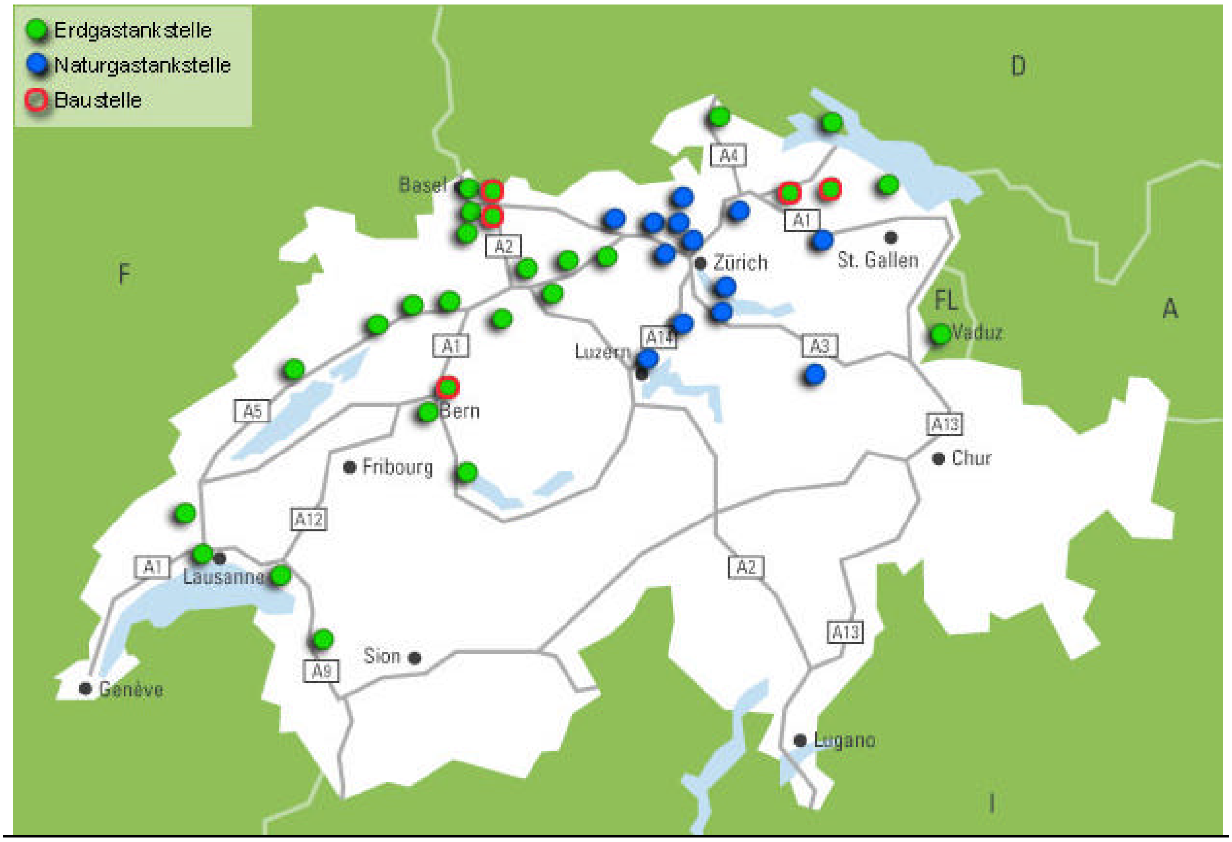

Market potential of compressed natural gas cars in the Swiss passenger car sector

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Abstract

Specific competitive conditions will decide on the successful introduction of compressed natural gas cars in the motor vehicle fleet. This study is part of the Alliance for Global Sustainability (AGS) project "Role of Innovative Technology for Promoting Sustainable Mobility" being carried out at MIT, PSI, and at the Swiss Federal Institute of Technology. The framework project estimates the future structure of vehicle fleets incorporating innovative drive trains, and evaluates its contribution to sustainable mobility.

