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Assessing Strategies for the Market Introduction of Natural Gas Vehicles in Switzerland

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ABSTRACT

The market introduction of cars fueled with natural gas, a technically and economically mature option to reduce air pollution, was studied for Switzerland. Worldwide experiences have shown that the market introduction is a complex dynamical problem. The process demands well timed actions and investments of numerous stakeholder groups, from car industry to gas companies and fueling stations, whilst economic chances and risks are distributed highly unequally.

Stakeholder analysis and system dynamics modeling techniques were used to characterize the system. The developed model incorporates all relevant stakeholders, and shows the consequences and indirect feedbacks of their possible actions. It enables to simulate numerous future scenarios and test different market stimulation policies, yielding a better understanding of pitfalls and success factors.

Analyses identify difficulties in the market penetration process of gas cars. For example, a critical balance between fueling station upgrade investments and gas car sales is needed. The approach of this balance is challenged by a short supply of car types running on gas, unclear profitability expectations for fuel station owners, and limited financial benefits for customers. However, a considerable variety of policy options exists to foster successful market introduction.

1. INTRODUCTION

Market introduction of natural gas vehicles (NGVs) is identified in Switzerland as one of the promising measures to reduce air pollution and reduce CO_2 emissions. Modern NGVs, directly available from car manufacturers (OEM), exhibit very low local emissions (in best cases even in compliance with the California's very strict emission standard for Super-Ultra-Low-Emission-Vehicles SULEV) and emit approximately 20-30% less CO_2 relative to an equivalent gasoline car.

The market introduction in Switzerland is in a start-up phase. The fuel infrastructure is still widely absent, and less than 1000 NGVs are presently operated in Switzerland. However, several stakeholders have interest in a substantial market share of NGVs. The gas industry, running their business mainly on distributing gas for households, would like to establish a market share in the transportation sector to increase natural gas sales. The Swiss national and regional governments see NGVs as one option to achieve their ambitious goals in reducing local pollution and the traffic-related impact on climate change.

The Swiss gas industry recently communicated their ambitious goals of 30'000 NGVs in 2010 and 300'000 NGVs in 2020 (i.e. almost 10% of the Swiss car fleet). Overall, more than 50 million Swiss Francs will be invested over the coming years to fuel the market introduction of NGVs. Investments include significant subsidies to the approximately first 100 filling facilities for Compressed Natural Gas (CNG). Full investment costs for a normal CNG filling facility range from 350'000 to 500'000 Swiss Francs. The government, in reaction, is working on reduction of fuel tax for natural gas and skipping taxes for renewable biogas (which is produced from biomass and can be used as a gaseous fuel for NGVs as well).

A clear introduction strategy is under development, being continuously adapted to new insights from the also emerging international NGV market. So far, the sales of gas cars are focused on both private (individual) users and organizations managing car fleets while several public transport buses running on natural gas strengthen the visibility of the new car technology. Efforts in various innovative regions and cities are currently combined within a national framework to foster market development of NGVs.

International case studies show that market penetration of NGVs is far from trivial. Success with market introduction e.g. in Argentina contrasts with expensive failures after a promising start e.g. in Canada and New Zealand. The need to learn from these cases, to prevent repeating similar mistakes, is obvious.

The case of market introduction of NGVs clearly falls into the category of the so-called chicken-egg problem: fuel station owners' investment as well as the supply of a broad spectrum of NGV types (models) by car manufacturers depends on market potential and customers' preferences, whereas customers see sufficient fuel station coverage and availability of sufficient NGV types as necessary preconditions before buying NGVs. In Switzerland, a strategy to circumvent this chicken-egg problem and early failure of the NGV initiative is still under development. For a problem like this, the system dynamics approach represent a clear added value as the interlinked demand- and supply-mechanisms can be understand in much more detail and insights into adequate policy options can be developed.

This system analysis is part of a broader research initiative that is focused on developing solutions for sustainable mobility, in particular by smoothing the impact of car traffic on health and environment. These research initiatives combine research on resources for renewable fuels from biomass, technology development for production of biogas and more efficient natural gas cars. Demonstration and pilot projects in the Novatlantis pilot region of Basel (a regional sustainability project) help testing state-of-the-art technology and enable learning together with numerous stakeholders while acceptance among consumers and citizens is tested in e.g. focus group analysis (Kasemir et al., 2004). The approach discussed in this paper focused on system dynamics is designed to support involved stakeholders and decision-makers in science, business and administration in the region of Basel and Switzerland.

In this work's approach focused on system dynamics modeling, we have proceeded in several steps. First, we have tried to learn from the *international case studies* (see chapter 2) by determining the main market mechanisms, searching for those factors that predominantly influenced success or failure of NGVs. In a second step, we conducted extended stakeholder dialogues to learn about the specific Swiss characteristics of the (emerging) NGV market. Our systematic *stakeholder analysis* (Ch. 3) and *cross-impact analysis* (Ch. 4) were necessary transfer steps to use the provided stakeholder information to define the *general model structure* (Ch. 5) and to develop several *modules* (Ch. 6) as part of the system dynamics model. The *policy-variable choice and scenario development* (Ch. 7) created the framework for the simulation of the market development and impacts of different policies.

2. INTERNATIONAL CASE STUDIES

The market introduction of NGVs has recently gained momentum worldwide. Smaller and larger initiatives are found in Argentina –the world leader with almost 800’000 NGVs _ , Brazil, Pakistan, India, the US and Europe. In Europe, larger initiatives are found mainly in Italy, France, Germany, and Austria. While in Italy the fleet of 400’000 NGVs is presently expanding after several decennia of relative stability (Mariani 2004). The “newcomers” France, Germany, and Austria are trying to start-up the market penetration. Germany appears to be the most ambitious, as government, car companies and natural gas companies have agreed on a goal to increase the NGV car fleet from at present approx. 18’000 NGVs (Jeken and Wackertapp 2004) to 4.5 million NGVs in the year 2020 (AP 2003).

Historically, New Zealand was world leader in the amount of NGVs during the 1980’s. Between 1979 and 1985, the amount of NGVs doubled every year reaching a fleet share of approximately 10% (Harris 2000). However, as a result of shortening subsidies, the NGV fleet shrunk quickly to a fleet share of less than 1%.

Figure 1 shows the world-wide status of all nations with a substantial amount of NGVs: the number of NGVs is presented against the number of fueling stations with a CNG filling facility. Argentina, Italy, Pakistan and Brazil contrast with a large number of gas cars to many countries trying to introduce gas cars into their car fleets (see lower left-hand corner). Among these are Germany, France, Egypt, Mexico, and also Switzerland.

It results from the figure that the countries with a large amount of NGVs all have a comparable ratio between the number of gas cars and the number of CNG fueling stations. The ratio is a result of a minimum profitability per fueling station and a minimum density of fueling stations needed by NGV drivers.

The emerging countries with NGVs generally show a much lower ratio, indicating that their filling facilities are often highly supported by grants to stimulate the NGV market introduction in the start-up phase. The US states represents an extreme case, having vastly invested in CNG filling facilities, but with the gas car fleet lagging behind (Lyon 2002). Germany also shows a high ratio of fuel stations to gas cars in the initial investment period, with a quickly growing fueling station infrastructure of approx. 250 public fueling stations (+ 150 non-public) in 2003, whereas the present 18’000 NGVs only show a moderate growth rate (Jeken and Wackertapp 2004).

