Endogenous energy efficiency improvement of large-scale retrofit in the Swiss residential building stock

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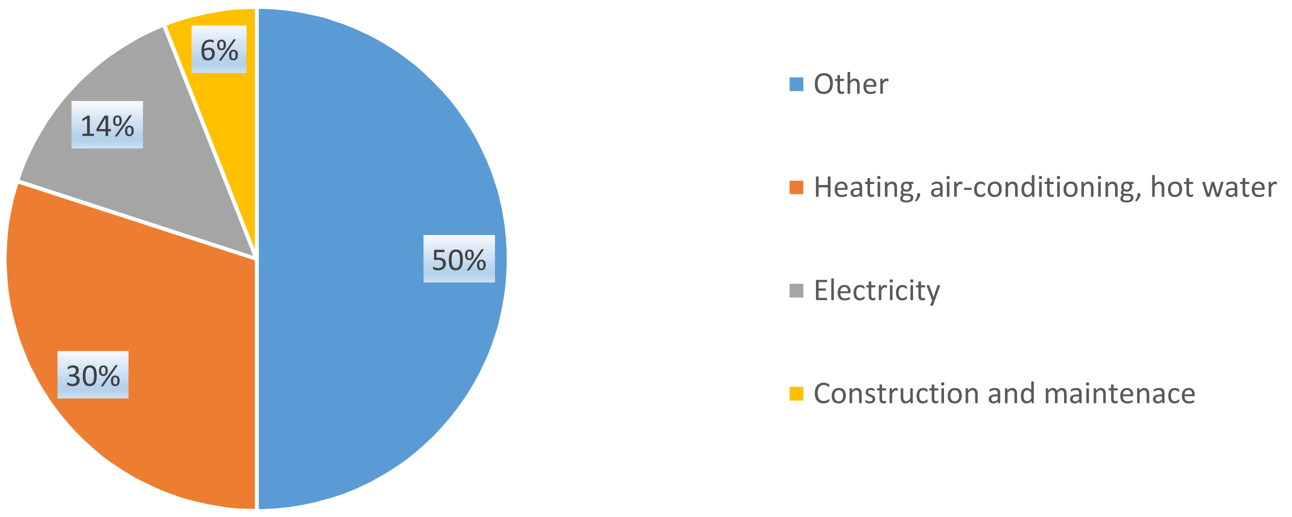
Introduction

According to SFOE: 50 % of energy consumption in Switzerland is attributable to buildings:

- The evolution of energy efficiency (EE) takes an important role for energy consumption



- In the literature in the field of Swiss energy and climate policies, the expansion of EE improvement is set exogenously
- It is considered to be unaffected by energy policies for innovation and the development
- It is important because making endogeneous EE improvement will probably help to more efficient energy policies

Objectives

Introduce a new methodology in an existing economic model of the Swiss economy targeting at a better representation of the acceleration of EEI due to energy and climate policies

Illustrate this by assessing the impacts of a set of realistic policies on the adoption of technologies associated with energy consumption in Switzerland

Policy relevance

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The model will allow addressing the following policy relevant key questions:

How effective are current and planned energy and climate policies in stimulating EEI?

What are the impacts of these policies on energy imports and use, on the energy mix and on CO_2 emissions?

How can existing models (CGE models) be improved efficiently to generate more realistic scenario results?

How can existing and planned policies be made effective in promoting EEI? What new instruments could be helpful?

Academic value added

The main academic added values are the following:

a) To demonstrate a theoretically founded and computationally tractable integration of endogenous technical change (ETC) due to policy into a macroeconomic simulation model

b) To show how relevant ETC can be for energy and climate policy simulation

Review of theoretical foundations

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- One reason why most economic models applied to energy policy content with exogenous EEI: the introduction of endogeneity is difficult to generalize to several sectors and to several countries.

- The lack of statistical database at a worldwide level is an important limitation

- **CONTRARY:** My project focuses on one country (Switzerland) and two representative sectors: housing and an *industry sector*

- Good availability of data will increase considerably its feasibility

Housing

A decomposition of the buildings stock of Switzerland that is relevant for its energy consumption is needed.

