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SUMMARY

The project started in August 2017 with the hiring of the PhD student and we have made the following progress in the past year:

WP 1 Housing

We conceived and coded a building stock model to endogenize energy efficiency in the housing sector. The model will be coupled with GEMINI-E3 and divides the Swiss building stock in different energy classes. It includes among other things a micro-economic model on retrofit decisions. In parallel we have been collecting data (e.g. on energy carriers, space heating demand, energy reference area of buildings). At this moment we have preliminary results on a reference and two policy scenarios. The model is not yet complete, as we are still calibrating it and some model-part are still missing.

WP 2 Industry

We choose the cement sector as a suitable sector to model endogenous energy efficiency improvements. This sector is suitable as its product is rather homogenous, the sector has a high energy intensity, there is still potential for improvements and data availability seems sufficient.

We are reviewing the literature on how to endogenize this industry sector. On data we made clarification which sources are available: We could use “lean case studies” from big companies and collect data directly from those companies. At the same time, we could use data from the emissions trading scheme and the targets on energy efficiency improvement.

Evaluation 2018 and Outlook 2019

The project has a slight delay as compared to the rough timeline we made at the proposal. But the project is still on track given its timeline.

In 2019 we will complete the building stock model and run a reference and several policy scenarios. Furthermore, we will have a running version of the industry model (or a hard-coupled version of GEMINI-E3) including the collected data from the cement industry.

Contents

List of abbreviations

EEI	Energy Efficiency Improvement
CGE	Computable General Equilibrium
ETC	Endogenous Technical Change
SFOE	Swiss Federal Office of Energy
FSO	Federal Statistical Office
ERA	Energy Reference Area
pdf	probability density functions

1 Introduction

1.1 Background and Motivation

The evolution of energy efficiency is of vital importance for future energy consumption. For example, large-scale energy retrofit of the Swiss residential building stock using the best available technology could result in energy savings of up 84% of current energy consumption (Streicher 2017).

That is why climate and energy policies frequently aim at accelerating energy efficiency improvement (EEI). Computable general equilibrium (CGE) models and bottom-up models (e.g. Markal 1997) are a way to estimate the impact of such policies. Yet, notwithstanding clear evidence that technological change is influenced by economic activity and responsive to policies, those CGE models depend mainly on autonomous energy efficiency improvement: the speed and expansion of EEI is usually set exogenously, i.e. unaffected by climate or energy policies. Therefore, one may assume that those CGE models systematically underestimate the impact of climate policies. Incorporating endogenous technical change (ETC) into CGE model shall improves upon this problem.

In this work, we therefore refine a CGE model (GEMINI-E3; see e.g. Bernard and Vielle 2008) to provide more realistic estimates of those impacts. To incorporate EEI as accurate as possible, we focus on a rather detailed description of the building sector and an industry sector, as those are very relevant for Swiss energy consumption.

1.2 Project goals

The fundamental objective of this research is to introduce a new methodology in an existing economic model of the Swiss economy (GEMINI-E3) targeting at a better representation of the acceleration of EEI due to energy and climate policies. The second target is to illustrate this by assessing the impacts of a set of realistic policies on the diffusion and adoption of technologies associated with energy consumption in Switzerland, and finally on energy use as well as structural changes. A prudent representation should as far as possible include the effects of barriers (incomplete information, uncertainty, bounded rationality, etc.). Such a representation can significantly influence the rigorousness of a policy (e.g. the level of a tax) as well as the implementation and realistic functioning (information, standards, financial incentives, etc.) which is indispensable to achieve a target. Thus, assessing the sensitivity of the results to these assumptions is another key contribution of the planned work.

1.3 Structure of this Report

The report is structured as follows. Chapter 2 describes our methodology (focus is the housing sector, as we have not yet started modelling the industry sector). In chapter 3 we show preliminary results for the housing sector (primarily as an illustration of the way the chosen approach works). Chapter 4 concludes with an evaluation of the achievements 2018 and an outlook for the working program 2019, including steps forward to improve the model of the housing sector and endogenize EEI in the industry sector.

2 Methodology

2.1 General Approach

GEMINI-E3 is a CGE model that has been specifically designed to assess energy and climate policies. In this work we will include two modules (housing and an industry sector) that allow us to introduce ETC into GEMINI-E3. There are in general two ways to do this: hard coupling and soft coupling. With hard coupling, the formulas within GEMIN-E3 will be refined. This is the more elegant way but there is a limit on amount of formula changes that can be done within a CGE model. That is why soft coupling is also a viable option, where a second independent model is coupled with the CGE. For housing, we use the soft coupling approach, as our building stock model is too detailed to be directly included into GEMINI-E3. For the industry sector, the approach has not yet been decided.