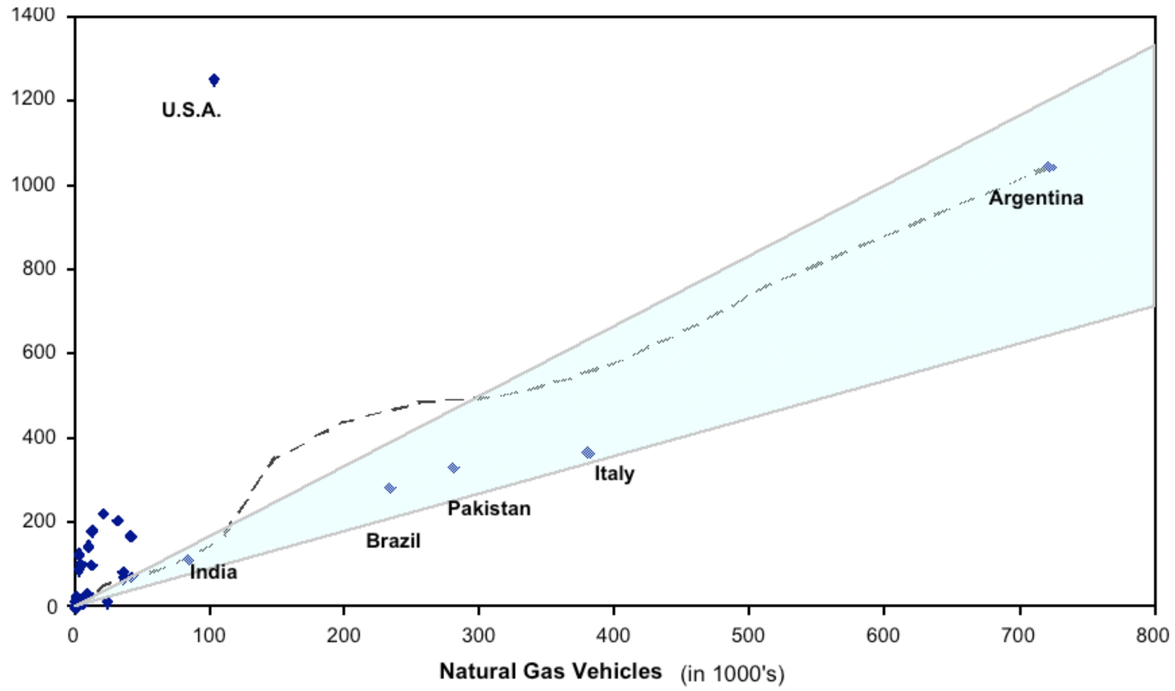

Figure 1: Number of natural gas vehicles versus CNG fueling stations worldwide (numbers refer to the period 2000 till 2002 (IANGV 2003)).

The international case studies suggest that a too low NGV: CNG-fueling-station ratio is a major hindrance for market development, whereas the a key mechanism can be most often described as follows: In an effort to build-up a sufficient infrastructure for gas cars, subsidies up to 50% of the investment costs are given to the first fueling stations installing CNG filling facilities. Fueling stations adopt quickly, leaving not enough time for the build-up of a NGV car fleet, sufficient to reach the fuel stations' profitability goals. Once subsidies for fuel stations and NGV customers dry out, the expected profitability of new CNG filling facilities is no longer attractive enough. In e.g. Canada, decreasing investments in fueling stations caused the collapse of the whole NGV sector.

A decisive factor in this problem is the price for natural gas, which may be imported or available from national resources. An extremely low natural gas price in Argentina left enough room for both, an attractive margin for fueling station investors and for customers buying NGVs. In contrast, natural gas prices in Canada (Flynn 2000) and New Zealand (Harris 2000),lower than gasoline but still relatively high, made the success of market introduction dependent on various kinds of subsidies.

In Switzerland, the gas price is lower than the gasoline price, but still much higher than in Argentina. Both fuel tax reductions in the order of CHF 0.50/kg of CNG and a grant in the order of CHF 250'000 per fueling station should compensate this unfavorable situation. The pitfall of a too low NGV: fueling station ratio is a challenge for the market development in Switzerland.

3. STAKEHOLDER ANALYSIS

A stakeholder analysis was conducted to collect the largest part of the information for the system dynamics model and to learn more about the Swiss case specifics. Most important stakeholder groups were discriminated and categorized into 6 larger sectors. Attributes were assigned to each stakeholder group, along (Scribner, Brinkerhof et al. 2000), such as resources, leadership and fragmentation-level.

In the course of the analysis 17 structured interviews were conducted covering all important stakeholder groups. A special focus was on the understanding of customers, with 6 interviews with commercial customers. For information on private customers we referred to an extended focus group study with consumers from the pilot region of Basel (Kasemir et al., 2004). To find specific information, a large amount of more informal inquiries has been done. Table 1 gives an overview of the stakeholder groups, the performed structured interviews and other inquiries.

Sector	Stakeholder Group	Structured Interviews	Other Sorts of Inquiries
Car Industry	NGV Special Parts Manufacturers	-	-
	Car Manufacturers	-	Yes
Import, Retail, Service	Importers	1	Yes
	Car Dealers	-	Yes
	Leasing Companies	1	Yes
	Garages	-	-
Customers	Private Customers	Focus group analysis	
	Commercial Customers	6	Yes
Fueling Stations	Fueling Stations	2	Yes
	Fueling Station Manufacturers	-	-
Gas Industry	Local Gas Utilities	1	Yes
	Regional Suppliers	2	Yes
	Gas Importers	-	-
Governmental Institutions	Research	1	Yes
	National Government	-	Yes
	Cantonal Government	3	Yes

Table 1, Sectors, stakeholder groups and inquiries performed

4. CROSS IMPACT ANALYSIS

A total of 27 possibly important variables were defined, covering all stakeholder groups. This set was reduced to 17 variables by joining similar variables. Ratings were worked out by discussions in the research team, based on Vester's paper computer (Vester 1990). Figure 2 shows the results of the cross-impact analysis.

