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Swiss Industry: Price Elasticities and Demand Developments for Electricity and Gas (SWIDEM)

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Contents

List of abbreviations

AC	Air conditioning
EQ	Electrical and ICT equipment
ETSAP	Energy Technology Systems Analysis Program (Technology Collaboration Programme of the International Energy Agency)
IFTP	Industry Food, Textile, Pulp and Paper
ICHM	Industry Chemicals
ICMN	Industry Cement and non-ferrous minerals
IBMT	Industry Basic metals (Iron and steel and non-ferrous metals)
IMMO	Industry Metal tools, machinery, other industries
ICNS	Industry Construction
LT	Lighting
MD	Mechanical drive
OT	Others
PH	High temperature process heat
SH	Space heating
STEM	Swiss TIMES Energy systems Model
WH	Water heating

Project goals

The objective of this project is 1) to conduct an empirical analysis of the price elasticities of natural gas and electricity consumption for Swiss industry (including sub-sectoral detail) based on historical time series, and 2) to investigate future long-term developments of the industry sector's energy demand patterns under different policy frameworks by considering demand elasticities, fuel and technology substitutions, and energy efficiency improvement measures.

Summary

In this project price elasticities of natural gas and electricity consumption for Swiss industry are investigated based on historic time series. In addition, future long-term developments of the Swiss industries' energy demands are analysed by employing an energy-econometric accounting framework combined with a techno-economic modelling approach. Therefore, a combination of the global macro-economic model E3ME and the Swiss energy system model STEM will be applied to conduct a multi-scenario analysis scoping on the Swiss industry.

Work undertaken and findings obtained

The project consists of two workpackages which are relatively independent from each other, and hence started both.

WP1: Empirical analysis of the price elasticities of energy consumption for the Swiss industry
The aim of the first work package is to estimate price demand elasticities for electricity and natural gas consumption by each industrial sub-sector for Switzerland (see Tables 1 and 2 in the appendix for an initial list, which may be extended depending on data).

The methodology used is equation specification used in the E3ME global macro-econometric model (CE, 2014). The econometric equations are estimated using a two-step error-correction methodology that is based on time series data covering the last four decades. The framework allows for the distinction of price elasticities for each energy user and fuel type. Fuel use equations are estimated for four energy carriers (coal, heavy oils, gas and electricity) with four sets of equations estimated for the fuel users (see Table 4) in each region. These equations are intended to allow substitution between the four energy carriers by users on the basis of relative prices, although overall fuel use and the technological variables are allowed to affect the choice. The specific functional form of energy demand equations for each fuel are outlined in Table 3 in the Appendix.

We are in the process of

- reviewing the existing Swiss industry data from international sources and
- comparing against more recent data from Swiss national sources
- refining the statistical basis of the E3ME model, and
- updating the data sources used as inputs to our model.

This data collection and collation for empirical price elasticities of energy consumption for the Swiss industry is the background exercise for our first deliverable (D1).

Focusing specifically on the estimation of price elasticities, the main data sources we are collating/reviewing are as follows:

Table 1: Data sources for price elasticity demand estimation

Data/Literature	Sources
Energy demand and prices data	International Energy Agency (IEA) – World Energy Balance and Energy prices and taxes series Swiss Federal Statistical Office (BfS, 2017b).
Investment/ R&D data	OECD: GFCF value, volume, deflator. No sectoral data. Arvanitis (R&D spending) Swiss Federal Statistical Office (BfS, 2017b).
Industry output by sector	OECD: value, volume, deflators by sector (up to 2015) Swiss Federal Statistical Office (BfS, 2017b).

