Assessment of price decomposition and distribution of fossil fuels

Behind the Cost of Fossil Fuels

Semester Project

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Abstract

The use of fossil fuels becomes more and more controversial. Human health issues, environmental impacts, economical conflicts are direct consequences of these sources of energy. Nevertheless, they are deeply rooted in the society, making the transition to greener technologies a real challenge. Fossil fuels industries are not completely transparent, meaning that the composition of final price is unclear. The aim of this project is to describe a model that allows to estimate the breakdown of the fossil fuels cost. The analysis is based on open-source data from the literature. In order to complete the breakdown, the remaining unknown costs are estimated using strategies developed in this project. Applied to the case of Switzerland, the results show that for mobility fuels, around 30% of the price concerns abroad processes and 20% are estimated to be direct margin for the exporting countries. Finally, the import of petroleum products to Switzerland, alone, amounts to 6 billions CHF in 2019.

Acknowledgement

I would first like to thank my supervisors, Jonas Schnidrig and Xiang Li, for following me throughout this semester and who were always present to answer my questions with great enthusiasm. I also thank Professor François Maréchal for having made possible the elaboration of this captivating semester project in the *IPESE* laboratory.

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Chapter 1

Introduction

1.1 Background

Coal, natural gas and oil represent 81% of the total world energy supplied (respectively 26.8%, 23.2% and 30.9%) [1]. Switzerland does not escape the rule. In 2020, 59% of its energetic needs is covered by fossil fuels [2]. The latter are the primary source of carbon dioxide, representing 65% of the global greenhouse gas emissions [3]. In addition to the major global warming and human health concerns related to the use of these resources, the guarantee of the supply at a constant price is also problematic [4]. The volatility, due to the instability of the market, is largely responsible of it. To illustrate this point, the 20th April 2020, for the first time, WTI (West Texas Intermediate) crude oil drops to a negative price and reaches -37$ per barrel (see Figure 1.1). The Covid crisis, a high level of speculation on oil prices and a disagreement between Saudi Arabia and Russia are the causes behind this historic drop [5]. 1 year and a half later (26th October 2021), oil market breaks the record of the last 5 years by reaching up to 85$ per barrel [6].

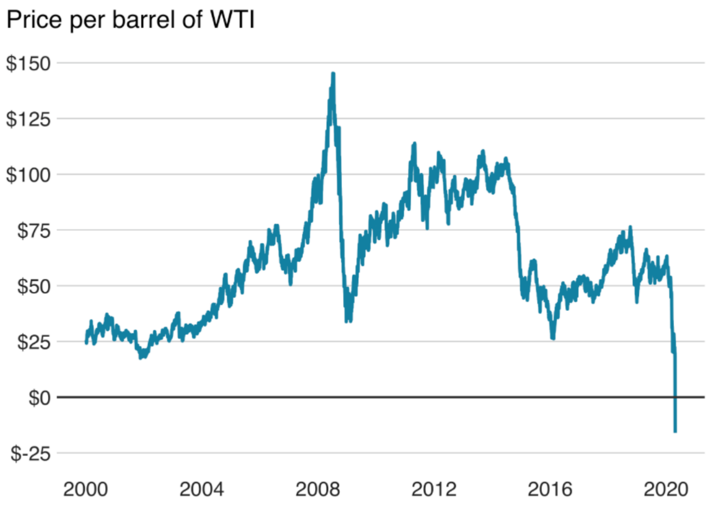


Figure 1.1: Price of the barrel of WTI crude oil.
Source: *BBC Business* [7]

An important and common property of fossil fuels is that they're not homogeneously distributed on earth, meaning that only few actors have access to it to supply the world. USA, Saudi Arabia and Russia are the main contributors. They represent 43% of world petroleum products production [8]. Moreover, an important and common property of these resources is the possibility of storage. Consequently, through an agreement, the suppliers can reduce the offer by storing it, leading to an increase of the market price. Despite the fact that the OPEC (Organisation of Petroleum Exporting Countries) aims to regulate and unify the world production of oil, some conflicts, in particular with Russia, leads to disagreements and a deregulation of the market. Russia, which is the main supplier of gas for Europe, use this advantage to be in a strong position to negotiate with EU, implying the large increase of the gas price by the end of 2021[9]. This spike can be seen in Figure 1.2.

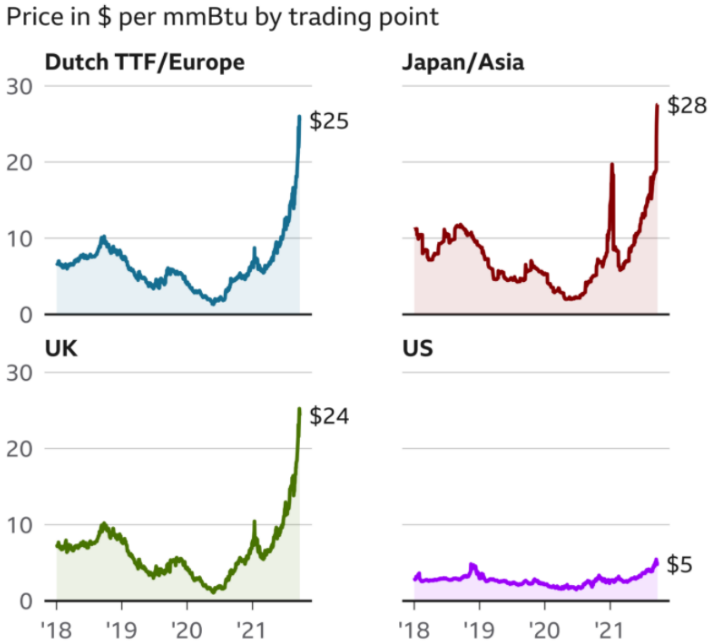


Figure 1.2: Price of gas for different regions.
Source: *BBC Business* [10]

Despite all these disadvantages, it is difficult to overcome these dependencies. In fact, fossil fuels represent a large part of the final energy consumption and countries do not have alternative sources of energy yet. If finding alternatives to the use of fossil fuels is a complex challenge, estimating the cost of these dependencies is however feasible. Becoming aware about the money that is spent every year abroad is indeed important and could be encouraging to convert these annual expenses into an investment in Switzerland.

1.2 State of the art

Many estimations of the breakdown cost of fossil fuels can be found in literature. *Fuels Europe* presents in *Statistical report 2020* [11] the breakdown of the mobility fuels. However the methodology that leads to the results is not explained. Moreover, the available studies either do not decompose the cost in details or do not apply to Switzerland. *Avenergy* gives, in an article [12], the main elements that is composing the Swiss fuel costs and the components that impact it.

Since fossil fuels are sold at the price fixed by the market, the industries are not transparent and do not share the real price of these resources. Only few prices data are available in the literature. This explains the fact that no complete decomposition of the cost can be found. This project estimates the price decomposition based on open source data at mainly three steps of the distribution. The first one is the market prices that are freely accessible. Then, the Swiss Federal Customs Administration is transparent with the quantities and the value of the importations. These data are available on the *Swiss Impex* data base [13]. An objective of this project is to provides results that are based on truthful and verifiable data and assumptions.

1.3 Problem Statement

This project has as target to develop a methodology and a model describing the price of fossil fuels from the production to the consumer and a methodology for estimating the cost at each step, relying on open source available data, creating a transparent cost decomposition from "cradle to grave".

1.3.1 Research questions

The project attempts to answer these following questions :

- How can the price of the fossil fuels be modelled from the production to the consumer ?
- How to estimate the cost at each step of the supply ?
- What is, then, the breakdown of the fossil fuels price in Switzerland ?

1.3.2 Objectives

In order to provide answers, the following strategies are used:

1. Analyse the main steps from the production of fossil fuels to the consumption and identify the major value-adding processes increase the price of the final product.
2. Create a base cost-decomposition model generally applicable to all fossil fuel energy vectors.
3. Apply the model based on the open source data such as price, production etc. allowing to estimate the hidden costs, validating by the final costs sold to the consumers.

