How carbon tax could contribute to greater CO_2 and electricity savings in Switzerland

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Abstract

In Switzerland, climate policy includes ambitious CO_2 emissions reduction targets, and a carbon tax is one of the major instruments to achieve them. Currently, about 30 % of carbon tax revenue is used to finance energy efficiency and renewable energy programs (EEREP), while 70 % is redistributed to the energy consumers. The future Swiss climate policy is still under discussion, but taken into account current legal and political basis it is likely that most or even full amount of carbon tax revenue will be redistributed back to energy consumers rather than used to finance EEREP. As another energy policy objective, Switzerland announced the phase-out of nuclear power by the 2030s. With a current share of nuclear power generation of about 40 %, Switzerland is now searching for solutions to replace nuclear energy by energy savings and renewable energy sources. Against this background, we discuss the potential impacts of using the carbon tax revenue for financing EEREP. According to our insights, such a policy choice would not only allow to achieve a considerable reduction of CO_2 emissions or electricity demand (approximately doubling the effect of the CO_2 tax), but it would also lead to other positive socio-economic impacts. CO_2-saving programs could trigger approximately 40 % higher GDP and 60 % higher employment compared with the situation where carbon tax revenue is reimbursed and used for general household needs. In the case of electricity-saving programs the respective values are approximately 10 % of GDP increase and around 25 % higher employment.

Introduction

Carbon taxation has attracted considerable attention from policy makers, researchers and other stakeholders due to its potentially high cost-effectiveness for emission reduction [1, 2]. Major research topics nowadays include interactions and comparison of carbon tax policy with other policies (for example, carbon emissions trading) [3–6]; socio-economic impacts of carbon taxation [7–11]; and impacts of carbon taxes on renewable energy development and energy consumption [2, 6, 12]. There is a large body of research on the optimal tax rate [2, 4, 13–16], while the question of optimal usage of carbon tax revenue received less attention [3, 17–20]. Only few studies advocate that carbon taxation is significantly more effective if the resulting additional revenues are used to finance energy efficiency and renewable energy programs (in the following referred to as EEREP) instead of their use for other purposes [9, 21]. In practice, we observe different ways to use carbon and energy taxes by countries. For example, in Finland, Norway, Sweden, the United Kingdom, Ireland, Australia, Canada (British Columbia) and Mexico, carbon tax revenue contributes to the government budget or is used for reduction of other taxes or for purposes other than climate policy [4, 22]. In contrast, carbon tax revenue is partly or fully used to finance renewable energy or other climate mitigation programs in Denmark, the Netherlands, France, Costa Rica, the USA (parts of Colorado and California), Canada (Quebec) and Japan [4, 22, 23]. Worldwide, only about one quarter of carbon tax revenue is used for “green” purposes [4].

Swiss climate policy objectives include CO_2 emissions reduction by 20 % for the country as a whole and by 40 % in buildings by 2020 compared to 1990 [24–26]. Carbon tax is among the major instruments foreseen for achieving this emissions reduction. Carbon tax is paid by consumers of fossil fuels for heating and process purposes (i.e., households and companies) [24, 27, 29]. In the period 2008–2010, carbon tax revenue was fully redistributed to the energy consumers. Since the adoption of the new *CO_2 Act in 2011* about 26 % of carbon tax revenue has been used to finance EEREP (i.e., *Programme Bâtiment*) and 2 % are assigned to a *Technology Fund* (i.e., *Fonds de téchnologie*) which supports innovation in the field of energy efficiency and renewable energy technologies [24, 27, 28]. All other carbon tax revenues (approximately 70 %) are redistributed to the energy consumers [24]. The carbon tax rate in Switzerland increased steadily over time: from CHF 12/t CO_2 in 2008 to CHF 36/t CO_2 in 2010, and to CHF 60/t CO_2 in 2014 [26].[1] In 2015, *Swiss Federal Office for the Environment* (FOEN) reported that carbon tax rate had not been sufficiently effective to achieve the CO_2 reduction targets established by CO_2 Act, resulting in a tax rise to CHF 84/t CO_2 since the 1st January 2016 [29]. The rate may be further increased to CHF 120/t CO_2 in 2018 [30]. Swiss climate policy is not yet defined for the period after 2020 [24, 26]. The major policy instruments for achieving CO_2 emissions reduction are likely to include the continuous increase of carbon tax rate and legal obligations for energy consumers to implement energy efficiency and renewable energy measures (further referred to as EEREM) [26]. However, the effectiveness of carbon tax can be questioned in times of low and strongly fluctuating fossil energy prices as nowadays. And according to current practice exemptions from legal EEREM obligations in Switzerland for technical and economic reasons are possible [26]. At the same time, there is not much policy support for EEREP: the programs may either continue to be financed from a maximum of 30 % of carbon tax revenue or they may be gradually abandoned [24, 26].

As another energy policy objective, Switzerland announced to phase out nuclear power (currently approx. 40 % of total power generation [31]) by the 2030s [32]. In this context, the country has to find solutions to boost energy savings or renewable energy generation in relatively short time frame.

Against this background this paper addresses the question whether it is advisable to use carbon tax revenue for financing EEREP in Switzerland in order to reach the Swiss climate and energy policy targets. It is the objective of our study to estimate the potential decrease in CO_2 emissions and electricity consumption in Switzerland if the carbon tax revenue, which is nowadays redistributed to households and companies, was used to finance EEREP. We also aim to evaluate socio-economic impacts which this policy choice could have in Switzerland. We first describe data sources and method used to estimate the budget available for financing EEREP, the potential CO_2 emissions reduction and electricity savings, as well as impacts on GDP and employment. We then present the results and compare them with available estimates of carbon tax impacts, as well as Swiss climate and energy policy targets. Finally, we discuss our results from the policy maker's perspective.

1. From 2008 to 2016 EUR to CHF exchange rate fluctuated between 0.98207 and 1.64760, with an average value of 1.07287 [28] XE. Currency Charts (EUR/CHF): http://www.xe.com/currencycharts/?from=EUR&to=CHF&view=10Y: XE; 2015.

Methodology and data sources

Swiss *climate policy targets* include total annual CO_2 emission reduction by 10.74 million t CO_2 in 2020 compared to the 1990 level, with 6.84 million t CO_2 to be saved in buildings [24, 25, 33]. By 2014, the total emissions had been reduced by 5.01 million t CO_2, with buildings contributing most to the savings (5.21 million t CO_2) [33]. Comparison of the target emissions in 2020 with projections according to current policy scenario by the *Federal Department of the Environment, Transport, Energy and Communications* (DETEC) shows a *gap* of 4.13 million t CO_2 in total, including 1.74 million t CO_2 in buildings, that should be addressed by additional policy measures (Figures 1–2) [24–26, 33].

Swiss *energy policy target* includes phase out from 26 TWh/year of nuclear energy by the 2030s (Figure 3) [31, 34].