Furthermore, we are reviewing the literature on price elasticities of energy demand for industrial sectors. We aim to use these studies to identify supporting data and to calibrate and benchmark our price elasticities estimates in particular comparing our top down macro level estimates to bottom up micro estimates. The studies we have identified so far are as follows:

- Eberli (Labour Productivity), Arvanitis (R&D spending),
- BAK Basel, 2015a (Pharma industry),
- Müller and Mohler, 2011 and 2012 (Manufacturing),Gogniat and Farsi, 2011 (Exports)
- BfS, 2017 (industrial production)
- Müller and Mohler, 2016 (Manufacturing & energy elasticities),

WP2: Investigation of future long-term developments of the Swiss industrial energy demand
In WP2, we will conduct a forward-looking analysis (until 2050) investigating long-term final energy consumption of Swiss industry for which we advance and apply the Swiss TIMES Energy systems Model (STEM). STEM is a technology-rich bottom up energy systems model for Switzerland which operates under a cost-optimisation paradigm with a long-term perspective. For the advanced analysis of industrial energy technology developments, the representation of the industry sector in STEM will be improved in this project. Currently, STEM distinguishes six industrial subsectors, as shown in Table 2 in the appendix, which illustrates the differences in industrial subsectors and the energy service demands (industrial energy usages) represented in STEM.

We started with task 1 of WP2 which deals with advancements regarding the representation of the industry sector in STEM refer to a re-calibration and further disaggregation of the industrial sub-sectors and the inclusion of further industry technologies. A first major step is the update of model input data according to latest available statistical data as well as with improved technology parameters.

Our re-calibration and re-analysis of industry sub-sectoral data is based on the the annual publications of the Swiss Federal Office of Energy (BFE) and the International Energy Agency (IEA) that publish statistical data on the industry related energy consumption for Switzerland. The aim of the re-calibration is to derive disaggregated energy balances for the different industry branches with information on fuel use per energy service demand. The latest statistical year for which all the required data sources are available is 2014. For re-calibration and sectoral disaggregation we also use data from the International Energy Agency (IEA, 2017) on the energy consumption in 13 industrial sectors, fuel usage for each industrial subsector, which we combine with statistical data on end-use types based on BfE sources. In the BFE data, the industrial sector is divided into 12 different branches with a division oriented to the NOGA classification - the official general classification of economic activities of the Swiss Federal Statistical Office (BFS). Information on the total amount of different fuels consumed by the industrial sector is taken from BfE (2015a). Aggregated for the entire Swiss industry

sector, BfE (2016b) provides date on the type of usage of fuel and electricity for different service demands, like space heating or process heat. This source also entails data on how the final energy for each service demand is allocated to the industrial sub-sectors.

Accounting of cogeneration technologies is treated differently in the energy balances of IEA and BfE. We consider in our calibration and sectoral disaggregation that for cogeneration, only the energy carriers used for the generation of heat and electricity consumed on site are documented as energy usage in BfE(2016b). Electricity generated by thermal applications in different industry sectors as well as the corresponding fuels consumed by cogeneration applications is derived from BfE(2015b). This source also provides data on the types of cogeneration units, an inidaction of their location (canton) and their capacities. We use this information in order to allocate the heat from cogeneration to the subsectoral level according to main industrial activities identified for the respective cantons. For further detailed cogeneration data we consider Rossi (2013) who analyzed combined heat an power application in the Swiss industry and dissagregated process heat demand to different temperature levels for 9 different sub sectors.

In 2014, the consumption of the industrial sector accounted for 19% (157 PJ) of the total final energy consumtion in Switzerland. Natural gas (42%) and electricity (24%) together represent two thirds of the total fuel consumption iin industry (figure 1). Almost half of the total fuel consumption is used for the generation of process heat, as shown in figure 1. Figure 3 shows the total energy consumption in the industrial sector for 2014, disaggregated into the seven industrial subsectors. The disaggregation presented in this figure indicates a possible revised disaggregation of the industry sector in STEM model with 7 subsectors for industry. Compared to the original model version, we model food industry and pulp&paper industry separately.