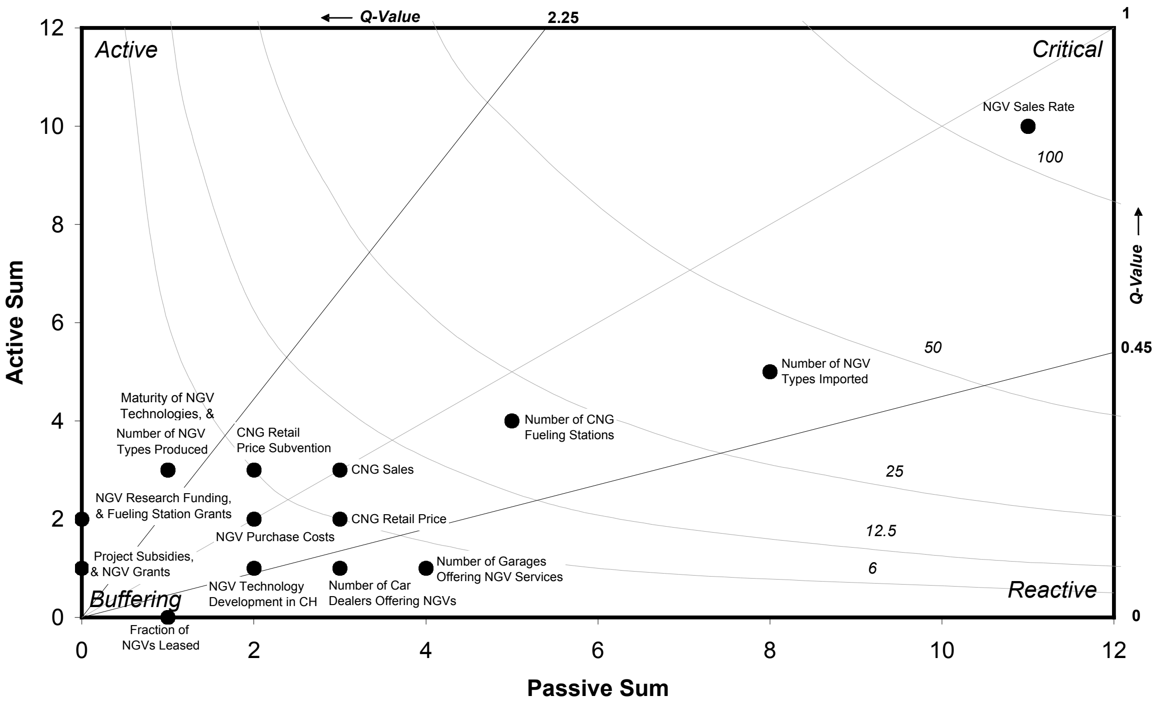

Figure 2: Results of the cross-impact analysis. The reduced set of 17 variables, arranged according to activeness and passiveness (some variables coincide). A Q(quotient)-value under 0.45 indicates a reactive behavior. A Q-value above 2.25 indicates an active behavior. A product-value (see hyperboles) fewer than 6 indicates a buffering behavior. A product-value more than 300 indicates a critical behavior. No critical variables were found in this study.

They indicate that the system for market penetration of NGVs in Switzerland is relatively loosely interconnected. There are no variables that can be called critical, according to Vester's definition. *NGV Sales* has the highest active-passive product, followed by the number of *NGV Types Imported* and the *CNG Fueling Station Density*. These three variables will therefore have central places in the model. Variables associated to the national government (*NGV Research Funding, Project Subsidies*) and the car manufacturers (*Number of NGV Types Produced)* are considered active, with low dependence from other variables, and thus will be inputs for the simulation model. Variables associated to the leasing companies, gas importers, cantonal government and NGV equipment suppliers are considered "buffering", i.e. have no relevant interactions on other variables. They will find no or a less important place in the model. All other variables are identified as being of intermediate importance.

5. GENERAL MODEL STRUCTURE

Using the results from international, stakeholder and cross-impact analysis, a first general structure was deduced, dividing the stakeholder sectors into three categories (see Fig. 3):

1. The *Policy Making Stakeholders* are the gas industry and the government. They have a special interest or leadership in the market introduction of NGVs in Switzerland and have the power to realize investments in the NGV market.

2. The *External Stakeholders,* the car industry sector. Due to the relatively small size of the total Swiss car market, NGV sales in Switzerland are thought to have little or no influence on the production of NGVs. The influences of this stakeholder category are therefore represented as fixed input.

3. The *Interdependent Stakeholders,* the customers, the fueling stations and the car importers including car retail and service. Because of their relatively high interdependence, they form the heart of the model.

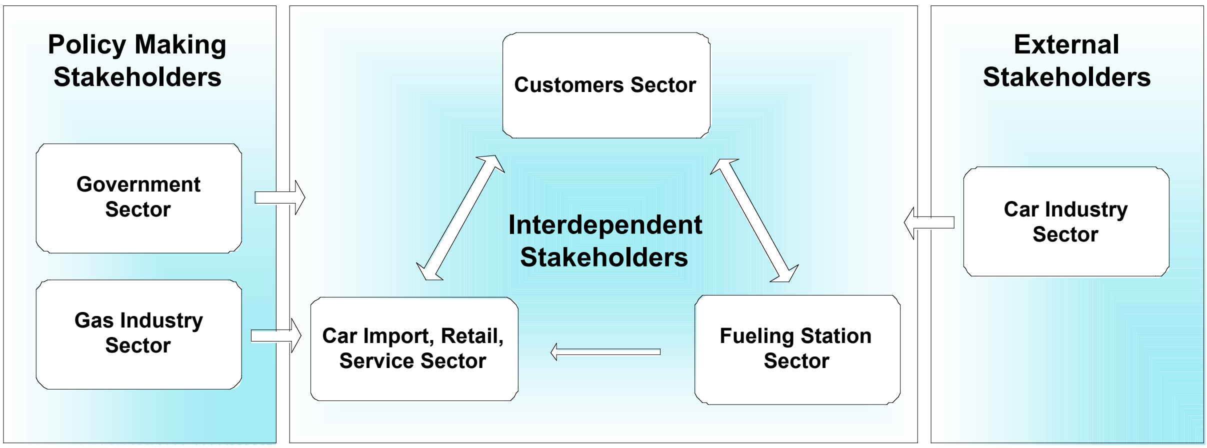

Figure 3: Three different stakeholder categories are considered in the model.

The general causal loop diagram for the Swiss model is shown in Figure 4. It shows the main variables and influences, leading to first insights on the behavior of the model. Three reinforcing and two balancing loops are discerned. In both the upper and the lower part of the diagram, a configuration with a balancing (B) and a reinforcing (R) loop can be found. The interaction of the loops R1,B1 and R2,B2 is mediated by the two variables *FS Growth Expectation* and *NGV Sales Rate*.

The equilibrium in the fueling station dynamics (R1,B1) is established by two forces: The reinforcing feedback between the growth of *Natural Gas Vehicle* and *CNG Fueling Stations* characterizes the 'Emerging market'. The balancing feedback between *CNG fueling Stations* and the expected profitability of new fueling stations characterizes 'Market saturation'.

The equilibrium in the car imports dynamics (R2,B2) is also established by two forces: The reinforcing feedback between the growth of *Number of NGV Types Offered* and *NGV Sales Rate* characterizes the 'Emerging market'. The balancing feedback between *Number of NGV Types Offered* and the expected profitability of new NGV type imports characterizes 'Market saturation'.

Both interactions between the upper and lower model parts are positive, which means that a growth in the configuration R1,B1 enhances the growth in R2,B2, and vice versa.

A forecasting mechanism has been modeled for the car importers, but not for the fueling stations. The reasons for this asymmetry lie mainly in the differences in possible profits and risks. Firstly, some car importers see the NGV market as an emerging market, in which extra cars can be sold, and with an attractive profit prospect. For fueling stations, however, the profit will probably be rather moderate. Secondly, fueling stations have to invest extensively in an emerging (thus high risk) market. Car importers, in contrast, can enter the market with relatively moderate investments. This is true especially for car importers that are allied with an international car manufacturing company, as they do not have to buy NGVs before offering them for retail. Car importers are thus more eager to enter the NGV market in an early stage, speculating on a persisting growth of the market.