First, it presents a transition analysis (change management) for natural gas cars from today's status as niche market product to a mass-market product. Here natural gas cars are considered as a substitution product for internal combustion engines (Carle (2004)). The evaluation was guided by the competition analysis technique developed by Porter (1998b; a). This technique relies on existing data to estimate potential competitive forces in future markets.

The second part of the paper describes the factors necessary in Switzerland for natural gas cars to become widely used. In other words it describes the success factors that may contribute to a breakthrough for natural gas cars from the niche to the mass market. This analysis also identifies critical factors that affect both market penetration time and the rate of product diffusion into the mass market.

Keywords

automotive industry, car industry, competitive advantage, competitive analysis, competitive strategy, five forces model, ngv, natural gas car, biogas, hybrid car, Michael Porter, – 3rd Swiss Transport Research Conference – STRC 2003 – Monte Verità

1. Introduction

Specific competitive conditions will decide on the successful introduction of compressed natural gas cars in the vehicle fleet. As an analysis instrument the competition analysis of Michael Porter (Porter (1998b; a)) is used, in order to achieve an overview of possible economic competition forces.

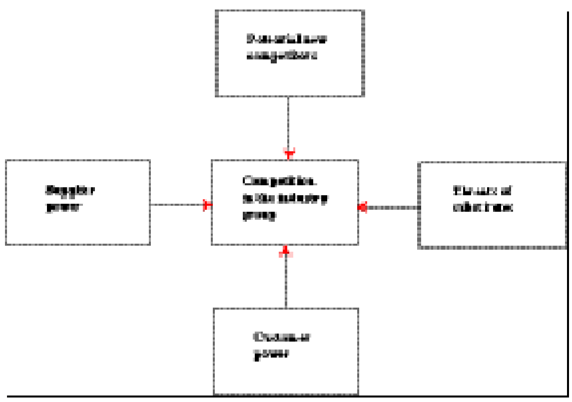
Natural gas cars function similarly to traditional vehicles. However, they use natural gas or biogas as fuel. Natural gas can power existing cars by converting the petrol engines to a bi-fuel engine. The conversion of internal combustion engines to natural gas engines requires additional gas tanks, fuel pressure regulators, fuel lines and an electronic module, which adjusts the engine to maintain comparable performance levels with either fuel.

2. Methodology

2.1 Five Forces Model

In 1980 Michael Porter developed a technique for analyzing industrial structure and its competitive forces (Porter (1998b; a)). Porter's technique is based on the "Five Forces Model" illustrated in Figure 1. This model describes an enterprise in relation to its economic environment.

Figure 1 Porter's Five Forces model



Source: Porter (1998)

The competitive position of an industrial enterprise depends on five competitive forces. These competitive forces for the natural gas car industry are illustrated in Figure 2. They are:

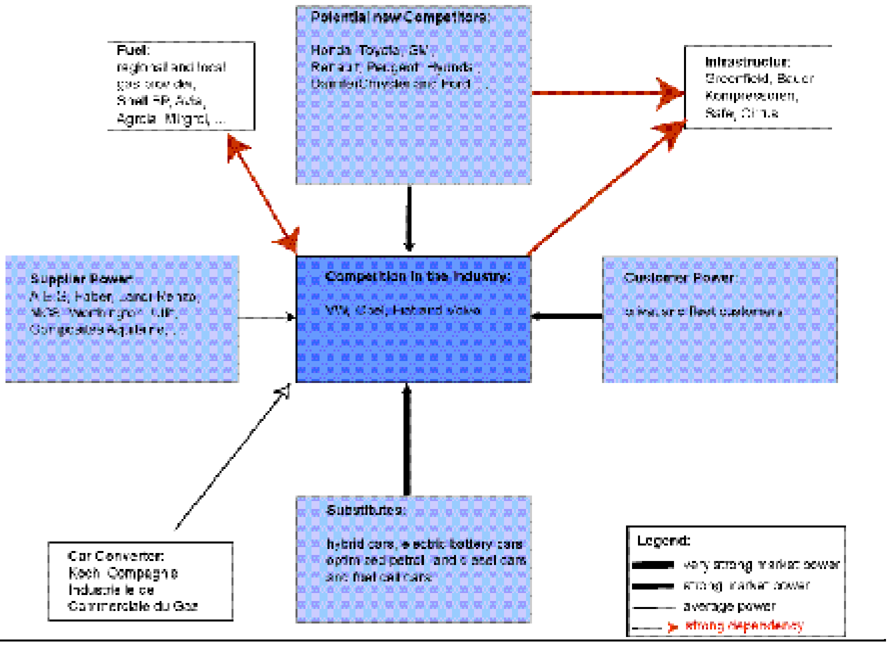
- Competitive market power of natural gas car manufacturers
- Threat of new competitors entering the market (i.e. new natural gas car manufacturers)
- Competitive market power of customers intending to buy a natural gas car
- Threat of substitute products (i.e. other alternatives to traditional internal combustion engines)
- Competition within the natural gas car industry (i.e. competition between different natural gas car manufacturers)