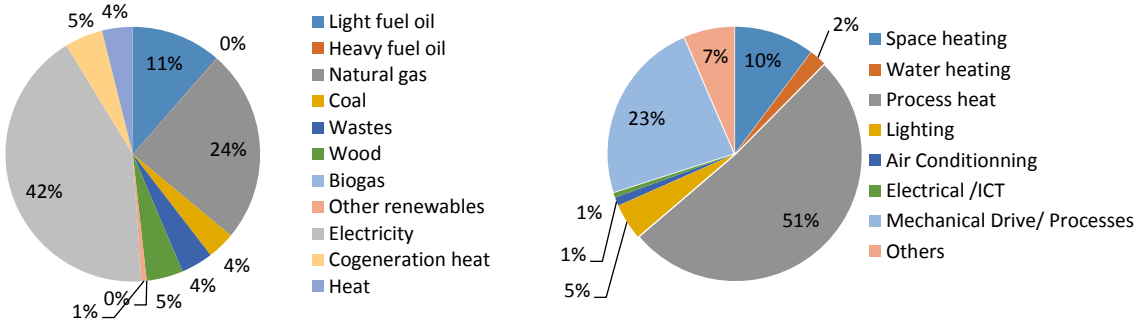

Figure 1: Final Energy consumption industry in 2014 by fuel (left) and by type of energy service demand (right)

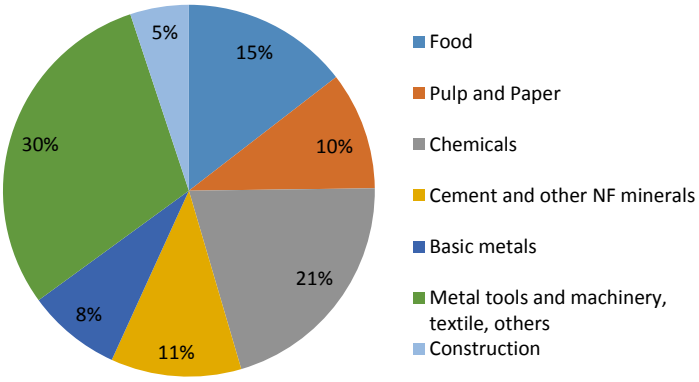

Figure 2: Final Energy consumption industry in 2014 by branches

Besides the aggregate of machinery, textile and other industries, which represents 30% of the total final consumption of the industry sector, chemical (21%) and food production (15%) are the second and third largest industry subsectors with respect to their share in final energy consumption. Pulp&paper and cement & other non ferrous minerals have a share of the industry sector's final energy consumption of one tenth each. The disaggregation of the industry sector in STEM depends on multiple factors, including available statistical indicators and figures as well as prospective data on demand developments, technology data, etc., which all will be taken into consideration for determining model further developments as envisaged in work package 2.

National cooperation

The energy system modelling work of this project links to several modelling activities performed under the Swiss Competence Centres for Energy Research (SCCER), in particular to the SCCER Joint Activity *Scenarios and Modelling* in which STEM model is applied to perform an integrated system analysis. This SCCER Joint Acitivity joins forces of all eight SCCERs with allows for synergies of industry sector focused model development as envisaged in SWIDEM with the research undertaken in SCCER Efficiency of Industrial Processes (EIP). A first contact has been made and further exchange on potential collaboration is planned for 2018.

International cooperation

The project team itself, with PSI and Cambridge Econometrics as partners, represents an international cooperation. In addition, both research teams are involved in different international cooperations based on other on-going research projects related to energy commodity elasticity analysis (CE) or related to energy systems modelling (PSI as member organisation of IEA-ETSAP).

Cooperation directly related to this project, in particular concerning the exchange of common data sources, is envisaged with the research group of the Centre for European Economic Research (ZEW) in Mannheim (Germany) that works on the SFOE funded research project on "Empirical Estimation of Electricity Demand Elasticities for Different Customer Groups in Switzerland and Implications for Energy Policies". The project kick-off meeting was held jointly.

Evaluation 2017 and outlook for 2018

The project has started with the kick-off meeting on 25 September 2017. Work on both work packages has been started according to schedule. For 2018, the main work will be to conduct the empirical analysis of the price elasticities, and to advance the STEM model with a more disaggregated representation of the industry in the model. In 2018, the mapping of STEM model to the macro-econometric model E3ME will be established in order to conduct a joint scenario analysis as envisaged for 2019.

