Schweizerische Eidgenossenschaft
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Department of the Environment,
Transport, Energy and Communication DETEC

Swiss Federal Office of Energy SFOE
Energy Research

Annual report 2019

Endogenous energy efficiency improvement

Date: 29.11. 2019

Location: Bern

Subsidiser:
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SFOE contract number: SH/8100087-00-01-03

SUMMARY

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

WP 1 Housing

We conceived and coded a building stock model to endogenise energy efficiency in the housing sector. The model divides the Swiss building stock in different energy cohorts. To simulate the retrofit decision of the owners, we developed a two steps model, which using data related to the energy consumption of energy carriers, energy reference area and price of heating in Switzerland. The two steps model is the core of our Building stock model introducing a innovative methodology to endogenise the energy efficiency improvement decision of property owners.

The model works and has many interesting features. At this moment we have run several scenarios including a deep carbonization pathway of the housing stock. As a last step the model will be coupled with GEMINI-E3.

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 quite homogeneous, the sector has a high energy intensity and there is data available, which we have collected and analysed. We may also conduct a reality check, contacting cement experts from Holcim. We defined the basic model, conducted first simulations and obtained preliminary results.

Abbreviations

EEI	Energy Efficiency Improvement
CGE	Computable General Equilibrium
ETC	Endogenous Technical Change
SFOE	Swiss Federal Office of Energy
ERA	Energy Reference Area

1 Introduction

1.1 Background information and current situation

The evolution of energy efficiency is of vital importance for the 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 to 84% of the 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) 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 are 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 improve upon this problem.

1.2 Purpose and objective of the project

The fundamental purpose of this research is to introduce a new methodology in an existing economic model of the Swiss economy (GEMINI-E3) targeting a better representation of EEI acceleration 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 (e.g. incomplete information). Such a representation can significantly influence the rigorousness of a policy (e.g. the level of a tax) to achieve a target as well as the implementation (information, standards, financial incentives, etc.). Thus, assessing the sensitivity of the results to these assumptions is another key contribution of the planned work.

Therefore, in this work, we show how energy efficiency improvement can be endogenised in a sufficiently tractable way to be used with CGE models. We shall prove the concept with our CGE model GEMINI-E3 (see e.g. Bernard and Vielle 2008). To incorporate EEI as accurately as possible, we focus on a rather detailed description of the building sector and the cement industry, as these are very relevant for Swiss energy consumption. We want to quantify the impact of these measures with plausible data and consider barriers to EEI.

2 Procedures and methodology

2.1 The Building Stock Model

The Swiss building stock is divided into seven energy classes, A to G, each representing a different range of space heating demand (kWh/m^2). The percentage ranges are defined based on the Cantonal Energy Certificate of Buildings energy standards.

First, we estimated a distribution of the Swiss building stock regarding these energy classes. The data is in addition distinguished by construction period, by energy carrier (heating oil, natural gas, etc) and by owner type.

The building stock becomes more energy-efficient because (i) a given share of buildings are retrofitted every year, (ii) new buildings are more energy-efficient, (iii) old buildings are demolished. We represent each of those steps separately. To represent (ii) and (iii), we draw on and extrapolate actual data for each energy class.

Regarding (i), the energy consumption of the building stock decreases when buildings are retrofitted[1], as a retrofit moves a building to a better energy class. To obtain realistic retrofit rates we introduce a two steps model that represents the property owners' retrofit decision. In the first step, we assume that owners are initially unaware of the costs and benefits of a retrofit. A certain percentage of the owners is triggered each year to conduct a respective audit. This trigger might be a letter from the community, speaking with his/her spouse, reading the newspaper, etc. In the second step, the triggered owners decide on doing a retrofit, depending on the result of the energy audit.

Moreover, if a house is rented, we use a split incentive parameter, which takes into account that only a part of the monetary energy saving can be recovered by the landlord through a rent increase. This split incentive represents a well-known barrier to the implementation of energy efficiency measures in buildings.