In addition to these 5 forces the following two forces play also an important role in the natural gas car sector:

- Influence of the market penetration of natural and biogas refuelling stations
- Influence of the natural gas and biogas price

All seven forces together provide a good overview of the attractiveness of this industry branch, and can help to estimate its further profit potential. This, in turn, can be used to assess the likelihood that natural gas cars may be widely adopted in the car manufacturing industry (since there will only be good profit potential in the industry if the technology is widely adopted).

Figure 2 Porter's Five Forces model applied to the compressed natural gas car industry



2.2 Substitution Conditions

Which market conditions must be fulfilled in order to have automobile manufacturers adopt compressed natural gas car as a substitute for existing (or alternative) technology? Natural gas car technology is a substitute for traditional gasoline and diesel internal combustion engines. Basic economic theory tells us that substitutes will only be adopted when they are cost competitive with the original good. In other words natural gas car technology will not be adopted unless it is in the same basic range as traditional gasoline and diesel engine technology.

3. Natural Gas Car Industry Competitive Analysis

3.1 Competition within the natural gas car industry

The development of gas cars began more than 150 years ago. The French Etienne Lenoir built in 1862 a gas engine vehicle, still before the first gasoline and diesel engine vehicles were developed. However, it took another 130 years till the first compressed natural gas car was produced as a serial product. After the unsuccessful launch of BMW’s 316g and 518g in 1995, Volvo was the first company offering natural gas cars as a serial product. Volvo's first compressed natural gas car came on the market in 1997. Since the year 2001 the redesigned models S60, V70 S80 are available as natural gas versions with underfloor gas bottles. In 2000, Fiat was the first company to offer a compressed natural gas car (again with underfloor gas bottles) as a serial product that provided the same indoor car volume and comfort as the equivalent gasoline vehicle. Already in the design phase, the Fiat Multipla was conceived as a bipower car running with natural gas and petrol. The Multipla is the car with the highest range of about 900 km.

Another recent model, the Opel Zafira, is more energy efficient than the Fiat Multipla bipower, as the engine of Zafira is optimized for compressed natural gas and not for petrol. An Opel Zafira CNG has about the same size and same amount of engine power as the Fiat Multipla, but consumes 15 % less natural gas per 100 km. The VW Golf Variant bi Fuel, a station wagon, consumes the same amount of natural gas as the Multipla. However, the carbon gas pressure tanks are not stored underfloor resulting in a smaller trunk.

Table 1 shows that in Switzerland, the Fiat Multipla bipower is the preferred natural gas car, followed by the Opel Zafira CNG and the different Volvo Bifuel models. The remaining 174 natural gas cars in Switzerland are converted ones, among which the most popular one is the Smart.

Table 1: Cumulative sales volume of compressed natural gas cars produced original equipment manufacturers, up to September 2003

Brand and model	**Sales volume in Switzerland** [1]	**Sales volume in Germany**	**Sales volume in Austria**
Opel Zafira CNG	101	1’272 [2]	26 [3]
Fiat Multipla Bipower	193	594 [4]	33 [5]
Volvo	New S60, V70, S80: 70 old S70/V70: approx. 50	1’300 [6]	15 [7]
Volkswagen Golf Variant BiFuel	15 [8]	450 [9]	0 [10]

Natural gas cars, directly produced by the car manufacturer, will gain market share in the next few years and conversion companies will have to find their niche market as more and more customers will choose a compressed natural gas car directly produced by the car manufacturers (Figure 2).