Distinguishing by:

Building typology (single- and multi- family houses)

Specific energy efficiency indicators (CECB classification) (Gebäudeenergieausweis der Kantone)

Energy carrier* (heating oil, natural gas, district heating, electricity, etc)

Formal model done

The housing stock is grouped into energy cohorts EC that will follow CECB (Cantonal Energy Certificate for Buildings) classification. The classification is given in Table 1

Each energy cohort has fixed specific space heating demand and the energy cohorts are ranked with the following relationship:

$$SHD_{A,t} < SHD_{B,t} < \ldots < SHD_{F,t} < SHD_{G,t} \quad \forall t$$

I need to combine my the model with GEMINI-E3* so that I will be able to perform policy simulations

GEMINI-E3 is a computable general equilibrium (CGE) model that was specifically designed to assess energy and climate change policies

Formal model done

The quantity of buildings in cohort: measured by the total energy reference area ERA (m^2) in the cohort

The ERA changes from one period to the next through:

a) Demolition b) New construction

c) Transfers between cohorts (refurbishment) *

*A cohort loses buildings whose energy efficiency is improved to a better EC label.

*It gains buildings from less efficient cohorts that get improved to its own EC label.

$$ERA_{EC,t+1} = (1 - DR_{EC,t}) \cdot ERA_{EC,t} + NC_{EC,t} - \sum_{A}^{EC' < EC} RM_{EC,t}^{EC'} \cdot ERA_{EC,t} + \sum_{EC' > EC}^{G} RM_{EC'}^{EC} \cdot ERA_{EC',t}$$

Table 1 CECB labels

	Efficiency of the building envelope	Overall energy efficiency
A	Excellent thermal insulation with triple- glazed windows.	State-of-the art technical installations in the building for the production of heat (heating and domestic hot water) and light; use of renewable energies.
B	New building achieved a B , rating according to the legislation in force.	Standard for new buildings and technical installations; use of renewable energies.
C	Older properties where the building envelope has been completely renovated.	Older properties that have been completely renovated (building envelope and technical installations), most often using renewable energies.
D	A building that has been satisfactory and completely insulated retrospectively, but with some thermal bridges remaining.	The building has been renovated to a large extent but presents some obvious shortcomings, or does not use renewable energies.
E	A building with significantly improved thermal insulation, including the installation of new insulating glazing.	A partially renovated building, with a new heat generator and possibly new appliances and lighting.
F	A partially insulated building.	A building partially renovated at best, with replacement of some equipment or use of renewable energies.
G	A non-renovated building with retro - fitted insulation that is incomplete or defective at best,and having exten - sive potential for renovation.	A non-renovated building with no use of, renewable energies and with extensive potential for renovation.

