 CHF/t CO_2 avoided).

The programmes and projects do not necessarily need to reduce CO_2 emissions from combustion processes; they can reduce any greenhouse gas in any sector. They are converted in CO_2 equivalent quantities for the fulfilment of the compensation requirement but they are ignored in our simulations when they do not affect CO_2 emissions from combustion processes.

Platform for businesses

The platform for businesses has a programme for carbon sinks in wood (0.81 Mt CO_2 cumulated over 2013-2020)[4] and several programmes and new projects for reducing non-CO_2 greenhouse

[3] The lasting effects mean that firms that exceed their targets up to 2020 will continue to do so after 2020. We assume that these firms will continue to obtain credits for that over-achievement, which they can transfer to KliK. This may differ from expected policy.

[4] Estimates published on KliK website, platform for agriculture, sum of different programmes; data collected on 10.05.2017.

gas emissions (0.174 Mt CO_{2eq}). None of these would lead to reductions in CO_2 emissions from combustion processes (source category 1A). Given that our simulations are limited to these emissions, we assume that they make no contribution. They merely reduce the compensation requirement, by 0.98 Mt CO_2 cumulated over 2013-2020. For the time span 2021-2035, we assume that the carbon sinks programme is extended with the same amount per year and that the other programmes and new projects have lasting effects. This implies a cumulative reduction of 2.10 Mt CO_{2eq} over 2021-2035, again only considered as a reduction of the compensation requirement for that time span.[5]

Platform for transportation

This platform has a programme and a new project for biofuels and fuel from waste oil, for a total of 0.6 Mt CO_2 for 2013-2020. In addition, it has smaller programmes for electric vehicles and transfer of freight transportation onto trains estimated to save 0.062 Mt CO_2. The latter can be expected to have lasting effects. We assume that the biofuels and waste oil programmes and projects are continued at the same level for 2021-2035. Total effects are 0.66 Mt CO_2 for 2013-2020 and 1.33 Mt CO_2 for 2021-2035.[6] These amounts can be subtracted from the CO_2 emissions of transport fuels in the WEM and WEM+ scenarios. They must also be subtracted from the compensation requirements as they replace fossil transport fuels.

Platform for agriculture

This platform encourages the reduction of non-CO_2 greenhouse gas emissions in agriculture. Given that our simulations are limited to CO_2 emissions from combustion processes, we must consider that they make no contribution. They merely reduce the compensation requirement, by 0.38 Mt CO_2 cumulated over 2013-2020 and, with their lasting effects, 1.26 Mt CO_2 cumulated over 2021-2035.[7]

Platform for buildings

A series of smaller programmes and many new projects on this platform improve the energy efficiency of buildings, promote heating networks and wood-based mobile heating, which could lead to estimated CO_2 savings of 0.77 Mt cumulated over 2013-2020. These effects should be

[5] This is the sum of 15 years of carbon sinks in wood (0.81/8×15) and 3.33 times the total reductions obtained from the other programmes and projects (0.174×3.33). If emission reductions accumulate constantly over the eight years of 2013-2020 and then stay at the level of 2020 for the fifteen years of 2021-2035, then total reductions over 2021-2035 are equal to 3.33 times the total reductions of 2013-2020.

[6] This is the sum of 15 years of fuel replacement programmes and projects (0.6/8×15) and 3.33 times the total reductions obtained from the other programmes and projects (0.062×3.33).

[7] 0.38×3.33.

lasting, so that 2.56 Mt CO_2 can be saved over 2021-2035. We shall model this in the form of an additional CO_2 price as detailed below.

Summary of compensations

The tables below summarize the estimations made above about the compensations that do not lead to additional reductions in CO_2 emissions from combustion processes and those that do.

Table 7: KliK compensations that do not lead to additional reductions in CO_2 emissions from combustion processes (Mt CO_2 or CO_{2eq} cumulated over each time span). The last column shows additional efforts needed to meet the compensation requirement

	2013-2020	2021-2035	2021-2035rev
Emissions rights phase I	3.05	0.00	0.00
Climate Cent Foundation	0.78	0.63	0.63
Platform for businesses	0.98	2.10	4.12
Platform for agriculture	0.38	1.26	2.47
Total	5.19	3.99	7.22

Table 8: KliK compensations that lead to additional reductions in CO_2 emissions from combustion processes (Mt CO_2 cumulated over each time span). The last column shows additional efforts needed to meet the compensation requirement

Expected compensations	2013-2020	2021-2035	2021-2035rev
Additional efforts	1.29	4.30	4.30
Platform for transportation	0.66	1.33	2.61
Platform for buildings	0.77	2.56	5.02
Total	2.72	8.19	11.93

Table 9: Total offset requirements and KliK compensations (Mt CO_2 cumulated over each time span)

	Required compensations	Expected compensations	Increased compensations
2013-2020	6.04	7.91	7.91
2021-2035	21.03	12.18	19.16
2013-2035	27.07	20.10	27.07

The sum of expected compensations from the existing and planned programs and platforms of KliK – 20.10 Mt CO_2 in Table 9 – is not sufficient for the required amount of compensations estimated in Table 5, namely 27.07 Mt CO_2 for the whole time span 2013-2035. There is a bit too much compensation over 2013-2020 (7.91 Mt CO_2 compared to required 6.04 Mt CO_2) and too little over 2021-2035. We assume that the excess compensation of 2013-2020 can be carried forward, in accounting terms, to 2021-2035. That still leaves a deficit of 6.97 Mt CO_2. The contribution of the emissions rights of phase I and the Climate Cent Foundation cannot be increased. It would be very costly to seek more additional efforts. Therefore, we assume that the four platforms are amplified pro rata. This is shown in the last column of Table 7 and Table 8. The contributions of these four platforms must essentially be doubled.

Procedure for representing the offsets funded by KliK in GEMINI-E3

Distribution of offsets through time

The cumulated offsets of measures with lasting effects must be distributed through time if we wish to replicate them in our simulations. The way we do this is detailed in section 4.3.2, in particular in tables 18 and 19, of our first report (INFRAS and EPFL, 2016). The only thing that changes is the longer time span – up to 2035 instead of 2030. Measures introduced linearly between 2013 and 2020 lead to cumulated emission reductions over 2021-2035 that are equal to 3.33 times the cumulated emission reductions over 2013-2020

In our simulations, we will set instruments that allow achieving the additional reductions of Table 7 and Table 8. They need not be exactly equal in every year, but the cumulated emission reductions should match the expected effects of the compensations funded by KliK.

Offsets in industrial sectors and buildings

Firms subject to the CO_2 levy reduce their emissions to the extent that the cost of doing so does not exceed the savings thus obtained, namely energy prices augmented by the CO_2 levy. A higher CO_2 levy encourages them to abate further. The abatement costs minus energy savings and the levy firms have to pay on residual emissions increase their production costs, which leads to higher prices for the goods and services they produce. Greenhouse gas-intensive firms can be exempted from the levy in exchange for the commitment to implement all abatement measures that are profitable for energy prices augmented by the CO_2 levy. We represent this through a shadow price on energy on top of the market price, designed to induce these firms to reduce their emissions as though they had to pay an actual levy, except that they do not really have to pay the shadow price[8]. This representation mimics imposed reduction targets. The firms benefiting from this preferential regime only bear the abatement costs (minus energy savings), which raise their production costs, but less than if they had to pay the levy.

[8] The shadow price appears only in the first-order condition, when they select their energy mix and their abatement efforts, not in their budget constraint, so it is not really collected. It would be equivalent to collect it and pay it back in the same amount to every firm, but that would require some considerable myopia on the part of firms.

