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Contributing to a green energy economy? A macroeconomic analysis of an energy efficiency program operated by a Swiss utility

Alisa Yushchenko *, Martin Kumar Patel [1]

Energy Efficiency Group, Institute for Environmental Sciences and Forel Institute, University of Geneva, Uni Carl-Vogt, 1211 Genève 4, Switzerland

HIGHLIGHTS

- Our input–output model allows estimating impacts of energy efficiency programs on GDP and employment in Switzerland.
- We provide with a deeper insight into modeling of income impacts of energy savings with regard to input–output method.
- Geneva case study demonstrates that energy efficiency programs can have positive macroeconomic impacts in Switzerland.
- Our results help to understand how to enhance positive macroeconomic impacts of energy efficiency programs.
- We provide policy recommendations for further development of energy efficiency programs.

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ABSTRACT

In order to enhance energy efficiency as a pillar of transition to a green energy economy it is important to understand whether and under which conditions energy efficiency programs could have positive economic and social impacts. There are a growing number of studies on macroeconomic impacts of energy efficiency programs for various countries and regions. However, in Switzerland only few evaluations have been performed. The present study evaluates the impacts on GDP and employment of Geneva's energy efficiency program portfolio *éco21* which is operated by the local utility. Two programs aiming for electricity savings in the residential sector are analyzed: *Eco-sociales* targets social housing and *Communs d'immeubles* focuses on common spaces in buildings. An input–output model is developed, based on the Swiss input–output table, program administrator data, Swiss, and European statistics. Both impacts of initial expenditure and energy cost savings are evaluated. We estimate and compare the impacts of the two programs and discuss factors that cause differences. Our results show that energy efficiency programs can have positive impacts on GDP and employment. According to our estimates, each Swiss Franc (CHF) spent within the energy efficiency program creates approximately 0.2 CHF of additional GDP compared to the reference case scenario. Net impacts on employment are approximately 0.7 and 1.6 additional jobs in full-time equivalent for 1 million CHF of expenditure driven by *Eco-sociales* and *Communs d'immeubles* respectively, compared to the reference case scenario. However, the results strongly depend on several hypotheses, including the impact of energy savings on the domestic energy sector, the import share in consumed goods and services, electricity prices, lifetimes of energy efficiency measures, and the assumed expenditure patterns. Based on our results we provide recommendations on measures for improving the macroeconomic impacts of energy efficiency programs: a preference for expenditure on local goods and services, maximization of cost effectiveness of energy efficiency programs, and their integration with energy supply planning. We conclude that energy efficiency programs and policies should be well coordinated with other policies in practice, the roles of stakeholders should be clearly defined, and all stakeholders should be provided with necessary instruments and powers.

1. Introduction

In a green economy, growth in income and employment are driven by investments that reduce negative environmental impacts while enhancing energy and resource efficiency [1]. Therefore, the transition to a green economy can be seen as a way to address

* Corresponding author. Tel.: +41 22 379 06 51.
E-mail addresses: alisa.yushchenko@unige.ch (A. Yushchenko), martin.patel@unige.ch (M.K. Patel).
[1] Tel.: +41 22 379 06 58.

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the modern environmental, economic, and social problems in a harmonized way. However, there is still a lack of understanding on how green economy may be implemented in practice [2].

Green energy policies and programs are considered as an important pillar of transition to a green economy [1,3], and are currently among the key energy policy priorities in Europe [4] and other regions [5]. In this context, it is necessary to better understand whether and under which conditions green energy policies and programs could have positive impacts on the economy as a whole [6]. For example, energy efficiency programs may stimulate employment in the sectors related to energy efficiency products and services. They can lead to energy cost savings that can be spent on other goods and services. However, investing in energy efficiency means diverting money from other spending options which may offer higher or lower economic growth and employment than the energy efficiency measures (further referred to as EE measures). Such effects can be analyzed by means of macroeconomic models.

The research base on macroeconomic impacts of green energy economy policies and programs is currently growing, especially in the United States [6–18]. In Europe, most studies focus on renewable energy [19–26], while the number of studies in the field of energy efficiency is much more limited [27–31]. In Switzerland there are hardly any publicly available studies in this domain [32]. Meanwhile, the results of macroeconomic studies highly depend on the content of energy policies and programs, and the structure of the economy [28]. Therefore, it is impossible to predict macroeconomic impacts for one location based on evaluation performed for another location.

There are different methods for performing macroeconomic studies, and they are in general well-described in the literature (see Section 2). However, for a number of reasons there is need for further development in the case of green energy economy policies and programs. Firstly, many researchers focus on estimating the impacts of a particular policy or program rather than on developing strategies for achieving certain macroeconomic objectives. And while the majority of studies conclude that the resulting macroeconomic impacts are positive, there are also examples of negative impacts, both for energy efficiency [10,18] and renewable energy [21,22,24] policies and programs. This does not mean that in such cases the respective policies and programs should not be implemented. It rather demonstrates that focusing uniquely on estimation of macroeconomic impacts is not sufficient. Instead, it is important to understand *how* to achieve and enforce positive impacts of green energy economy policies and programs [17]. Secondly, when modeling macroeconomic impacts of energy efficiency policies and programs, it is important to clearly understand all the income impacts of energy savings. This includes not only stakeholders who save energy by implementing EE measures, but also ratepayers and utilities. Existing studies do not always discuss these aspects in detail. For example, it is argued in the studies for Vermont [11] and Texas [12] that energy savings may lead to a decrease of electricity tariffs, but the underlying assumptions are not explained. And even if this statement is true for these particular cases, in other cases energy demand reduction may lead to tariffs increase as explained by Croucher [33]. Detailed information on the model choices regarding the interrelation of income changes among the stakeholders involved would not only ensure a better understanding of the results of the study in question, but also assist other researchers in their model development.

Against this background it is the objective of our paper to contribute to the growing body of knowledge on macroeconomic evaluation of green energy economy policies and programs at the example of energy efficiency programs. In particular, we aim to understand the principles that could allow achieving and enforcing positive impacts of energy efficiency programs on employment and GDP in Switzerland. The present work is based on a case study of the Geneva energy efficiency program portfolio *éco21*. We evaluate the impacts on GDP and employment of two programs aiming for electricity savings in the residential sector, *Eco-sociales* and *Communs d'immeubles* (Section 2). We provide a detailed methodology, including on modeling of income impacts of energy savings (Section 2). We compare the results of the two programs and analyze which factors cause the differences (Section 3). Finally, we propose measures for improving the macroeconomic impacts of energy efficiency programs (Section 3).

2. Methodology and data used

2.1. Case study

Case studies have become widely used in evaluation research [34,35], including in the energy domain [36–39]. As mentioned in Section 1, our work is based on a case study of the Geneva energy efficiency program portfolio *éco21*. *Éco21* was started up in 2006 and became fully operational in 2009. The program administrator is the publicly-owned utility Services Industriels de Genève (SIG) which runs the electricity saving and CO_2 reduction program portfolio *éco21* according to the agreement with the local authorities. The chosen case study is of special interest for Switzerland because *éco21* is one of a few examples of utility-led energy efficiency programs in the country [40]; in contrast, most energy efficiency programs are administered by state, the cantons and municipalities (for example, electricity-saving federal program *ProKilowatt* [41]). There are no energy efficiency obligations imposed on Swiss utilities, and the legal foundation for voluntary energy efficiency programs operated by utilities is underdeveloped [42]. Defining the role of utilities with regard to energy efficiency policy is one of the major topics of current political debate in Switzerland.

Fig. 1 presents the functioning of the program portfolio *éco21* which is similar to other ratepayer-funded energy efficiency programs [9]:

1. Ratepayers pay their energy bills to the utility.
2. The utility transfers a part of the revenue from the energy bills (i.e., energy efficiency surcharge) to the program administrator (e.g., *éco21* department of SIG).
3. A part of the energy efficiency surcharge is used to finance EE measures. The financing is used for full or partial coverage of the cost of energy equipment and its installation, training activities for installers, and energy advice for consumers. This is done through financial incentives for program participants or direct payments to contractors.
4. Another part of the energy efficiency surcharge is used to cover program administration costs.
5. In some programs third parties take part in financing EE measures (e.g., municipalities).
6. Participants pay the difference between total costs of EE measures and the part of costs covered by the program administrator and its partners
7. The participants' energy costs decrease due to implementation of EE measures.[2]

The present study focuses on two *éco21* programs called *Opérations éco-sociales* (hereinafter called *Eco-sociales*) and *Communs d'immeubles*.[3] Both of them started in 2009 and focus on electricity

[2] However, reduction in energy demand may lead to correction of electricity tariffs (see Section 2.5).

[3] Literal translation of "*Communs d'immeubles*": Common facilities of buildings.

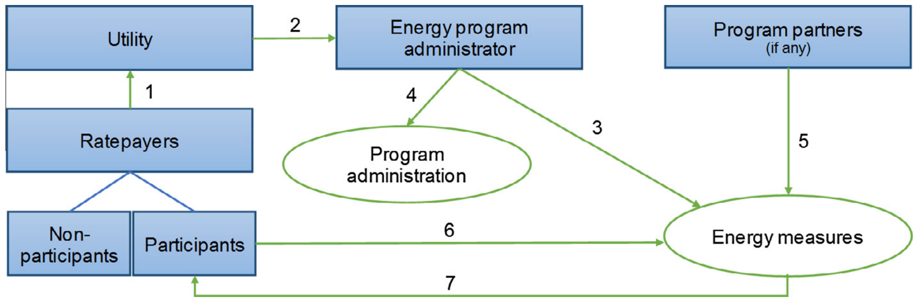

Fig. 1. Cash flows within the energy efficiency program portfolio *éco21*.

savings in the residential sector in the canton of Geneva. The program *Eco-sociales* targets social housing. The program administrator provides households free-of-charge with energy-efficient lighting equipment and on-site installation services, three types of household appliances that are also handed out free of charge (i.e., boilers, power stripes and hot water flow restrictors), and rebates on refrigerators. On-site installation is accompanied by energy advice. The program administrator works in partnership with municipalities, which partly cover the costs of EE measures. The program *Communs d'immeubles* targets common spaces in buildings (i.e., entrance areas, corridors, and cellars). It promotes energy efficient lighting, circulation pumps for heating systems, commonly used washing machines and laundry dryers. Initial expenditure on EE measures is incurred by program participants (e.g., building owners represented mainly by real estate companies) but the program administrator incentivizes these by means of subsidies based on the size of energy savings achieved and the chosen electricity tariff.[4] The two programs have performed in accordance with their initial energy saving objectives.[5] The total of all first-year energy savings of *Eco-sociales* and *Communs d'immeubles* amounted to 23.12 GWh in the period 2009–2014 (Table 1), which is about 27% of all first-year energy savings achieved by *éco21,* and about 0.1% of electricity consumption in the canton of Geneva (without CERN) in the respective period [43]. The initial expenditure (including on EE measures and program administration) was about 37 million CHF in 2009–2014, which is about 0.01% of Geneva's GDP in the respective period [44].