1.4 Project Background

This project is carried out as a semester project within the laboratory *IPESE* headed by Prof. François Maréchal. This work is part of the Energy Science and Technology Master program and is supervised by Jonas Schnidrig and Xiang Li.

Chapter 2

Modelization of the price of fossil fuels

2.1 Description of the model

In view of the many steps taken by the barrel before being sold to the consumer, it is difficult to access to a clear composition of its price. In order to learn about how the price at the gas station is composed, the origins of the fuels as well as the import/export activities of Switzerland need to be detailed.
According to the Federal Statistical Office about energy supply[14], Switzerland does not extract any fossil fuels, leading to import of all consumed fossil fuels such as, natural gas, coal and crude oil. Refined products are either imported or directly refined in Switzerland. The general model describing the cost evolution and decompostion from the producer to the consumer is represented in Figure 2.1. The figure shows an example for three oil products (i.e. gasoline, diesel, heating oil). The model can be extended to other oil products, other type of fossil fuels (like gas or coal) and is applicable as such to other countries. For the case of Switzerland, the model for natural gas and coal is simpler since there is no local refinery nor production. This project aims to give a methodology to evaluate the price at every stage of the model of Figure 2.1.

Literature review provides some of the prices, from which it is possible, using assumptions, to estimate the complete breakdown of the cost and to conclude how the money of the consumer is distributed. In Figure 2.1, the prices are represented by the notation ***Ci***. The price in the form ***Ci.j*** represents the price of product j at the step i. The different steps of the distribution can be described as follows:

- ***C1*** : The real cost of oil production. It aims to highlight the fact that the market price of fossil fuels is artificially increased and does not represent the real price of production.
- ***C2*** : Crude oil market price. Different benchmarks can be used as reference : WTI, Brent, Dubai Crude, etc.
- ***C3.1*** : Refined products market price.
- ***C4.0*** : Swiss import price of crude oil.

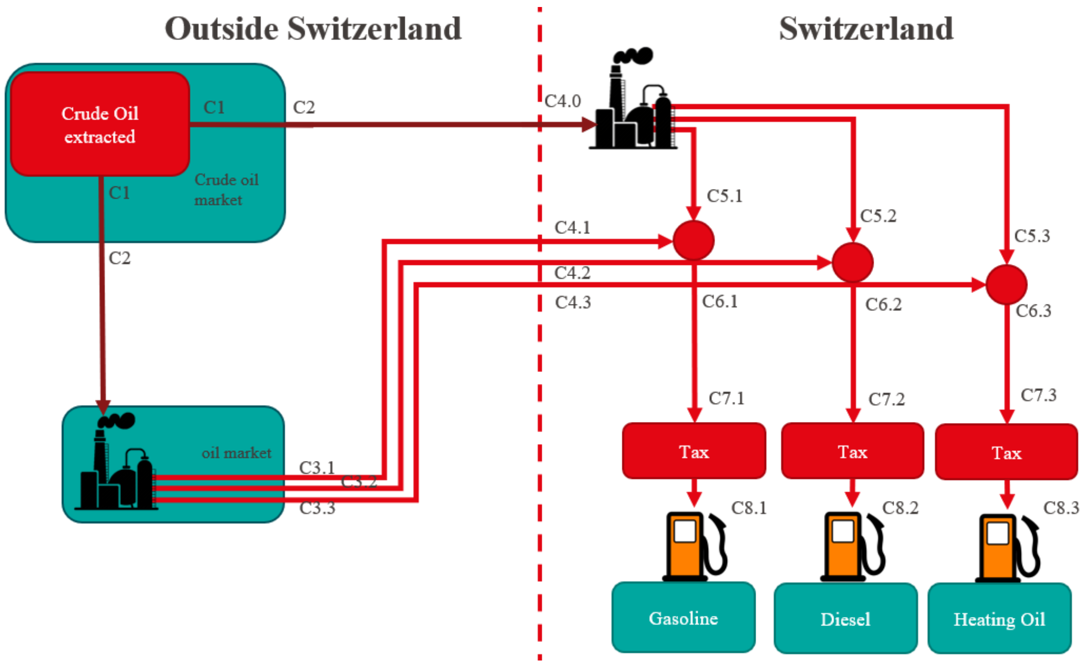


Figure 2.1: Modeling of the price of fossil fuels from production to consumer

- ***C4.i*** : Swiss import price of refined products.
- ***C5.i*** : Swiss refined product price. It indicates the cost at which the swiss refinery is selling the final products.
- ***C6.i*** : refined products before distribution.
- ***C7.i*** : final selling price without taxes.
- ***C8.i*** : Final selling price with taxes.

2.2 Assumptions

In order to reduce the complexity and to use the data found in the literature, some assumptions are made. The first one is that, the distribution network, including the transport to the consumer and the storage, are considered to be the same regardless of the origin (i.e. a product refined in Switzerland or abroad). In other words, once the product is refined in Switzerland, it is directly mixed, before the distribution, with the one imported. It can be also expected, that an extra cost of transport is needed for the Swiss refinery. This additional cost is however accounted in the operating cost of the refinery (i.e. between ***C5.i*** and ***C4.0***).

For reasons of clarity and in order to unify the results, this study shows the outcomes in CHF/kWh. In fact, the units used by the data sources can differ. A table in the Annex A.4 summaries all the values for conversion used throughout this study as well as the the exchange rate US$/CHF. Moreover, since the market of fossil fuels is highly volatile and can greatly change from one year to another, it is important to base the analysis over several years. It has been decided that, when it is possible, the results of this study are based on the average of the annual values from 2009 to 2019. This time range gives a fair number of data without taking too old data that could misrepresent the estimation for today. In addition to that, because of Covid-19 crisis, the economy during 2020 was completely destabilised and does not reflect the typical years. For this reason, it has been decided to not use the data after 2019. An exception is made for the investment in fossil fuels: the data have not been found for the desired time period.

Chapter 3

Estimation of the the costs of fossil fuels outside the borders

The goal of this chapter is to estimate the price of the model from the production to the border of the importing country. Some values can be found directly in the literature (e.g. the selling price, market price, etc.) and the rest needs to be estimated using different methods developed here. For the sake of clarity, the model is treated part by part and a strategy is developed to estimate to cost of each processes.

3.1 Real cost of fossil fuels *C1*

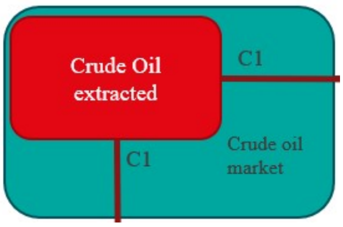


Figure 3.1: Section of the model corresponding to the real price of fossil fuels ***C1***.

The fossil fuels market does not reflect their real value. However, it can be estimated by looking at how much the industries invest yearly on producing these fossil fuels. By knowing the world annual investments made in the extraction of fossil fuels and the annual production of crude oil, coal and natural gas, the cost of producing those resources can be estimated. The annual value is given by Equation 3.1. Since the annual investments have not a direct impact on the production of the same year, the average cost $C1$ is calculated by dividing the sum of investments over all the year by the sum of the production, as shown by Equation 3.2.

$$C1_i \text{ [CHF/kWh]} = \frac{\text{annual upstream investment}_i \quad \text{[CHF/year]}}{\text{annual production}_i \quad \text{[kWh/year]}} \tag{3.1}$$

$$C1\ [\text{CHF/kWh}] = \frac{\sum_{i=1}^{n_{years}} \text{annual upstream investments}_i \quad [\text{CHF/year}]}{\sum_{i=1}^{n_{years}} \text{annual production}_i \quad [\text{kWh/year}]} \tag{3.2}$$

The investments dedicated for the fossil fuels can be divided into 3 levels: up-stream, mid-stream and down-stream. The first includes the exploration, drilling and extraction of the fossil fuels while the latter two account for the transport, refining and distribution [15]. The data collected for the estimation of this section concern only the upstream investments. In fact, according to the model, the cost for transport, refining and distribution are accounted later in the process.