We estimate the carbon tax revenue and its use in 2008–2016 based on publically available reports and statistics [27–29, 36, 37]. We establish the *total budget* that could theoretically have been used for financing EEREP as the amount of carbon tax revenue minus expenditure on the *Technology Fund*. We also estimate the budget potentially available for financing *additional* EEREP (further referred to as *additional program budget*) as the amount of carbon tax revenue minus expenditure on the *Technology Fund* and on *Programme Bâtiment*.

In order to assess how the alternative use of carbon tax revenue may contribute to the achievement of climate policy targets, we will study examples of Swiss EEREP that provide one-time financial incentives for CO_2 emissions reduction. With regard to energy policy targets, we limit the scope of our study to energy-efficiency programs (EEP) that provide one-time financial incentives based on electricity savings achieved. We do not study electricity-related renewable energy programs as they are financed through feed-in tariffs.

We calculate the *ratios of CO_2 and electricity savings per unit of financial incentives* based on publically available data and internal reports on Swiss EEREP: i) *Programme Bâtiment*[2] operated by *Swiss Federal Office of Energy* (SFOE) and the cantons [35, 38], ii) *ProKilowatt* operated by SFOE which organizes calls for tenders among potential future program administrators and chooses the most cost-effective proposals [39–41] and iii) the *éco21* program portfolio operated by Genevan public utility company *Services Industriels de Genève* (SIG) [42]. A brief description of the studied programs is given in Table 1.

We assume that 25 % of program budget is used to cover *program administration costs*, based on data on *Programme Bâtiment* and examples of large-scale energy efficiency programs in the USA [35, 43] (respective data on *ProKilowatt* is not publically available; we did not consider the cost structure of *éco21* due to relatively small scale of the program). We calculate potential CO_2 and electricity savings as the difference between *total* or *additional program budget* and *program administration costs*, multiplied by the *ratios of first-year CO_2 and electricity savings per unit of financial incentives* (in other words, *financial incentives* multiplied by *savings per unit of financial incentives*).[3]

2. *Building Program* in English, *Gebäudeprogramm* in German.

3. We use *first-year CO_2 and electricity savings* (as opposed to *savings over lifetime of technical measures*) to be in accordance with the climate and energy policy objectives of reducing *annual* CO_2 emissions and electricity consumption respectively.

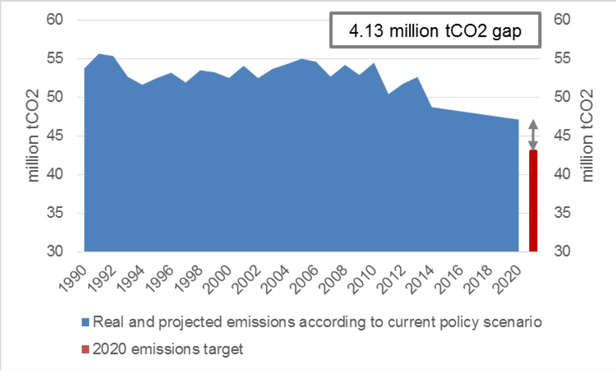

Figure 1. Total CO_2 emissions according to current policy scenario and CO_2 emissions target 2020 (all sectors) [24–26, 33].

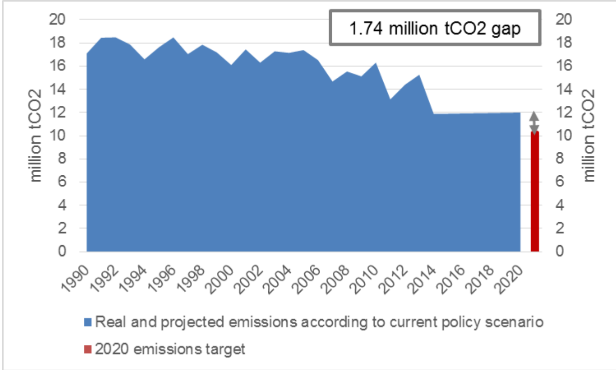

Figure 2. Total CO_2 emissions according to current policy scenario and CO_2 emissions target 2020 (buildings) [24–26, 33].

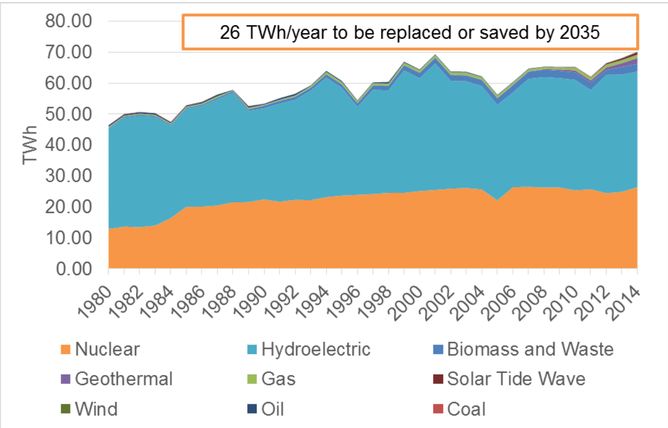

Figure 3. Electricity generation in Switzerland by energy source, TWh [31].

Table 1. Description of the studied EEREP*.

Program	Sub-program	Focus	Period
Programme Bâtiment	A	CO_2 savings through energy efficiency measures in buildings	2010–2014
	B	CO_2 savings through renewable energy measures in buildings	2010–2014
ProKilowatt	Programs	Electricity savings through energy efficiency measures in residential and non-residential** sectors (one measure type for multiple consumers).	2010–2014
	Projects	Electricity savings through energy efficiency measures in residential and non-residential** sectors (multiple measure types for one consumer).	2010–2014
éco21	Eco-sociales	Electricity and CO_2 savings in low income households	2009–2015
	Communs d'immeubles	Electricity savings in common spaces of buildings	2009–2015
	Ménages et indépendants	Electricity savings in households	2009–2012
	Chaleur renouvelable	Electricity and CO_2 savings in single-family households	2013–2015
	Négawatt	Electricity and CO_2 savings in big consumers (annual electricity consumption ≥1 GWh/year or fossil fuel consumption for heating and processes ≥4 GWh/year)	2012–2015
	Incitations transitoires	Electricity and CO_2 savings in big consumers (prior to program Négawatt)	2008–2012
	Optiwatt	Electricity savings in small and medium enterprises	2010–2015

** Sources: [38, 39, 42].*

*** Non-residential includes industrial, commercial and public sectors.*

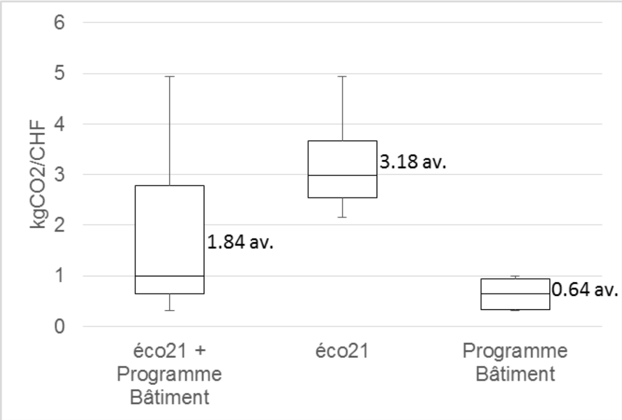

Figure 4. First-year CO_2 savings per unit of financial incentives paid by Swiss energy programs.