KliK obtains its emissions offsets by subsidizing abatement costs, which allows firms to reduce their emissions further without any impact on their production costs. We represent this in GEMINI-E3 by raising the shadow price on energy, computing the costs of the additional abatement (minus energy savings) and crediting this amount to the firms, funded by a levy on transport fuels. This keeps production costs and prices unchanged.

4.2.3. CO_2 compensation for gas-fired combined-cycle power plants

Gas-fired combined-cycle power plants (GCCPP) are introduced in the model when needed to balance the electricity market. According to the second CO_2 Act, they are required to compensate their emissions, with a minimum share of 50% domestic compensation. The rest can be compensated internationally. We fix the price of foreign certificates (linked to international compensation) at 10 CHF/t CO_2.

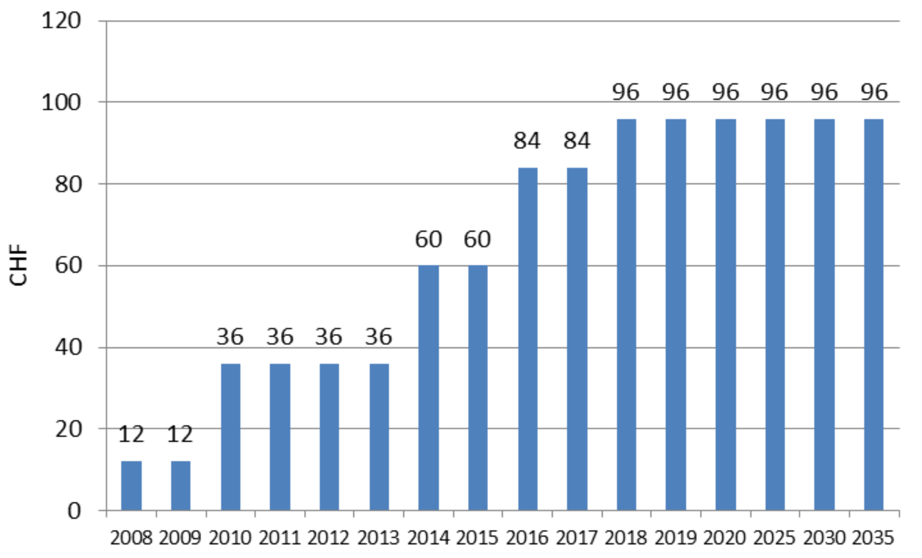
GCCPP are not part of the Swiss ETS since the new entrant reserve of emission certificates is too small to cover their emissions. The domestic compensations have to be obtained in the other sectors. The procedure is the same as described above for transport fuels under *Offsets in industrial sectors* and *Offsets in buildings*.

4.3. Model results

4.3.1. Endogenous CO_2 prices

According to the calculation of the model, the CO_2 levy will be raised from 84 to 96 CHF/t CO_2 in 2018. CO_2 emissions on fossil combustible fuels are expected to reach 73.4% of the 1990 emissions levels in the year 2016, which is above the minimum threshold set in the CO_2 Ordinance that would not lead to an increase (73%), but well below the level that would lead to an increase to 120 CHF/t CO_2 (76%). Figure 14 shows the evolution of the CO_2 levy in the WEM and WEM+ scenarios (model result).

Figure 14: CO_2 levy in CHF/t CO_2 (current prices) in the WEM and WEM+ scenarios (model result)



The ETS cap is reduced by 1.74% annually. This corresponds to a decrease by 12% between 2013 and 2020. Compared with our previous report (INFRAS and EPFL, 2016), we integrate in the ETS market the CO_2 emissions from industrial processes (see Figure 12), and keep them at the same level in all three scenarios. For the past, the ETS price is taken from the Swiss emission registry[9]. After some fluctuations, the price comes down to approximatively 7 CHF in 2017. According to our new estimations, the decrease of industrial emissions (from energy combustion as well as from industrial processes) combined with the shutdown of one of the two Swiss refineries, which creates "hot air" of approximately 0.5 $MtCO_2$ in 2016 and in the following years, does not require any further increase in the ETS price to meet the emissions cap. In fact, it would be met even if the ETS price fell to zero. Nevertheless, we assume a floor for the ETS price at constant 7 CHF (Figure 15). r The effects are illustrated in the stylized representation of Figure 16. Up to the time of the shutdown of the refinery, emissions of the firms in the ETS decline as required by the declining cap (strongly exaggerated in the figure). With the refinery shutdown, their total emissions drop. If the ETS price were allowed to fall to zero, total emissions would rebound to some extent. With the constant ETS price, the firms maintain their efforts and their emissions even decline slightly thanks to continued efficiency improvements. By 2035, they are still below the cap, so that no rise in ETS price is required. The WEM scenario does not account for excess certificates banked by firms (the area between the cap and the actual emissions) which may be used by firms at some point in the future.

[9] https://www.emissionsregistry.admin.ch

Figure 15: ETS price in CHF/t CO_2 (current prices) in the WEM and WEM+ scenarios

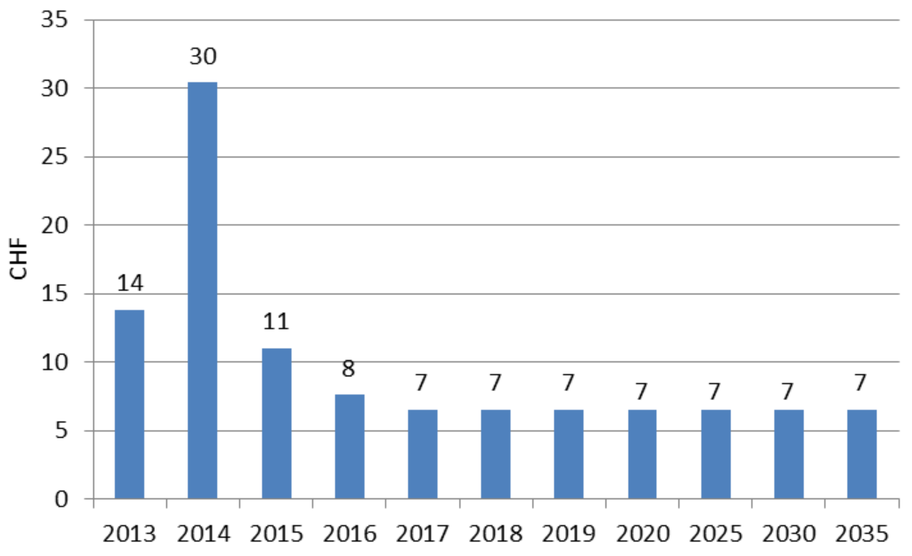
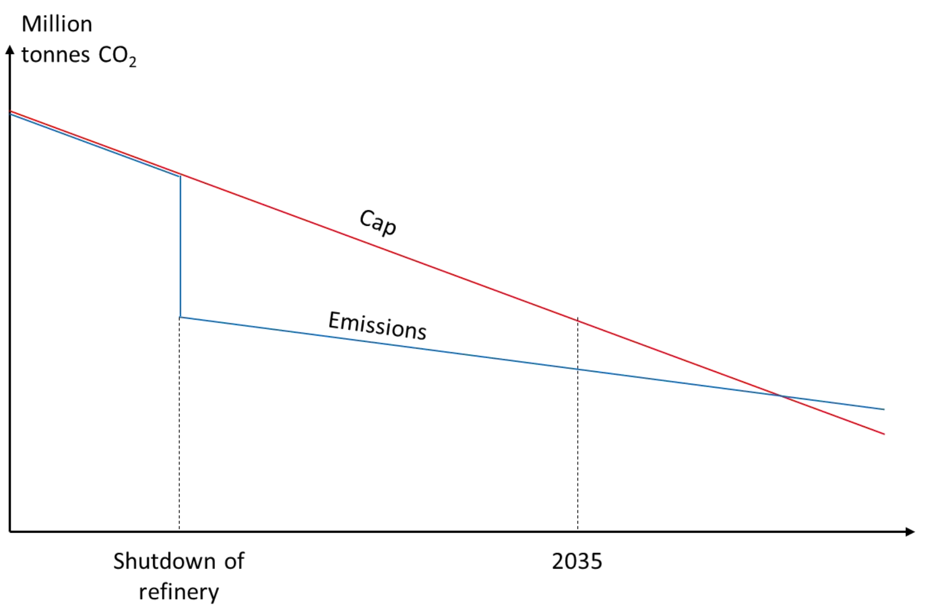