3.2 Importation of crude oil

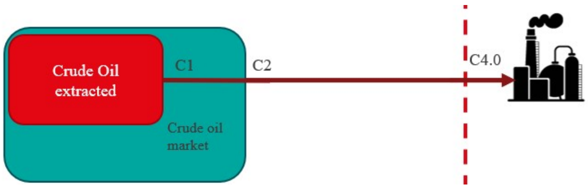


Figure 3.2: Model of the importation of crude oil in Switzerland

Where the crude oil is directly imported in the country in order to be refined locally (see Figure 3.2), it can be noted that it depends on what type of refinery the country owns. For the case of Switzerland, only crude oil can be refined locally since there is no gas refinery in the country.

The real price of producing the raw fossil fuels ***C1*** is estimated in the previous section. ***C2*** corresponds to the spot price. For this example, the *Brent* crude oil is taken as reference. This benchmark is used to fix the market price especially in Europe. [16]
The price at which the consumer country is importing the crude oil is denoted by ***C4.0***. The database Swiss-Impex, made available by the *Swiss Federal Customs Administration* [13] provides the quantity and the values of the importations for different products. It will also be used later for the importation of refined products.

3.2.1 Gross Margin

After extraction, the fossil fuel is available on the market. In order to use the supply and demand to increase the spot price of the resources, the sellers need to store it in tanks which represents a certain cost. It can then be considered that the difference between the market price ***C2*** and the price of extraction ***C1*** corresponds to the net margin plus the cost of storage:

$$C2 - C1 = \text{storage cost} + \text{Net Margin} = \text{Gross Margin} \tag{3.3}$$

The cost of the storage is difficult to estimate. However it can be imagined that a majority of these expenses are linked to the willingness to speculate. Therefore, it is not a necessary cost, but the consumer has to pay for it anyway. Nevertheless, a possible methodology to estimate the storage cost will be developed later, in section 4.4.

3.2.2 Transport

When Switzerland is buying crude oil, it has to pay for the transport. It can be estimated that the difference between the market price ***C2*** and the import price ***C4.0*** corresponds to the transport from the producer to the Swiss border:

$$\text{Transport}_{crudeoil,import} = C4.0 - C2 \tag{3.4}$$

3.3 Importation of refined products

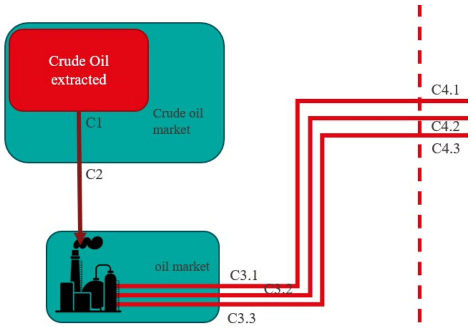


Figure 3.3: Model of the importation of refined products in Switzerland

When the country does not have sufficient refining capacity, importation of refined products is needed (see Figure 3.3). This is the case of Switzerland which is only able to refine about 1/4 to 1/3 of its consumption [17]. The Figure 3.3 shows that a abroad refinery is buying the crude oil on the market at the price ***C2*** and after processing, sell the refined products at the market price ***C3.i***. The final fossil fuel is then imported by the consumer at a price ***C4.i***. It can also be considered that the refineries use storage as a way to generate a larger margin, thanks to the supply and demand. However, it can be noted that, compared to the raw fossil fuels producer (crude oil, natural gas or coal), the refinery industry is not geographically limited. Therefore the competition is greater between refinery which reduces the possibility to take advantage of the market.

3.3.1 Transport

Concerning the transport from the refinery to the border, the same methodology as previously presented in Section 3.2.2 can be applied to the imported refined products:

$$\text{Transport}_{\text{refined,import}} = C4.i - C3.i \tag{3.5}$$

3.3.2 Refinery and Margin

It is assumed that between the crude oil market price ***C2*** and the refined product market price ***C3.i*** are included:

- The transport from the crude oil producer to the refinery. In contrast to the crude oil producers, the refinery are mainly based in Europe to deserve the EU market.
- The operation cost of the refinery which can be considered as a fixed cost per kWh of fuel produced.
- The net margin
- The storage cost

The decomposition of the cost can then be written as:

$$C3.i - C2 = \text{Transport}_{\text{crude oil to ref}} + \text{Refining} + \text{Margin} + \text{Storage} \tag{3.6}$$

Firstly, It can be considered that the transport cost and the refining cost are fixed expenses per kWh. This fixed component can be estimated to be at least, on a certain time period, equal to the minimum difference between the crude oil market price and the refined products market. The storage cost and the margin can be then be deduced as a variable element. Further details about estimating the fixed part of the refinery cost are presented in Section 4.2. Moreover, Section 4.4 develops a method to evaluate the cost of storage in Switzerland. This could be adapted to the world scale.

Chapter 4

Estimation of the the cost of fossil fuels inside the country

Now that the model outside the country is developed, this chapter focus on estimating the composition of the cost of fossil fuels from the border to the consumer. This part of the model is shown in Figure 4.1. The case of Switzerland is treated in this project but the same methodology can be applied to any country. In this case, the fuels sold to the Swiss consumers come either from a local refinery, or from abroad. The refinery of Cressier is the only one in operation in Switzerland. Crude oil imported from outside is converted in Cressier into gasoline, diesel, kerozene or heating oil and is mainly dedicated for the Swiss market [18]. As mentioned previously, the Cressier refinery provides 1/4 to 1/3 of the Swiss fossil fuel consumption [17].

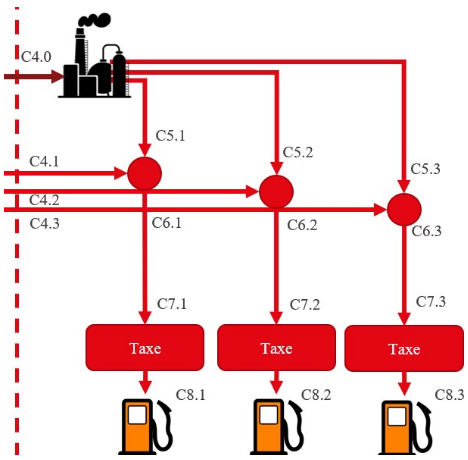


Figure 4.1: Model of the fossil fuels in the consumer country

It can be fairly assumed that, with an operation cost higher than in other countries of Europe, the Swiss refinery needs to align there prices to the European market in order to stay competitive [19]. Therefore, the products imported and the products refined locally are sold at the same price which allows to simplify the model by writing the relation:

$$C5.i = C4.i = C6.i \tag{4.1}$$

For each type of product, the price can be modelled like:

$$\begin{cases} P_{\text{selling}} = P_{\text{crude oil import}} + P_{\text{refinery CH}} + P_{\text{distribution CH}} + Tax \\ P_{\text{selling}} = P_{\text{refined import}} + P_{\text{distribution CH}} + Tax \end{cases} \tag{4.2}$$

$$\iff \begin{cases} \boldsymbol{C8.i} = \boldsymbol{C4.0} + P_{\text{refinery CH}} + P_{\text{distribution CH}} + Tax \\ \boldsymbol{C8.i} = \boldsymbol{C4.i} + P_{\text{distribution CH}} + Tax \end{cases} \tag{4.3}$$

with:

- $P_{\text{selling}} = \boldsymbol{C8.i}$: The selling price of a product in Switzerland (with taxes).
- Tax : The total amount of taxes including mineral tax, sur-tax, CO_2 tax, VAT and others.
- $P_{\text{crude oil import}} = \boldsymbol{C4.0}$: The crude oil price entering in Switzerland.
- $P_{\text{refined import}} = \boldsymbol{C4.i}$: The price of a refined product entering in Switzerland.
- $P_{\text{refinery CH}}$: The cost to produce a refined product from crude oil. It takes into account the extra transport cost in Switzerland compared to the imported refined products.
- $P_{\text{distribution CH}}$: Includes the storage, the transport, and the distribution across Switzerland

By using the model of the Figure 4.1 and the relation 4.1, the following expression can be deduced:

$$\begin{cases} \text{Tax} = C8.i - C7.i \\ P_{\text{distribution CH}} = C7.i - C6.i = C7.i - C4.i \\ P_{\text{refinery CH}} = C5.i - C4.0 = C4.i - C4.0 \end{cases} \tag{4.4}$$

For Switzerland, the selling price $\boldsymbol{C8.i}$ [20], the importation prices of petroleum products $\boldsymbol{C4.0}$ and $\boldsymbol{C4.i}$ [13] and the Tax [21] can be found in the literature. According to Equation 4.4, the unknown values $\boldsymbol{C7.i}$, $P_{\text{distribution CH}}$ and $P_{\text{refinery CH}}$ can then be estimated. The latter two are analysed in more details in the dedicated Sections 4.3 and 4.2.

4.1 Taxes

The Swiss tax law is complex and contains a lot of parameters. The tax depends first on the type of product that is sold but also on the use of it. Two main types of function can be distinguished: mobility fuel and heating fuel. The Petroleum tax and the sur-tax are mainly collected on the mobility fuels while a CO_2 tax is applied on the heating fuels like natural gas and heating oil. All these taxes do not depend on the origin of the products. Then, the fuel refined in Cressier or directly imported, are taxed in the same way. [21]

A summary of the taxes is presented in the Annex A.3. They are applied just before the sale. It is also interesting to mention how the government is investing the collected money. The figure 4.2 shows the distribution of the taxes. A large part of the tax on mobility fuels is used for the road and air traffic.

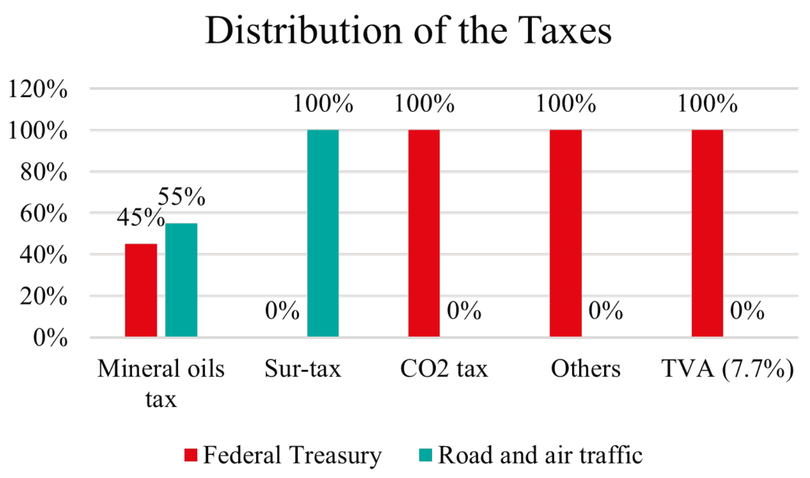


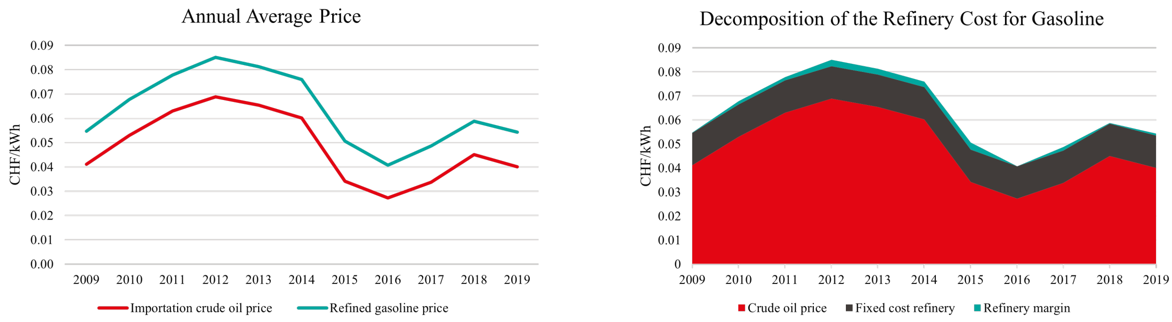
Figure 4.2: Distribution of the fossil fuels taxes
Data source : Swiss Federal Customs Administration [22]

4.2 Refinery cost

Another process in Switzerland is the refinery. The system of Equation 4.4 can be used to estimate the cost $P_{\text{refinery CH}}$ for different type of products. The results can give an idea on how much costs the refining process, which includes the process on itself and the margin. The latter remains hard to evaluate. However the approach developed in this part allows to give an order of magnitude of the margin made by the Swiss refinery industry.

In general terms, cost of refining and the margin are influenced by many internal or external points. Among internal factors, the size, the configuration of the facility and the localisation, which demands transport infrastructures, have a large impart on the cost. However this elements are not varying after the construction of the refinery. In the contrary, external factors are mainly linked to the market and to the international competition [23]. In fact, the market price of the crude oils and of the refined products are highly volatile. Being squeezed on both sides by the markets (i.e. ***C4.0*** and ***C4.i***), the margin of the refinery is then highly dependent on these external factors.

By considering that the cost to operate the refinery is fixed, a comparison between the import crude oil price and the price of the products after the refinery can leads to an estimation of the operating cost and of the margin. When, on a given time range, the difference between the two prices is minimum, the margin is considered to be null. The fixed operating cost is then deduced. The Figure 4.2 shows these two prices and the decomposition between margin and operating cost for each year. It can be noted that the two curves of the cost are varying in a very similar way. This emphasises the fact that the refined products prices are dictated by the crude oil price, meaning that the refineries cannot make as much margin as the crude oil producers.



(a) (b)

Figure 4.3: Example of margin estimation for gasoline
Data source : *Swiss Impex* [13]

4.3 Distribution cost

The cost of distribution $P_{\text{distribution CH}}$ represents all the infrastructures and expenses that allow to make the link between the border (or the refinery) and the final consumer. The estimation is given by Equation 4.4. In this section, the cost $P_{\text{distribution CH}}$ is divided into three elements.

Petroleum products are mainly imported by boat and pipeline which are the most profitable solutions. The products are then supplied across Switzerland to the selling points using rails or trucks which are more expensive. These infrastructures have, therefore, an impact $P_{\text{transport CH}}$ on the final price and are included in $P_{\text{distribution CH}}$.

Another element taken into account in the distribution cost $P_{\text{distribution CH}}$ is the storage cost. As a matter of fact, Switzerland needs to ensure to the consumers a secure fuel and heating oil supply. In fact, Switzerland is totally dependant on exporting countries and on the geopolitical situation, implying a risk of shortage. Moreover, in contrast to electricity which is produced and distributed on a just-in-time basis, the demand of fuels is not in phase with the importation or production. For this two reasons, a storage system is required. The cost linked to these infrastructures is represented by $P_{\text{storage CH}}$.

Finally, all the others expenses, not included in the two first, need also to be taken into account. It includes for example the logistic, marketing or tank-station amortisation.

The cost of distribution can then be detailed as:

$$P_{\text{distribution CH}} = P_{\text{transport CH}} + P_{\text{storage CH}} + P_{\text{other CH}} \tag{4.5}$$

Again, it is difficult to estimate the share of these components. However, the next section is developing a strategy to evaluate the cost of storage.

4.4 Storage cost estimation

The previous section explains the decomposition of the distribution cost $P_{\text{distribution CH}}$. A methodology to estimate the cost of storage is explained in this section but the results for the case of Switzerland are not calculated is this project. It can be noted that this demonstration is valid for one type of product. The same approach should then be repeated for each type of fossil fuels.