The housing sector approach is shown in more detail in Figure 1. GEMINI-E3 is soft-coupled with the building stock model. The building stock models will be run iteratively while the coupling variables are exchanged between the two models. GEMINI-E3 will provide price of energy carriers (oil, natural gas, electricity, wood, etc.), price of investment (used for retrofit[1] cost). The building stock model in turn provides the heating energy carriers, the investment in retrofit and new building, as well as the net tax revenue. Tax rates on energy consumption and subsidy rates on retrofits will be defined based on the scenario definitions (i.e. policy design).

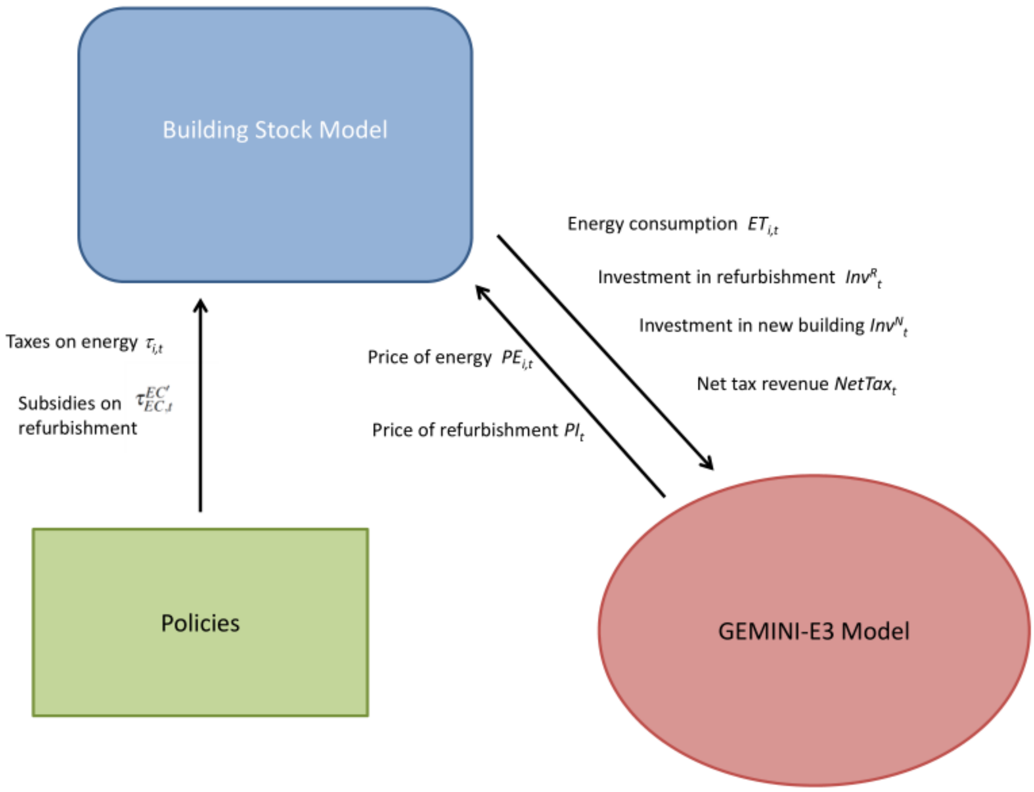

Figure 1: Coupling framework

[1] In the figure retrofits are called refurbishment.

2.2 Building Stock Model

Energy class transitions

We sort the Swiss building stock of single-family and multi-family houses into energy cohorts, labelled A–G. Each energy class represents a different range of space heating demand (SHD) in kWh/sqm (see Table 1). The labeling is based on the labels of the Cantonal Energy Certificate for buildings energy standards. It describes the efficiency of the thermal insulation of a given building compared to a reference value. We define the reference as 40 kWh/m 2 /a, based on the average space heating demand (SHD) per year of new single-family and multi-family houses as described by SIA 380/1. 40 kWh/m 2 /a corresponds to the threshold from Label B to C.

kWh/m^2(ERA)	< 20	20-40	40-60	60-80	80-100	100-120	> 120
Energy class	A	B	C	D	E	F	G

Table 1: Thresholds of energy classes and their space heating demand (SHD)

In any given period, a fraction of buildings in each cohort is retrofitted and thus gets more energy efficient. As a result, retrofitted buildings enter better cohorts. The owner's retrofit decision depends on two layers. Fist, general costs and benefits of retrofits, which we assume are the same for all buildings within a given energy class. Secondly, the specific characteristics of the owners or the buildings. Up to now we only modelled the first layer. The second layer will be added to the model as a next step (see outlook for 2019).

In this way, we are able to endogenize retrofit decisions that leads to energy efficiency improvement of the building stock model.

Concurrent improvement of the heating system

Concurrent to the retrofits of the buildings, often the heating system is improved as well (e.g. a change from oil heating to a heat pump). Apart from the energy efficiency due to improvement of the thermal insulation of the building, this is another important way to improve the energy efficiency of the building.