The competition between the different compressed natural gas car producers is not very strong. Fiat is the company with the best natural gas know-how. They are also the only ones producing their cars on an assembly line resulting in lower production cost. All other manufacturers pro-

[1] Eidg. Fahrzeugkontrolle (2002)

[2] Personal communication with S. Peiel from Opel Germany, 2003

[3] Personal communication with S. Peiel from Opel Germany, 2003

[4] Peronal communication with C. Cardacio from Fiat Switzerland, 2003

[5] Peronal communication with Herr Grause from Fiat Austria, 2003

[6] Personal communication with Mr. Ortmann from Volvo Germany, 2003

[7] Personal communication with Andrea Nell from Volvo Austria, 2003

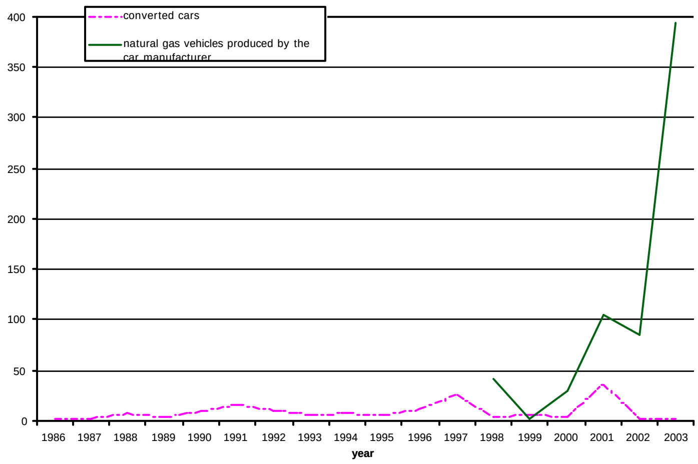
[8] Personal communication with Markus Müller from AMAG Switzerland, 2003

[9] Personal communication with Markus Müller from AMAG Switzerland, 2003

[10] Personal communication with Porsche Austria, 2003

duce first a petrol version, which is manually converted into a compressed natural gas variant in a special plant.

Figure 3 Sales volume development over the last 17 years



Nevertheless, compressed natural gas cars could be, at least during the next 15–30 years, a real alternative to gasoline/diesel fuelled and fuel cell vehicles, since compressed natural gas cars are relatively inexpensive to produce and operate and emit around 15 % to 20 % less carbon dioxide (CO_2) than a conventional gasoline car. Operating costs are especially low given the natural gas industry's determination to promote these cars even if they must subsidize the natural gas at the beginning. Also a total cost of ownership (TCO) analysis performed for Switzerland has shown that compressed natural gas cars have lower total costs than gasoline / diesel fuelled cars (Carle (2004)).

3.2 Threat of New Competitors Entering the Market

It won't be very difficult for new competitors to enter the market for compressed natural cars. First, the amount of money that has to be invested into research and development of compressed natural cars is not very high. A simple car conversion (i.e. VW Golf bi-fuel) costs between € 4'000 to € 6'000. The Association of the German Automobil Industry (Dübel (2003)) calculated that the development of a totally new engineered natural gas car amount to around € 1 Billion, which is, compared to fuel cell vehicles or a totally new designed gasoline/diesel car, not very much.

However, the development and market introduction of efficient hybrid natural gas cars emitting around 70 – 90 gram CO_2 per km as well as a super efficient compressed natural gas cars will take some more years till they are available as a serial product. Nevertheless, at the current market penetration stage these research & development efforts are not very interesting as the sales volume and the natural gas fuel infrastructure density are way too small.

3.3 Market power of customers intending to buy natural gas cars

The third factor in Porter's competition analysis is the strength of customers in negotiations with the manufacturer. In the case of natural gas cars, the customers are the car owners.