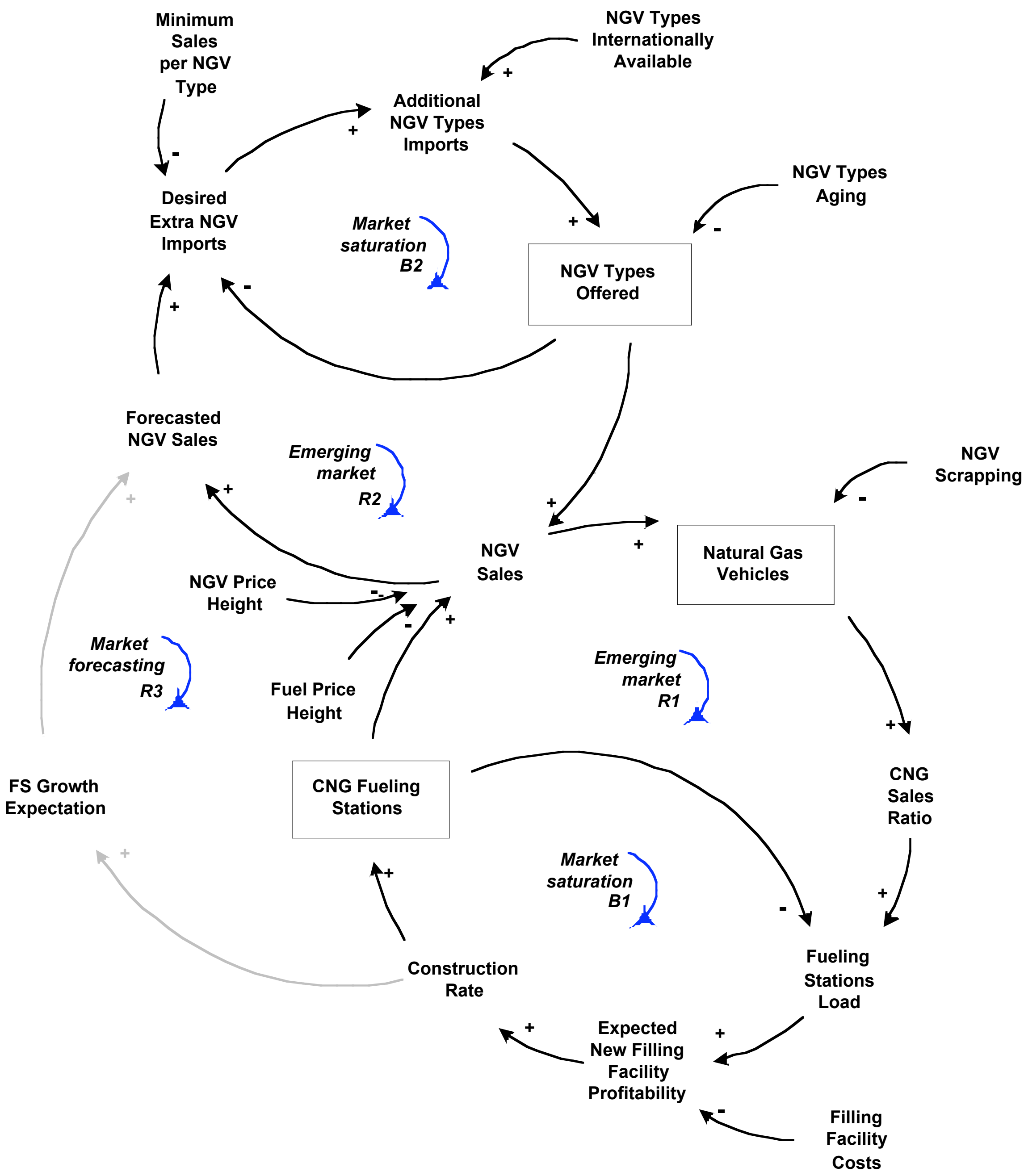

Figure 4: General causal loop diagram, describing the interactions between the consumer sector, fueling station sector, and the import, retail and service sector. The sectors government, car industry and gas industry influence the market, but are not influenced themselves.

6. MODULE DESCRIPTIONS

The six modules of the model and their interconnections are shown in the figure 5. Each of the three 'interdependent stakeholder groups' (see figure 3) is represented in two modules. The 'Car Import, Retail and Service Sector' is represented in the modules 'Importer Forecasting' and 'NGV Type Imports'. The 'Fueling Station Sector' is represented in the modules 'CNF Filling Facility Adoption' and 'CNG Filling Facility Abolishment'. The 'Customer Sector' is represented in the modules 'NGV Adoption' and 'NGV Abolishment'. The influences of the other stakeholder groups are represented as inputs into these modules.

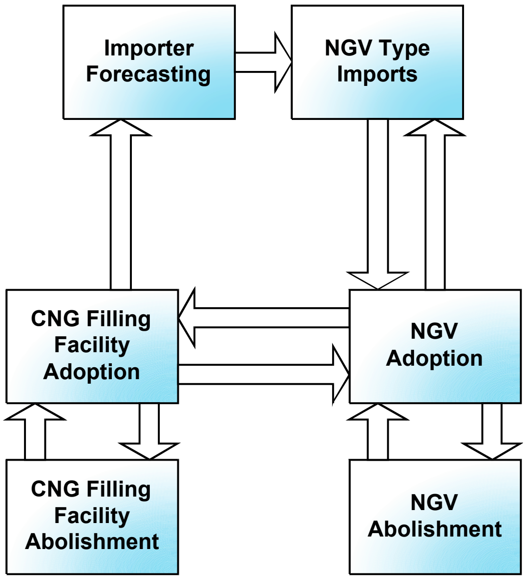

Figure 5: The modules of the model with their interconnections

Module 'CNG Filling Facility Adoption '

Upgrading of conventional fueling stations by CNG filling facilities (making "CNG fueling stations") is modeled with a Bass diffusion model (Sterman 2000, pp. 332). The basic assumption is that the fragmented fueling station sector will only take actions when the respective managers are aware of the product, through marketing and 'word of mouth'. Two extensions are added to the Bass diffusion model.

The first extension describes the response of the total market size to the profitability expectation (see fig. 6). The profitability is calculated on basis of mainly the investment and operating cost of the CNG fueling facility, the margin on the fuel price, the amount of fuel sold and subsidies given. It is assumed that the number of potential adopters increases with rising expected fueling station profitability. The variable *Potential CNG Adopters* reflects the number of fueling stations that can still be converted, given the present profitability expectation. For every fueling station adopting CNG, the number of potential CNG adopters diminishes by one unit.

The second extension describes competition between CNG fueling stations. As all are assumed to "fish in the same pool", the expected profitability for each new CNG filling facility will be lower than it was for the previous one (with constant number of NGVs). This is modeled by a link from *CNG Fueling Stations* to *Expected Filling Facility Profitability*, leading to the balancing loop B1. The link is represented in Figure 6 in a simplified form.

The present number of *potential CNG adopters* is estimated to be presently between 1.5% and 2.5%. We regards this fraction as proactive fueling station managers, as the expected profitability is presently very low, or even negative. These proactive of fueling station managers, often affiliated to gas companies, are the main focus in the start-up process. They can (once informed) build the first infrastructure, and stimulate the first sales of NGVs. It is expected that this proactiveness is limited to the year 2010, after which they will demand normal profitability prospects for further investments.