2.2 The Cement Industry Model

The cement industry is one of the most energy and CO2 intensive sectors in Switzerland. Currently, there exist six cement plants in Switzerland. 94% of the production is done in rotary dry kilns, the rest in semi-dry kilns. The six plants produce around 5 million tonnes of cement each year. The share of Swiss industry's total final energy demand in 2014 is 9% and the share of CO2 emissions is 10% (Zuberi and Patel 2016). From 2002 until 2014, final energy demand, CO2 emissions and cement production increase was 1.1%, 1.1% and 1.8% per year, respectively.

Zuberi and Patel (2016) provide a list of energy efficiency and CO2 abatement measures that are applicable in those Swiss plants. Using this data, we will calculate the net present value (NPV)[2] and the pay-back period (PBP) of all measures. With those two metrics we plan to establish a realistic decision rule regarding which measures the plant operator implements. If two energy measures would be implemented but this is technically not feasible simultaneously, the more profitable measure will be implemented.

Furthermore, following Zuberi and Patel (2016), we distinguish between essential unit process (EUP) measures and pure energy efficiency measures (PEEM). When a EUP measure is implemented the operation of the plant has to be stopped and such a measure may have benefits besides energy efficiency (e.g. mill replacement). When a PEEM measures is implemented the plant can continue working (e.g. waste heat recovery or optimization of the overall process control system). For EUP measures we calculate a stopping cost (SC) of the plant, which takes into account the construction time of the measure, the lost profit during that time and the fact that no energy is consumed during a stop. EUP measures may be implemented during annual maintenance shutdown periods.

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[1] It also decreases if a more efficient heating system is installed. Yet, this effect is not included in our model, as the focus is on retrofits of the buildings' hull. We do however model the change in energy carriers concurrent with those retrofits.

[2] Defined as investment costs minus operating costs such that NPV < 0 is profitable.

Using the data from Patel and Zuberi (2016), the NPV and PBP of certain measure are as given in the following figures.

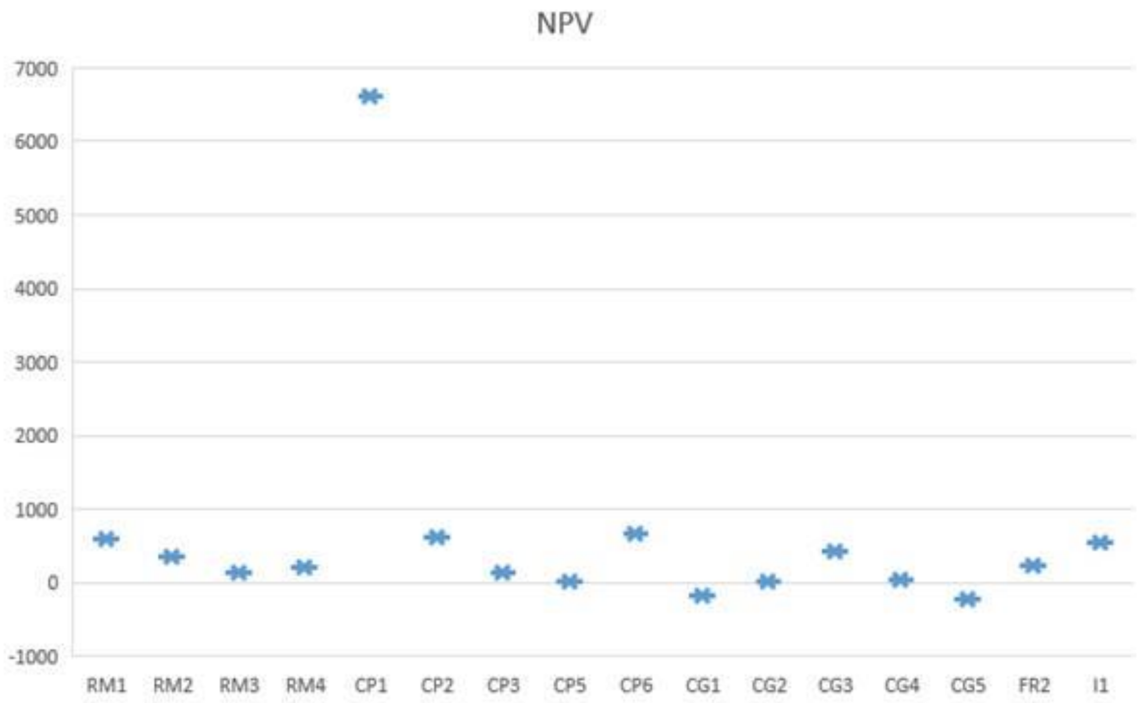

Figure 1: NPV for several measure (Unit: CHF/ ton of clinker; acronyms for measures according to Zuberi and Patel (2016))