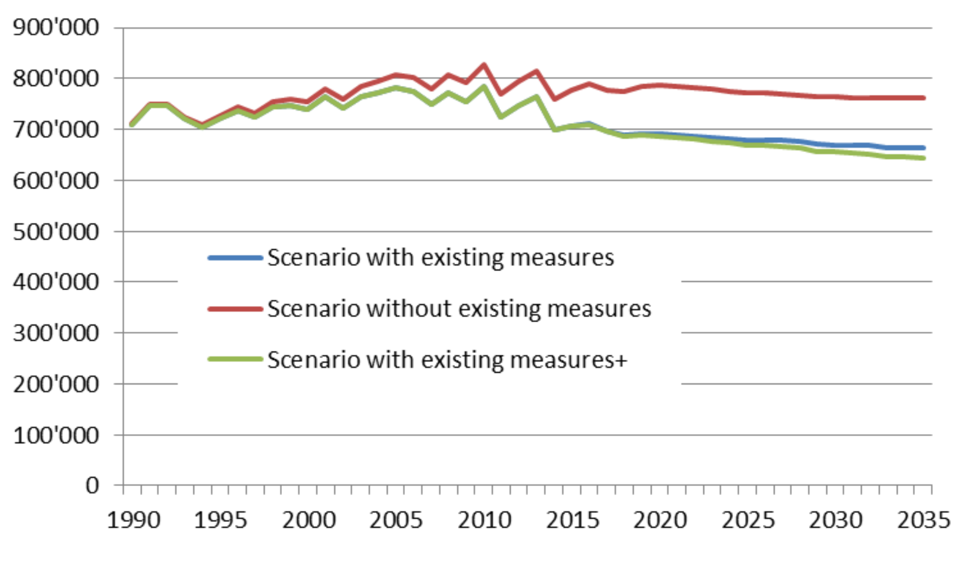
Figure 16: Stylized path of CO2 emissions by firms in ETS



4.3.2. Total final energy consumption

Figure 17 shows the final energy consumption in the three scenarios. It includes fossil energy consumption, electricity and district heating, but excludes renewables such as biofuels, in particular wood. Energy consumption by the energy industries (1A1) as well as energy consumption for international air transport are not accounted for. Between 1990 and 2015, total final energy consumption was relatively stable. It is expected to decrease slowly, by 0.3% per year, in the WEM scenario. Without measures, the energy consumption would have been 10% higher in 2015 and is projected to be 15% higher in 2035 (WOM consumption relative to WEM consumption).

Figure 17: Total final energy consumption (excluding biofuel, wood) in TJ



4.3.3. Electricity generation

The WEM, WEM+ and WOM scenarios assume that nuclear electricity generation is phased out in steps. Specifically, the five existing nuclear power plants will stop production when they reach the end of their service life and they will not be replaced by new ones. The operator of the Mühleberg power plant already decided to shut it down in 2019. For the other nuclear power plants, we assume a lifetime of 60 years. This means that the Beznau I power plant will be shut down in 2029 and that the Beznau II power plant in 2033.

In the WEM scenario, the promotion of renewable electricity generation and the compensation requirement for CO_2 emissions limit the deployment of fossil fuel power plants. In 2020, Swiss electricity generation reaches 71.5 TWh, of which only 1.7 TWh are produced with fossil energy (mainly produced by GCCPP). In 2030, total electricity generation equals 72.4 TWh with

2.3 TWh from GCCPP. In 2035, the production of new renewable electricity reaches 9.6 TWh, which is not sufficient to replace the decommissioned nuclear power plants. Therefore, GCCPP are needed for 3.3 TWh.

In the WOM scenario, electricity consumption reaches 72 TWh in 2020, 73.6 TWh in 2030 and 75 TWh in 2035. This is the result of low electricity prices when there is no feed-in-tariff and no carbon taxation for the natural gas used in GCCPP. The increased demand is mainly met with such plants, which produce 9.4 TWh in 2030 and 12.9 TWh in 2035. In 2030, new renewables (excluding hydro) account for 2.2 TWh in the WOM scenario instead of 7.1 TWh in the WEM scenario.

In the WEM+ scenario, more renewable electricity generation is available. In 2035, new renewables contribute 10.2 TWh instead of the 9.6 TWh of the WEM scenario. However, total electricity generation remains approximatively the same as in the WEM scenario.