2.2. Choice of method

There are different methods to evaluate macroeconomic impacts of green energy economy policies and programs. According to Berck and Hoffmann [45] the basic methods include supply and demand analysis of the affected sector, partial equilibrium analysis of multiple markets, fixed-price general equilibrium simulations (i.e., input–output and social-accounting matrix multiplier models), non-linear general equilibrium simulations (i.e., computable general equilibrium (CGE) models), and econometric estimations including, for example, time series analysis. Other methods are also applied, including the use of indices and multipliers derived from case-studies, and hybrid approaches combining several of the above-mentioned methods [28,29]. Among the widely used methods are input–output and CGE models [9,28]. Input–output models allow to capture the economy as a whole, while remaining relatively simple as they use fixed prices and coefficients. They are particularly suitable for modeling the impacts of small-scale programs and policies as well as estimation of short-term effects. For evaluating large-scale programs and policies over longer periods of time, CGE models are recommended. They account for changes in the structure of the economy through feedback mechanisms such as price adjustments or factor and consumption substitution [45].

Table 1
First-year energy savings in GWh in *Eco-sociales* and *Communs d'immeubles* in 2009–2014. *Source:* SIG internal communications.

Program	2009	2010	2011	2012	2013	2014	Total
Eco-sociales	0.12	0.20	0.59	0.67	0.42	1.03	3.03
Communs d'immeubles	0.79	2.27	2.38	6.04	5.04	3.57	20.09

Input–output tables (IOT) and similar statistical data (e.g., social accounting matrices) are used both in input–output models and in CGE models [45]. The geographical scope of statistical data has an important impact on the results and their accuracy. In the United States, regional models (such as IMPLAN or REMI) have been developed in order to account for the specific conditions in each state [9,10,18]. Since there are no relevant statistics for Geneva specifically we choose to use Swiss IOT for 2011 [46]. This is the most recent table available at the time of the study. The use of Swiss IOT allows to estimate impacts that take place on the country and not the cantonal level. Since the scale of energy savings and expenditure of *Eco-sociales* and *Communs d'immeubles* (and *éco21* in general) is too small to lead to substantial structural changes in the economy, we choose to develop and apply a static, fixed-coefficient input–output model.

2.3. Types of impacts and system boundaries

We analyze the impacts of the programs caused by the 6 year-operation period 2009–2014.

As foundation for input–output modeling we first analyze expenditure driven by the energy efficiency programs, i.e.:

- Expenditure on EE measures including equipment and installation services. This comprises expenditure borne by the program administrator, participants, and partners (Fig. 1).
- Program administration expenditure. This category includes expenditure related to administration of individual programs and to the *éco21* program portfolio in general. We distribute the general costs among the programs based on the staff employment in full-time equivalent (FTE) per program.
- Decreased electricity expenditure due to implementation of EE measures.

These expenditures have direct, indirect, and induced impacts on GDP and employment. *Direct impacts* take place in economic sectors that supply goods and services for the energy efficiency program, and in the energy sector supplying energy to program

[4] The content of both programs changed over 2009–2014, including in types and shares of different EE measures, in the level and composition of program administration costs.

[5] At the outset of the program, no quantitative macroeconomic objectives (including with regard to GDP and employment) had been formulated.

participants (e.g., contractors that implement EE measures, electricity-supplying utilities). *Indirect impacts* represent upstream multiplier effects on economic sectors that supply goods and services for intermediate consumption (e.g., companies supplying to contractors and utilities). *Induced impacts* are multiplier effects caused by the following income changes:

- Energy cost reduction represents an additional income that may be spent elsewhere in the economy. However, energy savings may also lead to decreased income (and therefore, expenditure) of ratepayers due to increased tariffs, and of utility owners due to reduced utility profits (see Section 2.5).
- Changes in the income of companies and their employees as a consequence of direct and indirect impacts (e.g. wages and salaries). These lead to changes in household consumption and capital formation by companies.

By summing up the direct, indirect and induced impacts described above we obtain *total gross impacts*.[6] However, gross impacts do not take into account that cash flows within the energy efficiency program are diverted from other expenditure options. In order to understand whether an energy efficiency program has real positive impacts on the economy, its *net impacts* should be evaluated. To this end, the difference between the situation with and without energy efficiency program is estimated, i.e. the impacts of a fictive *reference case scenario* are deducted from the impacts of *éco21 scenario* (i.e., gross impacts). The interrelation among the different types of impacts are presented in Fig. 2. The elements displayed in Fig. 2 are further explained in Sections 2.4–2.6.

2.4. Initial expenditure

The raw data on EE measures and program administration expenditure is only available in purchaser prices. In order to perform input–output analysis expenditure needs to be expressed in basic prices by deducting the trade and transport margins as well as net commodity taxes [47]. Due to the lack of information on trade margins on energy efficient equipment we use estimates made by program manager based on observed price discounts. In *Eco-sociales*, the program administrator directly purchases equipment and negotiates prices with contractors. Significant discounts on equipment are provided. Trade margins on energy efficient equipment are estimated at 20%, while margins without discount (i.e., on the market) are estimated at 70%. As the EE measures cost less with *Eco-sociales* than on the market, the respective price difference represents the avoided costs for households, which can spend this money on other goods and services. This is taken into account in calculation of net impacts.[7] There is less information on trade margins in the case of *Communs d'immeubles* as the program administrator does not have an active role in equipment purchase. It is estimated that no discount is provided to the program participants and the trade margins on all types of energy efficient equipment are in the order of 50%. Expenditure on other types of goods (e.g., computers, furniture) is comparatively low. The respective margins are taken from the Austrian IOT 2010 [48]. Austrian data has been chosen as its IOT was previously used for estimation of trade margins in the Swiss IOT [49]. It is assumed that margins are equal for domestically produced, and imported goods within an economic sector. The rates of net commodity taxes are taken from the Swiss IOT 2011.

Only expenditure on locally produced goods and services has an impact on the local economy. As the geographical scope of this study is limited to Switzerland, all goods and services produced within the country are considered as domestic, others as import. Impacts on foreign economies are not evaluated. All services are provided by Swiss companies. For goods, only the total volume of the purchases is known. In the case of *Eco-sociales*, the program manager estimates the import shares for energy efficient equipment at 85–96% depending on the year. This estimation is based on close collaboration with contractors and resulting knowledge on the origin of equipment (all equipment is imported, except for power stripes and hot water flow restrictors). Based on detailed information available from *Eco-sociales* we estimate an import share of 100% for *Communs d'immeubles*.[8] The import shares of other goods are taken from the Swiss IOT 2011.

In the case of *Eco-sociales*, payments for lighting equipment and installation services are made separately. The share of installation services in expenditure on lighting-related EE measures is in the order of 40%. Raw data on expenditure on EE measures in *Communs d'immeubles* is not split into costs of equipment, and installation services. We assume a 45% share of installation in the costs of EE measures. It is an intermediate value between the example of *Eco-sociales* and program manager's estimates (50%) that are based on comparison of equipment costs with, and without installation.

As the basis of the analysis is the Swiss IOT 2011, all prices are transformed to the 2011 level. For this purpose the Swiss production price index [50], and the Swiss import price index [51] are used.

2.5. Income impacts of energy savings

The raw data on energy savings represents first-year electricity savings in GWh by program by year (Table 1). These estimates are based on the difference between participants' electricity consumption before and after implementation of EE measures. Estimation and verification of the respective energy savings is performed by the University of Geneva for every program on a yearly basis [52,53]. In order to perform the macroeconomic analysis, energy savings should be estimated over the lifetime of EE measures and converted from physical to monetary values. This task is not as evident as it may seem at a first glance.

Firstly, it is important to understand what impact energy savings have on domestic generation, import, and export of electricity. Switzerland participates actively in electricity trade in Europe (Supplementary material 1) [54]. In general, the country is a net importer of electricity during October–March when domestic hydroelectricity production is low, and stays net-exporter during the rest of the year [42]. Based on this data and the assumption that the amount of energy savings (triggered by the programs) is similar in any month of the year,[9] we assume that 50% of energy savings account for avoided electricity import, and 50% account for the volume of domestic production not sold in Switzerland, but exported to Europe.

Secondly, program participants save on energy bills according to the retail price. At the same time reduction in electricity demand impacts utilities, their owners, and most likely ratepayers too. According to Croucher [33] electricity retail price includes generation, transmission, distribution, administrative costs, and taxes (Appendix A, Fig. A.1). When electricity sales decrease, it is never-

[6] In this paper "*total*" impacts mean the impacts related to both expenditure on EE measures and program administration, and to energy savings.

[7] The initial sum accounted in the *reference case scenario* (equal to expenditure on EE measures and program administration in the *éco21 scenario*) is reduced by the amount of avoided costs of EE measures.

[8] However, the types of equipment are different in *Eco-sociales* and *Communs d'immeubles*.

[9] This assumption is due to a lack of data on the impact of energy savings on the load. We consider this assumption to be acceptable because we nearly exclusively consider electricity savings from more efficient lighting and household appliances (i.e., not, for example, related to space heating).

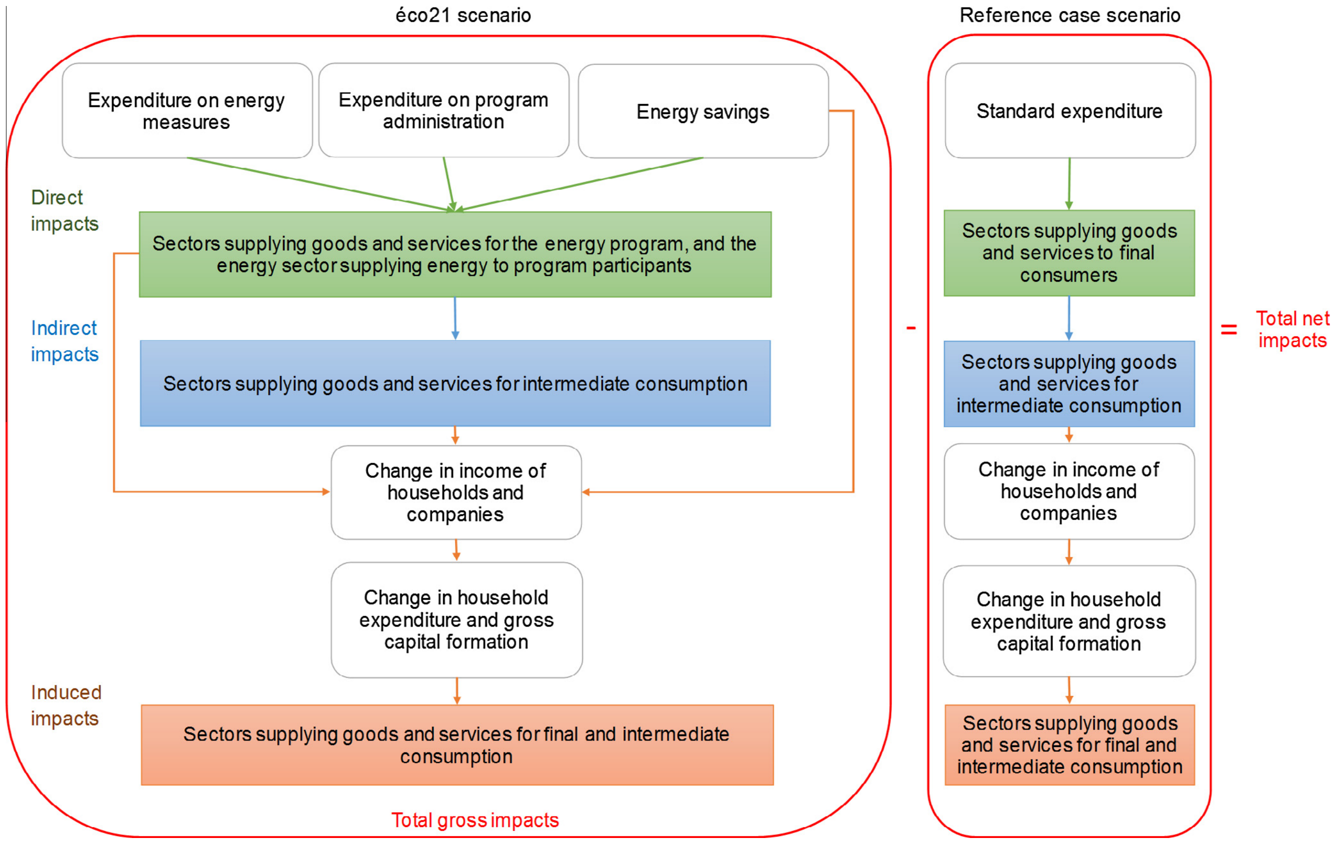

Fig. 2. Gross and net impacts accounted in the analysis.

