Conseptualising the substitution processes of technological change in the Swiss car fleet

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For the benefit of a sustainable global development of energy consumption and its climatic impact the per-capita energy consumption in Switzerland shall be reduced to the actual global average of 2000 Watts. This goal affects all sectors, particularly the mobility sector, as a main originator of CO_2-emssions in Switzerland. The market penetration of alternative, more eco-friendly drive train technologies is to be modeled to learn more about the fundamental processes of their diffusion, and to derive strategies contributing to their successful introduction. An existing system dynamics model forms the basis for further modelling and analysis. Necessary extensions, such as the introduction of different layers for alternative drive train technologies competing with each other, are discussed in this work. A game theoretical approach could link the exogenous stakeholders closer to the system dynamics model. Finally, some preliminary results of the first running model are discussed.

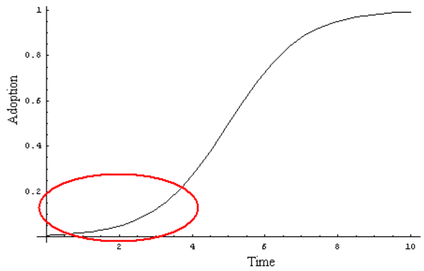
Keywords: Mobility, Sustainability, Technology Diffusion, Drive Train, Competition, Car Fleets, System Dynamics Modelling, Dynamical Game Theory

1 Introduction

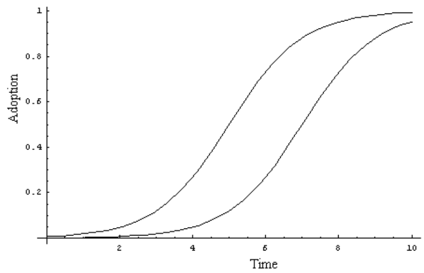
These days the worldwide per-capita energy consumption averages 18000 kWh/a, which corresponds to an average power of 2100 W. In Switzerland about 5000 W/cap is used, twice and a half more than the global average (novatlantis – Nachhaltigkeit im ETH Bereich (2005)). The vision of "novatlantis – Sustainability in the ETH-Domain" (novatlantis – Nachhaltigkeit im ETH Bereich (2005)) is the so-called "2000-Watt-Society", which aims at a reduction of the per-capita consumption in Switzerland to the current global average of 2000 W, establishing a balance between the industrial countries and the developing world. In view of the global climate change and its connection to CO_2-emissions by utilisation of fossil resources, as well as their shortage, not only a reduction in overall primary energy but a sustainable development towards more eco-friendly, renewable energies is needed. Emanating from a consistent progression in all sectors, the total energy consumption per year of the Swiss mobility sector in particular has therefore to be reduced from about 215 PJ in 2004 (Bericht des BFE (2004)) towards a 85 PJ landmark, accompanied by a promotion of alternative fuel technologies.

For a successful introduction of such technologies in the Swiss car fleet in terms of the 2000-Watt-vision, stimulation and support of an optimum technology-path is of fundamental importance. Aiming for minimum cost from a macro-economic point of view, this results in a particular, ideal fuel share in the road traffic. To be able to realise an adequate technology development-path, the most important factors and processes favouring or retarding this path must be identified.

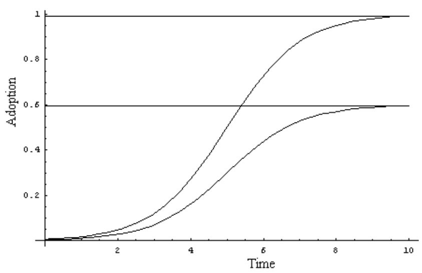
A simplified, idealised process of a general innovation diffusion curve follows – if successful – a sigmoid form, as it is shown in figure 1.a. The encircled area – the "take-off" phase – defines the potential of the further development, even though this turns out only later in time. Therefore the suitable preconditions for a positive development have to be created at this point. This can only be successful, if the fundamental factors and processes sustainably influencing the curve are known. Unfavourable or hindering circumstances or preconditions could for instance result in an extended diffusion time, an undersized growth or an unstable development-path, as illustrated in figures 1.b, c und d.