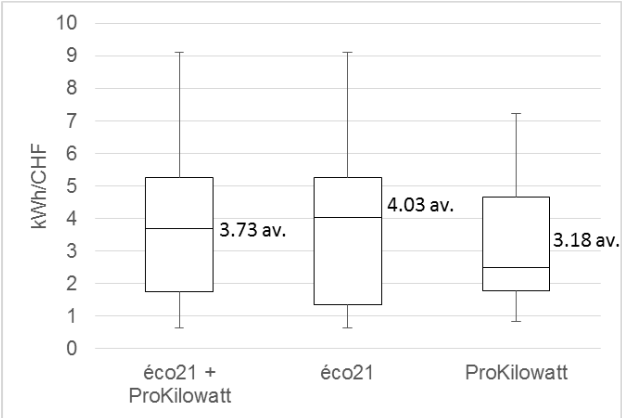

Figure 5. First-year electricity savings per unit of financial incentives paid by Swiss energy programs.

In order to evaluate impacts of EEREP on GDP and employment we use an input-output model developed by Yushchenko et Patel for Switzerland [44]. We evaluate both impacts related to initial investment (i.e., implementation of EEREM) and to energy cost savings (i.e., during post-installation period). In this approach, we estimate *CO_2 and electricity savings over the lifetime of the technical measures.*[4] In order to estimate *energy cost savings over lifetime of technical measures*, we use dynamic energy prices according to Swiss and European statistics and price projections by *Prognos*, *New Energy Policy* scenario [32, 45–52]. We use a discount rate of 2.5 %, based on data on 10-years Swiss government bonds [53], interest rates for households and the private sector [54, 55], and inflation rate in Switzerland [56]. As the carbon tax revenue is currently redistributed to households and to companies based on the payroll expenditure, we assume that households ultimately benefit from carbon tax revenue redistribution. When the carbon tax revenue is used to finance EEREP, the households carry the costs of EEREP[5] and a part of EEREM not covered by financial incentives (programme participant contributions), and at the same time they benefit from energy cost savings as a result of implementation of EEREM.[6]

Results and discussion

COST-EFFECTIVENESS OF EEREP

Figure 4 shows the values of *first-year CO_2 savings per unit of financial incentives* paid by the Swiss EEREP. Overall, for CHF 1 of financial incentive paid, 0.32–4.93 $kgCO_2$ were avoided per year (1.84 on average, 0.65 first quartile, 2.77 third quartile values).[7] The level of *first-year CO_2 savings per unit of financial incentives* is higher in the case of *éco21* compared to *Programme Bâtiment*.

The ratios of *first-year electricity savings per unit of financial incentives* paid by Swiss EEP are presented in Figure 5. For CHF 1 of financial incentive paid, 0.63–9.10 kWh are saved per year (3.73 on average, 1.75 first quartile, 5.27 third quartile values). The level of *first-year electricity savings per unit of financial incentives* is in the similar range in the case of *éco21* and *ProKilowatt* programs.

To obtain deeper understanding of the difference in cost-effectiveness of Swiss EEREP (Figures 4–5) we calculated the *ratios of financial incentives per unit of CO_2 and electricity savings over the lifetime of technical measures* by type of technical measure (where data is available) [35, 40, 41]. We saw that the programs make different assumptions about the lifetime of technical measures, with generally longer lifetimes being assumed in the case of *Programme Bâtiment* and *ProKilowatt* compared to *éco21*. Nevertheless, the amount of financial incentives paid per unit of CO_2 or electricity savings over the lifetime of technical measures is lower in *éco21*. For example, for windows, *Programme Bâtiment* pays CHF 74/t CO_2 over the lifetime of technical measure (37 years), while *éco21* pays CHF 18/t CO_2 over the lifetime of technical measure (22 years). In the case of lighting, *ProKilowatt* pays ctCHF 5.15/kWh over the lifetime of technical measure (16 years), while *éco21* pays ctCHF 4.02/kWh over the lifetime of technical measure (9 years). When evaluating potential impacts of EEREP, it is important to take into account that the financial incentives vary depending on the desired participation level and availability of other types of support provided by program administrator (e.g., energy advice, other non-financial incentives). As further explanatory factors, the characteristics of the technical measures (e.g. thermal insulation in *Programme Bâtiment* versus *éco21*) may differ. It should also be noted that EEREP with lowest financial incentives may ultimately not be the most effective because low financial incentives may potentially increase the share of free-riders, as they are not helpful to consumers who actually face financial constraints for implementation of EEREM [57]. The level of financial incentives may also differ depending on the program focus. For example, in a low-income household program *Eco-sociales* the level of financial incentives paid per unit of electricity savings over

4. We use *CO_2 and electricity savings over the lifetime of technical measures* (as opposed to *first-year savings*) to evaluate overall macroeconomic impacts, related to both initial investment and energy cost savings.

5. In this case, the households do not receive carbon tax reimbursement and are not able to spend this money on other goods and services.

6. This hence reduces the energy bills of households, allowing them to purchase of other goods and services.

7. Average values are calculated as arithmetic mean of annual values by the sub-program of the studied EEREP (Table 1). No weighting is applied with regard to program scale; but the results are determined by the number of data points, which is superior in case of *éco21* compared to *Programme Bâtiment* and *ProKilowatt.*

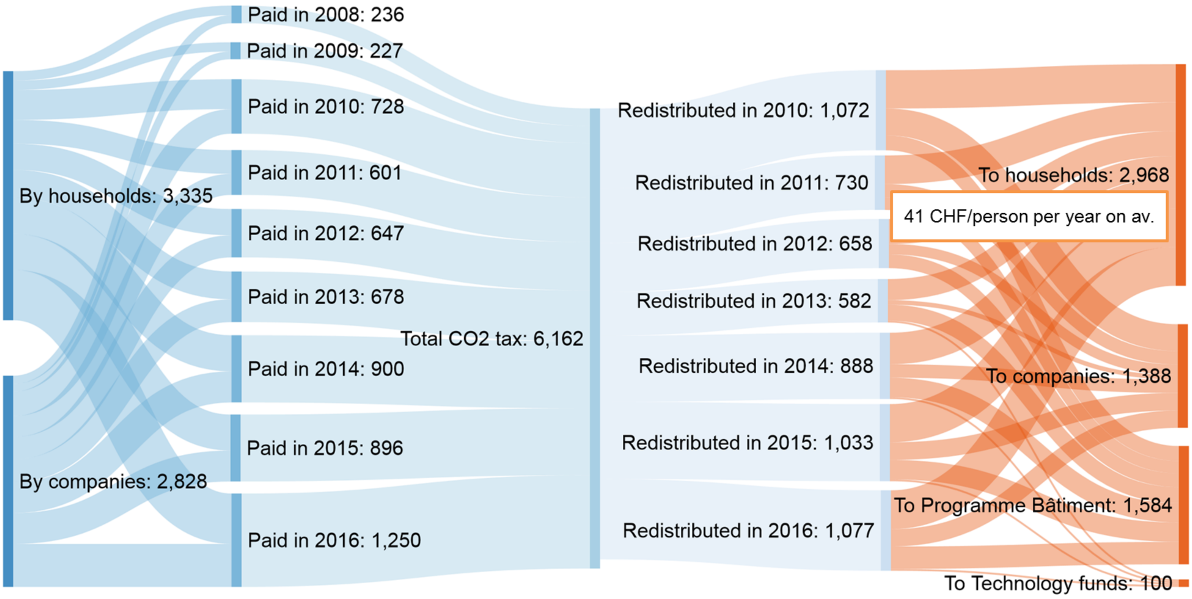

Figure 6. Carbon tax revenue and use (compiled based on [27, 35–37]).

the lifetime of technical measures is by nearly 2 up to 22 times higher than in the other *éco21* programs.