theless necessary to cover distribution, transmission, and administrative costs of existing facilities. And the capital costs related to past investments in electricity generation need to be covered too. It is also a matter of political choice whether or not to increase the taxes in order to maintain the public budget revenues, and respective public expenditure at the constant level. In addition, utilities need to decide whether or not to maintain their profits by increasing tariffs, unless they are limited by legislation. In this research we assume that electricity distribution, transmission costs, and taxes are fully recovered by increase of electricity tariffs. In the case when electricity import is avoided, utilities save on purchasing electricity at the level of wholesale prices, and recover the margin by increasing tariffs (in order to recover their fixed costs and maintain profits). In the case when domestically generated electricity is not sold in Switzerland but exported, the differences between domestic and export prices represent a change in utilities' profits. We simplify the model by not considering avoided costs of capacity purchase due to a lack of data on the impact of energy savings on the load. The described assumptions together with alternatives integrated in the model are presented in Appendix B, Figs. B.1–B.3.

Due to uncertainty in electricity price development and fixed-price character of the input–output model, constant prices are assumed for the whole analysis period. The assumed electricity retail tariff for *Eco-sociales* is 19.56 ct/kW h, including 10.25 ct/kW h for energy, 7.64 ct/kW h for distribution and transmission, and 1.67 ct/kW h for taxes. It is based on average SIG tariff in 2009–2014 for the group H2 "4-room apartment with electric cooker, consumption 2.5 MW h/year" [55]. The assumed retail tariff for *Communs d'immeubles* is 19.07 ct/kW h, including 10.36 ct/kW h for energy, 7.12 ct/kW h for distribution and transmission, and 1.59 ct/kW h for taxes. It is based on average SIG tariff in 2009–2014 for the group C3 "medium enterprise, consumption 150 MW h/year, maximum power 50 kW" [55]. Assumed electricity import price is 6.5 ct/kW h, which is an approximate average wholesale electricity price on European markets in 2009–2014 [56]. Export prices are assumed to be 7.26 ct/kW h, which is higher than import prices as a large share of hydroelectricity provides Switzerland with a flexibility to choose when to export [42].

A lifetime period of 10 years is assumed for all EE measures, based on the example of [57]. This choice was made due to a lack of information on energy savings by type of equipment, and on the remaining lifetime of the replaced equipment.

A 2.5% discount rate is used for calculations of energy cost savings over the lifetime of EE measures. This rate is chosen based on comparison with interest rate of 10-year Swiss government bonds which was below 2.5% during the studied period [58] and the assumed inflation rate 0% [59].[10] This represents a purely financial approach which does not take into account the decrease in efficiency gains of energy saving measures over time (for technical reasons such as aging and due to gradual efficiency improvement of the reference technology).

Due to a short- to medium-term time scope (i.e., impacts are evaluated for 2009–2023), and the scale of energy savings, we do not take into account avoided costs of investment in the electricity sector facilities that would have occurred if the energy savings had not been realized.

[10] The assumed 2.5% discount rate is also similar to the average interest rate of 10-years Swiss Government bonds in 1994–2015: 2.55% [58]. In addition, during the studied period inflation rate in the country actually varied between about +3% and −1.5% [59]. And the average real interest rate on Swiss government bonds was different, but generally lower 2.5% [58]. Therefore, we consider the used 2.5% value to be a conservative assumption. The impacts of changes in interest rate are assessed in Section 3.4.

2.6. Input–output analysis

We apply the method of input–output analysis to calculate impacts of *éco21* programs on GDP and employment. The principles of input–output analysis are well-described in the literature [7,28,29,47]. In general, input–output tables contain a separate data on supply of domestic, and imported goods and services (i.e., domestic output, and import). And it is possible to calculate domestic output change through a change in final consumption. In Swiss IOT import supply is not presented in detail [46]. This is why in our study calculations are made with a use of total supply (and not total domestic output) data.

We calculate Leontief inverse matrix as follows:

$$P = (I - A)^{-1}$$

where P – Leontief inverse matrix, I – identity matrix, and A – coefficient matrix representing shares of intermediate consumption of domestic goods and services in total supply.

We calculate change in total supply through final consumption change:

$$\Delta X = P * \Delta Y$$

where ΔX – total supply change, P – Leontief inverse matrix, and ΔY – final consumption change.

When calculating *direct*, and *indirect impacts* in the *éco21 scenario* final consumption change includes increased consumption of domestic goods and services in regards to expenditure on EE measures and program administration (Fig. 2), except for salaries of the program administrator that are directly accounted for in value added.

When calculating *induced impacts* in the *éco21 scenario,* final consumption change is composed of the following elements:

- Increased consumption due to obtained energy cost savings. It is assumed that energy cost savings are redistributed to households which use the money in line with the household consumption pattern according to the Swiss IOT 2011 (Supplementary material 2).
- Reduced consumption by ratepayers due to increased electricity tariffs. It is assumed that only households carry the costs of increased tariffs. They reduce their expenditure according to the standard consumption pattern (Supplementary material 2).
- Change in expenditure by utility owners due to change in profits. As the majority of utilities including SIG are publically owned [42], it is assumed that a change in utilities' profits leads to change in public expenditure according to government consumption pattern from the Swiss IOT 2011 (Supplementary material 2).
- Household consumption change as a consequence of direct and indirect impacts (Fig. 2). This step is done by using methodology described on pages 247–248 of the UN Handbook on Input–Output Table Compilation and Analysis [47]. Household consumption is assumed to change proportionally to value added change (value added includes wages and salaries as well as revenues of households from business ownership).
- Change in gross capital formation by companies as a consequence of direct and indirect impacts (Fig. 2). Here, the same method is used: capital formation is presumed to change proportionally to value added change.

We assume that all income changes impact only consumption and not savings of the respective stakeholders.

In the *reference case scenario* we assume for both programs that expenditure is incurred according to the standard household consumption pattern from the Swiss IOT 2011 (Supplementary material 2). This choice is based on two reasons. Firstly, *éco21* is financed through tariffs. We assume that households will most likely carry the costs of the energy efficiency surcharge. The private sector is assumed to be protected from tariff increase for competitiveness reasons. In addition, all large consumers (with annual consumption level over 100 MW h) can freely choose their electricity provider (the electricity market is partially liberalized in Switzerland), which makes it unlikely that an energy efficiency surcharge would be assigned to them [42]. Secondly, the programs target the household sector. We assume that the money spent by program participants on EE measures is redistributed to households in the *reference case scenario*.

We calculate GDP as a sum of value added, and net commodity taxes according to the UN Handbook on Input–Output Table Compilation and Analysis [47]. Impacts on GDP are calculated as follows:

$$\Delta \mathrm{GDP} = \sum_{i=1}^{49}\left(\frac{(Wi + Ti)}{X_i} * \Delta X_i\right) + \sum_{j=1}^{49}\left(\frac{T_j}{Y_j} * \Delta Y_j\right) + W_d + T_d$$

where ΔGDP – change in GDP, W_i – value added of sector i in the Swiss IOT 2011, T_i – net commodity taxes paid by sector i in the Swiss IOT 2011, X_i – total supply of sector i in the Swiss IOT 2011, ΔX_i – total supply change of sector i, T_j – net commodity taxes paid as part of final consumption of product j in Swiss IOT 2011, Y_j – final consumption of product j in Swiss IOT 2011, ΔY_j – final consumption change for product j, W_d – value added created directly from program expenditure (i.e., program administrator wages and revenues), and T_d – net commodity taxes paid directly from program expenditure.

The impacts on employment are calculated as follows:

$$\Delta J = \sum_{i=1}^{49}\left(\frac{J_i}{X_i} * \Delta X_i\right)$$

where ΔJ – change in employment, J_i/X_i employment coefficient of sector i (representing number of jobs in FTE in sector i per unit of total supply of sector i), and ΔX_i – total supply change of sector i.

We calculate employment coefficients based on Swiss IOT 2011, and Swiss employment statistical data. Namely, we use STATEM data on employment in FTE [60], completed with data on employment in the primary sector found on the website of the Swiss Federal Statistical Office [61], and SPAO data on self-employed persons [62] (Supplementary material 3).[11]

For the purpose of comparison, GDP and employment multipliers are presented in Supplementary material 2. They are calculated by multiplying diagonal matrices of GDP shares in total supply, and employment coefficients by Leontief inverse matrix, and summing up the resulting columns. These multipliers represent change in GDP and employment for all economic sectors caused by a change in final consumption of goods and services of a particular sector.

The resulting input–output model is static. It uses constant production and labor productivity coefficients. The developed model may be used for other energy efficiency programs in Switzerland.

2.7. Sensitivity analysis

We perform a sensitivity analysis to test the impact of the adopted hypotheses on the results. Firstly, we reduce the *discount rate* from 2.5% (default) to 0.5% because interest rates in Switzerland decreased significantly in recent years. The current interest rate on 10-years Swiss government bonds is even below 0.5% [58]. On the other hand, we increase the discount rate to 6.5% as

[11] SPAO data includes full-time and part-time jobs, not converted to FTE. There is no statistical data available on self-employed persons in FTE. We assume all self-employed persons accounted in SPAO statistics to work full-time.

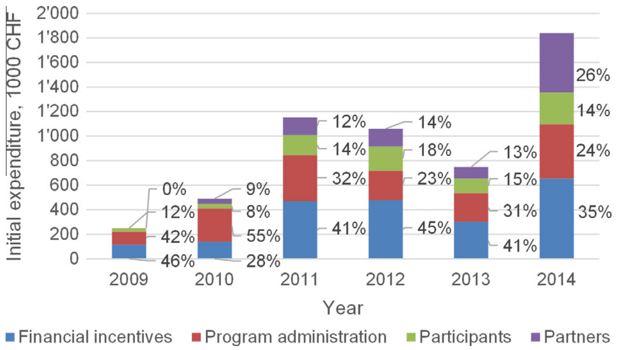

Fig. 3. *Eco-sociales*: initial expenditure in current purchaser prices, 1000 CHF.