Figure 18: Electricity generation in the WEM scenario

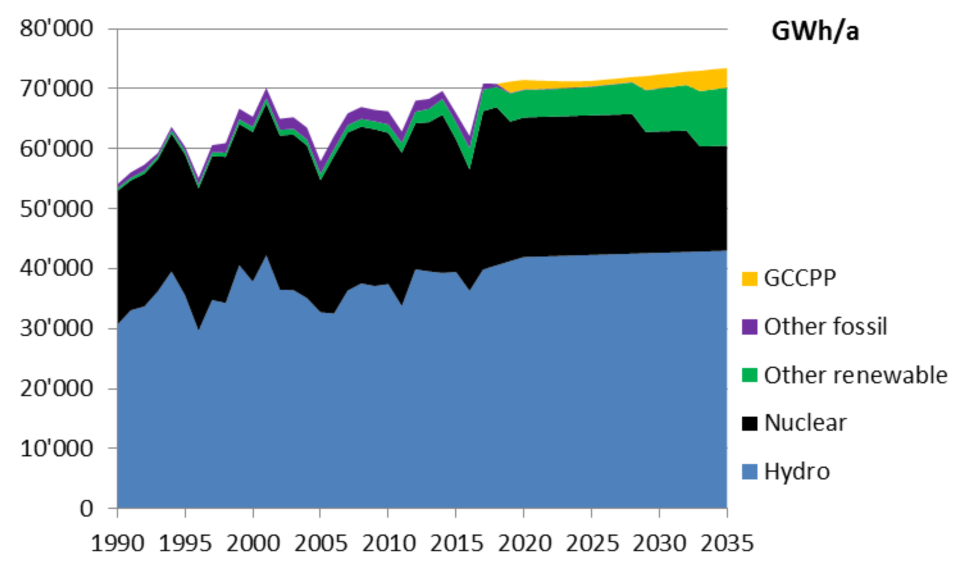


Figure 19: Electricity generation in the WEM+ scenario

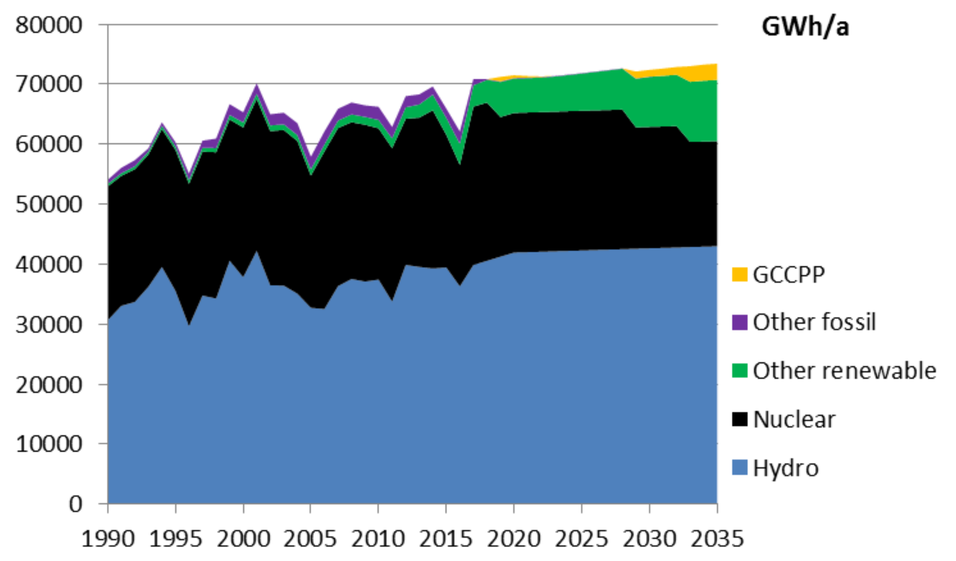
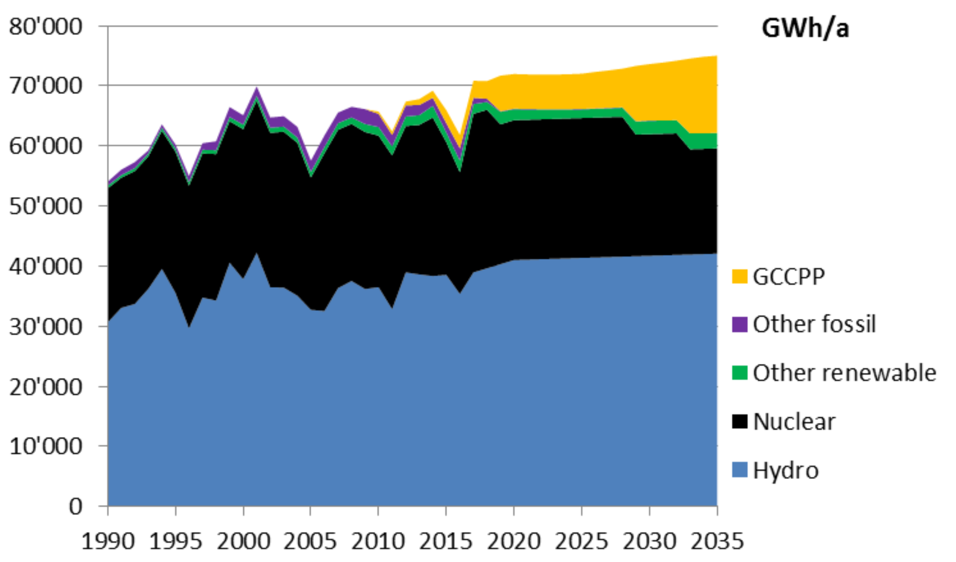


Figure 20: Electricity generation in the WOM scenario



4.3.4. CO_2 emissions by source category in the WEM scenario

In the WEM scenario, CO_2 emissions from energy combustion reach 35.0 Mt in 2020 (Table 10). Subtracting the 50% of emissions from electricity generation using natural gas that will be compensated through international compensation, total CO_2 emissions will equal 34.8 Mt, which represents a 15% reduction with respect to 1990 levels. In 2035, total CO_2 emissions will reach

30.5 Mt (including the international compensation), which amounts to a reduction by 25% relative to 1990 levels. In 2020, this is 1 Mt CO_2 or 3% less than in our previous report (INFRAS and EPFL, 2016). Lower emissions in the transport sector are the main explanation, due to lower transport demand[10] and the decrease of emissions linked to tank tourism. In contrast, emissions from energy industries increase by 0.16 Mt CO_2 compared to the previous report because new SFOE estimates assume less new renewable electricity generation, which has to be compensated by electricity generated with natural gas. The other sectors (especially industry and households) also contribute to the lower emissions compared to the previous report. In 2030, the total difference is equal to 1.6 Mt CO_2 (5%) mainly due to the decrease in emissions from transportation (1.1 Mt CO_2).

Table 10: CO_2 emissions from energy combustion in the WEM scenario (Mt)

Source category	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**	**2030**	**2035**
Energy industries (1A1)	2.5	2.6	3.1	3.8	3.8	3.3	3.6	4.0	4.3
Manufacturing industries and construction (1A2)	6.4	6.2	5.9	6.0	5.8	4.9	4.4	3.9	3.7
Transport (1A3)	14.4	14.0	15.7	15.7	16.2	15.2	14.9	13.6	13.1
Other sectors (1A4)	17.4	17.9	16.4	17.7	16.6	13.0	12.0	10.6	9.9
Commercial/institutional (1A4a)	*5.2*	*5.6*	*5.3*	*5.6*	*5.2*	*4.1*	*4.1*	*4.0*	*4.0*
Residential (1A4b)	*11.6*	*11.8*	*10.6*	*11.6*	*11.0*	*8.5*	*7.6*	*6.2*	*5.6*
Agriculture/forestry/fishing (1A4c)	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*	*0.4*	*0.4*	*0.3*	*0.3*
Military (1A5)	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total domestic (1A)	**40.9**	**40.9**	**41.3**	**43.3**	**42.6**	**36.6**	**35.0**	**32.2**	**31.1**
International compensation GCCPP							0.3	0.4	0.5
Total with international compensation	**40.9**	**40.9**	**41.3**	**43.3**	**42.6**	**36.6**	**34.8**	**31.8**	**30.5**

Table 11 shows the change in CO_2 emissions by source category relative to 1990. Two source categories – energy industries and transport – emit more CO_2 in 2020 than in 1990. The CO_2 emissions decrease in all other sectors with respect to their 1990 levels, even transport after 2022.

[10] This is in line with the assumptions of the pilot study on emissions in road transport by INFRAS (2017).

Table 11: Reductions of CO_2 emissions from energy combustion in the WEM scenario relative to 1990 (%)				
Source category	**2010**	**2020**	**2030**	**2035**
Energy industries (1A1)	55%	47%	61%	76%
Manufacturing industries and construction (1A2)	-10%	-31%	-39%	-43%
Transport (1A3)	13%	3%	-5%	-9%
Other sectors (1A4)	-4%	-31%	-39%	-43%
Commercial/institutional (1A4a)	*-2%*	*-22%*	*-24%*	*-24%*
Residential (1A4b)	*-5%*	*-35%*	*-46%*	*-52%*
Agriculture/forestry/fishing (1A4c)	*-13%*	*-29%*	*-34%*	*-37%*
Military (1A5)	-37%	-44%	-51%	-55%
Total domestic (1A)	**4%**	**-14%**	**-21%**	**-24%**
Total with international compensation	**4%**	**-15%**	**-22%**	**-25%**

4.3.5. CO_2 emissions by source category in the WOM scenario

Without policy measures aiming at reducing GHG emissions (WOM scenario), Switzerland's CO_2 emissions from energy combustion (1A) are projected to reach 43.3 Mt in 2020 and 41 Mt in 2030 and 2035 (Table 12).