Refurbishment behavior

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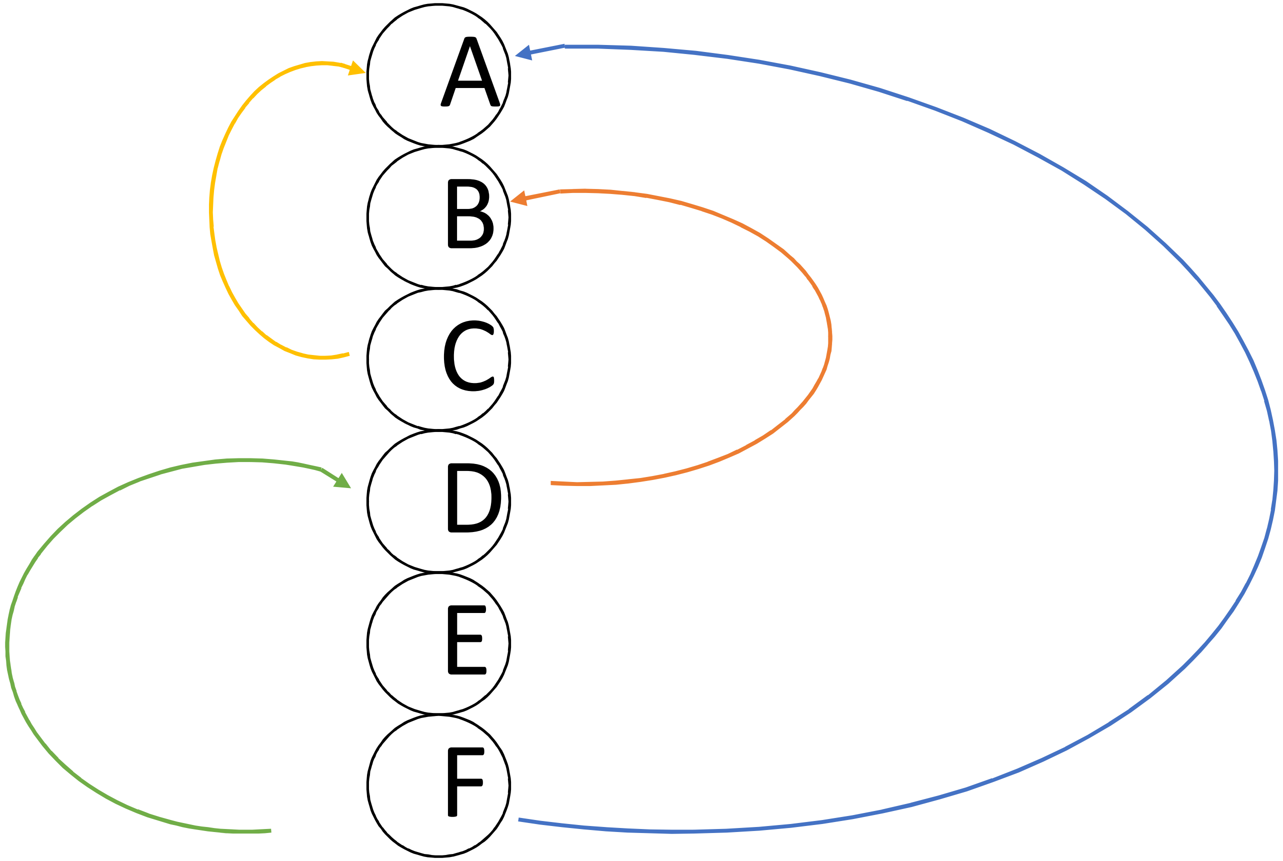
- The energy consumption of the building stock changes when buildings are refurbished and when the heating system is replaced

- Refurbishment moves buildings from one cohort to a higher cohort

- The better the energy refurbishment, the higher cohort the building moves to, i.e. it becomes equivalent to a more recent building



Housing

Refurbishment decision depends on:

1) First layer: pure economic costs, that is (i) investment costs and (ii) retrofit benefits in form of saved energy costs
2) Second layer: further individual characteristics of the buildings and owner, such as:

age of the building	*building type (single and multi-family houses)*
owner type	*location*
type and age of heating system	*owner preferences, risk attitudes*

Results

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4 main Scenarios were conducted:

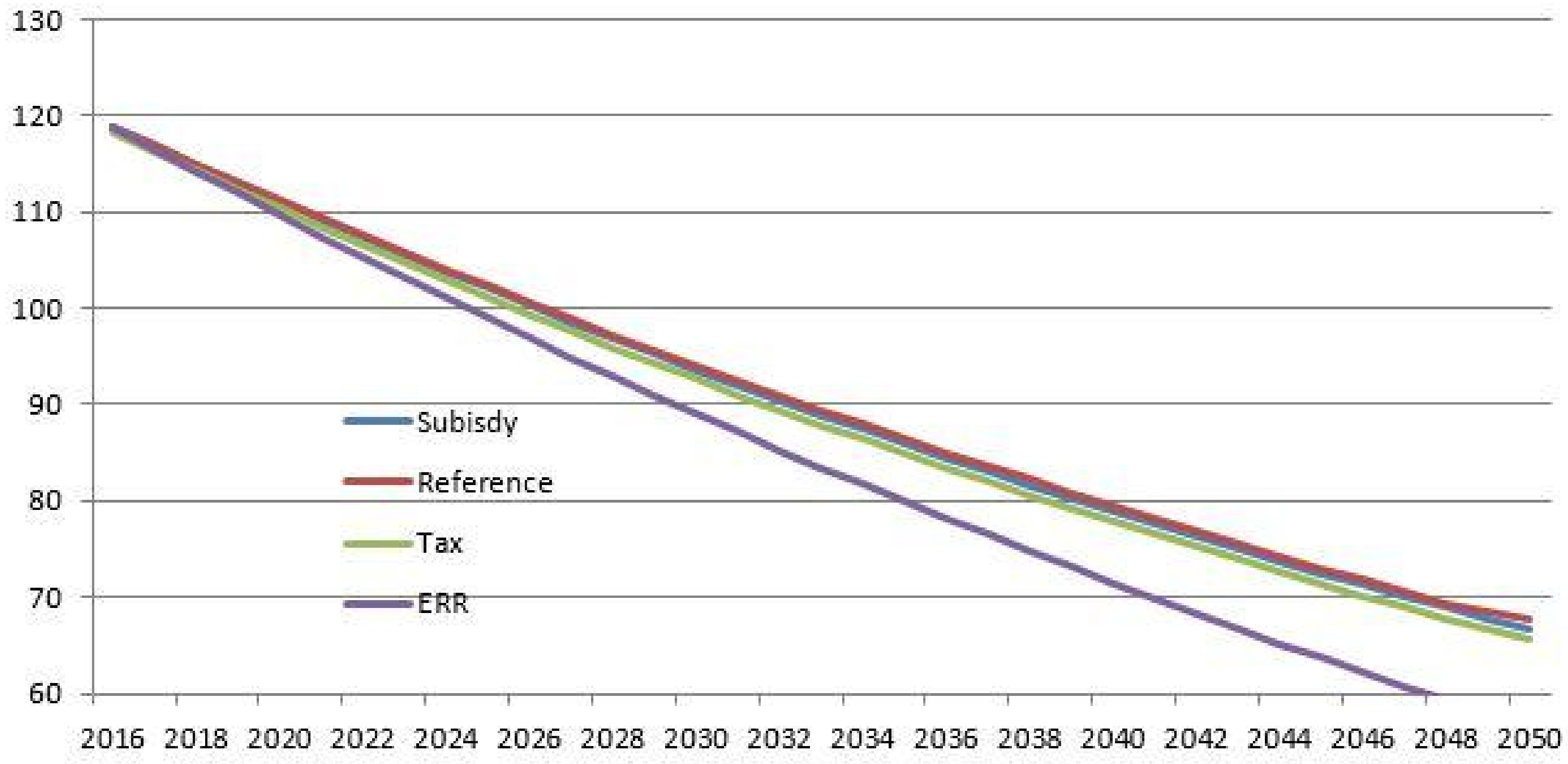
- ❑Reference scenario
- ❑Subsidy on retrofit (25%)
- ❑Tax on fossil energy (50%)
- ❑Exogeneous retrofit rate (1.5%)

Table 14: Value of parameter in the reference scenario

Duration of retrofit	T^R	40
Exogenous retrofit rate	ERR	0.01
Discount rate	r	0.03
CES elasticity of substitution	σ_{EC}	0.25
Technical progress on retrofit	τ_{RC}	0.01
Subsidy on retrofit	$\tau_{EC,t}^{EC'}$	0
Tax rate on energy consumption	$\tau_{i,t}$	0
Demolition rate	DR_EC	0.005
Share of cohort EC in construction	ϕ_A	0.7
Share of cohort EC in construction	ϕ_B	0.3