The storage of petroleum oils is supervised by the Swiss confederation and Carbura is the organisation responsible for it. [24]. According to the National Economic Supply Act (NESA), a minimal reserve of four and a half months is imposed for gasoline, diesel and heating oil (based on the three last years). For all products, more than 7 millions cubic meters of storage can be used in Switzerland and are spread out over around 60 installations on the territory [25].

The price of storage can be estimated by, firstly, calculating the total storage capacity of Switzerland. Then, using the investment cost of tank from the literature), a cost of storage can be evaluated. The quantity M_{stored} of fuel stored (i.e. amount added to the tank) during one period can be expressed by :

$$M_{stored} = M_{imported} + M_{refined} - M_{consumed} - M_{exported} \qquad \text{[kWh]} \tag{4.6}$$

The result of this expression gives a positive value when the tank is filled up and negative when it is emptied. The profile of stored fuel (i.e how much fuel does the tank contain), at each time step t, can be expressed as:

$$Total_{storage}(t) = Total_{storage}(t-1) + M_{stored}(t) \qquad \text{[kWh]} \tag{4.7}$$

$$\iff Total_{storage}(t) = Total_{storage}(0) + M_{stored}(1) + \ldots + M_{stored}(t-1) + M_{stored}(t) \quad \text{[kWh]} \tag{4.8}$$

It can be seen that the initial stored quantity $Total_{storage}(0)$ remains unknown. However, it is important to remember that a minimum reserve is required. By analysing the consumption of the three last years, the minimum level of the reserve $Total_{storage_{min}}$ can be determined (e.g. four and a half months of reserve for gasoline). It can then be assumed that, over all time steps, when the profile of stored fuel is at its lowest, this quantity is equal to $Total_{storage_{min}}$. In other words:

$$\min_{t} \quad Total_{storage}(t) = Total_{storage_{min}} \qquad \text{[kWh]} \tag{4.9}$$

This last assumption allows to fix the constant that was missing to completely describe the level of tank at each time step.

Then, the total storage capacity installed $Storage_{size}$ is the maximal value of the tank level profile:

$$Storage_{size} = \max_t \quad Total_{storage}(t) \qquad \text{[kWh]} \tag{4.10}$$

Finally, by knowing the investment cost $CAPEX_{sto}$ [CHF/year] of a storage infrastructure of size $Storage_{size}$ and the annual consumption of fuel $Cons$ [kWh/year], the cost of storage $P_{\text{storage CH}}$ can be deduced:

$$P_{\text{storage CH}} = \frac{CAPEX_{sto}}{Cons} \qquad \text{[CHF/kWh]} \tag{4.11}$$

Chapter 5

Fossil Fuel subsidies

Despite all the efforts made by many countries in the transition from fossil fuels to greener energy sources, the subsidies of fossil fuels are a big obstacle to this shift. On one hand, new renewable energy solutions struggle to reduce their cost in order to compete with classic energy sources. Consequently, the installations of green solutions need to be promoted. For example, in Switzerland, many subsidy programs are available for the consumer and concern mobility, insulation of houses, production of heat or electricity.
One the other hand, a large amount of money is still spend as subsidies for fossil fuels which is counterproductive to the development of renewable energies.

Two forms of fossil fuels subsidies can be considered: producer subsidies and consumer subsidies. The first represents the fact that the producer receives direct or indirect subsidies that increases the profitability of the production. The latter exists when the government protects the consumers by keeping the price low. Even with a green policy, the government cannot afford to let rise the price of fossil fuels: the consumers are still too much dependant on it.

The International Monetary Fund (IMF) estimates that, in 2015, the fossil fuels subsidies amounted to 5 Trillion of US$ and mostly to the consumer [26]. Moreover, according to Energy Policy Tracker, the financial support is higher for fossil fuels than for clean energy (41% against 37% of the total public money for energy). It is notably the case for Germany and France too. [27]

This chapter aims to find a way to estimate the subsidies that Switzerland (or any country) is granting to protect the consumers. This idea is to analyse the selling price and, by using the fixed costs estimated earlier in this study, check when the imported fossil fuel is too expensive and needs support from government.
Figure 5.1 shows an example for natural gas. The orange line represents the selling price (i.e. for the consumer). The yellow and orange area are the taxes and the distribution cost components (estimated earlier) that cannot be cropped. Then the red dashed line represents the cost limit, meaning that Switzerland cannot buy natural gas at a higher price than this limit. The blue line shows the actual

price of importation of natural gas and at some point, it exceeds the limit, meaning that, because of the fixed cost, the natural gas cannot be sold at the desired price. The government needs then to subsidise by paying the difference. By knowing the monthly consumption of natural gas, it is possible to estimate that, during this time range, the Swiss government has to compensate 125 millions CHF.

In order to have more accurate results, it would be interesting to investigate the Swiss law concerning the subsidies and under what conditions the government decides to act. Moreover, what happens when the fuel price is bellow the limit ? Is everything going to the Swiss fossil fuels industries as margin ? These questions could be investigated in a further study.

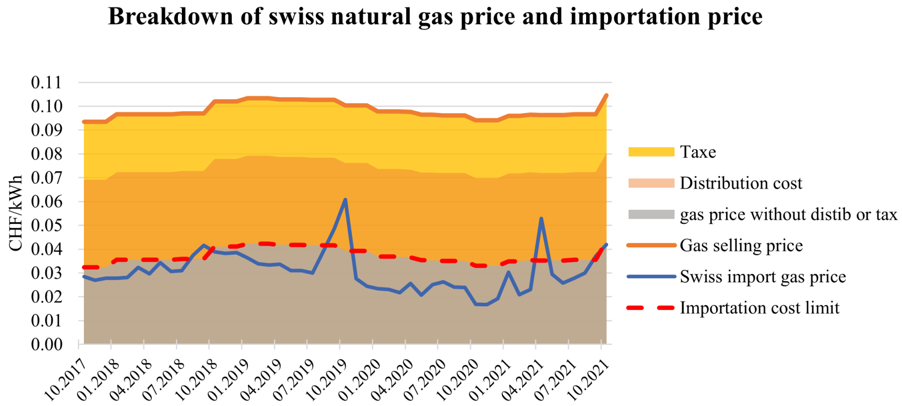


Figure 5.1: Model of the fossil fuels in the consumer country
Data source : Gas selling price (***C8.i***): [20], Swiss import gas price: *Swiss Impex* [13]

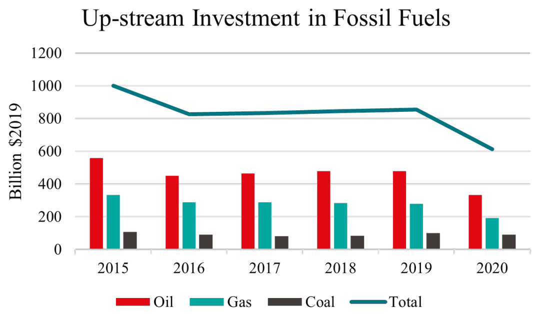
Chapter 6

Results

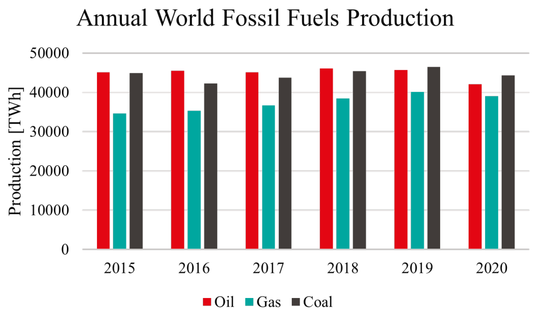
Now that the model is described and that methodologies to estimate the breakdown of the fossil fuel price have been developed, this chapter is focusing of the analysis of the case of Switzerland.