There are several reasons why these two improvements may happen concurrently:

- Certain retrofit types entail heavy construction work and habitants have to be resettled. If a change in the heating system seems appropriate (e.g. age close to live-time), it is likely that this is done at the same time as a retrofit;
- After a retrofit, houses need less high-temperature energy if e.g. a floor heating is installed. Therefore e.g. heat-pumps get more cost efficient in relation to oil-burners;
- On the other hand, if the replacement of an oil-burner is necessary, this may trigger a retrofit as a prerequisite for a heat-pump.

This is implemented into the model as follows: for each energy class there is a district fuel mix. When the energy class changes, the fuel mix and thus the heating system changes as well.

The building stock model is implemented with GAMS.

2.3 Data

In this chapter we provide the data sources we used in order to build the model.

Energy reference area (ERA): The Swiss Federal Office of Energy (SFOE [2] provides data on the energy reference area for several construction-periods (before 1919,1919-1945, 1946-1960,..., 2006-2015). This data is available for the years 2010 up to 2016.

Retrofit cost: We estimate the retrofit costs to improve a building's energy class based on Bundesamt für Energie 2015 [3], which shows the investment costs needed to move a building from energy class G to A. To obtain the intermediate investment cost, we linearly interpolate that costs. We do this for both single family and multi-family houses.

Duration of retrofit: This is the time when a retrofit has to be repeated. Based on the data from SFOE[4], we use an average lifetime of 40 years.

Newly constructed ERA: From Federal Statistical Office (FSO)[5] we have data on average surface[6] of new constructions by year. In order to find the overall surface of new constructions, we multiply average surface in each year by the quantity of new constructions in the corresponding year. For the moment we assume that averages surface equals ERA.

Estimated demolition rates: To estimate demolition rates we use data from FSO [7] on occupied houses in square meters from 2010-2016 categorized by construction periods. For each construction period, we compute the demolition of occupied houses from 2016 to 2010. For cohorts that are not represented in the data we interpolate.

Space heating demand: There is data on space heating demand (SHD) for Zürich[8] and Geneva. For Zürich the study's construction periods end in the year 2000. Therefore, we extrapolated the data to the year 2016. The data from Geneva has been provided to us by Dr. Flourentzos Flourentzou from ESTIA. Both have not been included into the model yet.

Energy consumption by energy carrier: Buildings are represented by construction periods (before 1919,1945-1960,....2006-2015). Data on energy carriers (oil, coal, gas, electricity and etc.) for single and multi-family houses stem from SFOE[9] and Prognos[10] (number of flats using particular energy carrier is given).

Collaborations: On data collection we have pending collaboration with Die Mobiliar, SCHL and ABZ (Allgemeine Baugenossenschaft Zürich).

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[2] https://www.bfs.admin.ch/bfs/fr/home/statistiques/catalogues-banques-donnees/tableaux.assetdetail.3822846.html

[3] https://www.endk.ch/de/dokumentation/harmonisiertes-foerdermodell-der-kantone-hfm

[4] https://www.bafu.admin.ch/bafu/en/home/topics/climate/info-specialists/climate-policy/co2-levy/exemption-from-the-co2-levy-for-companies.html

[5] https://www.bfs.admin.ch/bfs/fr/home/statistiques/catalogues-banques-donnees/tableaux.assetdetail.3502054.html

[6] Average surface is usually more than the ERA.

[7] https://www.bfs.admin.ch/bfs/fr/home/statistiques/catalogues-banques-donnees/tableaux.assetdetail.4582090.html

[8] https://awel.zh.ch/internet/baudirektion/awel/de/energie_radioaktive_abfaelle/veroeffentlichungen.html

[9]https://www.bfs.admin.ch/bfs/fr/home/statistiques/construction-logement/batiments/domaine-energetique.assetdetail.1621740.html

[10] http://www.bfe.admin.ch/themen/00526/00527/06431/index.html?lang=de&dossier_id=06421

3 Illustrative Results

3.1 Set-up

In this chapter, we demonstrate the functioning of the building stock model. As it is not yet complete (missing data and missing model components), we had to introduce some shortcuts to be able to run it, namely:

- We replace the energy label by date of construction (before 1919 corresponds to energy class I, 1919-1945 to energy class H, … and 2011-2016 to energy class A) as we have not yet included the data on space heating demand from Zürich and Geneva (see above).
- So far, the micro-economic decision model of the retrofit decision has only a “first layer”: we included retrofit cost and energy saving benefits from the transition of energy classes. Based on the first layer alone, an owner’s decision to retrofit would thus yield the same result for all buildings within an energy cohort (as buildings within an energy cohort have per definition the same specific energy demand and the same investment costs). The model would show a sudden surge in retrofits in the first year, followed by a rather low retrofit rate (as new retrofits would then only occur based on yearly decrease in retrofits costs and changes in energy prices). Currently we have circumvented this problem introducing an exogenous retrofit threshold (ERR) of 1%.
- The building stock model is not yet linked to GEMINI-E3.