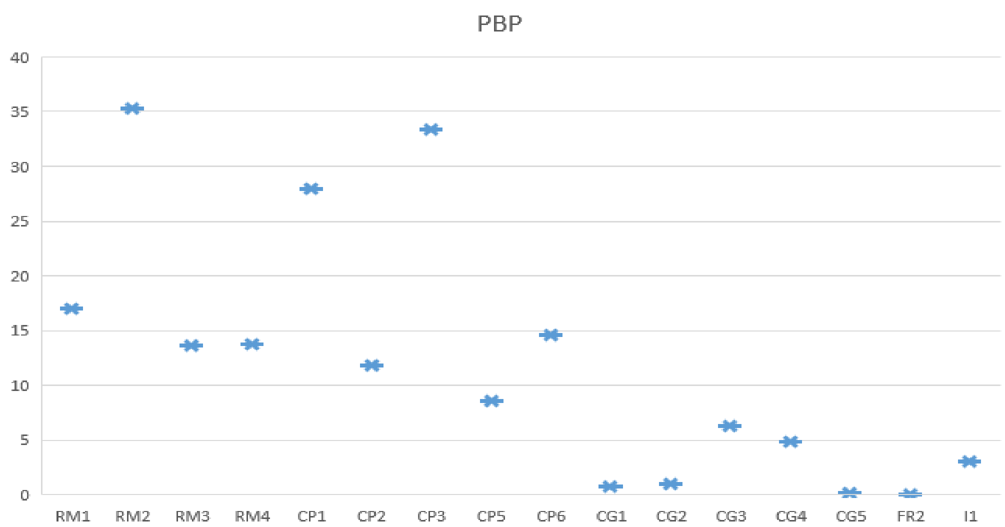

Figure 2: Pay-back period for each measure (Unit: years; acronyms for measures according to Zuberi and Patel (2016))

Additionally, the model will include specific refinements such as:

- Competing measures,
- Electricity consumption,
- Discount rates, age of equipment, measurements already implemented in all 6 existing plants in Switzerland.
- Energy related investment cost
- Technological progress (TP). Constant improvement with time: Investment costs decrease for all the measures by 2% a year
- Taxes, subsidies on investment
- The efficiency potential depends on how many measures are already implemented (Some measures save a fraction of the total energy consumption and not an absolute value)
- Fixed cost of implementing the measure
- Only one measure per period can be implemented

After modelling the implementation of the measures, we compare the resulting energy consumption with a reference scenario.

3 Activities and results

The following results are only related to the housing model. There are no comparable results for the cement model yet.

We run 1 reference case and 6 policy scenarios: Subsidies (1 scenario), CO2 tax (2 scenarios), Information level (1 scenario) and Combinations of different economic instruments (2 scenarios) (see Appendix). Although these scenarios are partly inspired by currently discussed options, they do not represent any particular policy. That is, these scenarios are illustrative and their main purpose is to demonstrate the functioning of the model.

In the reference scenario, there is a decrease of the retrofit of buildings from 2015 until 2050 (Figure 3). This shows that the policy instruments of the reference scenario do not suffice to incentivize enough retrofits. The same can be seen from the energy reference area (Figure 4) that demonstrates the share of buildings in energy class A, which consist of less than 50% of all the Swiss building stock in 2050. The third indication of the weakness of the instruments in the reference scenario are exhibited in the Figure 5 that presents the energy reference area (ERA) per owner group (see Table 1). It shows that in 2050 the owner groups from 1 to 4 are doing retrofits, whereas groups 5 and 6 (the private and institutional landlords) do not.