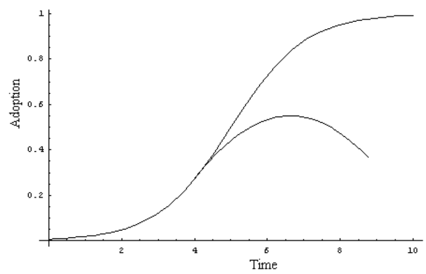
a) Take-off area of successful development



b) Extended diffusion time



c) Undersized growth



d) Instable development-path

Figure 1: Comparison of four different fundamental behaviours of the sigmoidal diffusion curve. These curves should be considered as qualitative.

In this early stage of the diffusion process the existing car fleets might play a more important role than private car holders, as argued for instance by Nesbitt (Nesbitt und Sperling (1998)). They may therefore shape the beginning market penetration of alternative drive train technologies, for the following reasons:

i) The large number of vehicles in a fleet supports the development of a fueling infrastructure and a mass production of alternative drive train vehicles.

ii) The mileage of such a vehicle is clearly greater than that of a private household vehicle. This would increase the benefits (reduction of emissions and energy consumption) in case of a reorientation to alternative drive train technologies, compared to a substituted household vehicle.

iii) Many fleet owners are national and governmental institutions or regulated companies, being politically compliant and increasing the public attention. Therefore they are key players in adopting alternative technologies.

iv) Finally fleets can easily be targeted by their owners, because a large number of cars is controlled by only a few decision makers.

Additionally, the handicap of a sparse fuel infrastructure – as it is still the case in Switzerland – does not bother fleet owners that much because the assignment of the vehicles is easier to be planned for them than it is for private pioneers (Zwyssig (2005)).
For these reasons one focus of the work will be on fleets and their owners as a part of the consumer sector. In contrast it must be questioned, if private pioneers form an indispensable additional factor in the transformation process to alternative technologies.
Another question to be discussed is that of the possible alternative fuels and their associated drive train technologies. The fuels can be distinguished by their derivation from fossil resources like coal, natural gas or crude oil, from biomass like wood, crops or wet biomass, or possibly from both. This is crucial because it has consequences for their renewability and their carbon cycle. However, another important criterion is the distinction between liquid and gaseous fuels, because this concerns the whole fueling infrastructure and motor technology. Different conversion routes like CTL (Coal To Liquid), GTL (Gas To Liquid), BTL (Biomass To Liquid) or LPG (Liquified Petroleum Gas) and others compete for example with CNG (Compressed Natural Gas), an important gaseous alternative in Switzerland, as bridging technologies to a hydrogen based future. They have all different ecological, technological and economical advantages, and it is necessary to find out if the technology path should include a sequence of different alternative technologies or not. It is also imaginable that certain fuel technologies hinder the aspired development to a hydrogen based mobility in the future.
The model to be built shall therefore include effects of competition between alternative fuel technologies and their transition processes.

2 Aim of the project and main research questions

The primary objective of the project reads:
To describe and explain the rate of diffusion of new drive train technologies and a profound understanding of the fundamental processes leading to the adoption of the new technologies.
The central questions to be answered are:

1. Which processes take us within the shortest time from the status quo to a strong rise of the fleet share of alternative drive train technologies?

2. What are the conditions for a stable development-path?

3. Are there potential competitive situations between different alternative drive trains, as exemplified by natural gas/biogas and hydrogen fuelled cars?

It is reasonable to further develop the existing model of Arthur Janssen (Janssen (2004)), instead of developing a totally new model from scratch. A local analysis concentrated on the take-off interval as descibed above (cf. figure 1.a) shall be performed. In doing so, it is important to include also psychological and organisational aspects to the mapping of decision-making processes of the different stakeholders involved, which represents a big challenge. In order to answer the above questions it is necessary to investigate the competetive conditions and substitution processes of different vehicle technologies, and to map them in a system dynamics model. Subsequently, critical quantities that yield to a stable development of the fleet share have to be identified. Finally, the model shall be verified with empirical data in order to be suitable for a policy- and scenario-analysis.