A problem is the higher natural gas car price. However, a total cost of ownership calculation proves that over the whole life-span natural gas cars are cheaper than petrol or diesel cars. Another critical factor is the development of an infrastructure to deliver the natural or biogas. This infrastructure has been slow to develop in Europe (with the exception of Italy). In Switzerland are, at the moment, just 30 natural gas fuelling stations covering the region from Geneva over Basel to St. Gallen, without any coverage in the cantons of Graubünden / Grisons, Uri, Schwyz, Ob- and Unterwalden.

The rather small model palette, the low natural and biogas refuelling infrastructure and the relatively high car price limits the amount of potential customers. As long as not more or less every type of car is available as a compressed natural gas car the market penetration will be rather slow and the customers will to a certain extent buy a substitute.

3.4 Threat of Substitute Products

Porter's fourth factor for the evaluation of the competitiveness of new technology is the threat of substitutes. This means identifying whether there are other products that could substitute the new technology. These alternatives must be less expensive or better (or both).

3.4.1 Substitute Products

There are four main competitors to natural gas cars: hybrid vehicles, optimized gasoline and diesel vehicles and later on fuel cell cars. Each is outlined below.

Hybrid cars

Today's parallel hybrid cars use two engines. A battery-powered electric motor is used in city driving, which is characterized by frequent stop and go activity, while a conventional spark-ignition gasoline or diesel engine is used on highways and for charging the battery. Hybrid vehicles have relatively high costs due to the technology required to connect two traction systems in the same vehicle, but they are energy efficient and generate low levels of emissions (Verband der Automobilindustrie e. V. (2002)).

Several vehicle manufacturers are currently producing hybrid vehicles and others are testing them. Toyota, Honda, Nissan and Mitsubishi manufacture hybrid cars. They are used by fleet operators in Japan while the Toyota Prius (Japan, Europe, USA), Honda Civic IMA (Japan, USA and Europe) and Honda Insight (Japan, USA) are available commercially.

Electric powered vehicle

The second competitor is the electric powered vehicle. The main drawback of electric vehicles is their limited range and their high weight with the existing battery technology. Most electric vehicles are limited to less than 160 km between recharging, which often takes several hours. Electric vehicles are also relatively expensive, although their benefits, no local emissions or engine noise, are significant enough to have created a commercial market. As with natural gas cars, electric vehicles are popular with fleet operators, especially for vehicles that remain in the same general area (e.g. local mail delivery).

Improved traditional gasoline and diesel engine

The third competitor is the improved traditional gasoline and diesel engine technology. New technology has made it possible to significantly improve both the energy efficiency and emissions levels of existing internal combustion engines. These improvements include variable valve control, cylinder disconnection, and fuel direct injection. In the long term it is possible to reduce fuel consumption for conventional gasoline or diesel passenger cars by 40-50%, with an efficiency improvement by 2005 between 17% and 23% (Geschka 2002). However, super efficient vehicles like the VW Lupo and the Audi A2, which use on average 3 litres of gasoline per 100 km, will remain niche products, since they are relatively expensive.