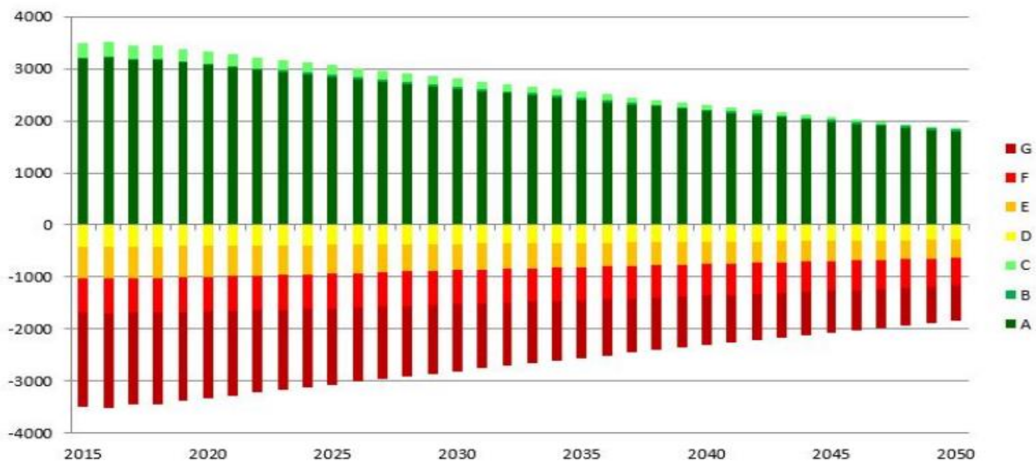

Figure 3: Retrofits in m^2 - Reference scenario (negative numbers are buildings that are subtracted, positive numbers are buildings that are added to an energy class)