Given the high variation in the values of *CO_2 and electricity savings per unit of financial incentives*, we choose to work with average, first and third quartile values of these parameters, and our results should therefore be interpreted as indicative.

CARBON TAX REVENUE AND USE

Estimates of carbon tax revenue and use are presented in Figure 6. In 2008–2016 approximately CHF 6.2 billion of carbon tax were collected (i.e., *total budget* accounted in our study), of which CHF 1.6 billion was used to finance *Programme Bâtiment*, CHF 0.1 billion were transferred to the *Technology Fund* and CHF 4.4 billion were redistributed back to energy consumers. *Additional program budget* is equal to CHF 4.5 billion which accounts for carbon tax revenue received minus redistributed to *Programme Bâtiment* and the *Technology Fund*.[8]

EVALUATION OF POTENTIAL CO_2 AND ELECTRICITY SAVINGS[9]

By combining the *total budget* of CHF 6.2 billion (Figure 6) with the average, first and third quartile values of *first-year CO_2 and electricity savings per unit of financial incentives* (Figures 4–5), we obtain an estimate of the cumulative potential CO_2 and electricity savings from 2008 to 2016, if all carbon tax revenue in 2008–2016 had been used to finance CO_2 and electricity-saving programs respectively (Figures 7–8).[10]

We estimate the potential CO_2 savings at about 8.1 million t CO_2 saved annually by 2016, with first and third quartile values of 2.9 and 12.2 million t CO_2 respectively (accounting for the difference in cost-effectiveness; Figure 4).[11] The average value represents about 75 % of all CO_2 emissions to be reduced in Switzerland from 1990 to 2020 (10.7 million t CO_2) and about 118 % of building emissions to be reduced within the same period (6.8 million t CO_2) [24–26, 33]. This high percentage indicates a substantial leverage of using CO_2 tax revenue for EEREP.

Recently, two evaluations of the impacts of current carbon tax in Switzerland (with reimbursement of the tax revenue to energy consumers) were published [58–60], according to which carbon tax allowed to save between 2.4 and 5.4 million t CO_2 annually by the year 2013 (Figure 7), with the lower value tending to be underestimated and the upper value being overestimated [58]. According to our estimates, the full use of carbon tax revenue for financing EEREP from year 2008 until 2013 could result in similar cumulative potential CO_2 savings as the effect of the carbon tax, i.e. it could approximately abate 4.2 million t CO_2 per year on average (Figure 7). Combining the effect of the carbon tax with the full use of the carbon tax revenue for financing EEREP could therefore allow to increase the impact of the carbon tax at least by a factor of 2.

If the full carbon tax revenue 2008–2016 were used to finance electricity-saving programs, this could result in about 16.4 TWh saved annually by the year 2016 on average, with first and third quartile values of 7.7 and 23.1 TWh/year respectively (accounting for the difference in cost-effectiveness; Figure 5). This average quantity represents about a quarter of all power

8. There is a 3 % difference between *additional program budget* accounted in the study (CHF 4,478 million) and the sum of carbon tax revenue redistributed back to energy consumers (CHF 4,356 million). According to our understanding this is due to the fact that not all carbon tax revenue collected was redistributed (CHF 6,162 million received vs. CHF 6,040 million redistributed back to energy consumers, *Programme Bâtiment* and the *Technology Fund*).

9. In the sections "Evaluation of potential CO_2 and electricity savings" and "Socio-economic impacts of additional EEREP" we evaluate the effects of using carbon tax revenue for financing EEREP (as opposed to redistributing carbon tax revenue back to energy consumers). We do not evaluate the direct effects of carbon tax (i.e., the fact of having the tax, impact of tax rate) on energy consumption.

10. Here, we take the sum of *total budget* for the purpose of comparing effectiveness of EEREP and carbon tax. Further, we will study potential contribution of additional EEREP with regard to Swiss *climate* and *energy policy targets* by using *additional program budget* in calculations.

11. These results account for 25 % of *total budget* to be used to cover program administration costs and 75 % to pay financial incentives.

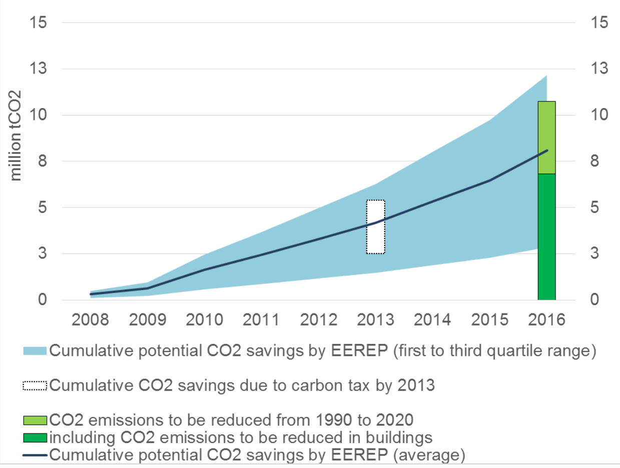

Figure 7. Cumulative potential CO_2 savings by EEREP (with use to total budget) compared to the impacts of CO_2 tax and climate policy targets.