6.1 Real price of fossil fuels

The world upstream investment and the fossil fuels production are summarised in Figure 6.1. A detailed table can be found in the Annex: Table A.1 and Table A.2.



(a) **Data source :** *World Energy Investment 2021* - IEA



(b) **Data source :** IEA

Figure 6.1: Annual production and investment for different type of fossil fuels

The results for the real price of fossil fuels are calculated and summarised in Table 6.1. It can be noted that the price of coal is smaller than two other types, which is in line with the fact that coal is known to be a cheap energy source.

6.2 Importation of crude oil

The three costs are represented in Figure 6.2. It can be noted that the crude oil extraction price is fairly constant, which is consistent, compared to the market price. A small drop can be noticed by 2020. The investments in fossil fuels went down because of the Covid crisis.

Table 6.1: Real price of fossil fuels

ctsCHF 2019/kWh	2015	2016	2017	2018	2019	2020	Average C1
Crude Oil	1.23	0.98	1.02	1.03	1.03	0.78	1.014
Gas	0.95	0.80	0.78	0.73	0.69	0.48	0.733
Coal	0.24	0.21	0.19	0.18	0.21	0.20	0.205

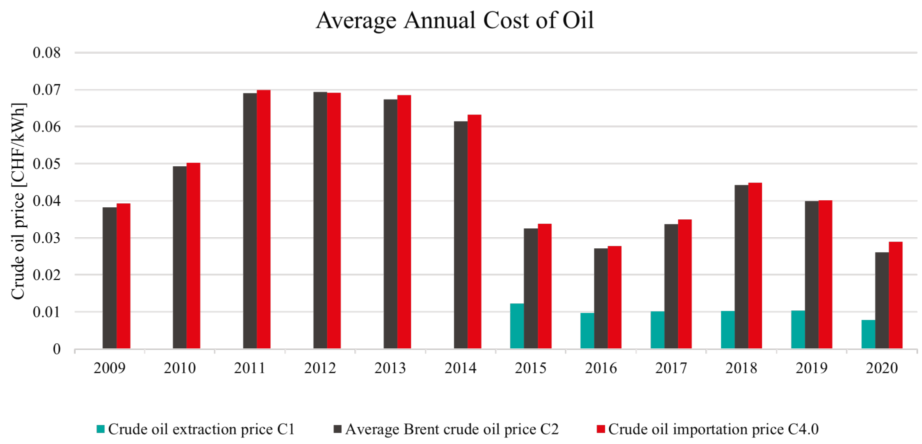


Figure 6.2: Model of the importation of crude oil in Switzerland
Data source : ***C4.0*** : *Swiss Impex* [13], ***C2*** : Statista [28]

6.2.1 Gross Margin

The estimation of the gross margin made by the producers of fossil fuels was given by Equation 3.3. As it can be seen in Figure 6.2, the gross margin (i.e. difference between ***C2*** and ***C1***) fluctuates a lot, showing the large dependence on the market. As a result of a lack of data for the up-stream investments, the outcomes, presented in Table 6.2, show only the average value for the time range 2015-2020. It can be imagined that the extraction price ***C1*** is also constant for 2009 to 2014 (see Figure 6.2). In this case the results for the margin would be slightly larger.

Table 6.2: The average Gross Margin of the producers of crude oil

2015-2020	Average	Min	Max	Std. dev.
Gross margin [ctsCHF/kWh]	2.38	1.73	3.40	0.61

6.2.2 Transport to Switzerland

The estimated cost of transport, given by equation 3.4, is summarised in Table 6.3. The results show that, despite the pretty high variance, the order of magnitude is really small compared to the price of the product. The high variation can be explained by the fact that the importing countries have several producers around the world, meaning that the transport distance can vary. The negative value can be explain by the fact that this estimation is based on the average Brent crude oil price. The price at which Switzerland buy the crude oil can then differ from this average which can lead to this kind of infeasible estimation.

Table 6.3: The average cost of transport of Crude Oil from production country to Switzerland

2009-2019	Average	Min	Max	Std. dev.
Transport [ctsCHF/kWh]	0.086	-0.020	0.29	0.053

6.3 Fossil fuels in Switzerland

The first step to estimate the different costs of fossil fuels in Switzerland is to find the data in the literature. The Table 6.4 presents the average values that are needed for the further calculations.

Table 6.4: Average cost for fossil fuels from literature

2009-2019	P_{selling} ***C8.i*** [CHF/kWh]	Tax [CHF/kWh]	$P_{\text{refined import}}$ ***C4.i*** [CHF/kWh]	$P_{\text{crude oil import}}$ ***C4.0*** [CHF/kWh]
Heating oil	0.0924	0.0279	0.0542	0.0484
Gasoline	0.188	0.094	0.0633	0.04848
Diesel	0.174	0.0904	0.0591	0.0484
Natural gas (heating)	0.0975	0.0238	0.0488	0.0484
References	[20]	[21]	[13]	[13]

6.3.1 Price of distribution and transport in Switzerland

Using the system of equation 4.4, the refinery price $P_{\text{refinery CH}}$ (for products refined in Switzerland) and the distribution cost $P_{\text{distribution CH}}$ (from border/refinery to the consumer) can be deduced. The results are shown in Table 6.5. Note that, the cost of distribution $P_{\text{distribution CH}}$ is also valid for the

fuels refined outside Switzerland, because it is assumed that they share the same distribution network. Moreover, as natural gas is not produced in Switzerland, there is no value for $P_{\text{refinery CH}}$.
The results show that, in term of volume (i.e. litre), the diesel and the gasoline have a cost of distribution that is close which is in line with the fact that their distribution system is quite similar. However, the cost is higher for heating oil. It can be explain by the fact that the latter is usually supplied directly at home in contrast to the mobility fuels that are supplied to the gas stations.
In addition to that, heating oil is a less refined product compared to diesel or gasoline. It is reflected in the results with a lower cost of refinery.

Table 6.5: Cost details of oil products refined in Switzerland

	$P_{\text{refinery CH}}$		$P_{\text{distribution CH}}$	
	[cts.CHF/kWh]	[cts.CHF/l]	[cts.CHF/kWh]	[cts.CHF/l]
Heating oil	0.58	6.28	1.03	67.58
Gasoline	1.49	13.40	2.99	26.87
Diesel	1.07	10.57	2.45	24.17
Natural gas (heating)	—	—	2.50	

6.3.2 Margin of the swiss refinery

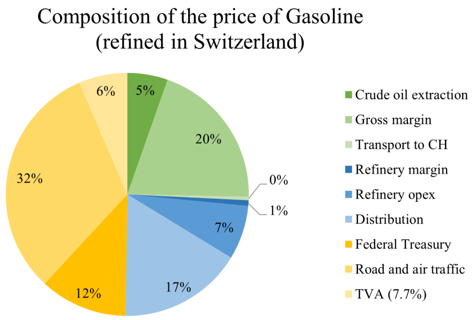
The Section 4.2 describes a method to estimate the minimum margin that a refinery can make by assuming a fixed cost of operation. The results are presented in Table 6.6.

Table 6.6: Decomposition of the swiss refinery cost

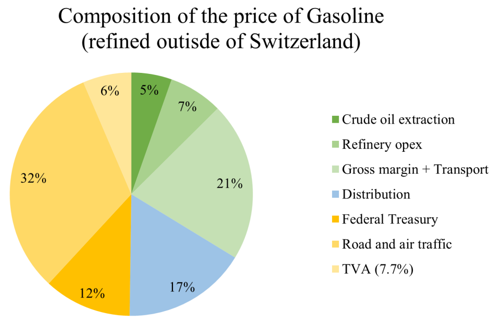
2009-2019	Fixed refining cost [cts.CHF/kWh]	Margin [cts.CHF/kWh]
Heating Oil	0.390	0.194
Gasoline	1.348	0.143
Diesel	0.777	0.294

6.4 Breakdown of the selling price

Now that the estimations for each step of the Swiss model are computed, the results can be assembled and are presented with pie charts. These graphics aim to show what the consumer is paying for and who he is paying. They are showing the composition of the price for the two origins of product, i.e. refined in Switzerland or abroad (except for natural gas which is only imported). In green is presented the expenses outside Switzerland, while the blue is for those inside the country. Finally the yellow parts account for the taxes. It can be noted that the results for this example could be even more detailed. For example, the transport cost has not been computed in this project for the imported refined product.