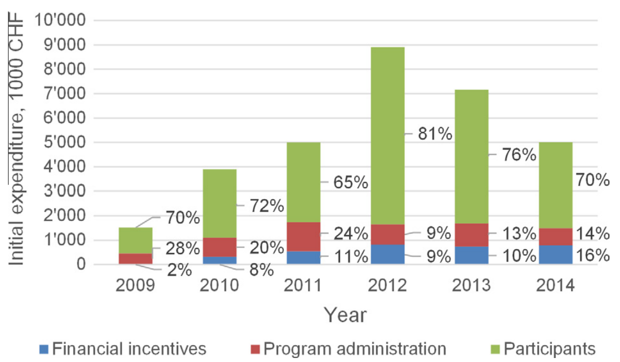

Fig. 4. *Communs d'immeubles*: initial expenditure in current purchaser prices, 1000 CHF.

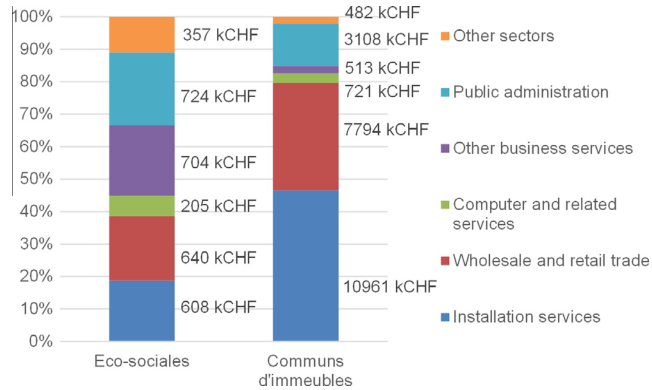

Fig. 5. Initial expenditure on domestic goods and services in 2011 basic prices, % and 1000 CHF.

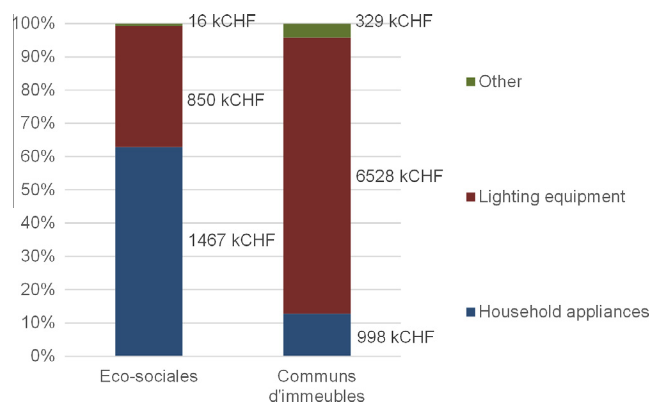

Fig. 6. Initial expenditure on imported goods and services in 2011 basic prices, % and 1000 CHF.

the energy savings may decrease over time due to lower efficiency of installed equipment or the improved baseline (efficiency of reference technology). This value is the sum of the default 2.5% plus 4% discount rate used in the French white certificate scheme for estimation of energy savings in physical terms (kW h cumac) over the measures' lifetime [63].[12,13] Secondly, we vary the *electricity import share* from 0% to 100% while retaining the assumption that the Swiss energy sector compensates domestic demand decrease by increasing export. This assumption is reasonable for the current state of the energy systems in Switzerland and Europe. However, we perform an *additional simulation* where the domestic energy sector is assumed not to be able to export electricity and therefore, has to reduce its production in response to energy demand decrease. Thirdly, we estimate the impacts if the *lifetime of EE measures* ranges from 5 to 15 years. Fourthly, we vary the *electricity import price* from 4.5 ct/kW h to 8.5 ct/kW h, and the *electricity export price* from 5.0 ct/kW h to 9.5 ct/kW h. This variation is within the observed ranges of wholesale electricity prices on the European markets during the studied period [56]. Two additional parameters are considered in the sensitivity analysis of *Communs d'immeubles* due to higher uncertainty of their values: we vary *trade margins* on energy equipment from 30% to 70%, and the *share of installation services* in costs of EE measures from 35% to 55%. Finally, we adopt two *alternative reference case scenarios.* In the *first* scenario we assume that changes in electricity tariffs impact not only households, but all actors involved in final use (e.g., government, non-profit organization, private sector). For this purpose we assume the total final consumption pattern from the Swiss IOT 2011 (Supplementary material 2) for the sum of the initial expenditure of *éco21* and the electricity tariff change caused by energy savings. This scenario is inspired by the Négawatt policy scenario study for France [27]. In the *second* scenario we assume that taxes included into electricity tariff (public charge and feed-in tariff charge) are not recovered through the tariff increase.[14] Expenditure on renewable energy development stays constant, public expenditure on other goods and services is reduced (Appendix B, Fig. B.3). For this scenario we apply the government consumption pattern from the Swiss IOT 2011 (Supplementary material 2).

3. Results

3.1. Initial expenditure and income impacts of energy savings

The *initial expenditure* (including expenditure on EE measures and program administration) of *Eco-sociales* and *Communs d'immeubles* is presented in Figs. 3 and 4 respectively. The 6 year-expenditure is about 5.5 million CHF in *Eco-sociales* and 31.5 million CHF in *Communs d'immeubles*. Both financial incentives, and program administration costs are covered by the program administrator. In both programs the shares of different expenditure types vary over the years. These variations may be explained by

[12] According to [63] "cumac" means "CUMulated ACtualised saving over the lifespan of the action or equipment".

[13] It is important to mention that the 4% discount rate used in the French white certificate scheme is based on financial approach and not on evaluation of EE measures efficiency reduction from technical perspective. Other studies use financial approach too. For comparison, in the study [11] for Vermont (USA) real discount rate 5.6% is used. And as in France and the USA interest rates are higher than in Switzerland we assume that the 2.5% assumption used in our default case is reasonable.

[14] More information on potential relationships between electricity savings and electricity tariffs may be found in Section 2.5.

Table 2
Eco-sociales – Energy cost savings over lifetime of EE measures, impacts on utility profits and electricity tariffs by year of program operation, 1000 CHF.

Item	2009	2010	2011	2012	2013	2014	Total
Energy cost savings, 1000 CHF	211	351	1035	1176	737	1807	5317
Change in tariffs, 1000 CHF	−120	−201	−592	−672	−421	−1033	−3040
Utility profits change, 1000 CHF	−16	−27	−79	−90	−56	−138	−407

The results over the lifetime of EE measures (2009–2023) are broken down by year of program operation (2009–2014). For example, the column 2009 reflects the impacts in the period 2009–2018 as a consequence of expenditure on EE measures and program administration that took place in 2009.

Table 3
Communs d'immeubles – Energy cost savings over lifetime of EE measures, impacts on utility profits and electricity tariffs by year of program operation, 1000 CHF.

Item	2009	2010	2011	2012	2013	2014	Total
Energy cost savings, 1000 CHF	1351	3883	4072	10333	8622	6107	34369
Change in tariffs, 1000 CHF	−754	−2167	−2272	−5765	−4810	−3407	−19174
Utility profits change, 1000 CHF	−110	−316	−331	−840	−701	−497	−2795

For explanation see note below Table 2.

evolution of the programs, namely changes in composition of administrative costs, and in the content of financial incentives.

Between 2009 and 2014, the participants' contribution in the initial expenditure was above 65% in *Communs d'immeubles* (Fig. 4) and below 18% in *Eco-sociales* (Fig. 3). This difference is explained by the design of the programs. *Eco-sociales* provides support for low-income households. The design is based on an assumption that this type of energy consumers is unlikely to spend on EE measures without considerable financial support. The design of *Communs d'immeubles* supposes that participating real estate companies have the financial resources and are motivated to reduce their operational costs (e.g. electricity bills).

The 6-year expenditure on domestic goods and services is presented in Fig. 5 for both *Eco-sociales* and *Communs d'immeubles*. Public administration includes salaries of the program administrator. Other business services include mainly marketing, advertisement, labor recruitment, and technical advice services provided by third companies to the program administrator. Fig. 6 shows 6-year expenditure on imported goods and services for the two programs.[15]

The share of import in initial expenditure is lower in *Communs d'immeubles* than in *Eco-sociales*: 25% vs. 42% respectively. The main reason is low trade margins on energy efficient equipment in *Eco-sociales* due to the provided discount. Another reason is higher share of lighting-related measures in *Communs d'immeubles*. Lighting-related measures include a relatively high share of installation services in their costs (40% and 45% in *Eco-sociales* and *Communs d'immeubles* respectively). These services together with trade and transport margins represent a contribution to domestic economy, which accounts for 52% and 73% of expenditure on the lighting-related measures in *Eco-sociales* and *Communs d'immeubles* respectively. Installation of household appliances is included in trade margins of supplying companies. Contribution to domestic economy accounts for 20% and 50% of expenditure on the respective measures for *Eco-sociales* and *Communs d'immeubles* respectively.[16]

Energy cost savings over lifetime of EE measures together with impacts on utility profits and electricity tariffs are presented in Tables 2 and 3 for *Eco-sociales* and *Communs d'immeubles* respectively. Positive change in tariffs mean that ratepayers have to pay their electricity at higher prices and therefore have to reduce their expenditure on other goods and services. There is no change in domestic generation due to the assumption that utilities compensate domestic demand reduction by increasing exports.

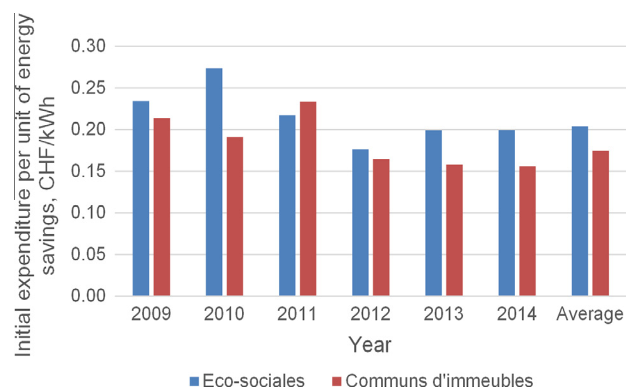

Fig. 7. Ratios of initial expenditure to energy savings.

Table 4
Total gross and net impacts of *Eco-sociales* by year of program operation.

Impact type	2009	2010	2011	2012	2013	2014	Total
Gross GDP, 1000 CHF	257	511	1094	983	736	1762	5343
Net GDP, 1000 CHF	50	77	189	188	140	345	989
Gross employment, FTE	1.4	2.7	6.2	5.9	4.1	10.2	30.5
Net employment, FTE	0.1	0.1	0.7	1.0	0.5	1.5	4.0

For explanation see note below Table 2.

For both programs, the ratios of initial expenditure to energy savings over the lifetime of the EE measures are presented in Fig. 7. The cost-effectiveness of *Communs d'immeubles* is somewhat higher compared to *Eco-sociales*: 0.17 vs. 0.20 CHF of initial expenditure per 1 kW h of energy savings. One reason is the lower share of administrative costs in this program: 9–28% vs. 23–55% in *Eco-sociales* (Figs. 3 and 4). Differences in the types of EE measures and the baseline situations is another reason. In particular, before 2005 legislation in Geneva obliged building owners to light common spaces 24 h per day [64]. The lighting use pattern did not change after the obligation was removed. Therefore, one of the core

[15] Expenditure on domestic and imported goods and services divided by year of program operation are presented in Supplementary material 4.

[16] Trade margins on household appliances are 20% and 50% for *Eco-sociales* and *Communs d'immeubles* respectively. Transport margins are 0.35% for both programs.