3 Previous work

The existing system dynamics model of Arthur Janssen (Janssen (2004)) forms the basis of this work. A simplified diagram of his model structure can be seen in Figure 2, showing two different blocks for exogenous (Policy Making and External) and endogenous (Interdependent) stakeholders:

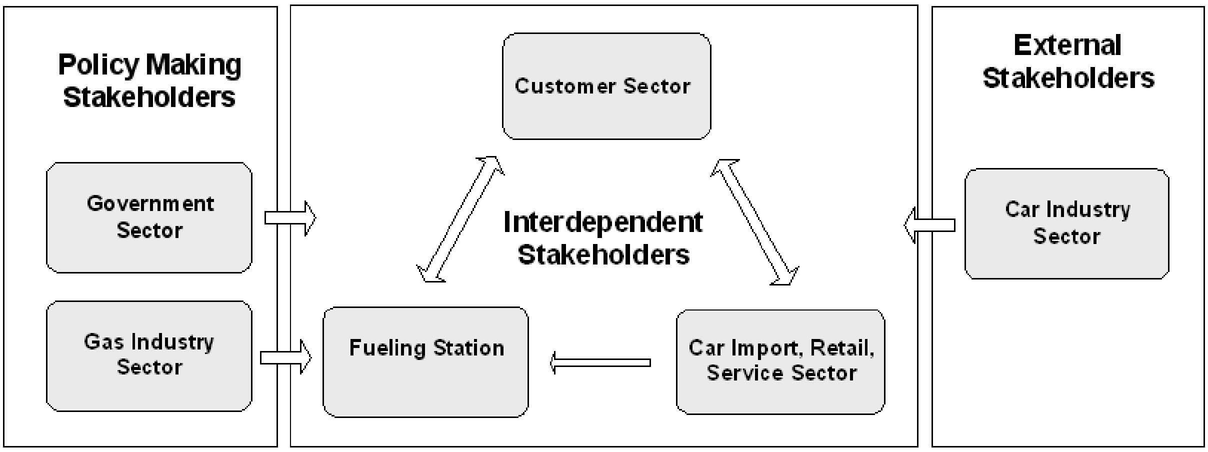


Figure 2: Box diagram of the model structure. The role of the exogenous stakeholders (policymaking and external stakeholders) is represented in the model by estimated, manually adjustable parameters, influencing the system dynamic model of the internal stakeholders (Janssen (2004)).

The endogenous stakeholders in the centre are subdivided into a 'customer', a 'car import, retail and service' as well as a 'fueling station' sector. These stakeholders are considered as interdependent, in contrast to the exogenous stakeholders like 'government', 'gas suppliers' and 'car industry'. The latter have insofar an influence on the model behaviour as there are assigned parameters, being set to certain values in different scenarios. The four scenarios in Janssen's model consist of parameter settings according to all possible combinations of 'Consumers' and 'Car Infrastructure' being either pro- or reactive.

4 Model conceptualisation

4.1 Different layers

The model of Janssen mentioned above (cf. Janssen (2004)) considers solely the market penetration of NGVs facing no other alternative drive train technology in the Swiss car market. Janssen treats the possible market penetration of fuel cell vehicles (FCV) separately in a niche market approach.
However, interesting questions arise from the presence of one or more additional drive train technologies – like fuel cell vehicles – on the same level as for example NGVs enter the market. What influence does the competition between them have? Does a temporally staggered introduction of – for instance – CNG-driven vehicles and eventually fuel cells lead to a faster or more efficient technology diffusion? Which are possible technology spillovers? Should the technology path go directly from liquid fuels to hydrogen based drive trains, or is it advantageous for the question of infrastructure to make an "indirec-