Therefore, the following figures only serve as an illustration that the model in principle works. We will discuss some general pattern, but not precise numbers, as those are not yet meaningful. We have made 3 simulations:

- a reference scenario with the parameters given in Table 2;
- a second simulation with a 25% subsidy on retrofits;
- a third simulation with a 20% tax on fossil energy consumption.

Scenario: Reference

Table 2 shows the value of the parameters used in the reference scenario.

Duration of retrofit	40
Exogenous retrofit rate	0.01
Discount rate	0.03
CES elasticity of substitution	0.25
Technical progress on retrofit	0.01
Subsidy on retrofit	0
Tax rate on energy consumption	0
Demolition rate	0.005

Table 2: The values of the parameters in the reference scenario

For each energy class and year, Figure 2 and Figure 3 show the results of a fist simulation of the building stock model, i.e. the resulting energy reference area and the amount of retrofits, respectively. Figure 4 shows the energy consumption by energy carriers (in TJ).

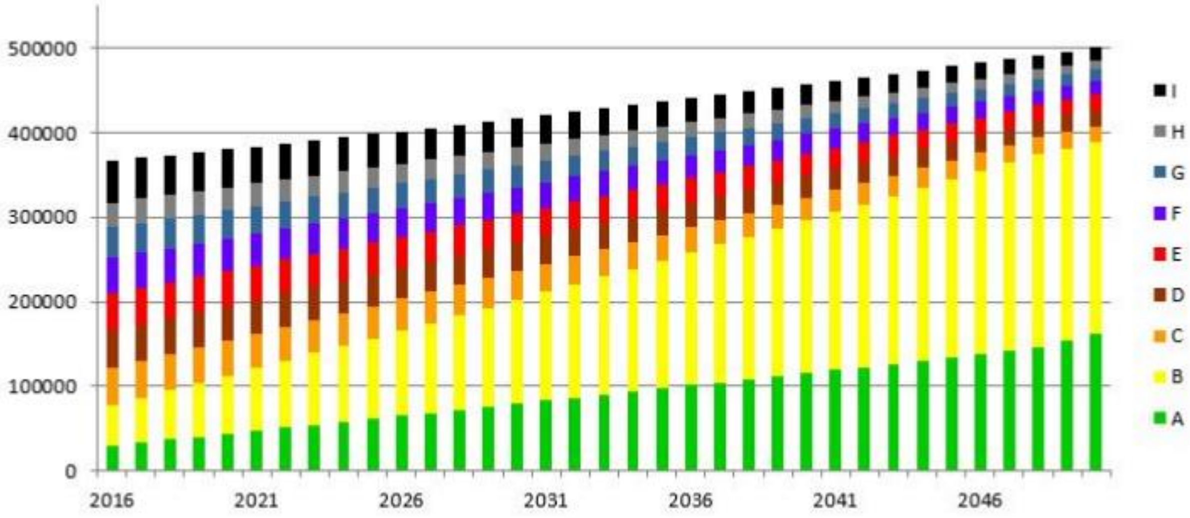

Figure 2: Energy reference area in sqm – reference scenario

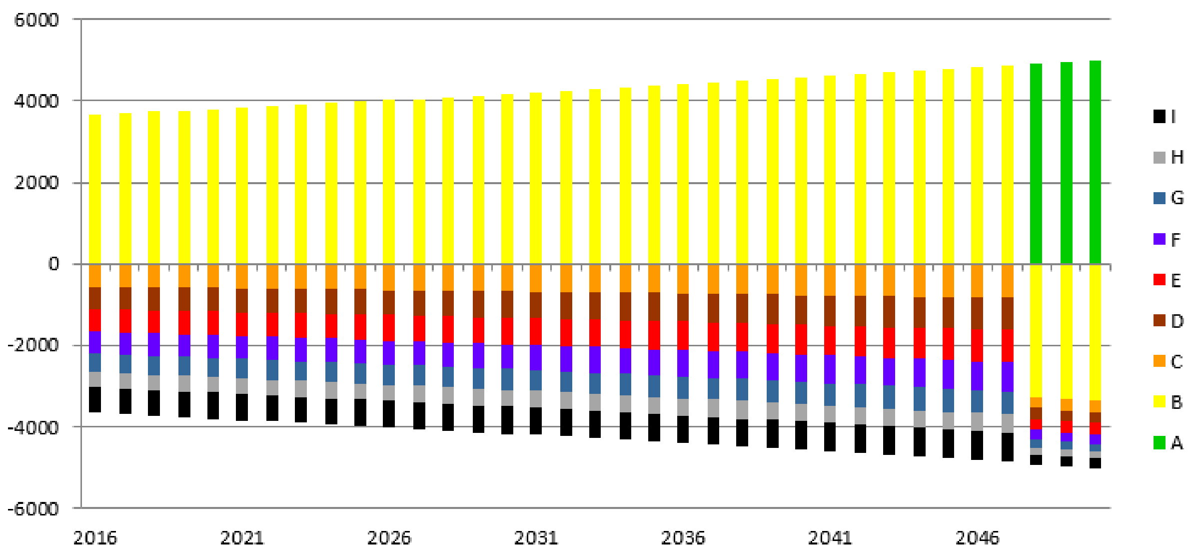

Figure 3: Retrofit in sqm – reference scenario (negative numbers are buildings that are subtracted, positive numbers are buildings that are added to an energy cohort)