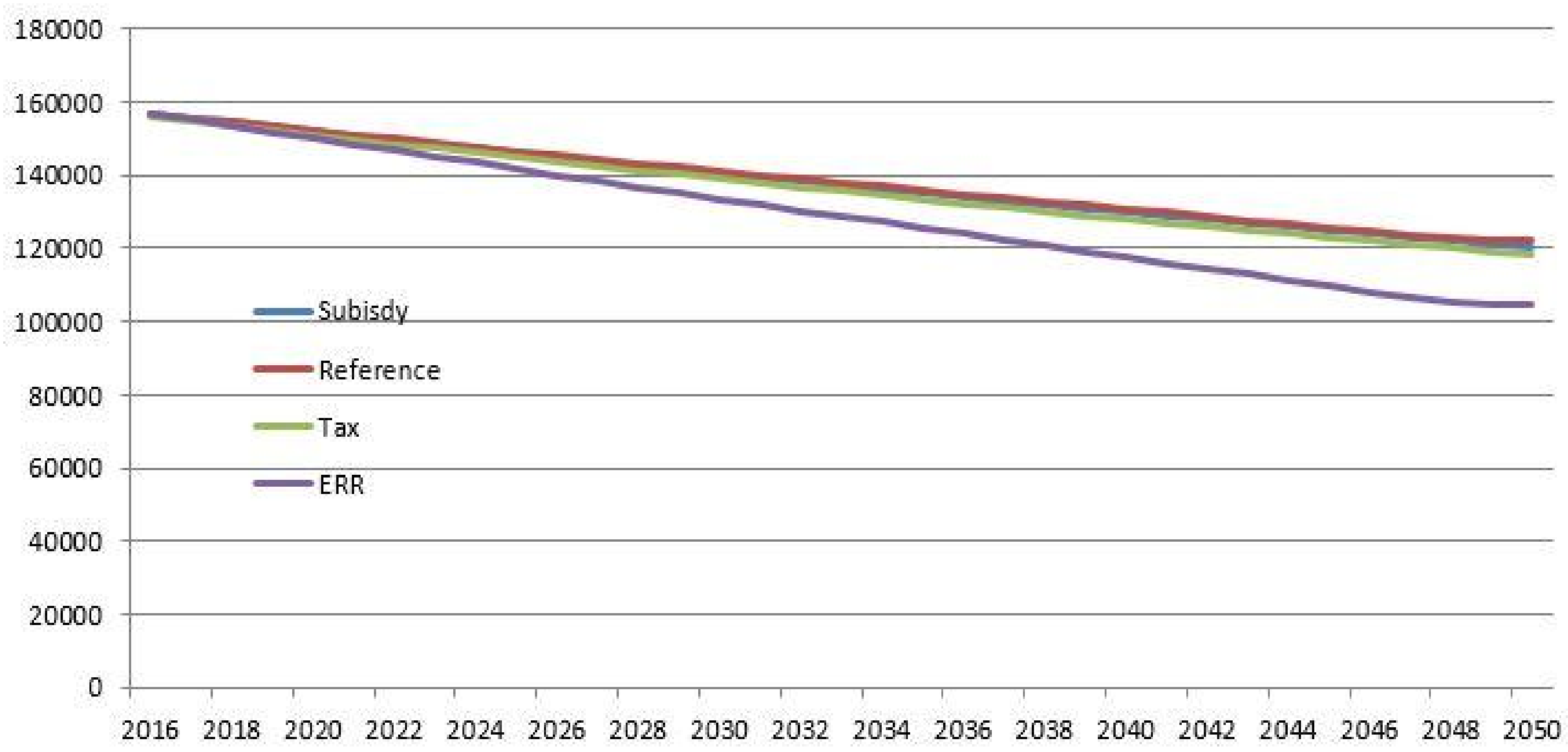
Comparison of Results

Space heating Demand (SHD)