Table 12: CO_2 emissions from energy combustion in the WOM scenario (Mt)									
Source category	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**	**2030**	**2035**
Energy industries (1A1)	2.5	2.6	3.2	3.8	4.0	4.0	5.1	6.4	7.6
Manufacturing industries and construction (1A2)	6.4	6.2	5.9	6.0	6.0	5.6	5.6	5.1	5.0
Transport (1A3)	14.4	14.0	15.8	16.0	16.9	16.0	15.7	14.6	14.0
Other sectors (1A4)	17.5	18.3	17.3	19.2	19.1	16.8	16.8	14.8	14.2
Commercial/institutional (1A4a)	*5.3*	*5.7*	*5.6*	*6.1*	*6.1*	*5.6*	*6.1*	*5.7*	*5.8*
Residential (1A4b)	*11.7*	*12.1*	*11.2*	*12.6*	*12.5*	*10.7*	*10.3*	*8.7*	*8.1*
Agriculture/forestry/fishing (1A4c)	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*	*0.4*	*0.4*	*0.4*
Military (1A5)	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total domestic (1A)	**41.0**	**41.3**	**42.3**	**45.1**	**46.1**	**42.5**	**43.3**	**41.0**	**41.0**

Over the whole time span 1990-2035, the CO_2 emissions in the WOM scenario increase for two source categories (Table 12). In energy industries (1A1), the increase of electricity demand and the shutdown of nuclear power plants require electricity generation from gas-fired combined-cycle power plants with large CO_2 releases. The growth of demand for commercial/institutional services combined with limited energy efficiency improvement in this sector induces a significant increase of its CO_2 emissions. In contrast, the emissions slowly decrease in the long term in the other sectors, even in the absence of measures, after peaking around 2010, thanks to autonomous energy efficiency improvements.

4.3.6. CO_2 emissions savings by source category

Table 13 shows the CO_2 savings obtained with all existing measures in the WEM scenario relative to the WOM scenario by source category. They can be calculated by simply taking the difference between the emissions in the WOM scenario (Table 12) and the emissions in the WEM scenario (Table 10). The same savings are expressed in percent of the emissions in the WOM scenario in Table 14. It shows that existing climate policy measures lead to reductions of CO_2 emissions by 8% in 2010, 19% in 2020, 21% in 2030 and 24% in 2035 relative to a scenario without these measures. When we reverse these ratios, we find that without greenhouse gas abatement measures (i.e. in the WOM scenario), CO_2 emissions would have been higher by 8% in 2010, 24% in 2020, 29% in 2030 and 34% in 2035 with respect to the emissions we observed or expect if we follow the current path of measures (WEM scenario).

The measures yield CO_2 savings in all sectors. The transport sector is the only major sector where the savings are smaller than 10% in 2020, 2030 and 2035.

Table 13: CO_2 savings from energy combustion in the WEM scenario relative to the WOM scenario (Mt), international compensation of CO_2 emissions from gas-fired combined-cycle power plants amounting to 0.3 $MtCO_2$ in 2020, 0.4 $MtCO_2$ in 2030 and 0.5 $MtCO_2$ in 2035 is not considered here

Source category	2010	2020	2030	2035
Energy industries (1A1)	0.2	1.5	2.4	3.3
Manufacturing industries and construction (1A2)	0.2	1.2	1.2	1.3
Transport (1A3)	0.6	0.8	0.9	1.0
Other sectors (1A4)	2.5	4.8	4.2	4.3
Commercial/institutional (1A4a)	*1.0*	*2.0*	*1.7*	*1.8*
Residential (1A4b)	*1.5*	*2.7*	*2.5*	*2.5*
Agriculture/forestry/fishing (1A4c)	*0.0*	*0.1*	*0.1*	0.0
Military (1A5)	0.0	0.0	0.0	0.0
Total domestic (1A)	**3.5**	**8.2**	**8.8**	**9.9**

Table 14: Change in CO_2 emissions from energy combustion in the WEM scenario relative to the WOM scenario (%), international compensation of CO_2 emissions from gas-fired combined-cycle power plants is not considered here				
Source category	**2010**	**2020**	**2030**	**2035**
Energy industries (1A1)	-4%	-29%	-38%	-43%
Manufacturing industries and construction (1A2)	-3%	-21%	-23%	-27%
Transport (1A3)	-4%	-5%	-6%	-7%
Other sectors (1A4)	-13%	-28%	-29%	-30%
Commercial/institutional (1A4a)	*-16%*	*-33%*	*-30%*	-31%
Residential (1A4b)	*-12%*	*-26%*	*-29%*	-31%
Agriculture/forestry/fishing (1A4c)	*-5%*	*-12%*	*-13%*	-11%
Military (1A5)	0%	0%	0%	0%
Total domestic (1A)	**-8%**	**-19%**	**-21%**	**-24%**

4.3.7. CO_2 emissions by source category in the WEM+ scenario

In the WEM+ scenario, CO_2 emissions reach 34.2 Mt in 2020 (including international compensation, Table 15), which is 16.3% less than in 1990. In 2030 and 2035, these emissions are equal respectively to 30.5 and 29.1 Mt.

Table 15: CO_2 emissions from energy combustion in the WEM+ scenario (Mt)									
Source category	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**	**2030**	**2035**
Energy industries (1A1)	2.5	2.6	3.1	3.8	3.8	3.3	3.2	3.6	4.1
Manufacturing industries and construction (1A2)	6.4	6.2	5.9	6.0	5.8	4.9	4.4	3.9	3.7
Transport (1A3)	14.4	14.0	15.7	15.7	16.2	15.2	14.7	12.8	12.0
Other sectors (1A4)	17.4	17.9	16.4	17.7	16.6	13.0	11.8	10.3	9.7
Commercial/institutional (1A4a)	*5.2*	*5.6*	*5.3*	*5.6*	*5.2*	*4.1*	*4.0*	*3.9*	*3.9*
Residential (1A4b)	*11.6*	*11.8*	*10.6*	*11.6*	*11.0*	*8.5*	*7.4*	*6.1*	*5.5*
Agriculture/forestry/fishing (1A4c)	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*	*0.4*	*0.4*	*0.3*	*0.3*
Military (1A5)	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total domestic (1A)	**40.9**	**40.9**	**41.3**	**43.3**	**42.6**	**36.6**	**34.3**	**30.7**	**29.6**
International compensation GCCPP							0.1	0.2	0.5
Total with international compensation	**40.9**	**40.9**	**41.3**	**43.3**	**42.6**	**36.6**	**34.2**	**30.5**	**29.1**

The emissions in the WEM+ scenario follow the same dynamics as in the WEM scenario, with supplementary reductions due to the measures of the first package of the Energy Strategy 2050. The additional CO_2 savings obtained with these extra measures are estimated at 0.6 Mt in 2020, 1.3 Mt in 2030 and 1.4 Mt in 2035 (including compensation for emissions from GCCPP). They are mainly obtained in transport, residential and electricity generation and are the results of stronger emission limits for new passenger cars and light duty vehicles, the increase of the earnings from the CO_2 levy earmarked for the national buildings refurbishment programme, and the increase in subsidies for renewable energy production.

Table 16: CO_2 savings from energy combustion in the WEM+ scenario relative to the WEM scenario (Mt)

Source category	**2020**	**2030**	**2035**
Energy industries (1A1)	0.4	0.4	0.2
Manufacturing industries and construction (1A2)	0.0	0.0	0.0
Transport (1A3)	0.2	0.9	1.1
Other sectors (1A4+1A5)	0.2	0.2	0.2
Commercial/institutional (1A4a)	0.0	0.0	0.0
Residential (1A4b)	0.1	0.1	0.1
Agriculture/forestry/fishing (1A4c)	0.0	0.0	0.1
Military (1A5)	0.0	0.0	0.0
Total domestic (1A)	**0.7**	**1.5**	**1.5**
International compensation GCCPP	0.2	0.2	0.1
Total with international compensation	**0.6**	**1.3**	**1.4**