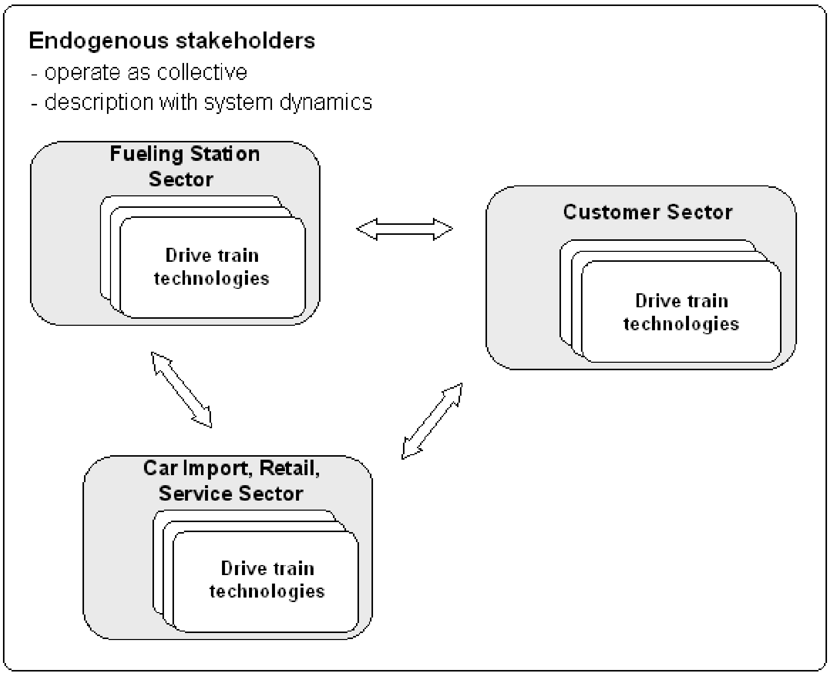


Figure 3: Box diagram showing a first Model structure extension: The simultanous handling of more than one alternative fuel technology with the resulting competition can be realised by the introduction of different layers with equal structure and coupled equations.

tion“ via compressed natural gas? Or to get to the point: Will the vehicles be adjusted to the fuels or rather the fuels to the vehicles, and which are the decisive processes?
To answer these questions the model must be extended to become capable of coping with more than one alternative drive train technology. This requires a great flexibility which can be achieved by introducing different layers (figure 3), each one representing a type of technology. The idea of different technology platforms was developed and implemented into a model by Struben (2004a), and will be used in our model in a similar, slightly modified manner. An additional feature to decide the presence of a certain technology-layer would be a further challenge and could be achieved by defining appropriate global parameters to switch a technology “on“ or “off“.

4.2 Introduction of fleets

A very important part and focused on by our work is the consumer adoption. The key quantity ist the NGV adoption rate, influencing the ratio between the stocks of different drive train technologies by converting the one to the other. Generally conversion runs in all directions, also from alternative drive train technologies back to conventional ICE vehicles, because consumers might get disappointed for some reasons.
An important assumption is that conversion can only happen when a car has exceeded its lifetime and has to be replaced. In this view, the owner has to decide whether he wants to buy another conventional car, or newly an alternative fuelled car. This decision is driven by parameters like the NGV type spectrum coverage, the fueling station satisfaction, the different car purchase and fuel prices, and so on.
Janssen’s model considers only private users, but what happens when we are taking fleet

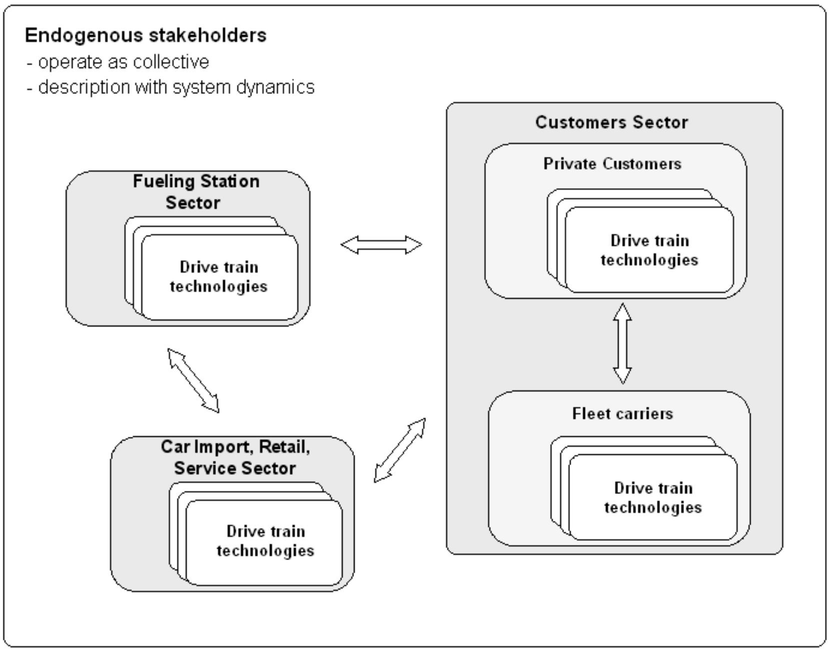


Figure 4: Box diagram of splitting the customer sector by distinction between fleet owners and private car owners. This will be the second fundamental change in the structure.