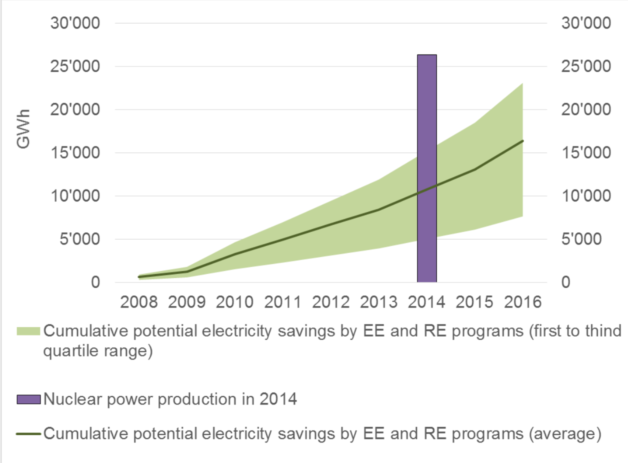

Figure 8. Cumulative potential electricity savings by EEP (with use of total budget) compared to the energy policy target.

generated in Switzerland or about 60 % of nuclear power generation (Figure 3).[12]

In the following we make similar comparisons as above but instead of basing them on the *total budget* of CHF 6.2 billion we assume only the *additional program budget* of CHF 4.5 billion (Figure 6). In combination with the average, first and third quartile values of *first-year CO_2 and electricity savings per unit of financial incentives* (Figures 4–5), we obtain an estimate of potential additional CO_2 and electricity savings. According to these estimates, *additional* EEREP could result in about 6 million t CO_2 saved annually by the year 2016 on average (with first to third quartile range of 2.1–9.0 million t CO_2). This covers *climate policy target gap* with regard to total emissions (4.13 million t CO_2, Figure 1) by about 145 %. *Climate policy target gap* in buildings (1.74 million t CO_2, Figure 2) could be covered by at least 120 % if all CO_2-saving measures were implemented in this sector. It should be taken into account that *additional* CO_2 savings are estimated based on the example of EEREP programs that cover about a quarter of EEREM costs[13] with financial incentives [35]. The rest of the costs are covered by program participants (i.e., energy consumers implementing EEREM). Such an approach has limitations for the buildings sector in Switzerland due to a high number of tenants (over 60 %) and legal constraints prohibiting building owners to transfer the costs of EEREM to the tenants or recover the benefits from energy bills reduction [61, 62]. Under these circumstances, energy contracting could be a more efficient alternative compared to financial incentives. Nowadays, energy contracting is not a common practice in Switzerland. Carbon tax mechanism could be used to boost this type of activity, e.g. by facilitating capital access for contracting projects.

If the *additional program budget* was used for electricity-saving programs, it could result in about 12.1 TWh saved annually by the year 2016 on average (first to third quartile values of 5.7–17.1 TWh/year). The estimated average amount of electricity saving is equal to 46 % of nuclear power generation in Switzerland in 2014. Two factors should be taken into account when interpreting these results. First, the electricity sector in Switzerland is interconnected with European markets. There is about an equal volume of domestic electricity production and import in the current consumption mix [52]. Second, power load of nuclear stations is constant. Therefore, electricity savings achievable by additional EEP would impact the electricity sector as a whole, and not directly lead to reduction in nuclear power generation.

To summarize, the use of the carbon tax revenue for financing EEREP would offer significant additional CO_2 and electricity savings compared to the Switzerland's current policy mechanism. While EEREP are sometimes criticized for the free-rider effect [57], this argument seems less relevant for Switzerland because the CO_2 tax revenue would otherwise anyway have been reimbursed. There could be various distributional effects, however, which call for further research.

SOCIO-ECONOMIC IMPACTS OF ADDITIONAL EEREP

Table 2 presents our estimates of potential socio-economic impacts of EEREP if they were financed from *additional program budget* (CHF 4.5 billion; Figure 6).[14] These results were calculated with an input-output model developed by Yushchenko et Patel for Switzerland [44].

In case of CO_2-saving programs we apply a conservative approach by assuming the same cost structure as in the case of *Programme Bâtiment* (more expensive than *éco21*; Figure 4). Envelope and energy supply solutions represent respectively 60 % and 40 % of EEREM implemented [35].[15] In the case of envelope solutions about 0.34 kg CO_2 are avoided per CHF 1 of financial incentives paid, financial incentives cover 26 % of EEREM costs of these envelope solutions [35]. In the case of energy supply solutions (more efficient heating/cooling) approxi-

12. The latest available data on nuclear power generation (for 2014) is used as basis for our comparison with the calculated *cumulative potential electricity savings* in 2016; this is justified in view of the continued operation of the Swiss nuclear power plants.

13. Costs of equipment and installation services.

14. As explained above, we assume that additional EEREP support EEREM in the residential sector.

15. Envelope and energy supply solutions correspond to EEREM measures supported within sub-program A and B of *Programme Bâtiment* respectively.

mately 0.94 kg CO_2 are saved per CHF 1 of financial incentives (Figure 4), with financial incentives covering 22 % of EEREM costs [35]. With the abovementioned hypotheses, the estimated impacts of additional EEREP would be CHF 6 billion of net benefits to households (i.e., energy cost saving minus program administration and EEREM costs). Net GDP increase would be about CHF 7 billion, which is +43 % compared to the reference case scenario (i.e., if the carbon tax revenue was redistributed back to energy consumers who used it according to standard household consumption pattern). The net impacts on employment would be about 62,000 jobs in full-time equivalent, which is +61 % compared to the reference case scenario.

Electricity-saving programs *ProKilowatt* and *éco21* are similar with regard to their cost-effectiveness (Figure 5). For our calculations we assume an average value of 3.46 kWh per CHF 1 of financial incentives paid, with financial incentives covering 22 % of EEREM costs. About 40 % of EEREM measures concerns lighting, the remainder includes heating equipment (17 %), domestic appliances (16 %), pumps and compressors (7 %), and other types of measures (less than 6 % for each category). Additional EEREP could result in about CHF 6.7 billion of net benefits to households. It could generate about CHF 2 billion of net GDP (+11 % compared to the reference case scenario) and a net employment effect of about 31,000 jobs in full-time equivalent (+26 % compared to the reference case scenario).

The socio-economic benefits are higher in the case of CO_2-saving EEREP compared to electricity-saving programs. This can be explained by a longer lifetime of technical measures as well as the fact that fossil fuels used for heating are imported, while a significant part of electricity supply originates from domestic generation [44].

LIMITS OF THE STUDY AND PROSPECTS FOR FURTHER RESEARCH

We use a simple approach in this paper, assuming that total amount of carbon tax revenue currently redistributed to households and companies is used to finance either carbon or electricity saving programs, and that cost-effectiveness of these additional programs is equal to the cost-effectiveness of the existing EEREP in Switzerland. We use this approach for illustrative purposes as the use of carbon tax revenue is rarely discussed by academia or policy-makers. In practice it is a matter of political decision whether to use the carbon tax revenue for increased funding of EEREP and if so, to what extent. And it is up to program administrators how they design their programs and use the program budget in general.

In order to perform more accurate estimates on how carbon tax revenue can be better used for achieving climate and energy policy targets in Switzerland, one should account for CO_2 and energy-saving potentials by sub-sector (e.g., multifamily houses, restaurants) and type of technical measure (e.g., lighting, compressors). It is also important to account for barriers that limit feasibility and slow uptake. How many consumers can be actually attracted to participate in EEREP per year (taken into account current equipment stock, achievable level of awareness about the energy programs, consumer willingness and financial opportunities to spend on EEREM)? How many EEREM can be actually implemented by year (taking into account the number of energy service companies on the market)?

When evaluating potential impacts of EEREP, it is important to remember that financial incentives are not the available only instrument. Apart from energy contracting discussed above, program administrators can run awareness campaigns for households, support implementation of energy management in companies and public sector, as well as provide trainings for energy managers, ESCOs and installers. These measures can contribute both to enhanced deployment of renewable energy and implementation of energy saving measures.