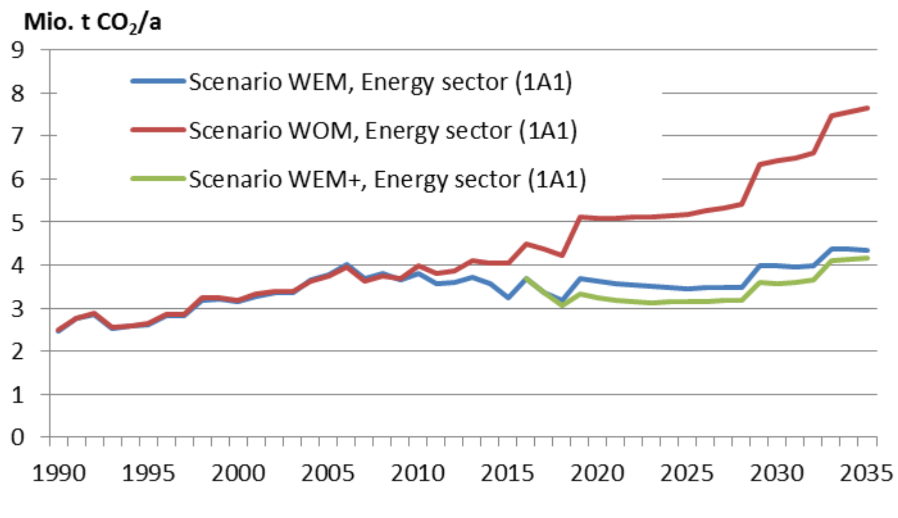
4.3.8. Evolution of emissions by source category in the three scenarios

This section compares the evolution of CO_2 emissions by source category in the WEM, WEM+ and WOM scenarios.

Energy industries (1A1)

In the WEM scenario, energy industries (energy conversion, in particular electricity generation) are projected to emit 47% more CO_2 in 2020 than in 1990, 61% more in 2030 and even 76% more in 2035 (Figure 21). This is mainly due to new gas-fired combined-cycle power plants (GCCPP), which replace the decommissioned nuclear power plants in 2019, 2029 and 2033, leading to stepwise increases of CO_2 emissions[11]. The increase is limited to 36% in 2020 relative to 1990 when the international compensation for CO_2 emitted by GCCPP is subtracted, 46% in 2030 and 54% in 2035. When domestic compensation is also taken into account, i.e. when the CO_2 emissions of GCCPP are entirely extracted from those of the energy sector, its emissions are 25% higher in 2020 relative to 1990, 30% in 2030 and 32% in 2035. Thanks to more subsidised renewable electricity, the CO_2 emissions by energy industries are 0.4 million tonnes lower in 2020 and 2030 in the WEM+ scenario compared to the WEM scenario.

Figure 21: CO_2 emissions by energy industries (energy conversion, in particular electricity generation, without compensations)



Transport (1A3)

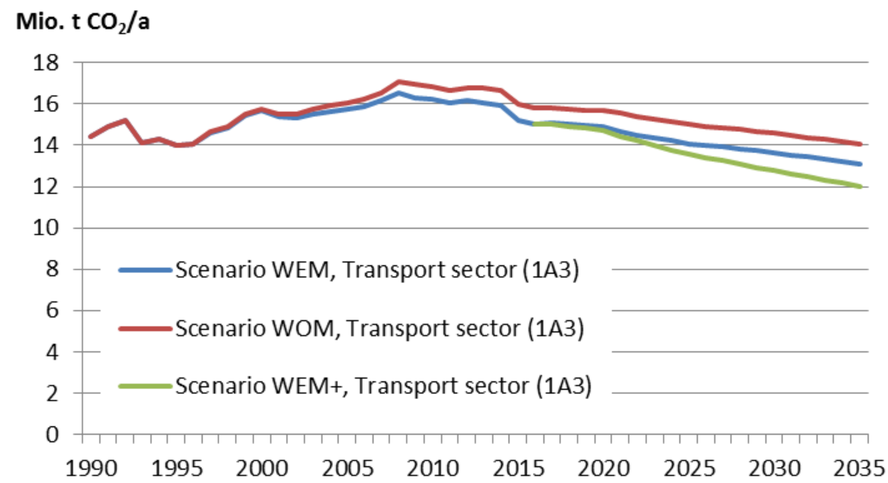
The second source category that experienced emission increases in the data with respect to 1990 is transport. Emissions from this source category include those related to fuel tourism (also called tank tourism), i.e. the transport fuels purchased within Switzerland but consumed abroad, taking advantage of price differentials between Switzerland and its neighbouring countries. In 2015, the Swiss National Bank stopped supporting the minimum exchange rate of 1.2 CHF per Euro, which led to an appreciation of the Swiss franc and affected fuel tourism. In Swiss GHG accounting, fuel tourism is aggregated with statistical differences and cannot be separated easily. However, in 2015, the emissions from the category "fuel tourism and statistical difference" dropped from 1.99 to 1.53 Mt CO_2. We assume that these 0.47 Mt CO_2 emissions decrease can

[11] The model shows a small increase in emissions in 2016 relative to 2015 because the reduction in hydropower and nuclear generation is replaced by fossil generation. In the most recent statistics, it seems that higher net imports replaced the reduced production.

be attributed mainly to fuel tourism. After 2015 and up to 2035, we assume no change in the CHF-Euro exchange rate and therefore no additional change in fuel tourism.

In 2020, CO_2 emissions from transport still exceed the 1990 level by 3.5% in the WEM scenario, but they are on a declining path since 2008 (Figure 22). In 2030, they are 5% below the 1990 level, and 9% below the 1990 level in 2035. These numbers do not consider the domestic CO_2 compensations procured by the KliK Foundation, which equal 10% of emissions in 2020, 2030 and 2035. Indeed, the respective compensations are attributed to other source categories whose emissions actually decrease not only but also thanks to these compensations. If they were subtracted from the CO_2 emissions of the transport sector, these emissions would fall below 1990 levels, by 7% in 2020 and 18% in 2035. With new regulations on CO_2 emissions limits for new motor vehicles (scenario WEM+), CO_2 emissions from transport are lower by 0.9 million tonnes in 2030 and by 1.1 million tonnes in 2035 compared to the WEM scenario.

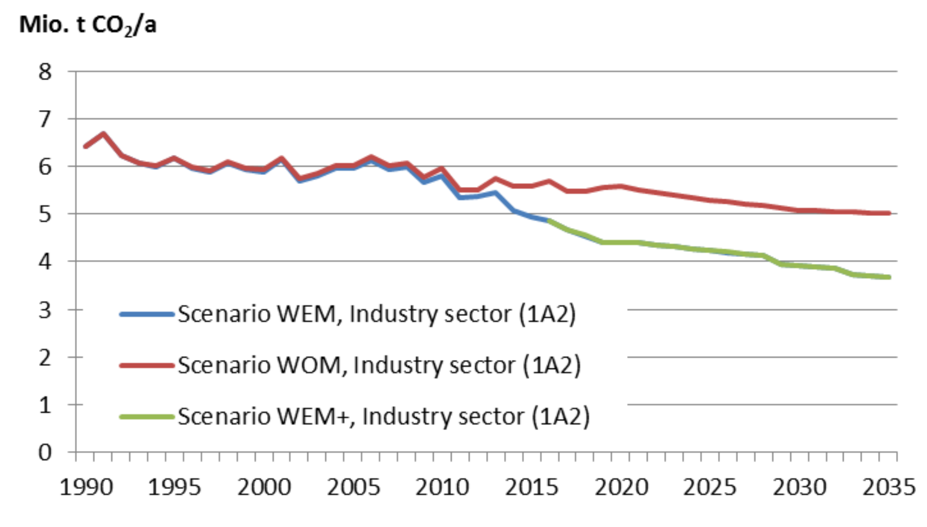
Figure 22: CO_2 emissions in the transport sector (domestic compensation is considered in other source categories)



Manufacturing industries and construction (1A2)

In the source category manufacturing industries and construction, there is a clearly declining trend of CO_2 emissions over the whole time span. This reduction includes savings related to the CO_2 compensation mechanism of the transport and the electricity generation sectors. CO_2 emissions from manufacturing industries and construction are projected to be 31% below their 1990 level in 2020 in the WEM scenario, and even 43% below in 2035. Compared to the WEM scenario, the industrial emissions are unchanged in the WEM+ scenario because the measures of the first package of the Energy Strategy 2050 do not affect this source category.