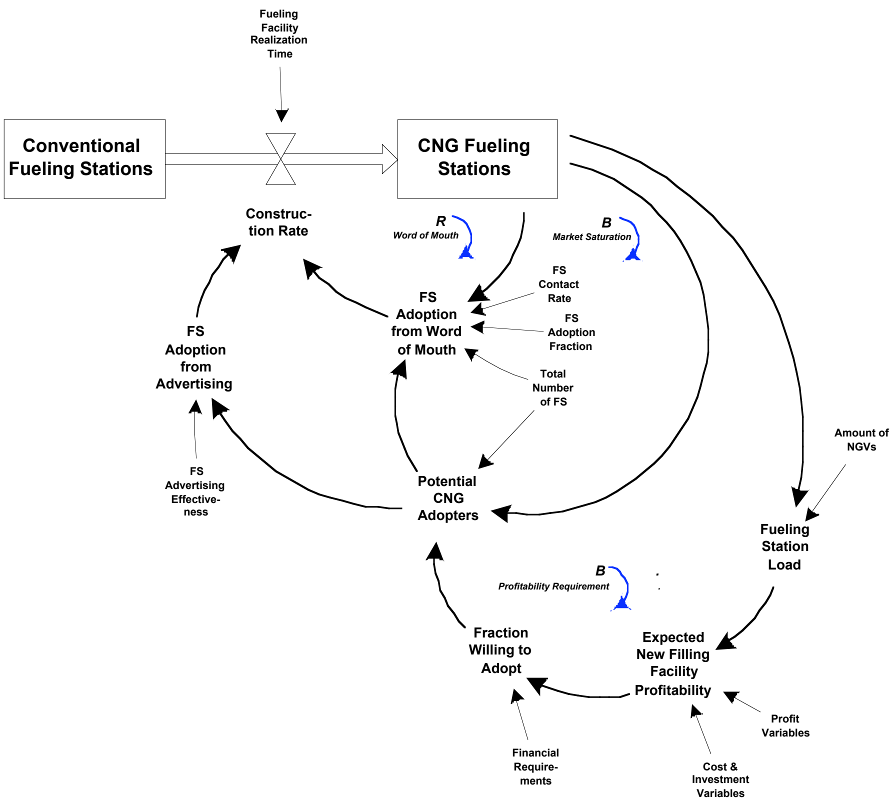

Figure 6: Module 'Fueling Station Adoption', a Bass diffusion model with extensions

Module 'Filling Facility Abolishment'

CNG filling facilities have an average life time of about 15 years. After that period, the fueling station manager will have to decide whether to renew the facility or to leave the NGV market. This decision is based on the expected profitability of the new investment (as calculated in the module 'Filling Facility Adoption') and enters the module in the form of the variable *Potential CNG Adopters*.

In case of a decrease in filling facility profitability, the variable *Potential CNG Adopters* can become negative, exerting a pressure on the CNG market by increasing the number of *Unsatisfied CNG Fueling Station Managers*. As a result, the number of fueling stations with a CNG filling facility reduces until *Potential CNG Adopters* becomes zero or positive (see Fig. 7).

If the profitability of the CNG filling facility is expected to be high enough, the manager will renew the facility so that the total number of fueling stations offering CNG is not changed.

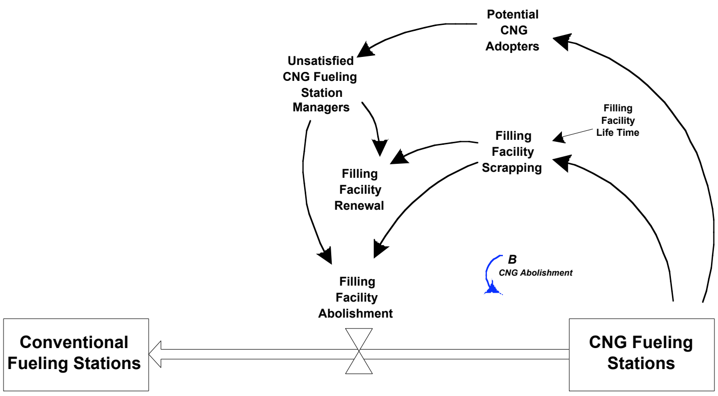

Figure 7: Module 'CNG Filling Facility Abolishment"

Modules 'NGV Adoption' and 'NGV Abolishment'

The customer sector is represented in two modules 'NGV Adoption' and 'NGV Abolishment' that are comparable to that of the fueling station sector ('CNG Filling Facility Adoption' and 'CNG Filling Facility Abolishment'). The main difference consists of the determination of the *Potential Adopter Fraction* in the module 'NGV Adoption'. Instead of by a profitability expectation, the number of potential adopters is determined by the comparison of an average NGV to an equivalent gasoline and diesel car.

Four NGV-related factors are included in the comparison of NGVs with gasoline and diesel cars:

1. The number of fueling stations with a CNG filling facility
2. The number of NGV types offered
3. The price of CNG
4. The purchase price of NGVs

The stakeholder analysis has shown that the first two factors are conditional (necessary) to most consumers. At least a consumer-specific percentage of fueling stations must provide CNG to enable stimulation of consumers to purchase NGVs by other means. Customers tend to first choose a car type (e.g. VW Golf), and then choose for a fuel.

Look-up curves for the first two factors yield fractions of the population being potential customers. It has been assumed that both conditions are not correlated and so, multiplication of both fractions yields the fraction for which both conditions are met.

The last two factors can be treated as normal utility. They are joined using a multinomial logit-function, in which an NGV is compared to equivalent gasoline and diesel options to determine the purchase probability.

The input parameters for consumer preferences proved to be rather unsatisfying, being relatively imprecise, and the model reacting sensitively to them. Various approaches have been undertaken to estimate each of the input parameters as precise as possible.

The two price related inputs (_-coefficients in multinomial logit) have been based on a study from Brownstone et al. (2000). The curve for fuel availability satisfaction has been based the focus group interviews in Basel (see Chapter 3) and the curve for NGV spectrum satisfaction has been chosen after studying the present conventional car market, focusing especially on the recent diesel car market penetration.

Finally, in contrast to the yearly sales of CNG filling facilities, the yearly sales of NGVs has a maximum. CNG filling facilities can be seen as an upgrade for fueling stations, but NGVs are a substitution product. “Conversion” of gasoline or diesel cars to NGVs is not seen as an option in Switzerland, because of the worse fuel efficiency of these conversions. Hence, the maximum amount of NGV sales is equal to the cars that are being replaced each year, which is approximately 10% per year.

Modules 'NGV Type Imports' and 'Importer Forecasting'

The modules for the car importers are implemented without a Bass diffusion model. Car importers actively inquire information about the national NGV status. New imports are planned based on forecasts of the near future NGV demand for new NGV types. The international availability of NGV types is a boundary condition (see Figure 8).

The forecasting is modeled by multiplying the present demand per NGV type with the forecasted growth in the number of CNG fueling stations. This leads generally to results that are more plausible than e.g. directly forecasting the NGV growth without taking the fueling station developments into account.

For modeling the forecasting of the fueling station growth, the molecule "Forecasting" (Hines 2000) has been implemented. It is calibrated for calculating the trend over the previous three years, and linearly extrapolates one year ahead. The time for the importer to perceive the actual situation of the infrastructure is set to 3 months.

The extra number of NGV types that can additionally be imported is a function of the forecasted NGV sales and the desired minimum sales per type. The number of NGV types offered is then updated, but restricted to the number of NGV types that are available for imports internationally.

Car manufacturers renew their car types every few years, in order to keep up with new technologies and new trends (e.g. design). As a result, the NGV types that are offered by the importers (for which national safety and emission test etc. have been performed) become outdated after a few years. The consequence is that the number of offered NGV types tends to diminish gradually.

The number of NGV types that is internationally produced is one of the critical factors that determine the potential NGV customer fraction. This number is presently limited to approximately 15 types, determining the maximum number of types that can be imported to Switzerland. For comparison, in Switzerland, one can choose between approx. 250 gasoline passenger car types and approx. 120 diesel passenger car types (TCS and Energie Schweiz 2003). It is widely expected that the number of NGV types will increase further, but at which rate and until which level is unknown.