Fuel cell vehicle

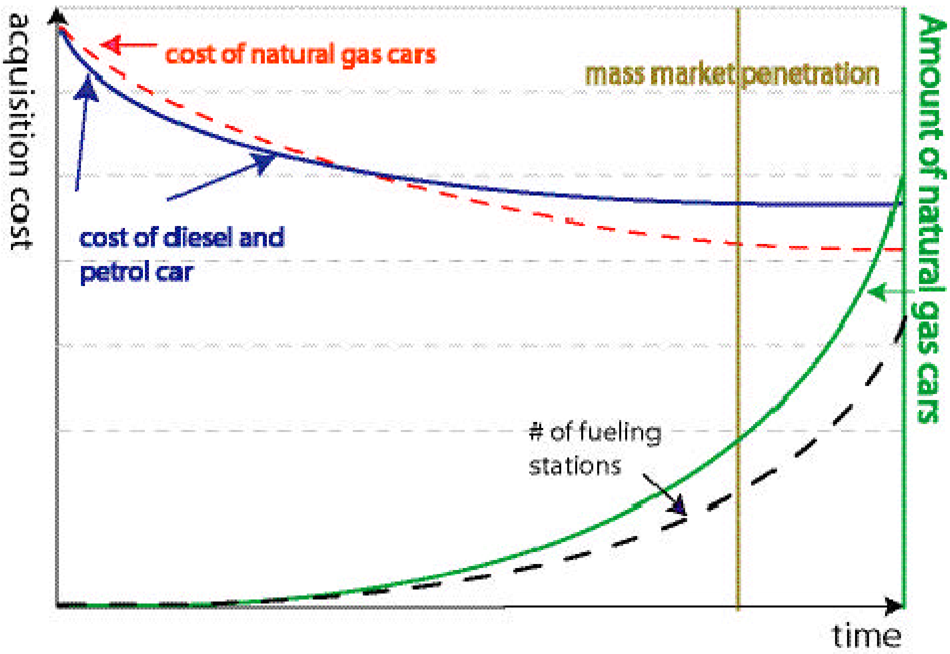
The fourth competitor is the fuel cell vehicle. Fuel cells combine hydrogen (from a fuel source like natural gas) and oxygen (from the atmosphere) to generate electrical energy with only water vapour as emissions. Since fuel cells create energy without harmful emissions they are widely thought to be an ideal technology for use in vehicles. The most appropriate technology for the fuel cell for transport applications is the proton exchange mechanism (PEM) fuel cell. Therefore, the vehicle industry has focused on PEM technology. However, there are till now only some prototype cars. Fuel cell cars that will be available for customers won't be on the market till about 2010. A critical factor in the market for fuel cell vehicles is development of an infrastructure to deliver the hydrogen they use as fuel. Until such an infrastructure is available, the market for fuel cell vehicles will be limited.

3.4.2 Competition from Substitution Products

Figure 4 illustrates the concept that compressed natural gas cars will need to compete with other technologies in the race for commercial success. This section discusses the factors influencing competition from substitute products on the compressed natural gas car industry.

Natural gas car competitors are hybrid vehicles, fuel cell vehicles, electric vehicles and optimized traditional gasoline and diesel engine vehicles. Competition from these vehicle types will be strong because some of them are further developed than natural gas cars – except of fuel cell cars - and also cost less. In addition, all these technologies, except for fuel cells, have a fully functioning infrastructure.

Figure 4 Cost development and market penetration of natural gas cars, schematic sketch



The traditional internal combustion engine is an established technology with good driving performance and poor efficiency. Unburnt hydrocarbons, CO, and NOx emissions have already been reduced to very low values for gasoline vehicles equipped with three-way catalysts, but NOx and soot remain to be a problem for diesel cars without particulate filters. In the mid-term tailpipe emissions for gasoline and diesel engines can be reduced to almost ambient air quality for a much lower cost than for any of the new vehicle technologies. However, very significant efficiency improvements of the traditional internal combustion engine will be difficult to achieve.

As long as natural gas engines cost over $60/kW and gasoline/diesel prices do not at least double, the gasoline and diesel engine will continue to play a dominant role in the vehicle market.

Hybrid vehicles are another reasonable alternative to fuel cell vehicles during the next 15–30 years. Hybrid vehicles still consume a considerable amount of fuel; the Toyota Prius uses approximately 4.3 litres per 100 km and is rather heavy.