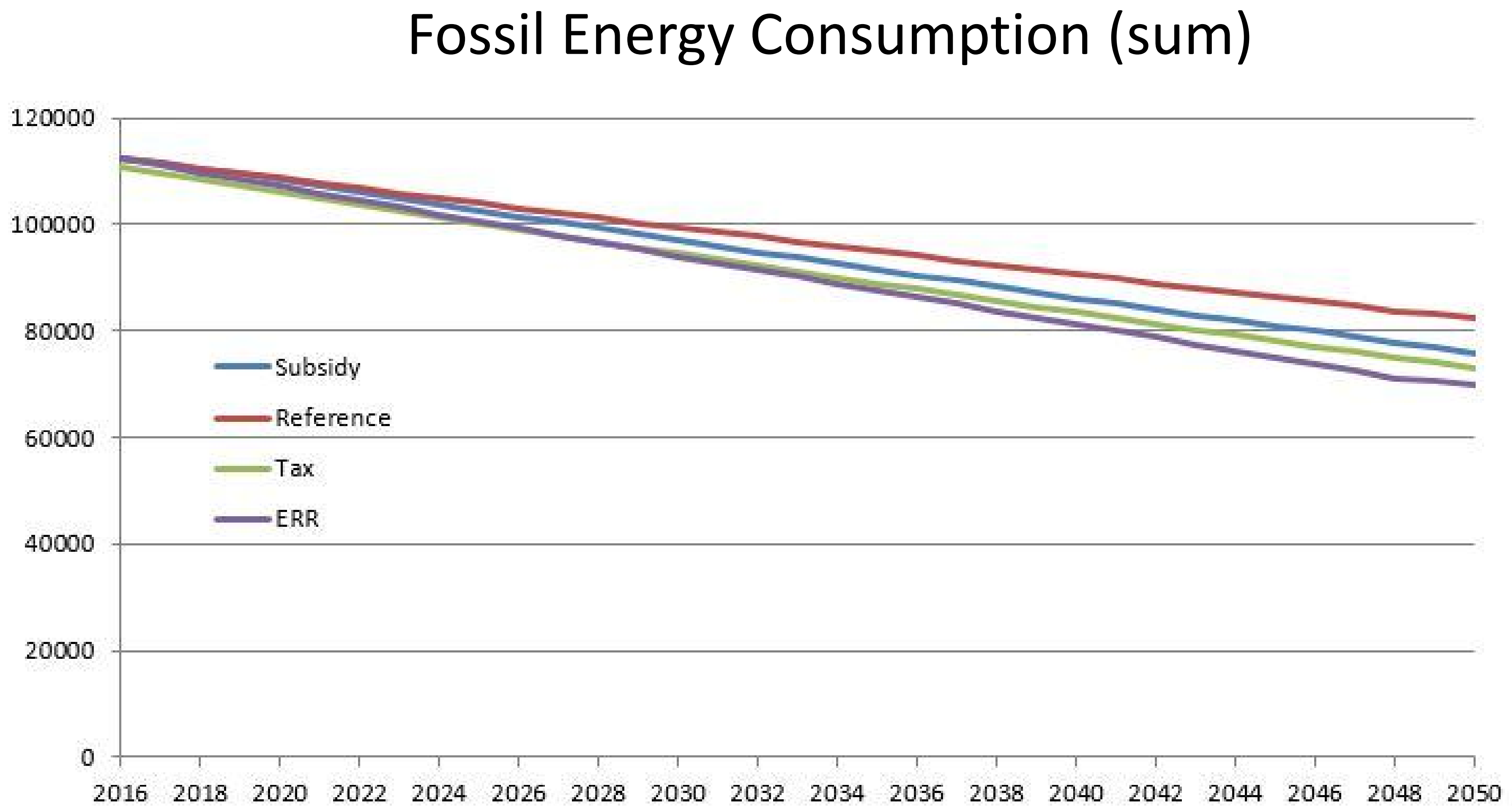


Comparison of Results

Energy Consumption (TJ)