Other potential impacts of EEREP should be taken into account as well. For example, EEREP can potentially contribute to decreasing costs of equipment and improving quality of installation services as a result of a higher rate of implementation of EEREM. There may also be spill-over effects when EEREP increase awareness and social acceptance of certain technolo-

Table 2. Socio-economic impacts of additional EEREP.

	CO_2 saving programs	Electricity-saving programs
Incremental energy impacts		
Cumulative first-year CO_2 savings, million t CO_2	1.96	0.00*
Cumulative first-year final energy savings, GWh	7,790	11,610
Incremental costs		
Program costs (financial incentives + program administration), million CHF	4,480	4,480
Costs for program participants (costs of EEREM minus financial incentives), million CHF	9,556	11,122
Incremental benefits		
Energy cost savings for participants, million CHF	20,050	22,950
Net GDP, million CHF	7,187	2,047
GDP change	1.43	1.11
Net employment, FTE	61,900	30,600
Employment change	1.61	1.26

** Electricity-saving EEREP in Switzerland do not result in CO_2 savings due to the overwhelming share of hydro and nuclear power (together about 95 %) [52].*

gies and these technologies become more easily adopted by energy consumers even without financial or any other incentives. In contrast, one should also account for potential rebound effects and increased marginal costs of CO_2 and electricity-saving measures (the most cost-effective potentials may gradually be used up and cost level could increase at one point). There may be conflicts between carbon- and energy-policy targets (e.g., saving CO_2 by replacing fossil fuel-based boilers by heat pumps leads to increased electricity demand). Also, there could be distributional impacts on households and companies if a lower share of the carbon tax is redistributed to them. In the case of Switzerland, these impacts would be rather insignificant: in 2016 households received about CHF 62.5/person of carbon tax refund, which accounts for only about 0.1 % of median gross annual wage [63].

Conclusions

Our results show that the implementation of a carbon tax at a given tax rate has approximately the same effect on CO_2 emissions reduction as an EEREP with a funding volume equivalent to the CO_2 tax revenue. While this finding does not provide strong arguments for one or the other approach, it is important to realize that use of carbon tax revenue for financing EEREP in Switzerland could at least double the overall policy impact and hence make a significant additional contribution to achievement of Swiss *climate* and *energy policy targets*. According to our estimates, if carbon tax revenue currently redistributed to households and companies in 2008–2016 had been used to finance CO_2-saving EEREP, it could have resulted in about 6 million t CO_2 saved per year by 2016, or about 145 % of the *gap* between 2020 emissions projected according to the current policy tendency scenario and 2020 target emissions. If this money had been used to finance electricity-saving EEP, it would have allowed to save about 12.1 TWh/year by 2016, which is equal to 46 % of the volume of nuclear power generation in Switzerland nowadays. It should also be noted that the cost-effectiveness of the various EEREP considered differs very substantially, indicating that a smart design of EEREP may allow to reach the same energy and climate policy goals at lower cost.

Using carbon tax revenue for EEREP can be seen as alternative or complementary measure to future increase of carbon tax rate. This is of particular importance given low price elasticity of heat demand [64, 65] and the fact that in practice carbon tax rate increase can be limited for various political reasons, which are not necessarily in accordance with economic reasoning of setting the tax rate to a sufficiently high level to achieve emission reduction goals [66, 67].

Our study represents a contribution to the current body of knowledge on carbon tax as we raise the question of how to better use carbon tax revenue, a question that has so far not received enough attention of academia and policy-makers. We use a simple approach to illustrate that there are alternatives to setting ever-higher carbon tax rates. Instead, the currently reimbursed carbon tax revenue can be used to support other policy mechanisms such as EEREP and consequently, have wider impacts on energy consumption. The results of this study can be of interest for other locations than Switzerland, as carbon tax exists in many countries while only some of them use the tax revenue to finance EEREP.

In practice, it is a matter of political decision whether to increase the share of carbon tax revenue to be used for financing EEREP in Switzerland. There is uncertainty about the social acceptance of this measure, as contrary to redistributing carbon tax revenue to households and companies, not everybody will benefit from financial incentives offered by EEREP [68, 69]. This barrier may be partially mitigated by greater emphasis on residential (and especially low income households) programs. And a relatively low level of carbon tax rate nowadays, which results in a small sum of tax revenue redistributed per person per year, could be seen as another alleviating factor. Another important argument is that using carbon tax revenue to finance EEREP can also bring benefits to households and the economy as a whole. CO_2-saving programs could trigger approximately 40 % higher GDP and 60 % higher employment compared to the situation when carbon tax revenue is reimbursed and used for general household needs. In the case of electricity-saving programs the respective values are approximately 10 % of GDP increase and around 25 % more employment.

If it is found politically and socially acceptable to use a higher share of the carbon tax revenue for financing EEREP, an equilibrium should be found with regard to financing different programs in order to maximize goal achievement of the various policy targets (e.g., CO_2 emissions reduction versus electricity generation reduction). EEREP could ultimately be used as tools for development of smart energy systems in which electricity, heat and transport networks are mutually coordinated in order to exploit synergies and assure maximum efficiency of the processes [70]. EEREP may also be designed to support energy contracting, offering a gradual transition towards more market-oriented approaches.

References

[1] Baranzini A, Goldemberg J, Speck S. A future for carbon taxes. Ecological Economics. 2000; 32: 395–412.
[2] Zhang K, Wang Q, Liang Q-M, Chen H. A bibliometric analysis of research on carbon tax from 1989 to 2014. Renewable and Sustainable Energy Reviews. 2016; 58: 297–310.
[3] Liu Y, Lu Y. The Economic impact of different carbon tax revenue recycling schemes in China: A model-based scenario analysis. Applied Energy. 2015; 141: 96–105.
[4] Carl J, Fedor D. Tracking global carbon revenues: A survey of carbon taxes versus cap-and-trade in the real world. Energy Policy. 2016; 96: 50–77.
[5] Abolhosseini S, Heshmati A. The Main Support Mechanisms to Finance Renewable Energy Development. http://repec.iza.org/dp8182.pdf: The Institute for the Study of Labor (IZA); 2014.
[6] Connor P, Bürger V, Beurskens L, Ericsson K, Egger C. Devising renewable heat policy: Overview of support options. Energy Policy. 2013; 59: 3–16.
[7] Jiang Z, Shao S. Distributional effects of a carbon tax on Chinese households: A case of Shanghai. Energy Policy. 2014; 73: 269–77.
[8] Mathur A, Morris AC. Distributional effects of a carbon tax in broader U.S. fiscal reform. Energy Policy. 2014; 66: 326–34.