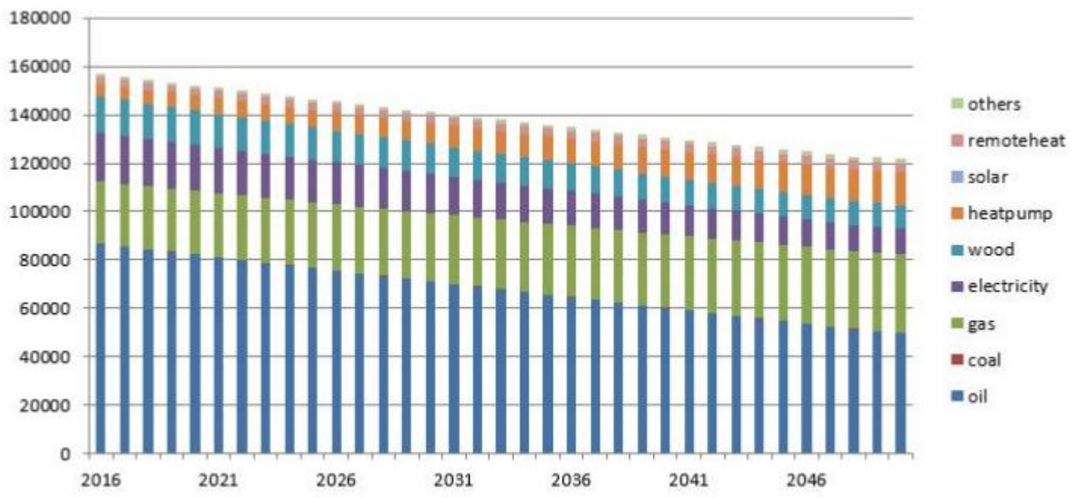

Figure 4: Energy consumption by energy carriers in TJ – reference scenario

Subsidy on retrofit

In this scenario we assume that there is a 25% subsidy on retrofit cost. In comparison to the reference scenario the amount of the buildings retrofitted is the same (Figure 5), because currently by assumption the exogeneous retrofit rate is the same (1%). But for example, the area of buildings in energy class A increases and the area in energy class B decreases. That shows us that the buildings previously in energy class B switched to the label A. Retrofits to energy class A are the most expensive ones, but since we have subsidies, it is still profitable to do the retrofit. Figure 6 and Figure 7 show retrofit in sqm and energy consumption by energy carriers.

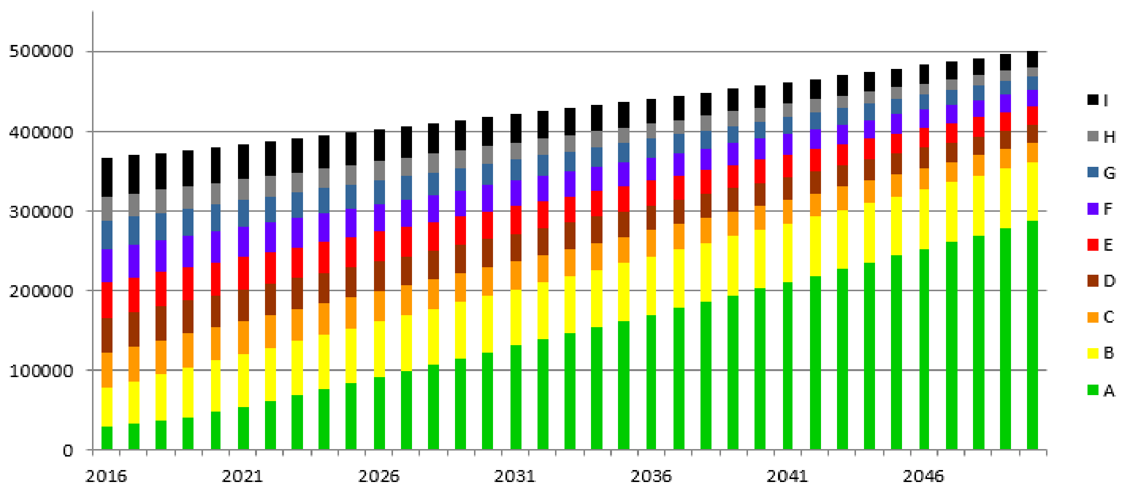

Figure 5: Energy reference area in sqm – Scenario Subsidy (25%)