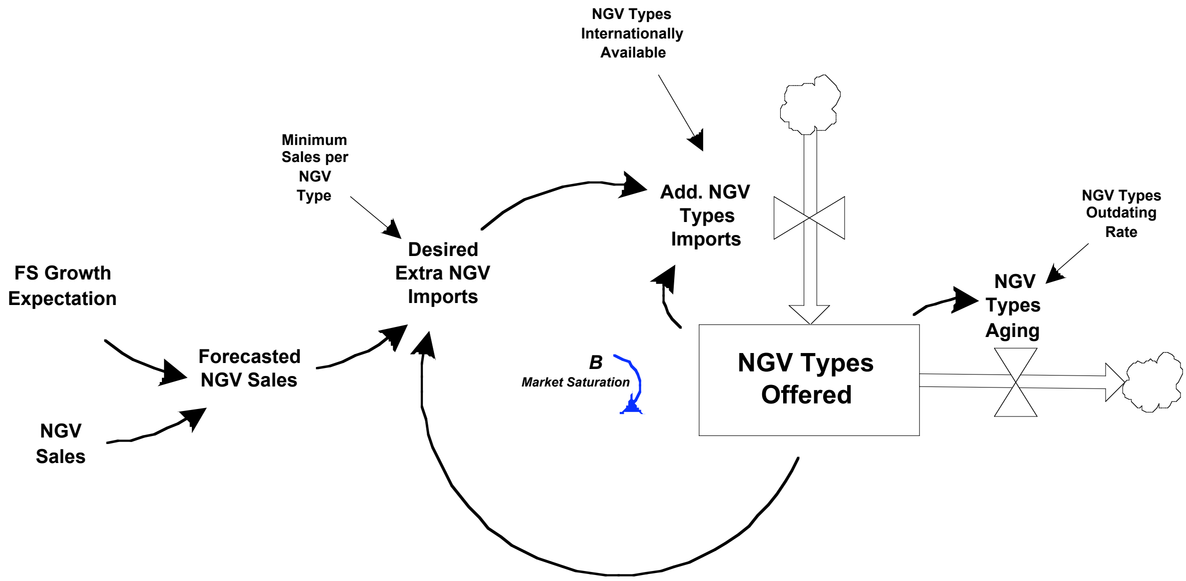

Figure 8: Module "NGV Type Imports"

7. SCENARIO DEVELOPMENT AND POLICY-VARIABLE CHOICE

We have combined two methods for analyzing strategies for the market introduction of NGVs. The first comprises the testing of various policy options, using input variables associated to the policy stakeholder sectors. The second comprises scenario analysis, translating uncertainty in data into four scenarios.

Policy Variables

For the assessment of policy options, input variables were chosen that represent the possible influences of the Swiss government and the gas industry. The variables for the scenarios are chosen from the (approx. 70) remaining input variables.

The following four input variables were chosen as policy variables: *NGV Subsidies*, *Fueling Station Subsidies, CNG Tax Reductions* and *NGV Advertising Effectiveness*. These policy variables do not necessarily represent all possible influences that the Swiss government and gas industry can exert on the market penetration process.

Other kinds of influences may be possible, such as laws forcing fleets to adopt clean vehicles. Also system changes could play a role, such as e.g. a strategy that focuses on the market penetration in several small regions.

The chosen policy variables represent those policies that are in discussion at present, have been planned, or have already been enforced. The set thus enabled us to analyze how these policies can best be used to stimulate the market penetration of NGVs, and to detect possible pitfalls of the policies.

Scenario Development

The variables were ranked according to *importance* and *uncertainty*, as recommended by Poot (2002). For all trends and developments, a score between 0 and 10 is attributed to each aspect. A score of zero stands for not important/very certain and a score of ten for very important/very uncertain. Although the ranking process is subjective, it provides a useful tool to discriminate between the variables, when based on discussions within the research group and further stakeholder analysis (see e.g. (Rits 2003)). The ranking is presented in Figure 9.

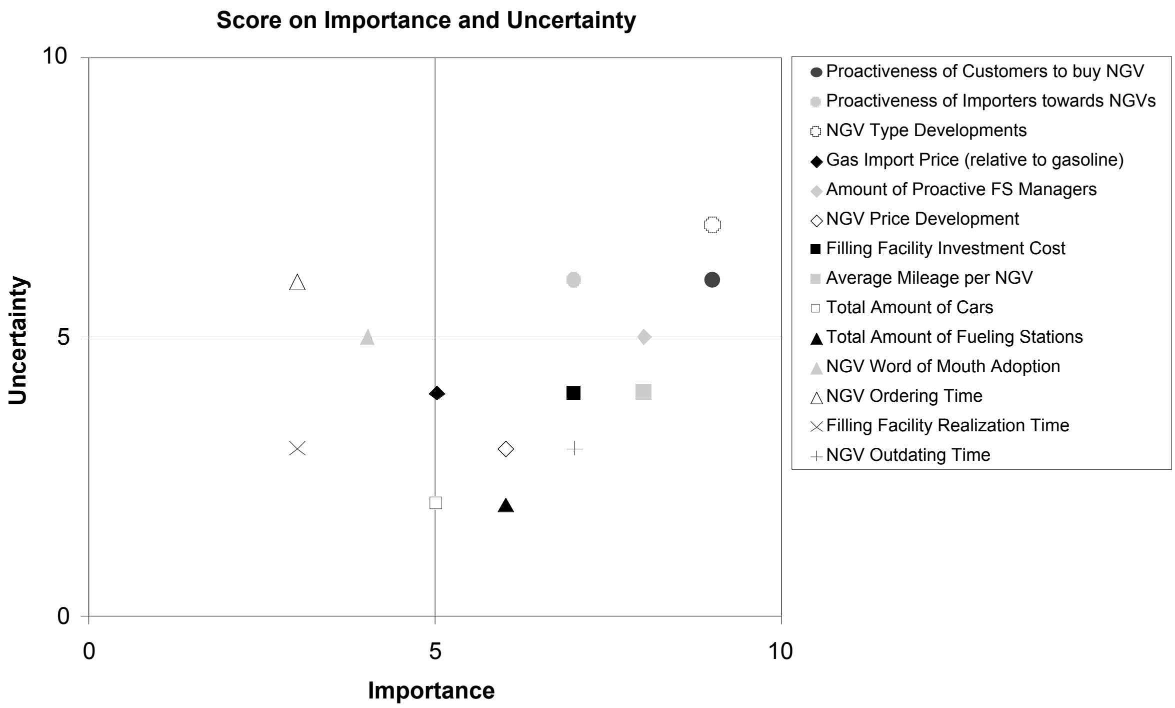

Figure 9: Ranking of scenario variables by importance and uncertainty, according to Poot (2002)

Main scenario variables were selected having a high score on importance and uncertainty. Two variable-sets were created, one representing the behavior of the customers and one representing behavior of the different industry sectors.

The variable sets are independent from each other in the sense that one set can be changed without making a change in the other set necessary. Two extremes were chosen for each variable set, depicted by "proactive" and "reactive". Proactive indicated a relatively positive position towards NGVs, reactive indicated a relatively reserved position towards NGV. The combination of two extremes for two variable sets leads to a total of four scenarios, as represented in Figure 10.