Table 5
Total gross and net impacts of *Communs d'immeubles* by year of program operation.

Impact type	2009	2010	2011	2012	2013	2014	Total
Gross GDP, 1000 CHF	1922	4837	6119	11214	9160	6378	39630
Net GDP, 1000 CHF	306	685	740	1528	1380	888	5526
Gross employment, FTE	11.5	31.3	38.7	75.5	59.5	41.1	257.8
Net employment, FTE	1.7	6.1	6.0	16.6	12.2	7.7	50.3

For explanation see note below Table 2.

measures in *Communs d'immeubles* was installation of movement detectors, which led to significant energy savings. We do not discuss this any further because the contribution of the various energy saving measures implemented in the two programs is not evaluated in this study.

3.2. Total impacts

According to our estimates the total gross and net impacts on GDP and employment are positive for both *Eco-sociales* (Table 4) and *Communs d'immeubles* (Table 5). This is in accordance with most of the reviewed studies, which also claim positive macroeconomic impacts of energy efficiency programs and policies in other locations [10–12,14,18,27,28,32,65]. However, as mentioned by Bower et al. [9], it is difficult to compare results of various studies due to methodological differences.

In line with the reviewed studies [10–12] our results show that the majority of positive macroeconomic impacts of the energy efficiency program are related to post-installation period when energy cost savings are used to purchase other goods and services (Figs. 8–11). Negative values of net impacts of expenditure on EE measures and program administration mean that GDP and employment generated by this expenditure is somewhat smaller compared to a situation where the program is not implemented (i.e., the *reference case scenario*). According to our results this is quickly compensated by GDP and employment generated due to energy savings.

In general, the estimated impacts are relatively low. This can be partly explained by the scale of the programs (Figs. 3 and 4) [43]. We point out that the results should be seen as indicative due to uncertainty related to our hypotheses and the linear character of the model. Among the major uncertainties is the unpredictability of the expenditure patterns in regards to the *reference case scenario*, use of energy cost savings, expenditure by ratepayers and utility owners. And in reality the relationships between final consumption, production, employment, and other parameters are more complicated than assumed in our model. For example, increased demand for goods and services does not necessarily lead to proportionally higher employment because of increased labor productivity [12,18]. It should also be taken into account that Swiss IOT is not detailed with regard to import (supply of domestic and imported goods is not separated).

Also, in some cases authors provide an example that negative employment impacts in the energy sector should not be seen as job losses, but as potential transfer of jobs to energy efficiency business [12,18]. In our case the negative employment impacts take place in sectors from which the expenditure is diverted in order to finance the energy efficiency program.[17] In any case, re-orienting workforce from one sector to another demands training and time. Therefore, in order to minimize employment losses and to support professional re-orientation, the energy efficiency programs should have a long-term character and be accompanied

[17] In our case there are no negative impacts on the domestic electricity sector due to the assumption that electricity demand reduction leads to decrease of electricity import in winter, while in summer Swiss power generators compensate domestic demand loss by export to Europe.

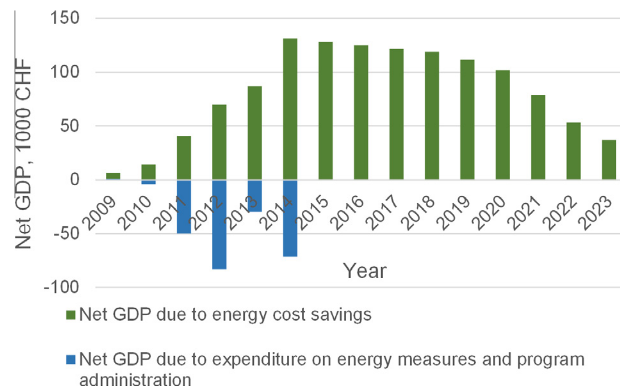

Fig. 8. Total net impacts on GDP of *Eco-sociales* in 2009–2023.

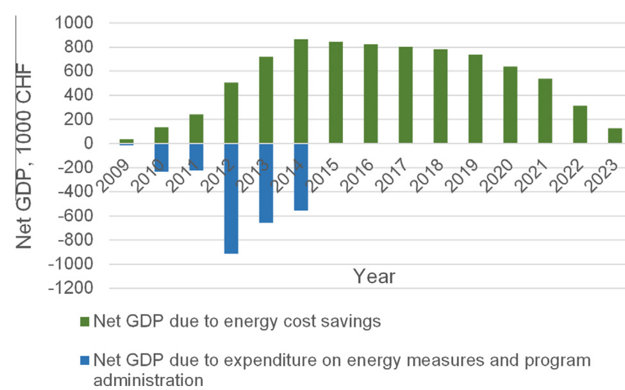

Fig. 9. Total net impacts on GDP of *Communs d'immeubles* in 2009–2023.

by adequate education and training policy. Considering the overall situation on the labor market in Switzerland as well as the extent of the employment effects determined (Tables 4 and 5), these aspects do not represent a concern for the programs studied. However, for large-scale programs (e.g. at the national level) this issue should be taken into account.

3.3. Program comparison

The ratios of total impacts on GDP and employment to initial expenditure are presented in Table 6 for both programs. The respective ratios by year of program operation are presented in Appendix C, Tables C.1 and C.2. *Gross ratios* represent overall impacts resulting from program deployment. For example, for every 1 million CHF of expenditure within *Communs d'immeubles*, there is about 1.3 million CHF of GDP created, and about 8 jobs in FTE generated. *Net ratios* represent values compared to the reference case scenario. For example, for every 1 million CHF of expenditure within *Communs d'immeubles* about 0.2 million CHF of GDP and 1.6 jobs in FTE are created in addition compared to a situation where the energy efficiency program does not take place. The ratios in *Communs d'immeubles* are slightly higher. Given the

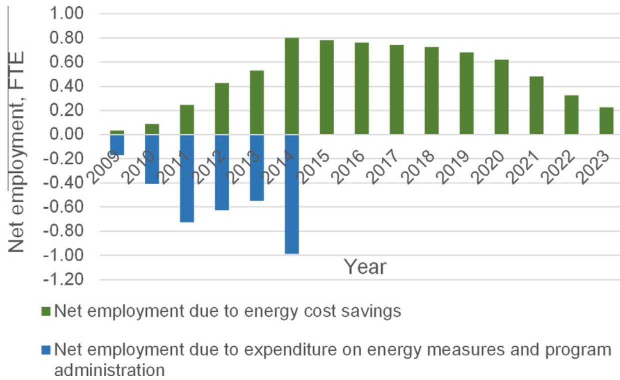

Fig. 10. Total net impacts on employment of *Eco-sociales* in 2009–2023.

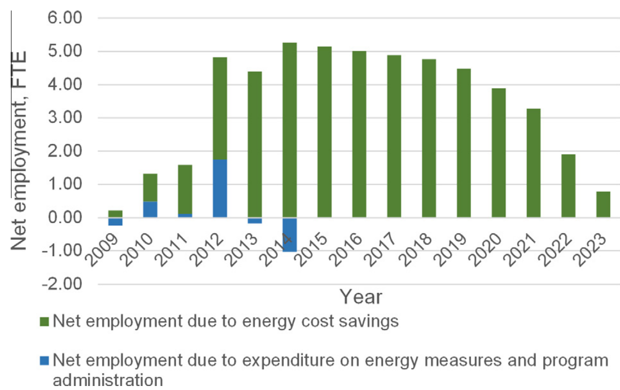

Fig. 11. Total net impacts on employment of *Communs d'immeubles* in 2009–2023.

uncertainty in the hypotheses we consider the differences between the two programs as insignificant. However, together with initial expenditure analysis this comparison allows to determine the factors that contribute to the somewhat higher macroeconomic impacts of *Communs d'immeubles* compared to *Eco-sociales*: higher cost effectiveness of EE measures (Fig. 7), lower import share in initial expenditure (Appendix D, Table D.1), and higher share of specialized installation services in expenditure on EE measures (due to higher share of lighting) (Figs. 5 and 6). Among the major reasons for higher import shares in *Eco-sociales* is the price discount on energy efficient equipment. As a consequence, local trade companies receive less revenues, which lowers the gross impacts of the program. At the same time the price discount represents avoided costs of EE measures which can be spent on other goods and services. This is accounted for in net impacts and has a positive influence on the results. However, this expenditure occurs according to the standard household consumption pattern (Supplementary material 2) where the mix of consumed goods and services is characterized by lower employment multiplier than multiplier of the trade sector (4.62 vs. 7.7). In other words, if no discount was provided, impacts on employment would be higher in our model. These results show the limits of input–output modeling as paying energy equipment at higher price does not change the employment needs of the supplying companies (i.e., the physical volume of equipment sold remains constant).

In our study the ratios of macroeconomic impacts to initial expenditure are lower than in most of the reviewed literature. For example, in the study for Vermont [11] the estimated net impacts on gross state product (GSP) are 5.5 USD per 1 USD of initial expenditure for the electricity-related program.[18] However, in the study on lighting and appliance measures in Greece [28] the estimated impacts are much lower: 1.93 EUR of GDP per 1 EUR of budget.[19] And in the cases of Washington [10] and Colorado [18] the impacts of electricity-related policies on GSP are even negative. The estimates of employment impacts also vary considerably in the literature. To illustrate, the review of nine studies performed by Imbierowicz and Skumatz [65] shows that estimated employment impacts vary between 5.6 and 71 jobs per million USD of program expenditures. The review performed by Bower et al. [9] shows variation of net employment impacts from 8 to 250 jobs per million USD. And Mirasgedis et al. [29] demonstrated variation of gross employment impacts estimates from 4.4 to 328 jobs created by 1 million USD of expenditure in 2010 prices.

One of the reasons for these variations is differences in methodologies (e.g., reference case scenarios, study boundaries, key assumptions). For example, in our study we assume that tariffs may increase as a consequence of decreased electricity demand. And even if the level of energy savings within the program may not be sufficient to actually impact the tariffs, we try to avoid over-estimation of results in our analysis. As mentioned in Section 1, methods used in other studies are not described in detail. In the studies for Vermont [11] and Texas [12] the authors only note that in their models reduction in electricity demand leads to a decrease in electricity tariffs for all ratepayers. In fact, one may argue that electricity tariffs may decrease as a consequence of avoided investments in the energy sector. But in this case a longer time frame should be considered, and the *reference case scenario* should include impacts of investment in energy facilities. Also, some authors advocate that energy efficiency programs lead to reduction in electricity tariffs as they contribute to demand reduction on the spot market (so, the most expensive units are not dispatched) [68]. However, we do not take this argument into consideration as the scale of the *éco21* program is not sufficient to impact the spot market prices in Switzerland and Europe.

Another reason for the different findings is the diversity of economic structure. For example, in the case of *éco21*, energy efficient equipment is imported, while in Vermont a part of energy efficient equipment is produced within the State [11]. In the cases of Washington [10] and Colorado [18] negative net impacts on GDP are caused by reduction in domestic electricity generation, while we assume no impact on domestic generation in our case.

Finally, different types of EE measures are likely to give different results. This is demonstrated in our study where a higher share of lighting equipment yields to higher impacts on GDP and employment as implementation of lighting measures requires specialized installation services. In some territories energy efficiency programs include measures with longer lifetime (up to 20 years for refurbishment) [9,12] which may contribute to higher positive impacts.