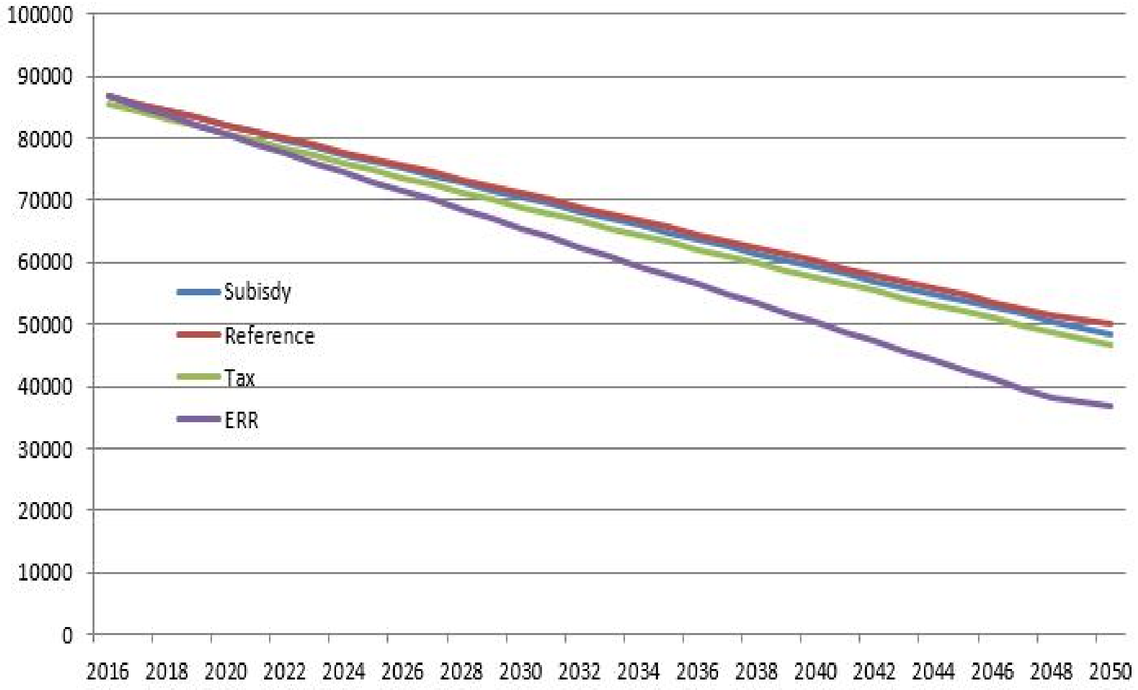


Comparison of Results

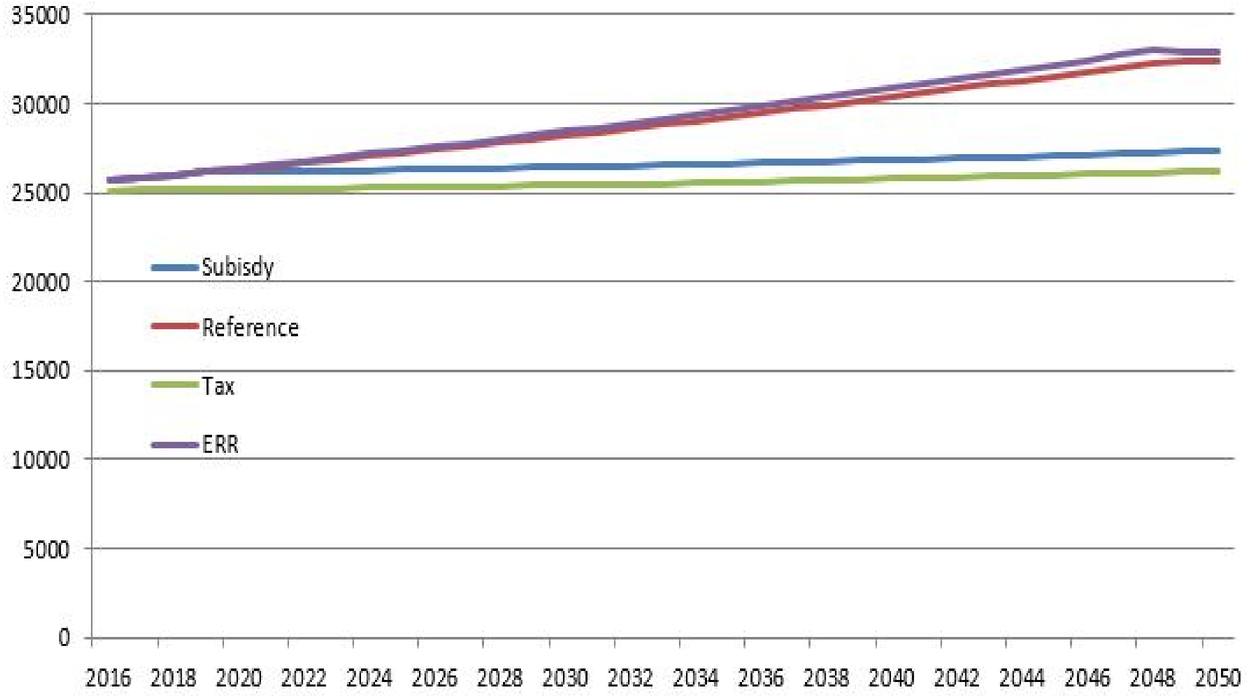


Comparison of Results

Fossil Energy Consumption (Oil)



Fossil Energy Consumption (Gas)



Further improvements

Housing

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We have two options how to include individual characteristics into the investment decision:

Version Histograms:

Construction of histograms of benefits/costs within an energy cohort (which finally determines the investment decision)

Version Discrete Choice:

The pure economic costs (first layer) and maybe some characteristics of the second layer will be used as input to a discrete choice model

Now it is not clear which approach is best suited for the respective barriers in the respective sectors.

It will depend on data availability and the complexity of an approach in comparison to the expected model improvements.

Housing

The validity of the model will be tested:

Through its ability to replicate the observed heating energy use of buildings

Several simple energy and climate policies, aimed at the housing sector will be simulated (with GEMINI-E3, including the effects of barriers)*

Integration of barriers into the model

A prudent representation will considerably effect rigorousness of a policy which is indispensable*

Barriers arise from incomplete information, uncertainty, bounded rationality, market failures.

The following steps will be undertaken to integrate barriers:

Find and improve suitable input data parameters / equations / structures in GEMINI-E3 to model barriers.

Conclusions

Database collection:

I need data in order to calibrate the model

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Parameter	Unit	Source