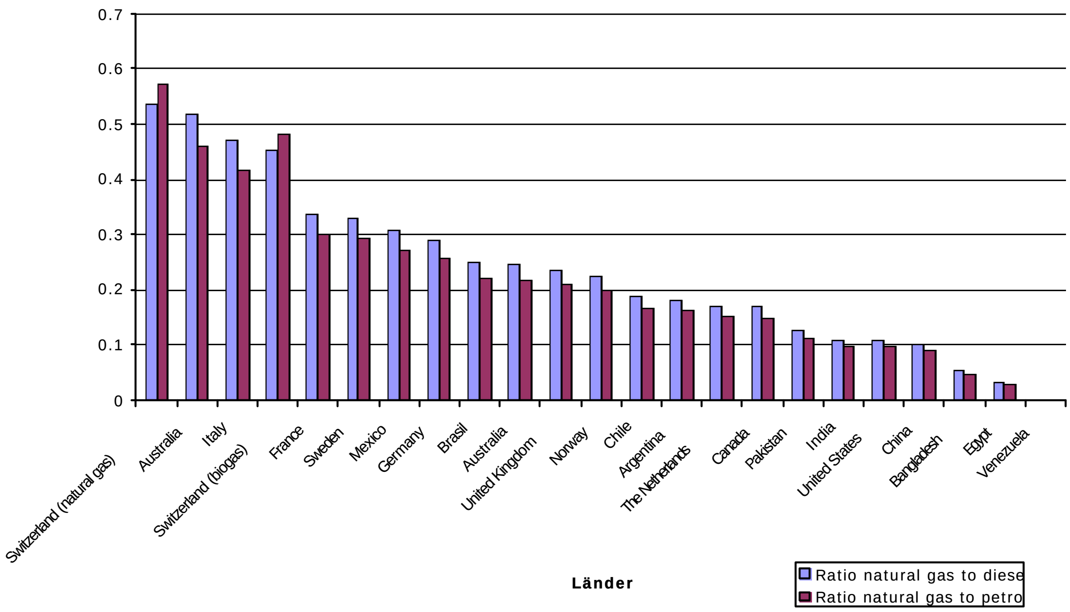
A significant advantage most of these alternatives have in comparison to natural gas cars is that they can use the existing fuel infrastructure.

3.5 Power of the fuel price

If countries with a high natural gas car market penetration are taken as a benchmark for successful gas vehicle introduction, then the Swiss natural gas price is too expensive compared to diesel or petrol. Countries like Venezuela, Argentina and India have a much more favourable fuel price ratio (natural gas price to petrol price). In these mentioned countries natural gas is at least 80 % cheaper than petrol. An exception is Italy, where the ratio is more or less like in Switzerland. However, Italy has a rather high natural gas car market share since over 20 years, a dense refuelling infrastructure, as well as a competitive passenger car conversion market.

With the proposed Swiss federal mineral oil tax change, which will be effective in 2006 or 2007, natural and biogas will be exempted from the mineral oil tax, which is right now at 0.40 Swiss Francs per kg (Kommission für Umwelt Raumplanung und Energie SR (UREK-SR) (2001)). In addition, the potential CO2-tax will be a further driver for a faster market penetration.

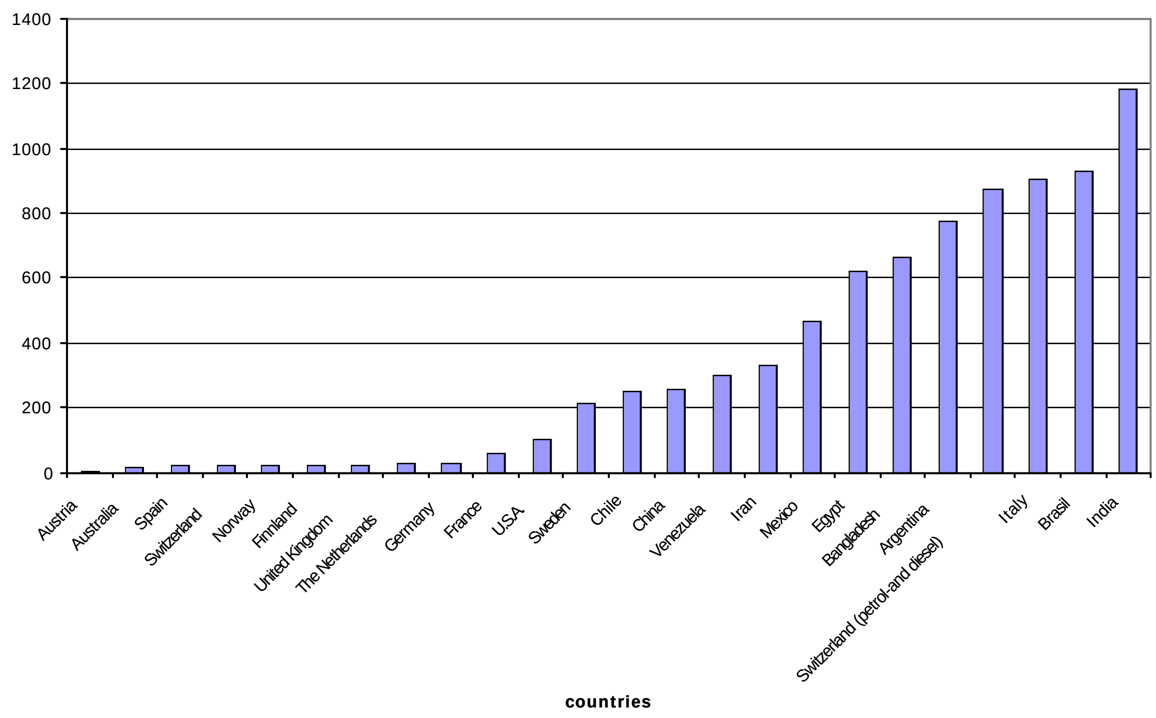
Figure 5 Ratio between petrol and diesel price to the natural gas and biogas price, September 2003