The opportunity costs of public spending can be estimated by comparing the impacts of *éco21* programs with the impacts of standard public expenditure in Switzerland (based on Swiss IOT 2011). *Communs d'immeubles* has the same value of GDP created per unit of expenditure (1.26 CHF/CHF) and a higher number of jobs created per unit of expenditure (8.19 vs. 7.94 FTE/1 million CHF respectively). *Eco-sociales* has lower values: 0.96 CHF/CHF and 5.5 FTE/1 million CHF. However, as mentioned in Section 2.4, EE measures cost less with *Eco-sociales* than on the market due to the provided discount on equipment. The respective price difference represents the avoided costs for households, which can spend this money on other goods and services.[20] Taking these into

[18] In the period 2011–2013, the exchange rate of USD to CHF varied between 1.21 and 0.75 [66].

[19] In the period 2011–2013, the exchange rate of EUR to CHF varied between 1.63 and 1.07 [67].

[20] These avoided cost have been accounted for when calculating *net* impacts as described in the first paragraph of Section 2.4.

Table 6
Ratios of total impacts on GDP and employment to initial expenditure of *Eco-sociales* and *Communs d'immeubles* in 2009–2014.

Index	*Eco-sociales*			*Communs d'immeubles*		
	EE measures and program administration	Energy cost savings	Total	EE measures and program administration	Energy cost savings	Total
Gross GDP/initial expenditure (CHF/CHF)	0.74	0.22	0.96	1.00	0.26	1.26
Net GDP/initial expenditure (CHF/CHF)	−0.04	0.22	0.18	−0.08	0.26	0.18
Gross employment in FTE per 1 million CHF of initial expenditure	4.15	1.35	5.50	6.62	1.57	8.19
Net employment in FTE per 1 million CHF of initial expenditure	−0.63	1.35	0.72	0.03	1.57	1.60

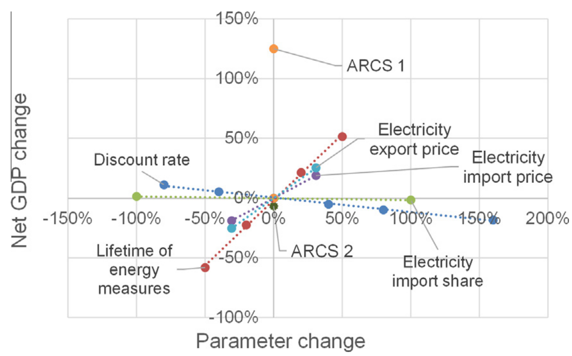

Fig. 12. Sensitivity analysis of total net impacts on GDP of *Eco-sociales* deployment.

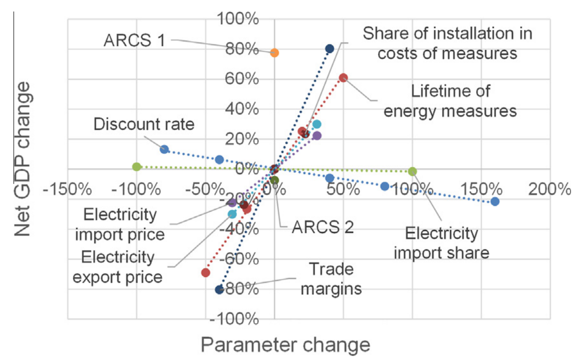

Fig. 13. Sensitivity analysis of total net impacts on GDP of *Communs d'immeubles* deployment.

account, the impacts of *Eco-sociales* would be comparable to the impacts of public expenditure: 1.27 CHF/CHF and 7.35 FTE/1 million CHF.

3.4. Sensitivity analysis for 2009–2014

The results of the sensitivity analysis of *net* impacts are presented in Figs. 12–15 (except for the results of the *additional simulation*[21] which is shown in Appendix E, Figs. E.1 and E.2).[22] The results assuming *alternative reference case scenarios* are presented with the labels "ARCS 1" and "ARCS 2" for the *first* and the *second* scenario respectively.

According to our calculations, changes in *discount rate* have a relatively low impact on the results compared to changes in other parameters. Variation of the *electricity import share* from 0% to 100% neither has a significant impact on the results, as we assume that the Swiss energy sector compensates domestic demand decrease by increasing exports. However, if the domestic energy sector is not be able to export saved electricity and therefore, would have to reduce its production in response to energy demand decrease, the results would differ very substantially (Appendix E, Figs. E.1 and E.2). In such a case, the less energy savings contribute to energy import reduction (vs. domestic production reduction), the lower the macroeconomic impacts of the energy efficiency program would be, up to negative. This issue is demonstrated in a number of studies [10,12,18]. The performed variation of *lifetime of EE measures* demonstrates the importance of this parameter (and therefore, of the overall quantity of energy savings) on the results. Estimation of lifetime of EE measures is complicated in our case as there is no data on the remaining lifetime of the removed equipment. It would be useful to develop a reference case

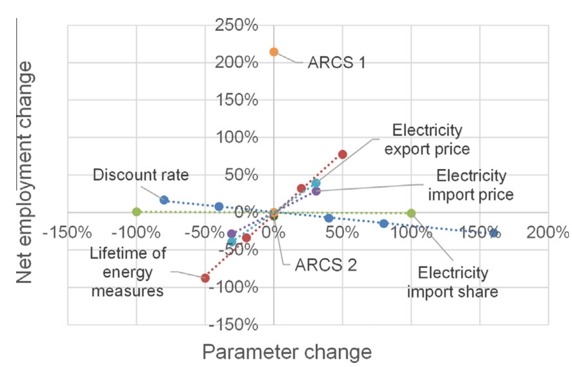

Fig. 14. Sensitivity analysis of total net impacts on employment of *Eco-sociales* deployment.

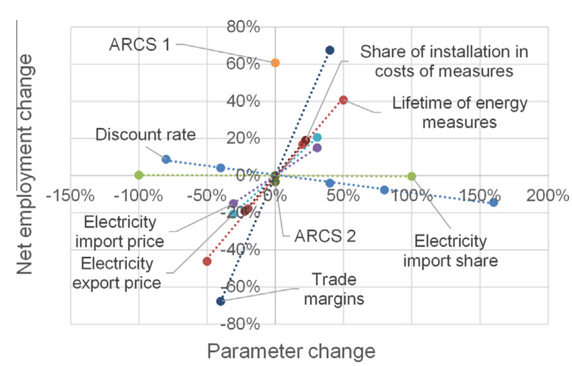

Fig. 15. Sensitivity analysis of total net impacts on employment of *Communs d'immeubles* deployment.

scenario in which EE measures are undertaken anyway, without participation in the energy program, but with the equipment installed corresponding to the minimum energy efficiency requirement defined in legislation or to the market average. It is not done

[21] In the *additional simulation* we change the electricity import share while assuming that domestic energy sector is not able to increase export of electricity (and therefore has to reduce its production) in response to energy demand decrease.

[22] The results on *net* impacts are also provided in tabular form in Supplementary materials 5 and 6. The results on *gross* impacts are presented in Supplementary materials 7 and 8.

due to a lack of information on energy savings by type of equipment. Further, there is relatively significant change in results as a consequence of *electricity import* and *export price* variation.[23] Changes in *trade margins* and in the *share of installation services* have considerable impacts on the results too. This indirectly demonstrates the importance of purchasing domestically produced goods and services, and that different types of EE measures may have different macroeconomic impacts (namely, measures requiring specialized installation services may result in higher GDP and employment). The results are much higher when the *first alternative reference case scenario* is adopted (compared to the default case). The major reason is the higher import share in the mix of consumed goods and services in the final consumption pattern compared to the household consumption pattern (23% vs. 15% respectively). This leads to lower impacts accounted for in the alternative reference case scenario, and as a consequence – higher *net* impacts (Fig. 2). However, it should not be directly concluded that the costs of energy efficiency programs and increased tariffs should be carried by all consumers, as it may cause competitiveness problems for domestic companies. The results for the *second alternative reference case scenario* show that electricity tariff increase or reduction of public expenditure in response to lower tax revenues from electricity consumption lead to comparable net impacts on GDP and employment. It could be further studied what macroeconomic impacts would be if investment in renewable energy was reduced (due to lower total revenues from feed-in surcharge). However, this would call for a separate study on investment patterns in the Swiss renewable energy sector.

The resulting impacts on GDP and employment vary considerably depending on adopted assumptions. This situation is not an exception in modeling of macroeconomic impacts of energy policies and programs. For example, Imbierowicz and Skumatz [65] mention that the results may vary by more than 200% depending on underlying assumptions. The variation of our results could be lowered by reducing uncertainties in the parameters. For example, this can be done by improving the accuracy in estimates of energy savings over lifetime of measures, conducting a survey to better estimate trade margins on energy equipment, the share of installation services in total costs of EE measures, and direct employment impacts. The impact of energy savings on the load could also be estimated in order to include the avoided costs of capacity purchase into the model.

The reviewed impacts change in different proportions in *Eco-sociales* and *Communs d'immeubles*. This can be explained by differences in the cost structure (e.g., content of EE measures, share of program administration cost in initial expenditure), commercial conditions (discount provided in *Eco-sociales*), and ratios of energy savings to initial expenditure. This leads to different import shares and different allocation of expenditure to economic sectors that are characterized by different GDP and employment multipliers.

Overall, the sensitivity analysis shows that the following factors have the largest influence on the macroeconomic impacts of the energy efficiency programs: the amount of energy savings (depends on the lifetime of EE measures), the share of import in consumed goods and services, electricity prices, the impact of energy savings on domestic energy sector (e.g., whether domestic energy production decreases or not), and the assumed expenditure patterns.

[23] The variation of export price has relatively higher impact on the results compared to the import price. It is due to the assumption that export price variation changes the revenues of the utility owners and not the tariffs as in the case of import (Appendix B, Fig. B.2). The mix of consumed goods and services in the expenditure pattern of utility owners, public sector, is characterized by higher employment multipliers (Supplementary material 2) and lower import share compared to the mix in the household consumption pattern.

3.5. Energy efficiency programs from a green energy economy perspective

Our results show that energy efficiency programs operated by utilities can contribute to the transition to a green energy economy in Switzerland by combining energy savings with positive impacts on GDP and employment. This may also be relevant for programs administered by public bodies like the state and the cantons, at least if such programs have a similar funding and expenditure structure and if they support similar EE measures (this may, for example, be the case for the energy efficiency program *ProKilowatt* which is administered by the Swiss Federal Office of Energy). However, positive macroeconomic impacts of energy efficiency programs are not unconditionally granted. The outcomes depend on multiple factors related to the programs themselves (for example, their cost-effectiveness, types of measures supported and purchase patterns), but also to the energy sector from a wider perspective (e.g., structure of energy supply, impact of energy savings on energy supply). There are a number of measures which program administrators and policy makers could undertake in order to maintain and enhance positive macroeconomic impacts of energy efficiency programs.