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Appendix

Table 2: Overview of the industry sector in STEM (Kannan and Turton, 2014)

Industry sectors	Industrial energy usage
IFTP -- Food, Textile, Pulp and Paper ICHM -- Chemicals ICMN -- Cement and non-ferrous minerals IBMT -- Basic metals (Iron and steel and non-ferrous metals) IMMO -- Metal tools, machinery, other industries ICNS -- Construction	SH - Space heating WH - Water heating PH - High temperature process heat LT - Lighting AC - Air conditioning EQ - Electrical and ICT equipment MD - Mechanical drive OT – Others

Table 3 Energy sectors (Fuel Users) covered in E3ME (industry sectors are highlighted in red)

1 Power own use & transformation	12 Other industry
2 Other energy own use & transformation	13 Construction
3 Iron and steel	14 Rail transport
4 Non-ferrous metals	15 Road transport
5 Chemicals	16 Air transport
6 Non-metallic minerals	17 Other transport services
7 Ore-extraction (non-energy)	18 Households
8 Food, drink and tobacco	19 Agriculture, forestry, etc
9 Textiles, clothing & footwear	20 Fishing
10 Paper and pulp	21 Other final use
11 Engineering etc	22 Non-energy use

Table 4: E3ME Disaggregate Energy Demand Equations

Equations used for F = coal (C), Heavy Fuel Oil (O), Natural Gas (G), Electricity (E).

Co-integrating long-term equation:

LN(FRF(.))		[fuel used by energy user]
=	BFRF(.,10)	
+	BFRF(.,11) * LN(FR0(.))	[total energy used by energy user]
+	BFRF(.,12) * LN(PFRP(.))	[price ratio]
+	BFRF(.,13) * LN(FRTD(.))	[R&D by energy user]
+	BFRF(.,14) * LN(ZRDM)	[global R&D in machinery]
+	BFRF(.,15) * LN(ZRDT)	[global R&D in transport]
+	BFRF(.,16) * LN(FRK(.))	[investment by energy user]
+	ECM	[error]

Dynamic equation:

DLN(FRF(.))		[fuel used by energy user]
=	BFRF(.,1)	
+	BFRF(.,2) * DLN(FR0(.))	[total energy used by energy user]
+	BFRF(.,3) * DLN(PFRP(.))	[price ratio]
+	BFRF(.,4) * DLN(FRTD(.))	[R&D by energy user]

+	BFRF(.,5) * DLN(ZRDM)	[global R&D in machinery]
+	BFRF(.,6) * DLN(ZRDT)	[global R&D in transport]
+	BFRF(.,7) * DLN(FRK(.))	[investment by energy user]
+	BFRF(.,8) * DLN(FRF(-1))	[lagged change in energy use]
+	BFRF(.,9) * ECM(-1)	[lagged error correction]

Identity:

PFRP = PFRF(.)/PFR0(.) [price ratio]

Restrictions:

BFRF(.,3 .,4 .,5 .,6 .,7 .,12.,13 .,14 .,15 .,16) <= 0 [‘right sign’]

BFRF(.,2 .,11) >= 0 [‘right sign’]

0 > BFRF(.,9) > -1 [‘right sign’]

Definitions:

BFRF	is a matrix of parameters
FRF	is a matrix of fuel used by 22 energy users for 53 regions, th toe
FR0	is a matrix of total energy used by 22 energy users for 53 regions, th toe
PFRF	is a matrix of prices for energy carrier F, by 22 energy users for 53 regions, $/toe
PFR0	is a matrix of average energy prices for 22 energy users and 53 regions, $/toe
FRTD	is a matrix of R&D by 22 energy users for 53 regions, m euro at 2005 prices
ZRDM	is R&D in machinery by the EU, m euro at 2005 prices
ZRDT	is R&D in transport by the EU, m euro at 2005 prices (oil equation only)
FRK	is a matrix of investment by 22 energy users for 53 regions, m euro at 2005 prices