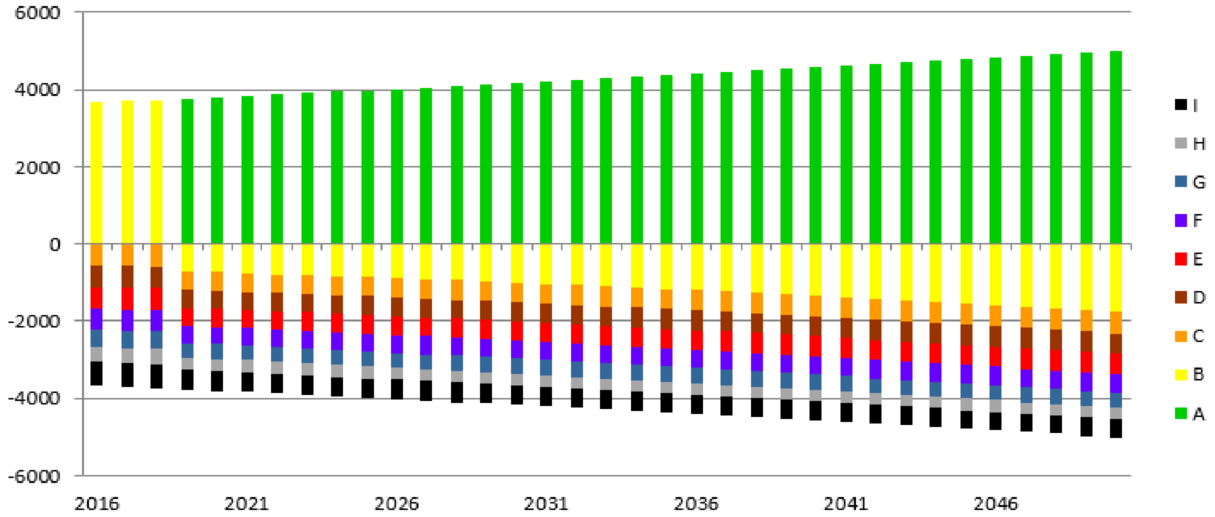

Figure 6: Retrofit in sqm –scenario subsidy (25%) (negative numbers are buildings that are subtracted, positive numbers are buildings that are added to an energy cohort)

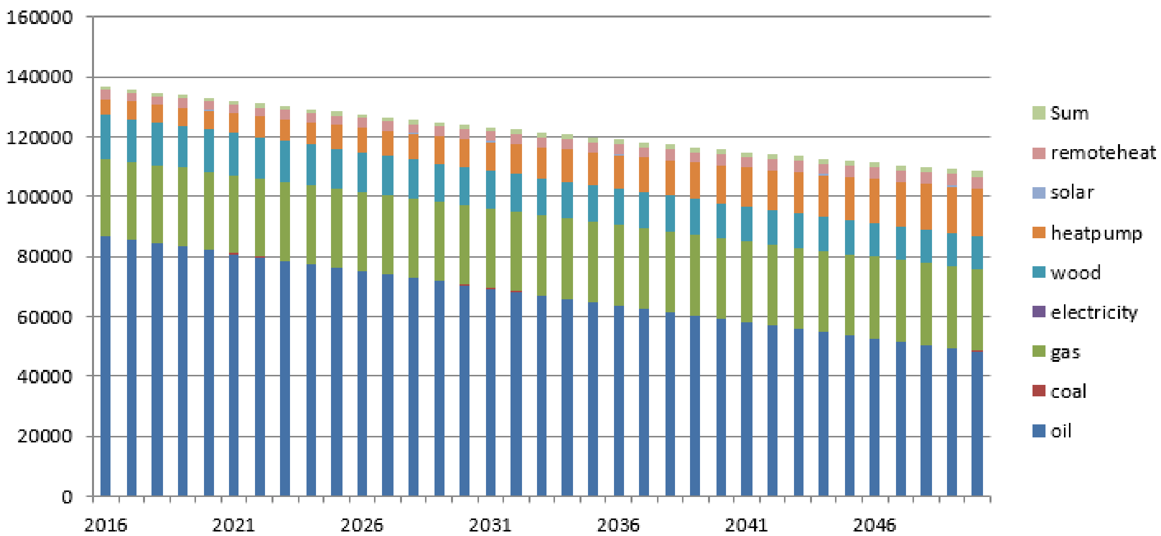

Figure 7: Energy consumption by energy carriers in TJ – Scenario Subsidy

Tax on fossil energy consumption

In this scenario, we assume a tax on fossil fuel energy of 20%. In comparison to the reference scenario the amount of retrofitted buildings is again the same (see Figure 8). But the area of buildings in energy class A increases and the area in energy class B decreases. In this scenario the results are slightly better than in the scenario of subsidies. As in the previous case, this shows for example us that more buildings previously in energy class B switched to the energy class A. Retrofits to energy class A are the most expensive ones, but since we introduced the tax on fossil fuel energy, it gives higher incentive to do the retrofit. Figure 8 and Figure 10 show Retrofit in sqm and energy consumption by energy carriers.