Firstly, program administrators should target to increase cost-effectiveness of their programs (i.e., maximize energy savings per unit of expenditure, including expenditure of participants and partners). One of the possible options would be through economies of scale. This could allow to decrease both relative program administration costs and equipment costs due to the stronger negotiating power of utilities when striking contracts with equipment suppliers and with contractors (as in the case of *Eco-sociales* program).[24] In practice there are two main barriers with regard to development of large-scale utility-led energy efficiency programs. One of the barriers is that budget allocation to energy efficiency programs is complicated and constrained. As mentioned in Section 2, *éco21* is run on voluntary basis by the local utility according to the agreement with the public owners. There is no large-scale firm political instrument or legal framework that assures funding of utility-administered energy efficiency programs in Switzerland for now. Another barrier is the very considerable difference in size among Swiss utilities. It might be too costly and time-consuming for most of the very small utilities to run their own energy efficiency programs [40]. One of possible solutions would be cooperation: an implementation of joint energy efficiency programs with participation of several utilities which, however, calls for a relevant political and legal framework.

Secondly, a preference could be given to expenditure on local goods and services (for example, engagement of local contractors). This could not only increase direct positive impacts on domestic economy (in terms of jobs and GDP generated by companies engaged within the program), but also foster energy efficiency business development in general (spillover effects), and potentially increase public acceptance and engagement in energy efficiency programs. However, in practice such preference is limited by public procurement law and might apply to minor contracts in the services sector only. No preference may be given to domestically produced equipment as a consequence of Swiss international trade agreements. Nevertheless the strategy of fostering the production of highly specialized and competitive energy efficiency goods and services deserves more attention.

Thirdly, energy efficiency should be recognized as fuel or a resource, and thus be integrated with energy supply planning [69]. This means that energy efficiency program administrators should carefully consider energy supply needs. For example, EE

[24] When interpreting the results of *Eco-sociales* in regards to the provided discount, it is important to account for the limitation in the model described in the first paragraph of Section 3.3.

measures may help to reduce peak demand, minimize investment into energy facilities and contribute to the achievement of renewable energy supply objectives [69]. Such integration could also allow to target reduction of energy import rather than decreasing domestic energy production. This can enhance positive macroeconomic impacts of energy efficiency programs and also improve the security of supply (while, however, conflicting with international electricity market liberalization). In practice, integration of energy efficiency programs with energy supply calls for active participation of utilities. However, as mentioned in Section 2, most of current energy efficiency programs in Switzerland are operated by the state, the cantons or municipalities. The role of utilities in not yet clearly defined.

The above-mentioned challenges show that in order to make energy efficiency programs and policies a successful tool of the transition to a green energy economy, they should be well coordinated with other policies in practice. Such coordination should not be limited within the energy domain (energy supply, efficiency, renewables), but should expand to other domains like clean technologies development and urban planning. In addition, the roles of stakeholders should be clearly defined, and these should be provided with the necessary instruments and powers. In the case of Switzerland, a new policy and legal framework is needed to make utilities an active actor in the field of energy efficiency. It could be done by establishing an energy efficiency obligation scheme, or a voluntary instrument that would encourage utilities to deploy their energy efficiency programs or join in such with other utilities and stakeholders (for example, energy efficiency companies, public bodies) as it is done in the United States, and some European and Asian countries [70]. This could not only allow to increase the number of energy efficiency programs operated by utilities, but most importantly stimulate integration of energy efficiency programs into energy supply planning. A strong policy support may also encourage program administrators to long-term commitments and increased scale of their programs. Such an approach can also give signals to various economic actors. Namely, it can attract energy efficiency business, support professional education and re-orientation, as well as potentially lead to positive spillover effects (e.g., encourage energy consumers to opt for efficient solutions even if not taking part in the program).

4. Conclusion

We developed an input–output model that allows estimating impacts of energy efficiency programs on GDP and employment in Switzerland, and we applied it to the utility-operated program portfolio *éco21* in Geneva. According to our estimates the two *éco21* programs studied (*Eco-sociales* and *Communs d'immeubles*) have net positive macroeconomic impacts in Switzerland. In more detail, each Swiss Franc (CHF) within the energy efficiency program creates approximately 0.2 CHF of additional GDP compared to the reference case scenario. Net impacts on employment are approximately 0.7 and 1.6 additional jobs in full-time equivalent for 1 million CHF of expenditure driven by *Eco-sociales* and *Communs d'immeubles* respectively, compared to the reference case scenario. However, these results are highly dependent on several hypotheses, including the impact of energy savings on the domestic energy sector, the share of import in consumed goods and services, electricity prices, lifetime of EE measures, and assumed expenditure patterns. Comparison of the programs shows that *Communs d'immeubles* has relatively higher impacts on GDP and employment per unit of initial expenditure compared to *Eco-sociales*. Among the major reasons are higher cost effectiveness of EE measures, lower import share in initial expenditure, and higher share of installation services in *Communs d'immeubles*.

From methodological perspective our study represents a contribution to a growing body of knowledge on macroeconomic evaluation of green energy economy policies and programs. We provide a deeper insight into modeling of income impacts related to energy savings. In particular, we provide a detailed modeling scheme of possible impacts of energy demand change on the energy sector and on ratepayers which can be useful for other researchers using input–output method (Appendix B, Figs. B.1–B.3). The developed input–output model is suitable for estimation of impacts of small to medium-scale energy efficiency programs like *éco21*. For further research on energy efficiency programs and policies in Switzerland, it would be useful to develop a dynamic model that would allow to account for restructuring of economy in response to large-scale, long-term energy savings. The pallet of indicators should be further extended in order to address more green energy economy targets (for example, emission levels, health impacts, other non-energy benefits). The model can be also developed by integrating energy intensities by sector to account for direct, indirect and induced rebound effects on energy production.[25]

From the policy-making perspective our findings show that energy efficiency programs can contribute to the transition to a green energy economy by combining energy demand reduction with positive impacts on GDP and employment, which is in accordance with other studies in the field. However, we state that the positive macroeconomic impacts are not unconditionally granted. There are a number of possible measures which program administrators and policy makers could adopt in order to support and enhance positive macroeconomic impacts of the programs. These include a preference for expenditure on local goods and services, maximization of cost effectiveness of energy efficiency programs, and their integration with energy supply planning. In this view, energy efficiency programs and policies should be well coordinated with other policies in practice, the roles of stakeholders should be clearly defined, and all stakeholders should be provided with necessary instruments and powers. While the case of Switzerland is particular due to the structure of its economy and political context, the key features of energy efficiency programs and the challenge of their integration with other policies in practice is equally relevant for other countries. The issue of how to make utilities an active actor of green energy economy transition needs to be further studied. Case studies of successful and failed experiences are always related to the local circumstances but they nevertheless offer insights that can support researchers and decision-makers in their work.

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[25] Also, decision-makers on cross-country level (e.g., the EU) need informational support to develop common policies. In this context, a large-scale study on European level may be of great value in order to understand whether, for example, the expected larger share of domestic production of energy-efficient goods results in even more positive results compared to Switzerland or whether this is compensated by, for example, reduction of overall energy production.

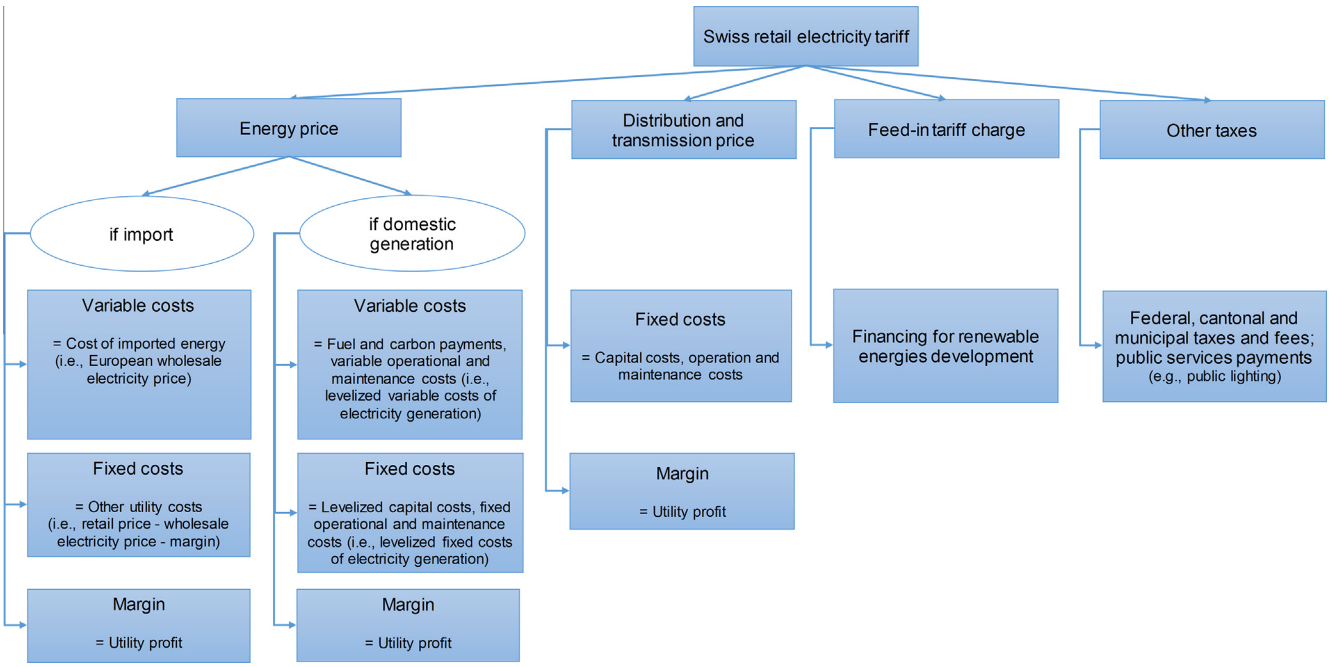

Fig. A.1. Composition of retail electricity price.

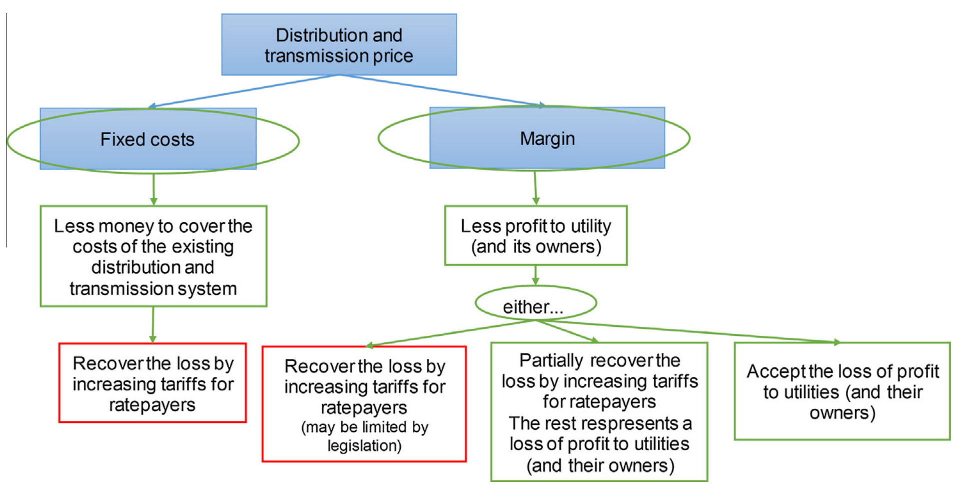

Fig. B.1. Possible impacts on energy sector and ratepayers in the case of electricity demand decrease, for the "distribution and transmission price" part within the retail electricity tariff (chosen options are marked in red). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Swati Mayor (all with SIG), Daniel Cabrera, Franco Romerio and Jean-Luc Bertholet from the University of Geneva, and Carsten Nathani from Rütter Soceco for providing information and advice.