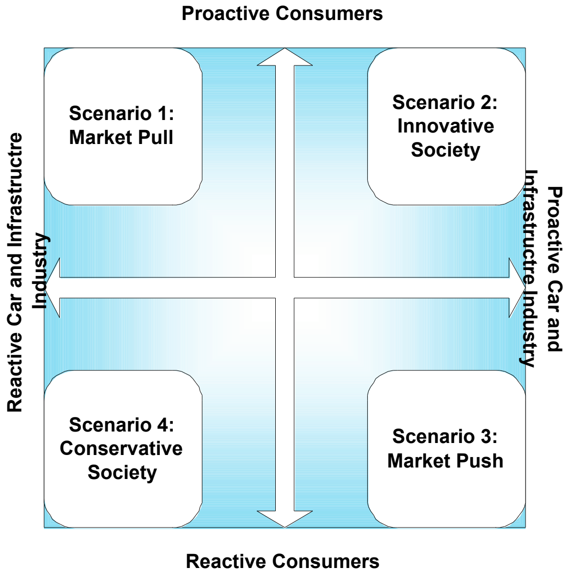

Figure 10: Different combinations of relative reactive and proactive behavior, for industry and consumers, lead to four scenarios

8. SIMULATION RESULTS

Four Scenarios for the Swiss NGV Market Introduction

Three of the four above explained scenarios (see Fig. 11) lead to market development for NGVs in our respective simulations. In the most optimistic scenario "Innovative Society", market penetration resulted from relatively moderate policy instruments, although some minimum level of stimulations was necessary. In the intermediate scenarios "Market Push" and "Market Pull", strong but realistic policy measures were necessary to start the process and moderate policy measures were needed to ensure further growth and a sustainable market share. In the most pessimistic scenario "Conservative Society", the market penetration died out shortly after its start for any realistic policy measures.

In all the three cases with sustainable market penetration, growth of the NGV fleet was between 20% and 40% per year until about 10'000 cars were reached, depending on the scenario and the level of stimulations. This is comparable to the growth in Germany between 1995 and 2002, in which its NGV fleet grew by 30% per year from 2'000 to 13'000 NGVs

(Erdgasfahrzeuge 2003). The simulations indicate a continuous growth at a comparable rate towards 50’000 vehicles, even when the fueling station subsidies are removed (after reaching a critical limit of the NGV: fueling station ratio). Interestingly, market development tends to change character beyond a fleet size of around 50’000 NGVs in all three scenarios: The exponential NGV growth changes to an approximately linear growth, sustaining over many years.

Our simulations suggest that the goal of 30’000 cars till 2010 and 300’000 cars till 2020, communicated by the Swiss gas distributors, is rather ambitious and can be reached under very favorable circumstances only. In the scenario “Innovative Society”, a simulation has been made with policy instruments as planned by the gas distributors. These include a tax reduction of 0.4 CHF per kilogram of CNG (starting in 2006), and a grant of CHF 200’000 for each of the first 100 upgraded fueling stations. In addition, a high level of marketing was assumed. Figure 11, shows the resulting growth for the CNG fueling stations and the NGV fleet for this very favorable scenario implementation.

The absolute results of this model have to be interpreted with care because parameter values often have considerable uncertainty. However, the fact that most scenarios show sustainable market development only for quite strong policy measures suggests that the Swiss NGV initiative is a real challenge. This result is especially important for the decision makers in the gas distributors, having to invest more than 50 million Swiss Francs.

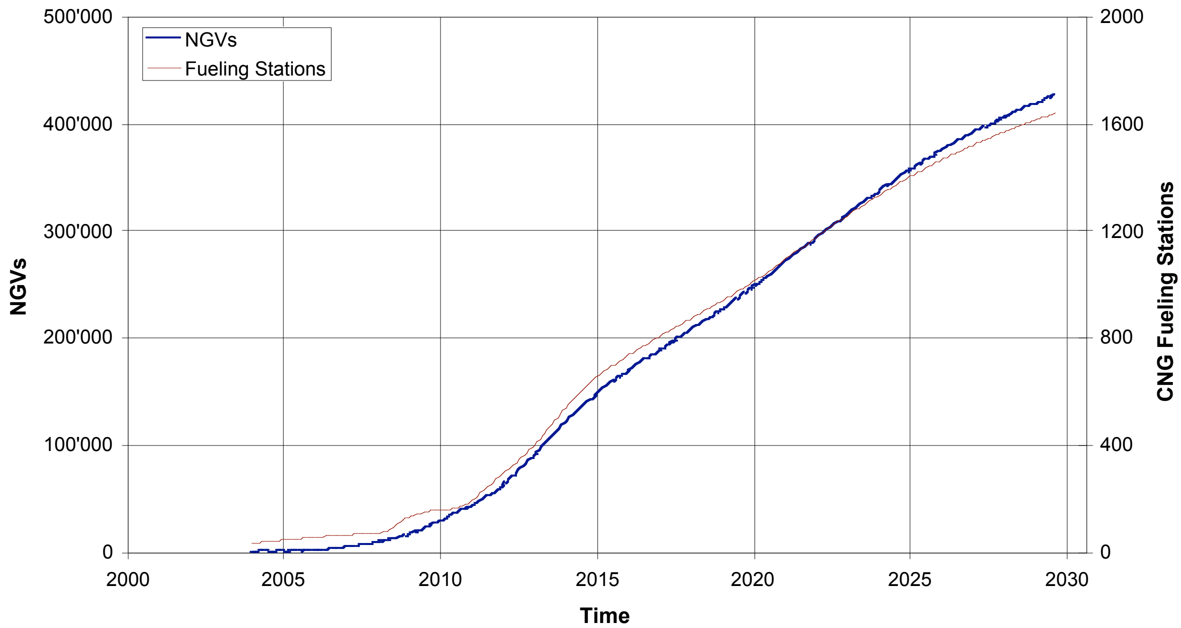

Figure 11: Most positive simulated case. For the strongly stimulated growth in the favorable scenario "Innovative Society", the development of the number of fueling stations and NGVs is shown

Critical Windows for Policy Timing

Figure 12 gives results related to the scenario “Market Push” (see Fig. 10), showing possible developments for the number of fueling stations with CNG facilities. In this scenario, with relatively reactive customers but proactive car and fueling industry sectors, the time points for ending one or the other of two stimulation measures were varied. It shows that these time points critically and non-linearly influence the further development of the market penetration.

The first measure (Measure 1 in Fig. 12) is the ending of a subsidy of CHF 200’000 per installation of a CNG-filling facility. According to the intentions of the gas distributors, the subsidy should be ended after the first 100 filling facilities are built. This number is reached in these simulations in 2011 and the simulated ending of the subsidies shortly afterwards leads to Alternative 2 (see Fig. 12) indicating a dying NGV-market. Because of low fuel availability (only few CNG fueling stations), the NGV market saturates quickly and a vicious circle sets in: the number of car imports is reduced because of stagnating sales, and this causes further stagnation of car sales. Finally, fueling station investments for CNG are abandoned, leading to a decay of the CNG infrastructure.

Waiting with Measure 1 until 2015 leads to an impressive exponential growth (see Alternative 1). Again, the stop of subsidies for CNG fueling stations leads to a reduction of the number of filling facilities to a new equilibrium established around 2018. However, due to an already good ratio between NGVs and filling facilities of then approximately 220, growth sets in again.