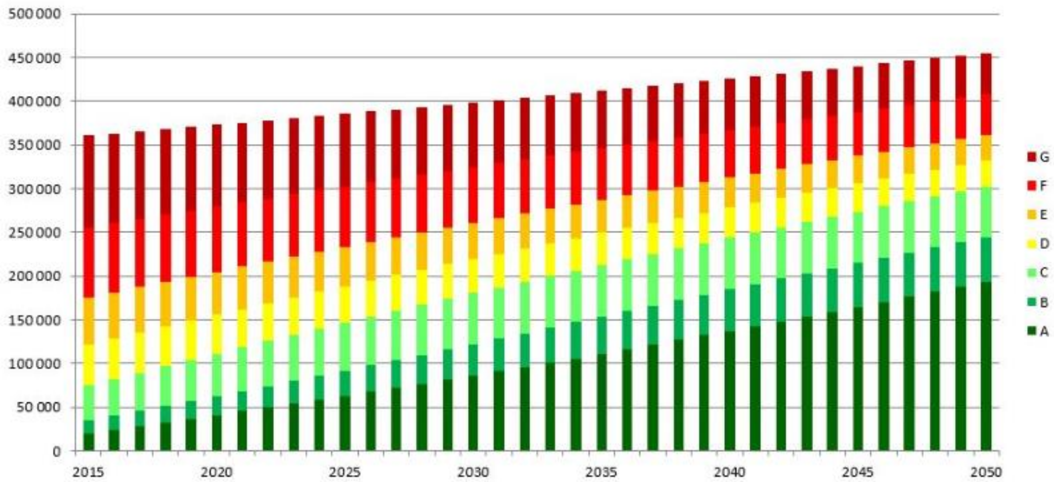

Figure 4: Energy reference area in m^2 - Reference scenario

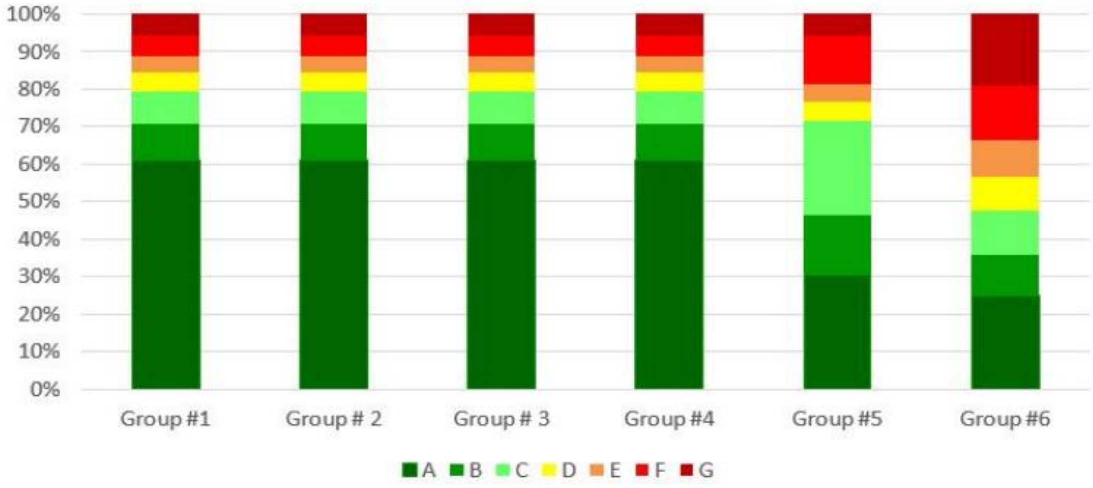

Figure 5: Energy reference area in % per energy classes by owner groups (2050) – Reference scenario

Group *OT*	Owner type	Characteristics	Share of owner type
1	owner - occupied	young and wealthy	8%
2	owner - occupied	other	24%
3	owner - occupied	old and/or poor	8%
4	landlord	cooperative & municipalities	6%
5	landlord	investment corporations & pension funds	18%
6	landlord	households	36%

Table 1: Owner Types

Table 2 shows that for the reference scenario in the year 2050, the share of buildings in energy class A is 50% whereas the buildings in energy class E, F, and G together account for 21% of the Swiss building stock. In 2050, the average retrofit rate is 0.88% while the average energy consumption is 55 kWh/$\boldsymbol{m^2}$. The CO2 emissions decrease by 59% with respect to emissions in year 2015. Table 1 also shows the shares of energy classes and the concurrent energy efficiency improvements for the different policy scenarios. Especially the combined scenarios exhibit a high retrofit rate (to 2.52% or 2.62%, respectively) and deep decarbonisation, as CO2 emissions drop by 93% and 95% respectively. There is a significant increase in the share of buildings in the energy class A in the 1st scenario (83%) and in the 2nd scenario (85%). Additionally, buildings in energy class E, F, and G almost disappear completely.

These results suggest that it is necessary to combine various policy instruments, in order to obtain deep decarbonization.

Share of owner-occupied/rental	Reference Scenario	Information level	Tax CO_2 9 CHF	Tax CO_2 26 CHF	Subsidy rate	Combined 1st	Combined 2nd
Average retrofit rate	0.88%	1.64%	0.92%	0.98%	1.24%	2.52%	2.62%
Average energy consumption in 2050 in KWh/m2	55	44	55	54	46	26	25
CO2 emissions change with respect to 2015	-59%	-72%	-62%	-67%	-70%	-93%	-95%
Share of energy classes in 2050							
A	50%	69%	51%	52%	57%	83%	85 %
B	11%	11%	11%	11%	10%	8%	8%
C	12%	9%	12%	12%	10%	5%	5%
D	6%	3%	6%	5%	6%	1%	1%
E	5%	2%	5%	5%	5%	1%	1%
F	8%	3%	8%	7%	6%	1%	0%
G	8%	3%	8%	7%	6%	0%	0%

Table 2: Comparison of scenarios

4 Evaluation of results to date

We conducted a meeting in the Swiss Federal Office of Energy where we demonstrated the results of the Building Stock Model. The results were discussed and analysed. We are currently responding to feedback, comments and suggestions from our last discussion. Indeed, the suggestions on the new simulations will considerably improve the results. The test and validation of the model was achieved according to the project description timeline (1st October 2019).

Additionally, we presented the theoretical background of the Cement industry model and the intended lay-out of the model. SFOE confirmed that it is a satisfactory way to go further. The first simulations are already running.