Appendix A

Composition of retail electricity price in Switzerland.

Appendix B

Possible impacts on energy sector and ratepayers in the case of electricity demand decrease.

Appendix C

Ratios of total impacts to initial expenditure.

Appendix D

Shares of import in initial expenditure.

Appendix E

Impacts of electricity import share in the volume of avoided electricity consumption on the results if domestic demand decrease is not compensated by export.

Appendix F. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.apenergy.2015.12.028.

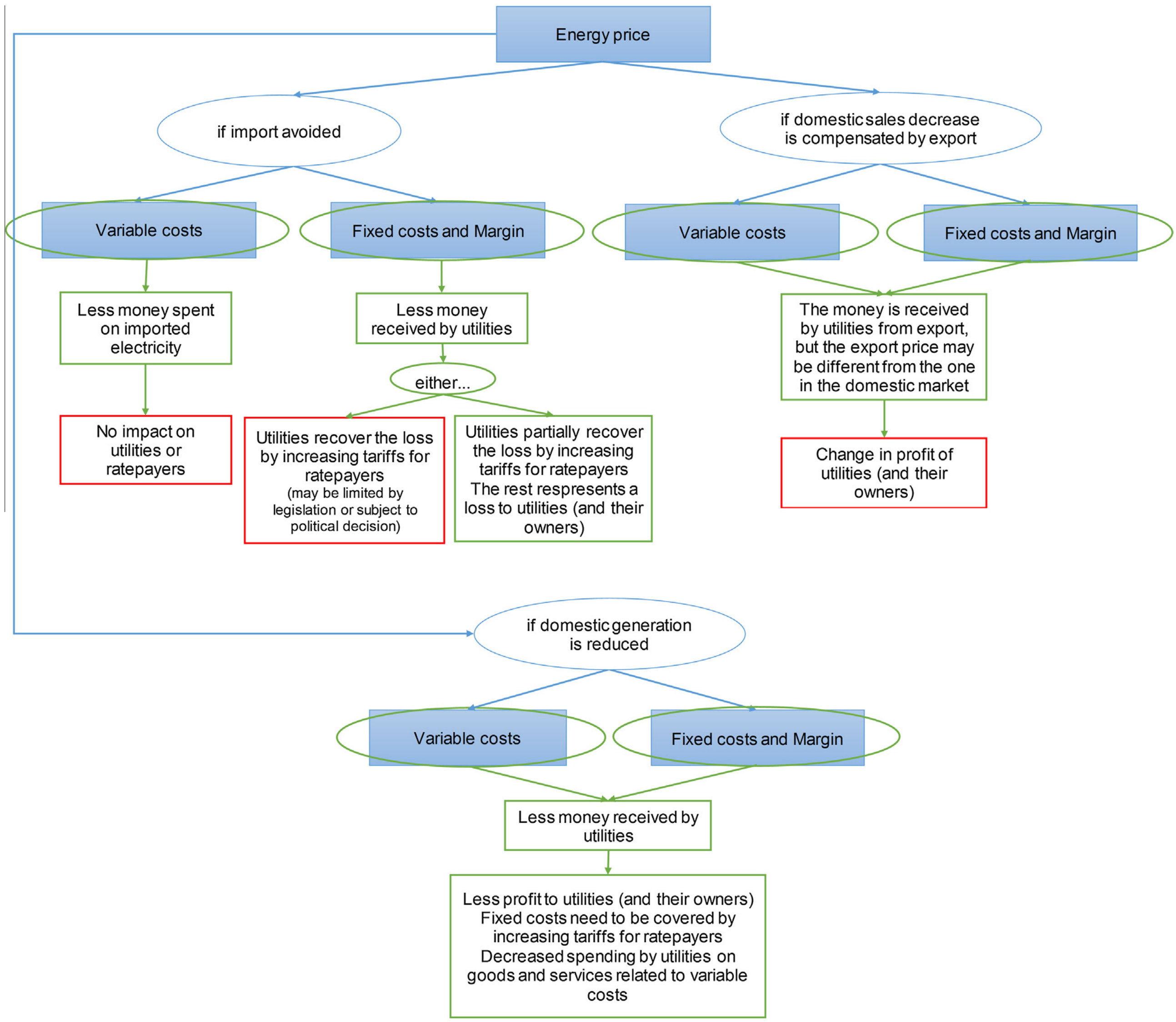

Fig. B.2. Possible impacts on energy sector and ratepayers in the case of electricity demand decrease, for the "energy price" part within the retail electricity tariff (chosen options are marked in red). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

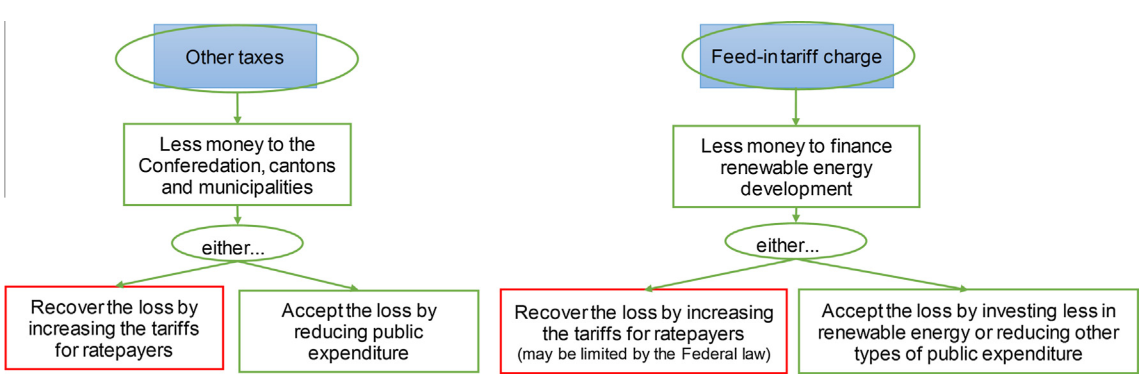

Fig. B.3. Possible impacts on energy sector and ratepayers in the case of electricity demand decrease, for the "other taxes" and "feed-in tariff charge" parts within the retail electricity tariff (chosen options are marked in red). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Table C.1
Ratios of total impacts to initial expenditure of *Eco-sociales*.

Index	2009	2010	2011	2012	2013	2014	Total
Gross GDP/initial expenditure (CHF/CHF)	1.02	1.04	0.95	0.93	0.98	0.96	0.96
Net GDP/initial expenditure (CHF/CHF)	0.20	0.16	0.16	0.18	0.19	0.19	0.18
Gross employment in FTE per 1 million CHF of initial expenditure	5.51	5.55	5.42	5.52	5.48	5.52	5.50
Net employment in FTE per 1 million CHF of initial expenditure	0.50	0.18	0.63	0.96	0.65	0.84	0.72

Table C.2
Ratios of total impacts to initial expenditure of *Communs d'immeubles*.

Index	2009	2010	2011	2012	2013	2014	Total
Gross GDP/initial expenditure (CHF/CHF)	1.27	1.24	1.22	1.26	1.28	1.28	1.26
Net GDP/initial expenditure (CHF/CHF)	0.20	0.18	0.15	0.17	0.19	0.18	0.18
Gross employment in FTE per 1 million CHF of initial expenditure	7.62	8.05	7.75	8.47	8.31	8.23	8.19
Net employment in FTE per 1 million CHF of initial expenditure	1.13	1.56	1.20	1.86	1.71	1.55	1.60

Table D.1
Shares of import in initial expenditure in *Eco-sociales* and *Communs d'immeubles*.

Program	2009 (%)	2010 (%)	2011 (%)	2012 (%)	2013 (%)	2014 (%)	Total (%)
Eco-sociales	36	30	41	48	43	42	42
Communs d'immeubles	20	22	21	26	27	28	25

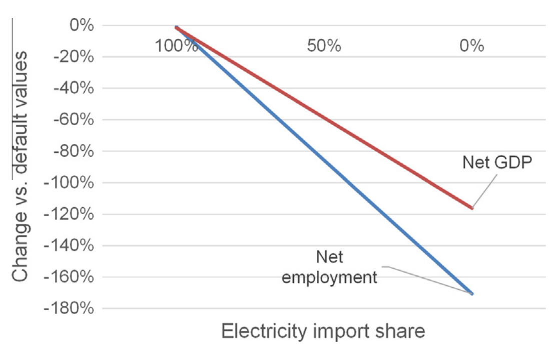

Fig. E.1. Impact of electricity import share on the results of *Eco-sociales* if domestic demand decrease is not compensated by export.

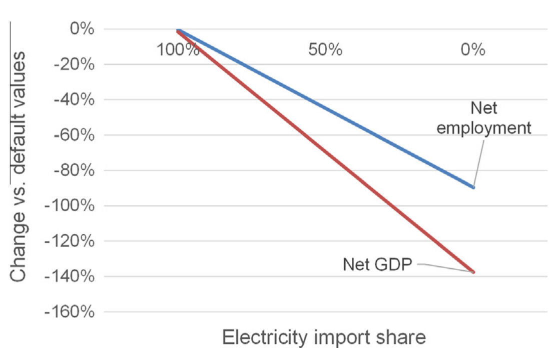

Fig. E.2. Impact of electricity import share on the results of *Communs d'immeubles* if domestic demand decrease is not compensated by export.

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Glossary

Direct impacts: impacts that take place in economic sectors that supply goods and services for the energy program (incl. program administration), and in the energy sector supplying energy to program participants.
Domestic output: supply of domestically produced goods and services for intermediate and final consumption.
Energy cost savings: reduction in expenditure on energy services.
Energy efficiency program: a program operated by a government agency, a utility or any other agent, that targets energy savings and (or) CO_2 emissions reduction.
Energy efficiency measure: an action that allows to achieve energy savings and (or) CO_2 emissions reduction, by installing a more efficient equipment or changing energy consumption behavior.
Energy savings: reduction in energy consumption due to implementation of one or more energy measures.
Final consumption: goods and services consumed by households; government, non-governmental institutions, and social security systems; companies in regards to gross capital formation; and goods and services used for export.
Green energy policy/program: a policy/program that targets renewable energies development and (or) energy efficiency improvement.
Gross impacts: overall impacts caused by an economic activity, without comparison to impacts of an alternative economic activity.
Indirect impacts: upstream multiplier effects on economic sectors that supply goods and services for intermediate consumption.
Induced impacts: multiplier effects of change in final consumption as a result of income change.
Initial expenditure: expenditure on energy measures and energy program administration.
Input–output table: statistical data representing interrelationship between economic sectors in regards to production, import, and consumption of goods and services.
Intermediate consumption: goods and services (apart from capital goods) used for production of other goods and services.
Net commodity taxes: commodity taxes (on domestic and imported goods) minus commodity subsidies (on domestic and imported goods).
Net impacts: overall impacts caused by an economic activity compared to impacts of an alternative economic activity.
Total impacts: direct, indirect, and induced impacts caused by initial expenditure and energy savings.
Total supply: supply of domestically produced and imported goods and services for intermediate and final consumption.
Value added: a value created by economic sectors through production of goods and services (equal to output minus intermediate consumption).
Multiplier: a value representing an impact on all economic sectors caused by a change in final consumption of goods and services of a particular sector.