[9] Pereira AM, Pereira RM, Rodrigues PG. A new carbon tax in Portugal: A missed opportunity to achieve the triple dividend? Energy Policy. 2016; 93: 110–8.
[10] Rocchi P, Serrano M, Roca J. The reform of the European energy tax directive: Exploring potential economic impacts in the EU27. Energy Policy. 2014; 75: 341–53.
[11] Klenert D, Mattauch L. How to make a carbon tax reform progressive: The role of subsistence consumption. Economics Letters. 2016; 138: 100–3.
[12] Levin T, Thomas VM, Lee AJ. State-scale evaluation of renewable electricity policy: The role of renewable electricity credits and carbon taxes. Energy Policy. 2011; 39: 950–60.
[13] Landis F, Rausch S, Kosch M. Is a Uniform Carbon Tax a Good Idea? The Case of Switzerland. https://www.mtec.ethz.ch/content/dam/ethz/special-interest/mtec/cer-eth/economics-energy-economics-dam/documents/people/srausch/paper_SCCER_CREST_Landis_Rausch_Kosch_Feb2016.pdf2016.
[14] Hammar H, Jagers SC. What is a fair CO_2 tax increase? On fair emission reductions in the transport sector. Ecol Econ. 2007; 61: 377–87.
[15] Mori K. Modeling the impact of a carbon tax: A trial analysis for Washington State. Energy Policy. 2012; 48: 627–39.
[16] Amstalden RW, Kost M, Nathani C, Imboden DM. Economic potential of energy-efficient retrofitting in the Swiss residential building sector: The effects of policy instruments and energy price expectations. Energy Policy. 2007; 35: 1819–29.
[17] Barker T, KÖHler J. Equity and Ecotax Reform in the EU: Achieving a 10 per cent Reduction in CO_2 Emissions Using Excise Duties. Fiscal Studies. 1998; 19: 375–402.
[18] Allan G, Lecca P, McGregor P, Swales K. The economic and environmental impact of a carbon tax for Scotland: A computable general equilibrium analysis. Ecological Economics. 2014; 100: 40–50.
[19] Murray B, Rivers N. British Columbia's revenue-neutral carbon tax: A review of the latest "grand experiment" in environmental policy. Energy Policy. 2015; 86: 674–83.
[20] Johnson KC. Refunded emission taxes: A resolution to the cap-versus-tax dilemma for greenhouse gas regulation. Energy Policy. 2007; 35: 3115–8.
[21] Lees E. Energy Efficiency Obligations – the EU experience. eceee briefing for DG Energy on EU energy efficiency obligations on energy companies and their importance in meeting climate change and energy security challenges. http://www.eceee.org/policy-areas/EE-directive/energy-efficiency-obligations: Eoin Lees Energy; 2012.
[22] C2ES. Options and Considerations for a Federal Carbon Tax. http://www.c2es.org/publications/options-considerations-federal-carbon-tax: Center for Climate and Energy Solutions; 2013.
[23] Sovacool BK. Energy policymaking in Denmark: Implications for global energy security and sustainability. Energy Policy. 2013; 61: 829–39.
[24] Federal Council. Federal Act on the Reduction of CO_2 Emissions 641.71. https://www.admin.ch/opc/fr/classified-compilation/20091310/201301010000/641.71.pdf: The Federal Council; 2011.
[25] Federal Council. Ordonnance sur la réduction des émissions de CO_2 641.711. https://www.admin.ch/opc/fr/classified-compilation/20120090/201306010000/641.711.pdf: The Federal Council; 2012.
[26] DETEC. Politique climatique de la Suisse. Rapport explicatif relatif au projet mis en consultation. https://www.admin.ch/ch/f/gg/pc/documents/2801/Politique-climatique-de-la-Suisse-post-2020_Rapport-expl_fr.pdf: The Federal Department of the Environment, Transport, Energy and Communications (DETEC); 2016.
[27] FOEN. Fiches de redistribution du produit de la taxe sur le CO_2 à la population et aux entreprises. http://www.bafu.admin.ch/klima/13877/14510/14749/index.html?lang=fr: Federal Office for the Environment; 2016.
[28] XE. Currency Charts (EUR/CHF). http://www.xe.com/currencycharts/?from=EUR&to=CHF&view=10Y: XE; 2015.
[29] FOEN. Objectif de réduction 2014 manqué: hausse de la taxe CO_2 sur les combustibles en 2016. https://www.news.admin.ch/message/index.html?lang=fr&msg-id=58016: Federal Office for the Environment; 2016.
[30] FOEN. Émissions de gaz à effet de serre visées par la loi sur le CO_2 révisée et par le Protocole de Kyoto, 2^{e} période d'engagement (2013–2020). http://www.news.admin.ch/NSBSubscriber/message/attachments/39137.pdf: Federal Office for the Environment; 2016.
[31] The Shift Project. Breakdown of Electricity Generation by Energy Source. http://www.tsp-data-portal.org/Breakdown-of-Electricity-Generation-by-Energy-Source#tspQvChart: The Shift Project; 2016.
[32] Prognos. Die Energieperspektiven für die Schweiz bis 2050. Energienachfrage une Elektrizitätsangebot in der Schweiz 2000–2050. Ergebnisse der Modellrechnungen für das Energiesystem. In: Prognos A, editor. Basel: Prognos AG; 2012.
[33] FOEN. Tableau 8 (inventaire de gaz à effet de serre) : Émissions de gaz à effet de serre visées par la loi sur le CO_2 et le Protocole de Kyoto, par secteur (cf. tableau 10, inventaire de gaz à effet de serre, pour le détail de la composition des secteurs). http://www.bafu.admin.ch/klima/13879/13880/14486/index.html?lang=fr&download=NHzLpZeg7t,lnp6I0NTU042l2Z6ln1ae2IZn4Z2qZpnO2Yuq2Z6gpJCHeXt2gmym162epYbg2c_JjKbNoKSn6A--: Federal Office for the Environment; 2016.
[34] SFOE. Message relatif au premier paquet de mesures de la Stratégie énergétique 2050 et à l'initiative populaire fédérale «Pour la sortie programmée de l'énergie nucléaire» http://www.admin.ch/opc/fr/federal-gazette/2013/6771.pdf: Swiss Federal Office of Energy; 2013.
[35] SFOE. Le Programme Bâtiment. Rapports généraux de gestion. http://www.dasgebaeudeprogramm.ch/index.php/fr: Swiss Federal Office of Energy; 2014.
[36] UVEK. Liste abgabebefreite Unternehmen – Emissionsziel. Eidgenössisches Departement für Umwelt, Verkehr, Energie und Kommunikation UVEK Bundesamt für Umwelt BAFU Abteilung Klima; 2016.

[37] SFSO. Bilan de la population résidante permanente. http://www.bfs.admin.ch/bfs/portal/fr/index/themen/01/02/blank/key/bevoelkerungsstand/02.Document.199360.xls: Swiss Federal Statistical Office; 2016.

[38] SFOE. Le Programme Bâtiments. http://www.dasgebaeudeprogramm.ch/index.php/fr/: Swiss Federal Office of Energy; 2016.

[39] SFOE. ProKilowatt. http://www.bfe.admin.ch/prokilowatt/: Swiss Federal Office of Energy; 2016.

[40] SFOE. ProKilowatt. Projets soutenus. http://www.bfe.admin.ch/prokilowatt/06034/06035/index.html?lang=fr&dossier_id=05957: Swiss Federal Office of Energy; 2016.