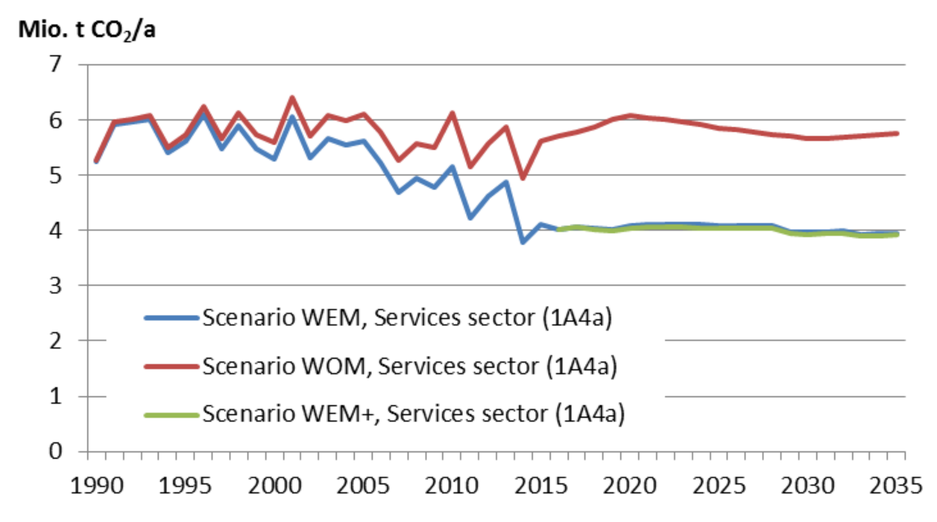
Figure 23: CO_2 emissions in manufacturing industries and construction



Commercial/institutional (1A4a)

In the services sector, CO_2 emissions are 22% below their 1990 level in 2020. This is mainly obtained by measures dedicated to the buildings stock of this sector: the building codes of the cantons, the national buildings refurbishment programme, and the SwissEnergy programme. In 2035, the CO_2 emissions of this sector are projected to amount to 4.1 Mt CO_2 in the WEM scenario, 24% below 1990 emissions. The WEM+ scenario does not change these emissions significantly: they are only 0.04 million tonnes below the WEM scenario.

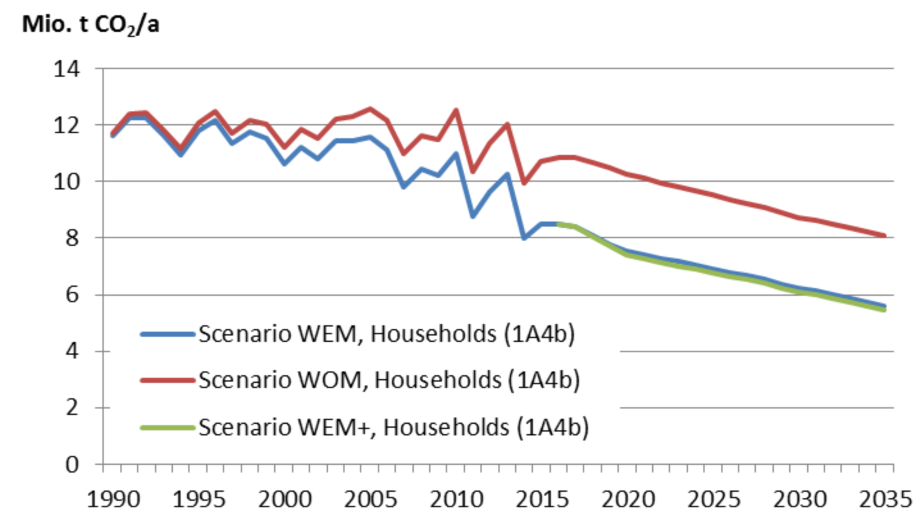
Figure 24: CO_2 emissions in the commercial/institutional (services) sector



Residential (1A4b)

The CO_2 emissions in the residential sector significantly decrease over the time span 1990-2020. In 2020, they are 35% below 1990 levels in the WEM scenario. As for the commercial/institutional sector, these reductions are mainly driven by the implementation of measures related to the use of energy in buildings, reinforced by the CO_2 levy on heating fuels. After 2020, CO_2 emissions decrease mainly due to expected autonomous energy efficiency improvement, and thus in parallel for all scenarios.

Figure 25: CO_2 emissions in residential sector



In the WEM+ scenario, the measures of the first package of the Energy Strategy 2050 in the national buildings refurbishment programme allow to decrease by 0.1 million tonnes the CO_2 emission for the years 2030 and 2035.

4.3.9. Decomposition of total CO_2 savings by cluster of measures

Figure 26 shows the contribution of each cluster of measures to total CO_2 savings relative to the WOM scenario. These contributions have been estimated by removing individually each measure in the WEM scenario. For example, we have simulated the WEM scenario without taking into account the CO_2 prices (CO_2 levy and ETS price). The difference between the CO_2 emissions of this scenario and those of the WEM scenario is an estimation of the contribution of the carbon prices to total CO_2 savings.

We include in the transport cluster not only the impacts related to *EcoDrive*, the heavy vehicle charge and other measures inducing general energy efficiency improvements, but also the partial compensation of CO_2 emissions from transport fuel use. The same assumption is made for the electricity generation cluster, which includes not only the feed-in tariff but also the domestic compensation of CO_2 emissions by gas-fired combined-cycle power plants. As can be seen by comparing Figure 26 with Table 13, the sum of each individual measure gives an amount of CO_2 abatement smaller than the difference in emissions between the WOM and the WEM scenario. This difference represents the combined effects of the different measures that lead to additional CO_2 savings. For example, the combination of a CO_2 levy on heating fuels and subsidies to building refurbishment reinforces the impacts on CO_2 saving of each measure. Nevertheless, these combined effects remain limited and represent at most 17% of the total CO_2 saving.

Figure 27 shows the same decomposition but for the WEM+ scenario and relative to the WEM scenario.

Figure 26: Total CO_2 savings by cluster of measures in the WEM scenario relative to WOM scenario (top-down estimation)