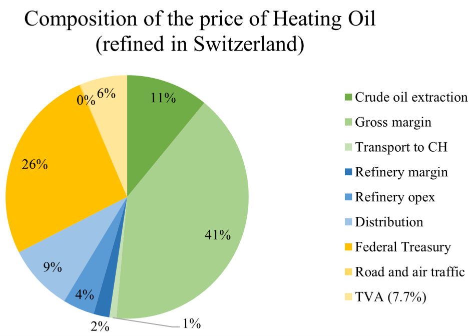


(a) Refined in Switzerland

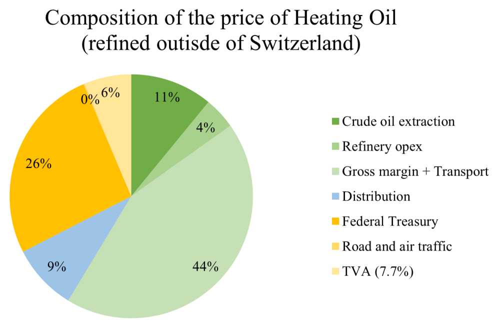


(b) Refined outside Switzerland

Figure 6.3: Breakdown of the gasoline price



(a) Refined in Switzerland



(b) Refined outside Switzerland

Figure 6.4: Breakdown of the heating oil price

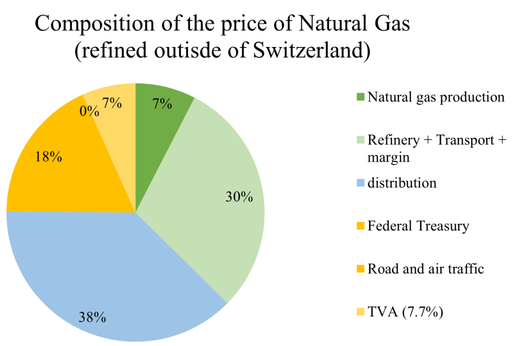


Figure 6.5: Breakdown of the natural gas price

Since the breakdown of the cost of products refined in and outside Switzerland is different, the Table 6.7 shows the contribution of the Swiss refinery to supply the domestic market. By using the average value, the global decomposition of the price for the Swiss market can be estimated. The Figure 6.6, that presents the Swiss price of fossil fuels, highlights the fact that a large part of the price is for abroad industries.

Table 6.7: Refinery's share of domestic sales

[%]	2015	2016	2017	2018	2019	2020	average
Gasoline	36.7	29.6	29.4	28.5	27.3	29	30.08
Diesel	34.3	31.8	29.7	31.8	28.2	33.9	31.62
Heating oil	35.8	38.2	33.8	38.8	31.3	30.6	34.75

Data source : *Annual report 2020* - Avenergy [17]

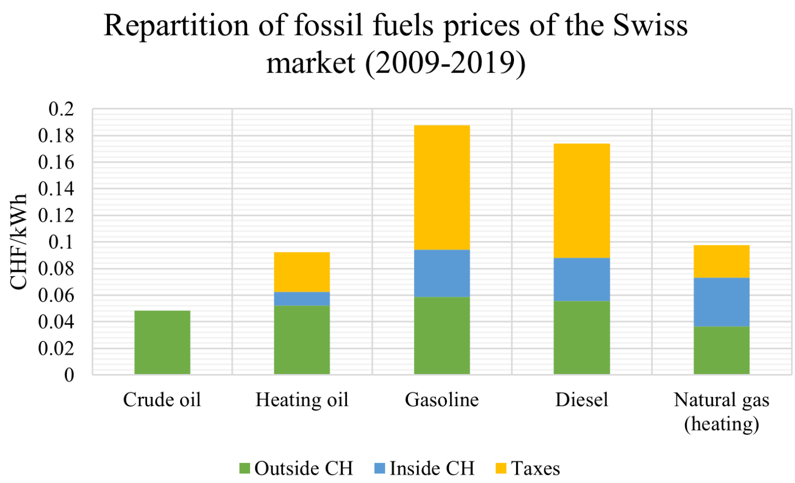


Figure 6.6: Breakdown of the global fossil fuels price for the Swiss market

Chapter 7

Discussion

Concerning the mobility fuels (see Figure 6.3), the first important point to highlight is that the taxes account for 50% of the bill. However a large part of this tax (32% of the total) is used for the maintenance of the Swiss roads. More concerning, using the average ratio of Table 6.7 and Figure 6.3, it can be estimated that 30.6% of the price is leaving Switzerland. Moreover, 21% is directly the margin made by the producers. The share that corresponds to the cost to produce the fuel (extraction and refinery) accounts only for 12% of the price, which is smaller than the cost of distribution across Switzerland. It indicates that when considering fossil fuels, the share for the distribution is as important as the production and that it should not be neglected.
Since there is no CO_2-Tax for the mobility fuels (see Table A.3 for details), the price does not includes any incentive fee to promote the renewable energies. In 2019, the tax revenues for gasoline and diesel amount to 4.4 billions CHF [17], meaning that, even with only a small percentage of this tax revenue used to promote renewable energies, it would represent a great potential. To compare with, the actual CO_2-Tax generates 1.4 billions per year [22].
It is interesting to see that the transport cost to import crude oil accounts for less than one 1% which is very low compared to the cost of distribution of gasoline inside Switzerland (12%). It can be explained by the fact that the crude oil is transported to Switzerland in large quantities and mainly by pipeline, ship and rail [29], which are greatly cheaper than truck transport [23]. Once it is delivered to Switzerland, the distribution to gas stations needs, at some point, to be done using trucks, explaining the highest cost. Moreover, refined products are less stable and more sensitive to contamination which demands adapted and more expensive infrastructures than for crude oil [23].
The Diesel charts, which follow the same trend, can be found in Annex A.1.

Regarding the price of heating oil (see Figure 6.4), the taxes are less impacting compared to the mobility fuels, and are logically not used for roads. However, 56% of the price is leaving the country. Moreover, more than 40% is directly linked the margin of the producer.
Compared to mobility fuels, a CO_2-Tax is collected on this product, representing 85% of the total tax and 27% of the heating oil price.

Finally, for natural gas (see Figure 6.5), the cost of distribution in Switzerland takes the largest part of the total price (38%). It can be explained by the fact that the gas is supplied across Switzerland through a large network of pipelines. This infrastructure is expensive to operate and to keep in good condition. 37% of the cost are expenses outside Switzerland. In general terms for heating fuels, the tax share is lower than for mobility fuels. It can be explained by the fact that heating fuels are considered as a more necessary good compared to gasoline or diesel. Figure 6.6 illustrates this difference.

It is also interesting to look at it in term of quantity. The Figure 7.1 represents the mass flow of oil products in Switzerland in 2019. One quarter of the total consumption is supplied by the imported products. Only a small part is exported. In term of capital invested each year, the net importation of petroleum products amounts to 6 billions CHF. In term of comparison, the investment cost for a small scale PV system is 2.6 CHF/W and lasts 20 years [30]. Assuming a interest rate of 5%, the annualised investment cost is 0.209 CHF/W/year, meaning that the annual expenses of 6 billions CHF/year could be invested in 28 GW in PV rather than in petroleum products. With a Specific Yield of 985 kWh/kW [31], the annual production of electricity would be 27.58 TWh which represents 46% of Swiss electricity production of 2020. [32]. For comparison purposes, according to Roger Nordmann [33], 50 GW of solar would be the objective for Switzerland in order to reach a complete energy transition.