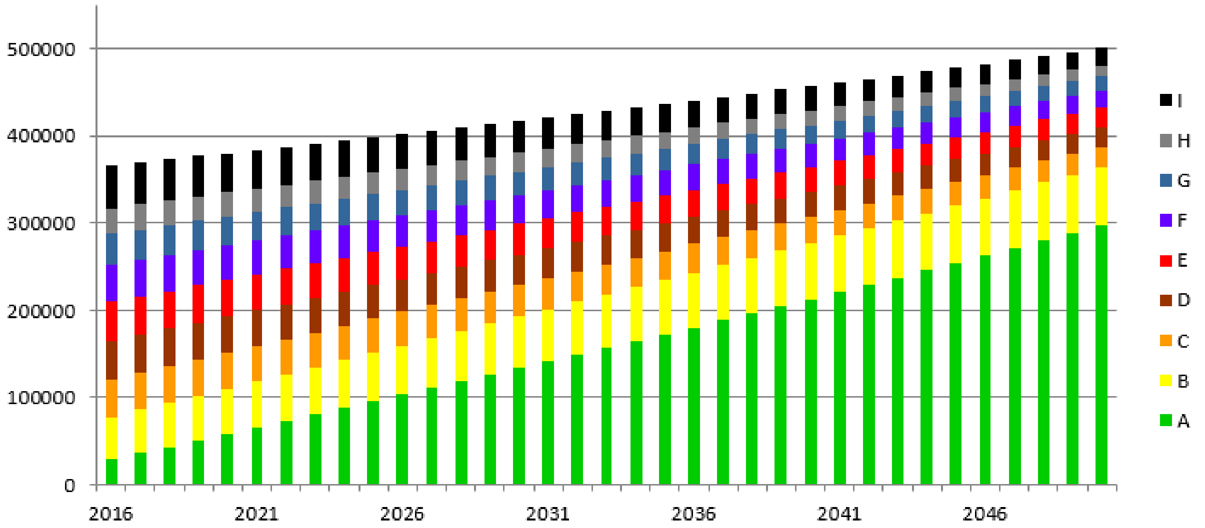

Figure 9: Energy reference area in sqm – scenario tax on fossil energy (20%)

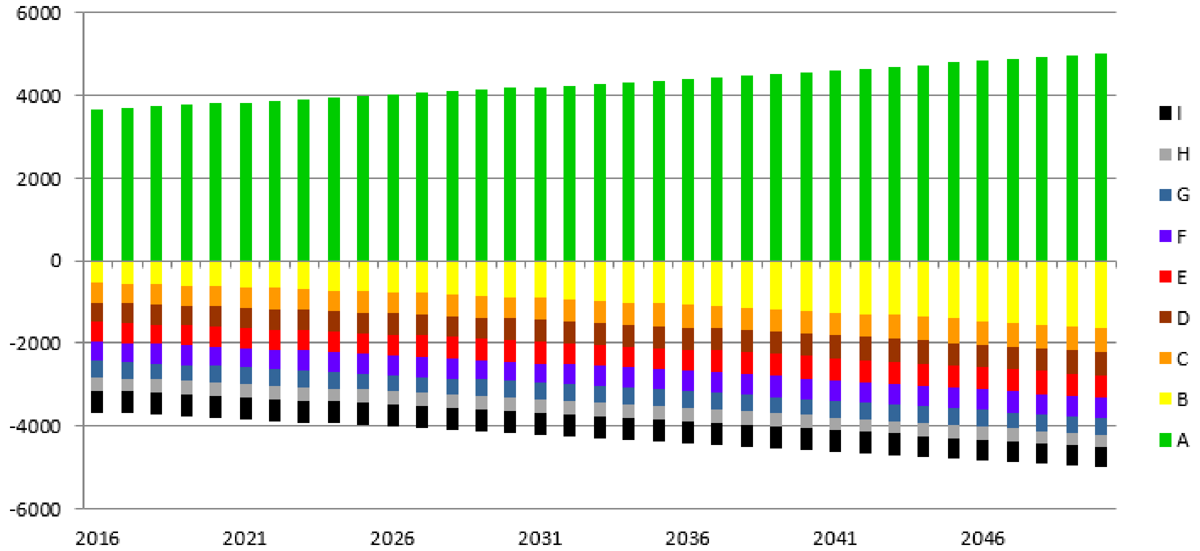

Figure 8: Retrofit in sqm – scenario tax on fossil energy (20%) (negative numbers are buildings that are subtracted, positive numbers are buildings that are added to an energy cohort)