5 Next steps

Next steps are:

1) Finish the Building stock model
2) Finish the Cement industry model by April 1st, 2020
3) Couple both models with GEMINI-E3.
4) Dissemination of the results

Regarding step 3) For housing and cement models, we use a soft coupling approach, as our building stock model is too detailed to be directly included (i.e. hard coupling) into GEMINI-E3. The building stock models will be run iteratively while the coupling variables are exchanged between GEMINI and the add-on models two models. GEMINI-E3 will provide price of energy carriers (oil, natural gas, electricity, wood, etc.), price of investment (used as an input for the retrofit cost). The building stock model in turn provides the energy carriers, the investment in retrofit and new building, as well as the net tax revenue.

6 National and international cooperation

We presented preliminary results at:

10th SAEE (Swiss Association for Energy Economics) Student Chapter Workshop 2018, ETH Zurich, (23 Nov, 2018), Oral presentation.

3rd AIEE (Italian Association for Energy Economics) Energy Symposium on Energy Security, Bocconi University, Milan, (10-12 Dec, 2018), Oral presentation.

18th SSES (Swiss Society of Economics and Statistics) Annual Congress, Geneva, (13-14 June, 2019), Oral presentation.

16th IAEE (International Association for Energy Economics) European Conference, Energy Challenges for the Next Decade, University of Ljubljana, (25-28 August, 2019), Oral presentation.

CISBAT 2019 – Climate Resilient Cities - Energy Efficiency & Renewables in the Digital Era, International Scientific Conference, EPFL Lausanne, (4-6 September, 2019), Oral presentation.

Swiss-US Energy Innovation Days 2019, Austin and San Antonio, Texas, USA, (6-9 Oct, 2019), Oral presentation. Accepted with a full travel grant.

7 Publications

Conference Paper: CISBAT 2019 – Climate Resilient Cities - Energy Efficiency & Renewables in the Digital Era, International Scientific Conference, EPFL Lausanne, (4-6 September, 2019),

8 References

A. Bernard and M. Vielle, 2008. GEMINI-E3, a general equilibrium model of international–national interactions between economy, energy and the environment. Computational Management Science, (3): 173–206,

K. N. Streicher, D. Parra, M. C. Bruerer, and M. K. Patel, 2017 Techno-economic potential of large-scale energy retrofit in the Swiss residential building stock. Energy Procedia, 122:121–126,

M. Jibran S. Zuberi and Martin K. Patel. Bottom-up analysis of energy efficiency improvement and CO2 emission reduction potentials in the Swiss cement industry. Journal of Cleaner Production, 142:4294–4309, jan 2017. doi: 10.1016/j.jclepro.2016.11.178

9 Appendix: Housing Model: Reference and Policy-Scenarios

Reference case:

- Subsidy on retrofit: remains at 30% till 2030 and decreases linearly thereafter till 0% in 2050[3]
- CO_2-Tax: remains at 96 CHF till 2050
- Information: remains at level=1 till 2050
- Energy prices: based on the World Energy Outlook (WEO2018 - Current Policies[4])

Scenarios (indicated are changes as compared to the reference case)

1) **Only Subsidies** on retrofit:
   - Increase of subsidy by 1 percentage point per year from 2015 until 2050 (to 65% in 2050)

2) **Only CO_2-tax**: Increase of CO_2-tax per year
   - 9 CHF (to appr. 400 CHF in 2050)
   - 26 CHF (to appr. 1000 CHF in 2050)

3) **Information level:**
   - Increase of the Information level every 5 years up to Inf=4 (i.e. from 2030-2050 Inf=4)

4) **Combined instruments** (deep decarbonization):
   - 9 CHF increase of CO_2-tax per year + 1% percentage point subsidy increase per year increase + Information level increase as in 3)
   - 26 CHF increase of CO_2-tax per year + 1% percentage point subsidy increase per year increase + Information level increase as in 3)

[3] Note that the results depicted in the main part assume a slightly different time path of the subsidy. The scenario will be repeated for the final report and this should have not significant impact on the results.

[4] See https://www.iea.org/weo2018/ (29.11.2019)