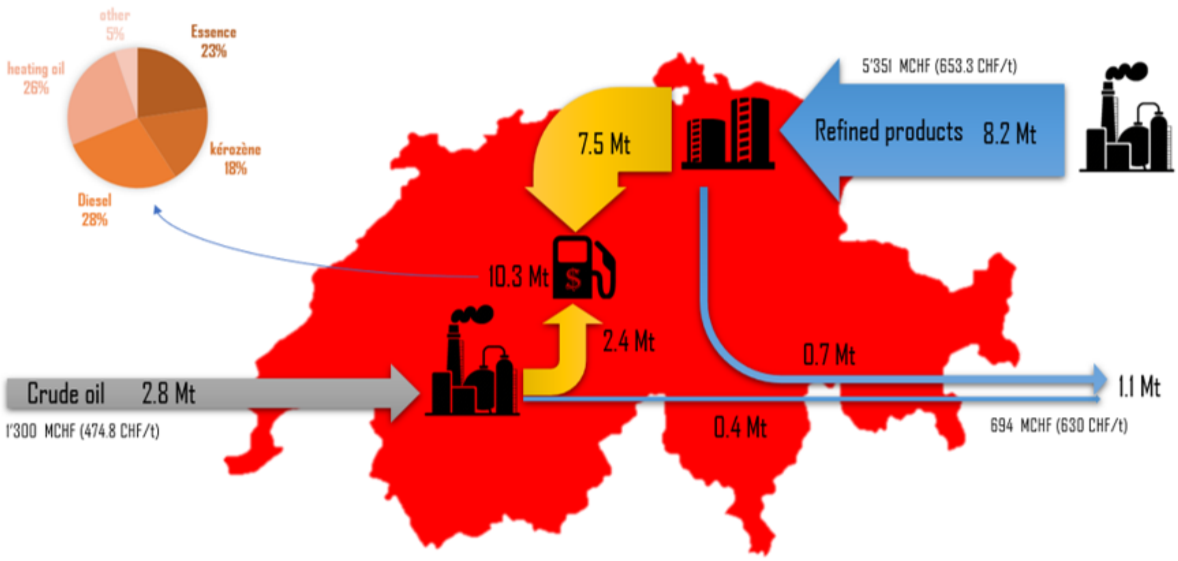


Figure 7.1: Oil Products Flow (2019)
Data source : *Annual report 2020* - Avenergy [17]

Chapter 8

Conclusion

All along this project, the model that describes the price of fossil fuels has been developed. A large number of processes from the production to the consumer were described and a strategy to estimate their prices has been established. The model can be adapted to any importing country and to different fossil fuels. Applied to the case of Switzerland, it has shown that the results were consistent with expectations. It highlights the fact that a large part of the selling price of fossil fuels is used directly outside Switzerland: 30.6 % for gasoline, 38% for diesel, 56% for heating oil and 37% for natural gas. Moreover, more than half of this shares are estimated to be margin made by the producer. The annual abroad expenses made in petroleum products could allow to produce 46% of the Swiss electricity production it was invested in PV systems.

It was also noticed the importance of the data selection and that the outcomes depend on the source but also on the time range that is chosen, especially when the volatility is high. Selecting the right data is, therefore, a key element for the success of the analysis.

It would be interesting to further the analysis regarding the storage cost for fossil fuels in Switzerland, using the strategy developed in this project. It would allow to model in *EnergyScope* the size and the price of the Swiss storage system in function of the consumption.

The substitution of fossil fuels by renewable energies is an important challenge for the near future. The potential of replacing the annual expenses in fossil fuels by renewable technologies was pointed out. However, when comparing the fossil fuels imports expenses to the PV investment cost, an important element is not taken into account. In fact, the inconvenience of focusing the national production of electricity on intermittent sources (e.g. PV panel or wind turbine), is that a large electricity storage capacity is now required. The infrastructure involves an important investment that needs to be accounted. This aspect is often neglected when speaking about the cost of renewable energy. Implementing storage technologies on *EnergyScope* would allow to estimate the storage investment needed to compensate the intermittence of these technologies and to figure out what is the real investment cost of the energy transition.

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Appendix A

databases

Table A.1: World investment in fossil fuel upstream in billion CHF

(billion CHF 2019)	2015	2016	2017	2018	2019	2020	2021
Crude Oil	553.4	445.1	460.1	472.8	472.8	328.9	361.6
Gas	329.5	284.3	285.1	281.0	275.9	188.6	235.3
Coal	106.5	88.9	80.9	82.9	98.1	89.3	89.7
Total	989.4	818.3	826.1	836.6	846.8	606.8	686.7

Source: IEA - World Energy Investment 2021 [34]

Table A.2: World production of fossil fuel

(kWh)	2015	2016	2017	2018	2019	2020	reference
Crude Oil	45061	45525	45084	46048	45729	42099	IEA - Oil [35]
Gas	34670	35333	36694	38433	40111	38992	IEA - Natural Gas [36]
Coal	44905	42306	43702	45432	46470	44328	IEA - Coal [37]

Table A.3: Summary of the taxes applied on fossil fuels

[CHF/kWh]	Gasoline	Diesel	Heating oil	Natural gas (fuel)	Natural gas (heating)
mineral oils tax	0.0477	0.0449	0.0003	0.0081	0.00015
sur-tax	0.0332	0.0293	0.0000	0.00790	0
total mineral oils tax	**0.0809**	**0.0742**	**0.0003**	**0.0160**	**0.00015**
CO2 tax	0.0000	0.0000	0.0254	0	0.01741
Others	0.0004	0.0005	-0.0014	0.000145	0.000145
TVA (7.7%)	0.0121	0.0113	0.0058	0.00772	0.00653
Total	**0.0934**	**0.0860**	**0.0300**	**0.0239**	**0.0242**

Source: working document of IPESE [38]

Table A.4: Energy density of fossil fuels

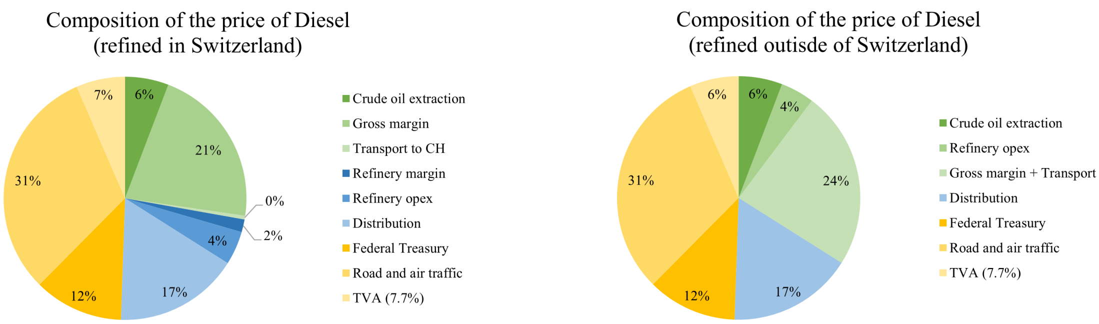
	MJ/kg	kWh/kg	KWh/Litre	kg/m3	kg/litre
Gasoline	43.4	12.1	8.98	745	0.745
Diesel	42.8	11.9	9.87	830	0.83
Heating oil	45.58	12.7	10.76	850	0.85
Crude oil	42.7	11.9	10.23		0.862
Natural gas	48	13.3			
Coal	22.7	6.3			

Source: EngineeringToolbox [39], Total Energies [40], FioulMarket [41]

Table A.5: Exchange rate USD to CHF

	2018	2019	2020	2021
CHF/USD	0.98	0.99	0.94	0.91

Source: MacroTrends [42]



(a) Refined in Switzerland

(b) Refined outside Switzerland

Figure A.1: Breakdown of the diesel price