[41] SFOE. ProKilowatt. Programmes soutenus. http://www.bfe.admin.ch/prokilowatt/06034/06036/index.html?lang=fr&dossier_id=05957: Swiss Federal Office of Energy; 2016.

[42] SIG. éco21. http://www.eco21.ch/eco21.html: Services Industriels de Genève; 2016.

[43] Friedrich K, Eldridge M, York D, Wite P, Kushler M. Saving Energy Cost-Effectively: A National Review of the Cost of Energy Saved Through Utility-Sector Energy Efficiency Programs. American Counsil for an Energy-Efficient Economy; 2009.

[44] Yushchenko A, Patel MK. Contributing to a green energy economy? A macroeconomic analysis of an energy efficiency program operated by a Swiss utility. Applied Energy. 2016; 179: 1304–20.

[45] ELCOM. Site Internet de l'ElCom concernant les prix de l'électricité. https://www.prix-electricite.elcom.admin.ch: Federal Electricity Commission ElCom; 2015.

[46] DEFR. Site du Surveillant des prix relatif aux prix du gaz naturel. http://gaspreise.preisueberwacher.ch/web/index.asp?l=1: Federal Department of Economy, Education and Research (DEFR); 2016.

[47] ERDOEL. Mazout – Moyenne Annuelle. https://www.erdoel.ch/fr/combustibles-chauffage/chiffres-faits/mazout-moyenne-annuelle: Union Pétrolière; 2016.

[48] SFSO. IPC, prix moyens de l'énergie et des carburants, valeurs mensuelles (depuis 1993) et annuelles (depuis 1966). https://www.bfs.admin.ch/bfs/fr/home/statistiques/prix.assetdetail.1281416.html: Swiss Federal Statistical Office; 2016.

[49] SFOE. Evolution des marchés des énergies fossiles. http://www.bfe.admin.ch/themen/00486/?dossier_id=04356&lang=fr: Swiss Federal Office of Energy; 2016.

[50] EC. Market analysis. Gas and electricity market reports. Quarterly Reports On European Electricity Markets. https://ec.europa.eu/energy/en/statistics/market-analysis European Commission; 2016.

[51] EC. Market analysis. Gas and electricity market reports. Quarterly Reports On European Natural Gas Markets. https://ec.europa.eu/energy/en/statistics/market-analysis European Commission; 2016.

[52] IEA. Energy Policies of IEA Countries. Switzerland. 2012 Review.: International Energy Agency; 2012.

[53] Trading Economics. Switzerland Government Bond 10Y. http://www.tradingeconomics.com/switzerland/government-bond-yield: Trading Economics; 2015.

[54] World Bank. Deposit interest rate. http://data.worldbank.org/indicator/FR.INR.DPST: The World Bank; 2015.

[55] World Bank. Lending interest rate. http://data.worldbank.org/indicator/FR.INR.LEND/countries: The World Bank; 2015.

[56] Trading Economics. Switzerland Inflation Rate. http://www.tradingeconomics.com/switzerland/inflation-cpi: Trading Economics; 2015.

[57] Mark F. Olsthoorn. Yes, but no. Adoption and rejection of demand-side energy innovations. Grenoble: Grenoble Ecole de Management; 2016.

[58] Ecoplan, EPFL, FHNW. Wirkungsabschätzung CO_2-Abgabe – Modellrechnungen. http://www.bafu.admin.ch/klima/13877/14510/14511/index.html?lang=fr&download=NHzLpZeg7t,lnp6I0NTU042l2Z6ln1ae2IZn4Z2qZpnO2Yuq2Z6gpJCHeoB6fmym162epYbg2c_JjKbNoKSn6A--: Ecoplan, EPFL and FHNW; 2015.

[59] GmbH TE, Soceco R. Wirkungsabschätzung CO_2-Abgabe – Direktbefragungen. http://www.bafu.admin.ch/klima/13877/14510/14511/index.html?lang=fr&download=NHzLpZeg7t,lnp6I0NTU042l2Z6ln1ae2IZn4Z2qZpnO2Yuq2Z6gpJCHeoB6gGym162epYbg2c_JjKbNoKSn6A--: TEP Energy GmbH and Rütter Soceco; 2016.

[60] FOEN. Fiche d'information. Estimation des effets et évaluation de la taxe sur le CO_2 prélevée sur les combustibles. www.bafu.admin.ch/klima/13877/14510/14511/index.html?lang=fr&download=NHzLpZeg7t,lnp6I0NTU042l2Z6ln1ae2IZn4Z2qZpnO2Yuq2Z6gpJCHeoB6gWym162epYbg2c_JjKbNoKSn6A--: Federal Office for the Environment; 2016.

[61] SFSO. Logements occupés selon le statut d'occupation et taux de logements occupés par leur propriétaire, par canton. Swiss Federal Statistical Office; 2014.

[62] Swiss Federal Counsil. Ordonnance sur le bail à loyer et le bail à ferme d'habitations et de locaux commerciaux 221.213.11 (OBLF). https://www.admin.ch/opc/fr/classified-compilation/19900092/201407010000/221.213.11.pdf: Swiss Federal Counsil,; 1990.

[63] SFSO. Gross monthly wage (median, Q1, Q3) by economic sections. http://www.bfs.admin.ch/bfs/portal/en/index/themen/03/04/blank/key/lohnstruktur/nach_branche.Document.108955.xls: Swiss Federal Statistical Office; 2016.

[64] Bernstein MA, Griffin J. Regional Differences in the Price-Elasticity of Demand for Energy. http://www.nrel.gov/docs/fy06osti/39512.pdf: National Renewable Energy Laboratory 2006.

[65] Hanemann M, Labandeira X, Labeaga JM, López-Otero X. Energy Demand for Heating: Short Run and Long Run. https://www.google.ch/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&uact=8&ved=0ahUKEwjb6deO29fOAhWCWhQKHf2eCcoQFggsMAE&url=http%3A%2F%2Feforenergy.org%2Fdocpublicaciones%2Fdocumentos-de-trabajo%2FWP07-2013.pdf&usg=AFQjCNEinzesvhoySaI6SqYHSHoxnpbfNw&sig2=PyzMJELNODI-xop16x5xDA: Economics for Energy; 2013.

[66] Harrison K. The Political Economy of British Columbia's Carbon Tax: OECD Publishing.
[67] Schatzki T, Stavins RN. Using the value of allowances from California's GHG cap-and-trade system. http://www.analysisgroup.com/uploadedfiles/content/insights/publishing/value_allowances_california_ghg_cap_trade_system.pdf: Analysis Group; 2012.
[68] Gevrek ZE, Uyduranoglu A. Public preferences for carbon tax attributes. Ecological Economics. 2015; 118: 186–97.
[69] Bristow AL, Wardman M, Zanni AM, Chintakayala PK. Public acceptability of personal carbon trading and carbon tax. Ecological Economics. 2010; 69: 1824–37.
[70] Lund H, Andersen AN, Østergaard PA, Mathiesen BV, Connolly D. From electricity smart grids to smart energy systems – A market operation based approach and understanding. Energy. 2012; 42: 96–102.

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