3.6 Power of the refuelling infrastructure

At present a total of 30 natural or biogas refuelling stations are in Switzerland available – 19 offer natural gas and 11 biogas (VSG (2002)). Further 20 stations are in a planning phase. Until the year 2006 100 natural gas or biogas refuelling stations are planned. The ratio of fuelling stations to natural gas cars is 1:20 in Switzerland, i.e. 20 cars per refuelling stations. This is very low, compared to countries with a high natural gas car market penetration. In the long term the ration should be around 1: 400 to 1:800 as in Italy, Brazil and Argentina (Figure 6). A smaller ratio leads to an unprofitable refuelling infrastructure, which may be a danger for the market penetration of natural gas cars in the long term.

Figure 6 Natural gas cars per fuelling station, September 2003



4. Conclusions

Natural gas cars could be, at least during the next 15–30 years, a real alternative to gasoline/diesel fuelled and fuel cell vehicles, since compressed natural gas cars are relatively inexpensive to produce and to operate, even though the fuel price ratio between natural gas and petrol is much higher than in other countries. Operating costs are relatively low given the natural gas industry's determination to promote these cars even if they must subsidize the fuel as well as the cars at the beginning. A total cost of ownership (TCO) analysis performed for Switzerland has shown that natural gas cars have lower total cost of ownership than gasoline/diesel fuelled vehicles.

In contrary to Italy, the Swiss natural gas car market is in a very early stage of market growth. Natural gas cars, which use bio or natural gas, must compete against the strong market power of their substitutes. Only heavy financial investments in infrastructure, model variety, marketing and an attractive fuel price may lead to a successful market penetration in the next 10 years.

The entrance barriers into the mass market of the natural gas cars will be not very high. In comparison to fuel cell for transport applications natural gas cars need neither very special know-how nor a lot of capital investment. An important key factor is the market size: If there were a world-wide rapidly growing natural gas car market, manufacturers would offer many new natural gas cars, which again would boost the market. In addition, economy of scale has its positive influence on the vehicle price. Above a certain amount of vehicle output, assembly line serial production on standard platforms will be possible.

A strong competition force comes from the possible substitution goods. Further developed gasoline and diesel engines, and eventually also hybrid vehicles, will have better competition chances in the medium term. These substitution goods have also a good fuelling infrastructure, which hardly exists for natural gas cars.

The negotiation strength of the suppliers will not be very strong. The necessary material needed is widely available on the market. The transfer costs of the manufacturers from a supplier to another will be rather low as various suppliers offer similar products. In addition, a supplier forward integration (i.e. their own production of natural gas engines) will not take place, since these do not have the necessary know-how.

The converters will keep a certain market share in the segment of the special passenger cars (i.e. SUV, cars with above average engine power and delivery vans), as long as the car manufacturers offer only a minimum model range.

The negotiation strength of the customers is large. The actual economic situation leads to considerable price deduction leading to cost attractive substitutes.

In order to solve the 'chicken and egg' problem, the gas providers need to speed up the market penetration of natural gas and biogas fuelling stations. The negotiation strength of the infrastructure operators and fuel providers is very strong, as they decide on the build-up of a dense fuelling station network.

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