Annual Increase in housing	number	SFOE
Occupied Housing	number	SFOE
New constructions	number	SFOE
Average surface per year and per number of rooms	square meter	SFOE
Degree-days of heating	degree	SFOE
Average surface per inhabitant	number	SFOE
Population	number	SFOE
Buildings by canton, building category, heating system, hot water production, energy agent and time of construction	number	SFOE
Energy Reference Area (ERA)	square meter	SFOE
Buildings by type of heating, energetic agents used for heating and cantons	number	SFOE
Distribution of buildings according to the energy agents of heating and hot water	percentage	SFOE
Distribution of buildings by heating system	percentage	SFOE
Dwellings by type of heating, energetic agents used for heating, by age of construction and renovation	number	SFOE
Buildings by territorial division, by type of heating and energetic agents used for heating	number	SFOE

Parameter	Unit	Source
Average Space Heating Demand per ERA and year of construction of Single and Multi family houses (Useful and Final energy)	kWh / m^2	Martin Patel (UNIGE)
Share of total Swiss Space Heating Demand per year	percentage	Martin Patel (UNIGE)
Energy Reference Area (ERA)	square meter	SCEER
Average surface per cohort	square meter	Our estimations
Demolition rate	percentage	Our estimations
New constructions per capita	number	Our estimations
New constructions' overall surface	square meter	Our estimations
Energy consumption of Single and Multi Family houses by energy carrier	Joule	Our estimations
Refurbishment Cost	CHF / m^2	Our estimations
Space heating demand	kWh / m^2	Our estimations
Energy consumption per square meter for Canton of Zurich	kWh / m^2	Energie in Wohnbauten (AWEL, Zurich, 2014)