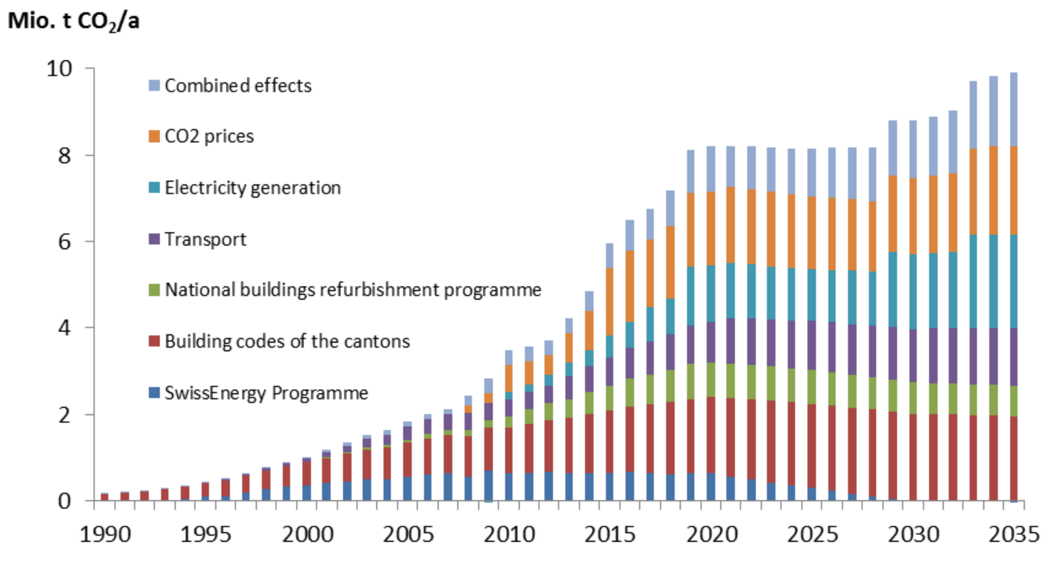
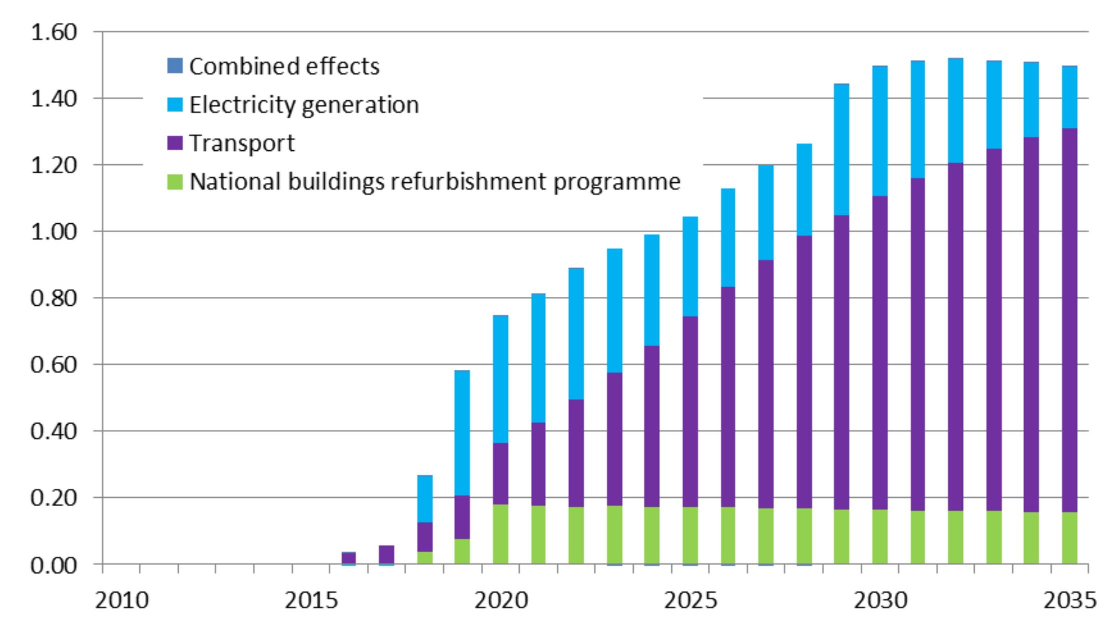


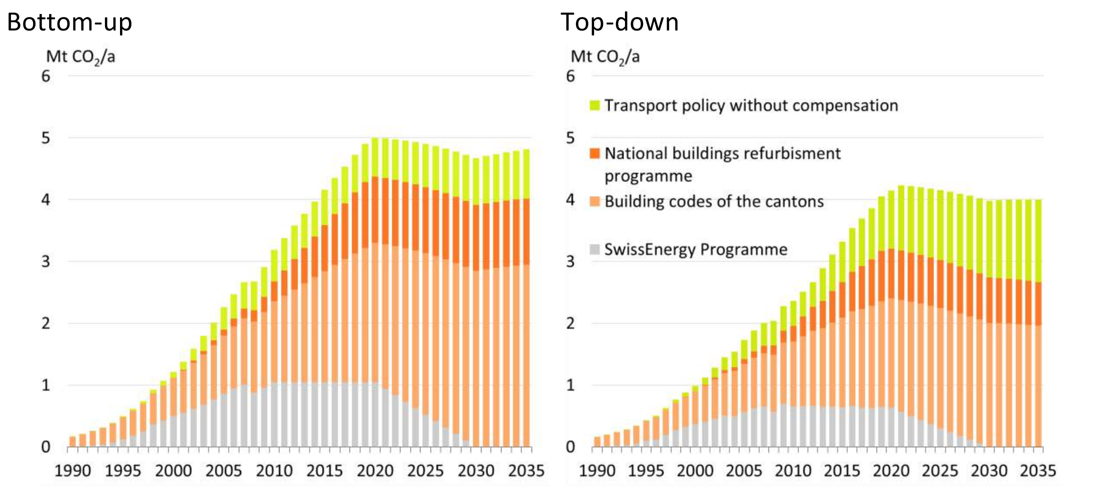
Figure 27: Total CO_2 savings by cluster of measures in the WEM+ scenario relative to WEM scenario (top-down estimation)



4.3.10. Comparison of bottom-up and top-down impact assessments

Figure 28 compares our bottom-up and top-down estimations of the CO_2 savings obtained by the four clusters of measures in the WEM scenario compared to WOM. It is very similar to the comparison made in our first report (INFRAS and EPFL 2016) and we refer our readers to section 4.4.7 of that report for a discussion of the differences between the two approaches and their results.

Figure 28: Comparison of top-down and bottom-up impact assessment in the WEM scenario



In this figure, the transport cluster does not include the CO_2 compensation for transport fuel imports.

5. Discussion and outlook

We refer to the corresponding section of our first report (INFRAS and EPFL 2016) for a discussion of the lessons learned regarding the complex set of instruments used in Swiss energy and climate policy and the difficulties met in modelling the corresponding mitigation effects. Here, we want to point out the main differences in results between this and our earlier report.

The revised scenarios for transport development, less tank tourism due to the appreciation of the Swiss franc, the closure of one of the two Swiss refineries, slightly lower growth rates of GDP and of energy reference area and the decrease of CO_2 emissions in 2015 relative to 2014 are all factors that lead to lower emissions than in the scenarios we estimated last year. Lower expected world prices for crude oil and natural gas operate in the other direction in the short run. In the net, CO_2 emissions from energy combustion are lower by 1 million tonnes in 2020 in the WEM scenario than in our first report. Consequently, the CO_2 levy is no longer raised to 120 CHF/t CO_2 in 2018, but to 96 CHF/t CO_2.

With the measures adopted on 21 May 2017 as part of the first package of measures of the energy strategy 2050 (WEM+ scenario), CO_2 emissions from energy combustion are further reduced by 0.7 Mt in 2020. The additional mitigation impact increases over time, reaching 1.5 Mt or 4.8% in 2035.

When considering these results, it is important to be aware of what is included in the WEM and WEM+ scenarios. Indeed, the individual policies are modified quite rapidly and it is not always obvious what has to be considered as "existing" already and what still needs parliamentary confirmation. We have tried to be very conservative, considering only measures whose introduction or extension was firmly confirmed at the time of writing this report.

Further, the recursive dynamic nature of the model used for the simulations has an impact on the model results and explains a part of the differences in emissions reductions compared to the previous report. For instance, the energy prices (crude oil and gas) are lower in the current version compared to the previous report at around the current year, but (according to the projections used) reach about the same values in 2030. This implies that prices have to rise at higher rate, which sets a stronger price signal. Due to the recursive dynamic set-up of the model, where foresight of the agents (households, firms) is limited to the next year, this leads to additional reductions of emissions compared to the previous report. In 2030, this effect amounts to approximately 0.4 Mt CO_2. In a model with perfect foresight where agents would optimize over the entire time span and take the projected development of prices into account, this effect would be much smaller. The 0.4 Mt CO_2 are therefore a reduction triggered mostly by the inherent dynamics of the model and only to a smaller extent by the fact that energy prices were lower than projected in 2015.

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