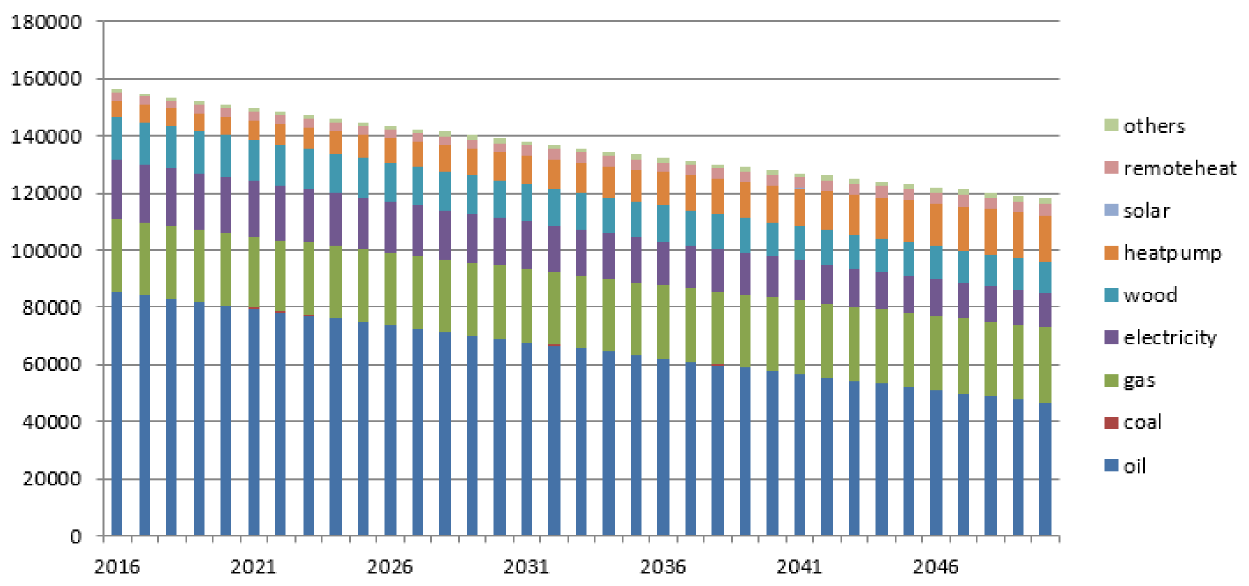

Figure 10: Energy consumption by energy carriers in TJ – scenario tax on fossil energy (20%)

4 Evaluation 2018 and outlook for 2019

Evaluation 2018

This was the first year of the project.

For work package 1, we have collected data and implemented a preliminary version of the building model (transition dynamics of a reference and two policy scenarios). We made the calibration of the model, based on the data as listed above. We have not endogenized parts of the retrofit decision (there is still an exogenous retrofit rate) and are thus slightly behind schedule.

For work package 2, we have defined the cement sector as the appropriate sector for our analysis and made suggestion on data collection. Prior to the selection of the cement sector, we have defined criteria (high energy intensity, significant energy consumption in Switzerland, homogeneous goods, data availability, past and future potential of energy efficiency improvements, Value added of the sector). We made this choice in agreement with the SFOE. We have not yet any results of the literature review phase on approaches to endogenize technological progress and on the description of the technology. Therefore, we are behind schedule with WP 2.1.

Overall, the project is in slight delay as compared to the rough timeline we made at the proposal. But the project is still on track given the timeline of the project.

Outlook for 2019

Building stock model

In the building stock model, we mainly shall resolve the shortcuts as described in the Section 3.1. most importantly, we will refine the micro-economic decision model of the retrofit decision. In the final model we will remove the threshold ERR (as described above) and completely endogenize the retrofit rate. To do so, we will implement idiosyncratic characteristic and barriers as a second layer. Currently, we see two options:

1. Version Histograms: We may construct histograms or probability density functions (pdf) of benefits/costs within an energy cohort which finally determine the investment decision. That is, if net benefits are positive, the owner makes a retrofit with 100% probability; if they are negative, with 0% probability (the retrofit decision is a step function). In such a model all further idiosyncratic characteristics would have to be monetarized in some form and be included into the benefits/costs. In a first step we may merely explain the shape of the histogram/pdf using those further characteristics. To more clearly show their effects, we may - as a refinement in a second step use some of those characteristics to explicitly model the shape of a histogram (e.g. 10% of all buildings within a cohort have prohibitively high retrofit costs due to certain barriers, etc.)
2. Version Discrete Choice: We may use the pure economic costs (first layer) as an input into a discrete choice model. The shape of the discrete choice model is determined by the characteristics of the second layer (for example Jakob et al. 2016 uses a discrete choice approach for various parts of their model).

Industry sector:

We will to define a way do endogenize EEI in the cement sector based on a literature review. As a next step we will collect data. Potential data sources are the targets on energy efficiency improvement and the emission trading scheme. In addition, we may conduct lean case studies together with some cement companies.

Presentations

The results will be presented in

- 3rd AIEE Energy Symposium (Milan, 10 -12 December);
- SAEE Student Workshop 2018 (Zürich, 23 November).

We plan to submit abstracts to:

- Annual Meeting of the Swiss Society of Economics and Statistics (SSES/SGVAS) (Geneva, 13-14 June);
- CISBAT 2019 International Scientific Conference (Lausanne, 4 - 6 September);
- IAEE International Conference 2019 (Montreal, 29 May- 1 June).

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