The second measure is related to customers of NGVs and consists of reducing tax advantages, subsidies for NGV purchases and marketing effort (i.e. a reduction of *advertising effectiveness*). In Alternative 1 (see Fig. 12), Measure 2 is realized in 2020, leading again to a temporary reduction of the number of filling facilities. Fortunately, a turning point is reached in 2024, after which the market continues to grow slowly. It has to be pointed out, that also during this latest period, a moderate level of tax advantages and NGV subsidies is needed. Without these measures, our simulations suggest that the NGV market would again stagnate and then fall to a lower level without recovery.

The policy Alternative 3 shows that financial resources can be saved by realizing Measure 1 after 2011, but well before 2015. Activating Measure 1 in 2013 and Measure 2 in 2020, leads to a strong and sustainable growth. Though the respective numbers of CNG fueling stations and NGVs are lower compared to policy Alternative 1, they can compete in the long term. However, activating Measure 2 too early can cause a failure of the market penetration, as illustrated by Alternative 4. Although robust growth seemed to have started already in 2016, the system turns out to be still vulnerable to Measure 2 in 2017.

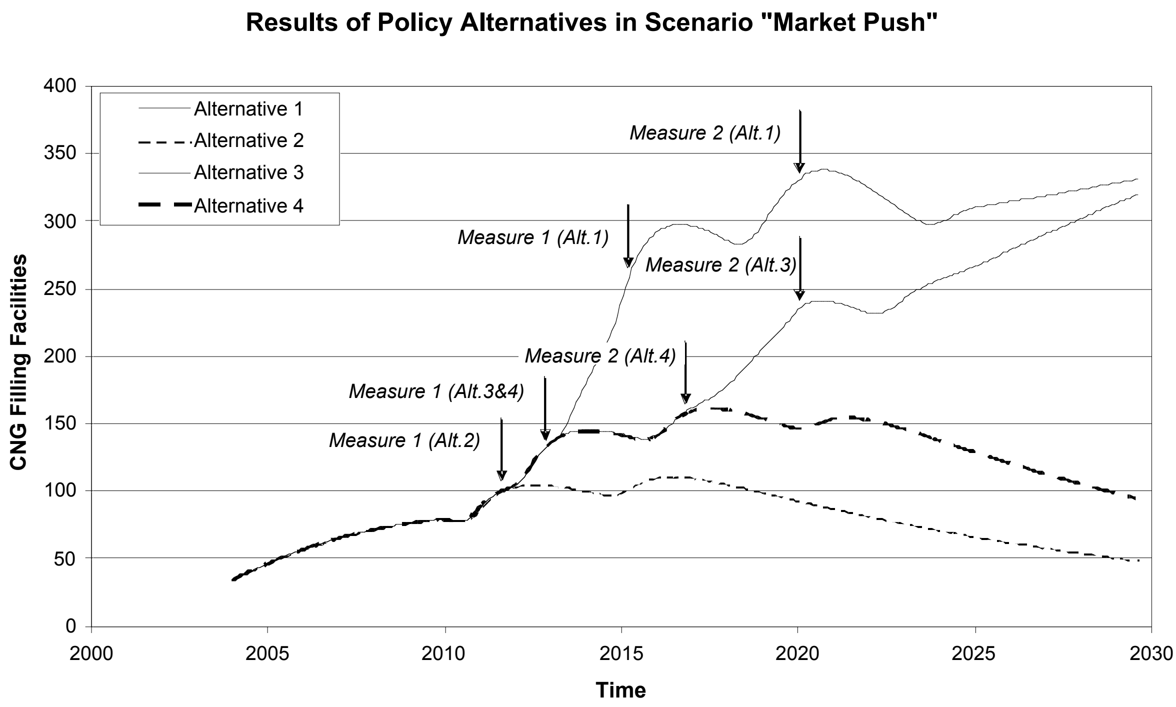

Figure 12: Results for policy alternatives within the scenario “Market Push”

9. DISCUSSION

Application of the Model

The model met its goal to enhance understanding and to set various expectations of stakeholders against a clearly defined background. Additionally, it revealed to be a valuable tool to better quantify necessary levels of subsidies or to help deciding at which time point measures can be ended without causing a collapse of the ongoing market penetration process. An important result is e.g. that fixing the number of subsidized fueling stations already at the beginning of the market introduction process might be premature. This quantitative decision should be postponed and made after closely observing the progress of the market introduction and recalibrating the model to these observations.

Although the benefit of the model seems clear, we would like to point out that the model should never be used as a forecasting tool. It does not take into account many processes that may strongly influence the outcomes of the model. These consist of e.g. the oil price relative to the gas price or the developments of new advanced car technologies such as hybrids or fuel cell cars. Besides the impossibility of forecasting, also the quantitative interpretation of the model is generally limited. High uncertainties exist mainly in the possible maximum market share and in consumer preferences.

Various Considerations

Simulations show that one important indicator for success seems to be the ratio between NGVs and fueling stations. It can be directly interpreted as the extent to which the CNG filling facility can be profitable for the fueling station shareholders. Further, it is also an important measure for the maturity of the NGV market. Only with a sufficiently high ratio, the NGV market can survive on a long-term basis. The ratios of successful countries have been identified to lie between 600 and 1100. Our model yields a long term ratio between 250 and 350. The difference is surprising, but can be explained by a comparison with Argentina. In this leading country, the CNG costs approximately 35% of the gasoline price, whereas in Switzerland, CNG costs approximately 75% of the gasoline (based on energy equivalent, including the anticipated tax reduction on CNG). It can therefore be expected that the profit on CNG in Switzerland is much higher than in Argentina. Furthermore, in Argentina are many “pure” CNG fueling stations, whereas in Switzerland, it is foreseen that all CNG filling facilities will be integrated into existing fueling stations, saving extensive overhead costs. The combination of higher profit and less overhead costs makes it possible to operate a CNG fueling station for a much lower NGV to fueling station ratio.

Effective marketing seems to be a critical instrument to stimulate the car sales in the start-up phase of the market introduction. In the scenarios “Market Pull” and “Market Push”, the policy variables *Advertising Effectiveness* needed to be set to rather high values of approximately 50% per year during the start-up phase and 20% per year later. It is, however, difficult to associate costs to these relative values.

The dependence on the international car industry introduces a high level of risk into the Swiss ambitions. In case that the Europe-wide growth of the NGV market does not continue following the internationally communicated ambitions, success in Switzerland becomes questionable. It might be impossible to reach a good market share, when the number of available NGV types does not overcome its current level of 15 types, or when the price of (OEM) NGVs remains at the present high level.

A strategy to enlarge the NGV cars to CNG fueling stations ratio in the start-up phase might be based on focusing on regions. With this method, various CNG filling stations are first built in a densely populated region, where it is then easier to attain a relatively high sales rate of NGVs per fueling station. This method cannot be analyzed with the present model. Its success, however, is expected to be limited, because the focus has to be set only on drivers not leaving the considered region.

10. CONCLUSIONS

The here presented system dynamics tool for the study of possible scenarios for the development of a NGV-market helps to analyze the effectiveness of some policy measures for market stimulation development in Switzerland. It is based on knowledge from international case studies on NGV market development and on specific stakeholder dialogues undertaken in Switzerland. Simulation results for different scenarios, covering a wide range of assumptions, suggest that the introduction of NGVs into the Swiss market is an ambitious challenge with considerable risk. In most cases, market introduction of NGVs successfully reaches stable or slowly growing NGV-fleets. However, the simulations suggest that the goals of the initiators are reached in advantageous situations and with considerable levels of subsidies only. A quantitative interpretation of the simulation results is limited mainly due to the high uncertainties in assumptions for consumer preferences and market potential.

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