owners into account? Their decisions to restructure a fleet have on the one hand more impact on the adoption fraction. On the other hand they are influencing private users perceiving the NGVs on the street, and thus governing their adoption by a third factor besides marketing and word of mouth: perception in everyday life. This increases the familiarity with this new type of car and might help to reduce fears of gaseous fuels and other psychological aspects of the customers. In figure 4, a first effort of the necessary change in the model structure is indicated. The customer sector is divided into two interdependent subsectors of private customers and fleet carriers.

Especially in an early stage of the development alternative driven fleet cars could be better perceived when being labeled as such cars, perhaps contributing to the image of a company. This makes up an additional impact private NGVs would not have. However, it might be very difficult to estimate or even measure the extent of such influences. Several stakeholder interviews are to be performed to get an idea of how this could be incorporated into the model.

A similar problem concerns the decision-making process of a fleet owner considering a restructuration of his car pool. Assuming that his deliberation regarding the car type spectrum coverage and the fuel availability (depending on the number of fueling stations) would be similar to the one of private consumers, there will certainly be a difference about the profitability and the funding, respectively. The return of investment time and the capital he would have to raise will play a major role. Beside that the fleet owner is an entrepreneur and will think about the 'soft' profitability, e.g. the effect the restructuring will have on the company's image, affecting its clientele. This has certainly to be a part of the model, and should include all relevant factors a fleet manager's decision is based on. Here the stakeholder interviews will help to cover the important points.

To calculate the financial profitability, as a first approximation, a separate model has been developed, estimating the values for capital and return of investment by applying a standardised fleet conversion strategy. The output is to be used in the calculation for fleet conversion profitability, which is an important input for the decision of a fleet owner whether he should adopt a new technology or not. The standardisation is necessary due to the big variety of fleets and their cars, and will depend on the results of the interviews to be performed. Since the size of a homogeneous car fleet in this model only affects the capital to raise, but not the return of investment time, it can be neglected. The normalisation of the two values by division with a capital and a time constant, respectively, should also be based on stakeholder statements.

4.3 Game theoretical extension

The aforementioned distinction between endogenous (‘customers‘, ‘fueling stations‘, ‘car import, retail and service‘) and exogenous stakeholders defines the model boundaries of the system dynamic model. These boundaries will be kept in principle for the SD model of the endogenous stakeholders, but the representation of the exogenous ones must be changed in order to get realistic and reasonable scenarios. This idea leads to the next step of model extension.

Many parameters incorporated into the model are constant over time or static in the sense that they must be adjusted manually whilst an interruption of the running simulation, without being influenced by each other, by the model's state or its behaviour. The reason is that they depend on external stakeholder decisions and strategies not included in the model. The parameters are estimated and adjusted – if necessary – as the modeler “thinks best“. However, it would be preferable to have a framework making different scenarios reasonable and putting the parameter values in a major context. Their actual values should be derived from policy-making stakeholders as a reaction to the perceived system behaviour.

The initial position with different individuums or parties pursuing different interests forms a conflict situation, characterised by interaction of all parties involved in terms of rational statements about the participants, their possible conducting, their strategies and mutual information exchange. The analysis of such situations is the quintessence of game theory (cf. Manteuffel und Stumpe (1977)).

Since the stakeholders in our model shall be able to react, i.e. to change their input to the system dynamics model according to their strategies, we need by any means a dynamical theory of games as provided for example by Krabs (2005). The whole system conveys a given starting condition within a finite number of time steps to a different subsequent state, normally an arbitrary one. This leads to the introduction of a steering function, bringing the system to a desired state, now being a fixpoint in the time evolution. This function would include policy measures and apply at the leverage points of the SD model part. The model structure from figure 4 should therefore be extended as shown in figure 5. The coupling would lead to a combined model comprising a system dynamical as well as a game theoretical part. The realisation and implementation of a totally dynamical model with a dynamical game theoretical part redefining a new equilibrium after a certain number of time steps will be a big challenge. However, a non-dynamical explanation of the exogenous conditions given by the stakeholders would yet mark an improvement.

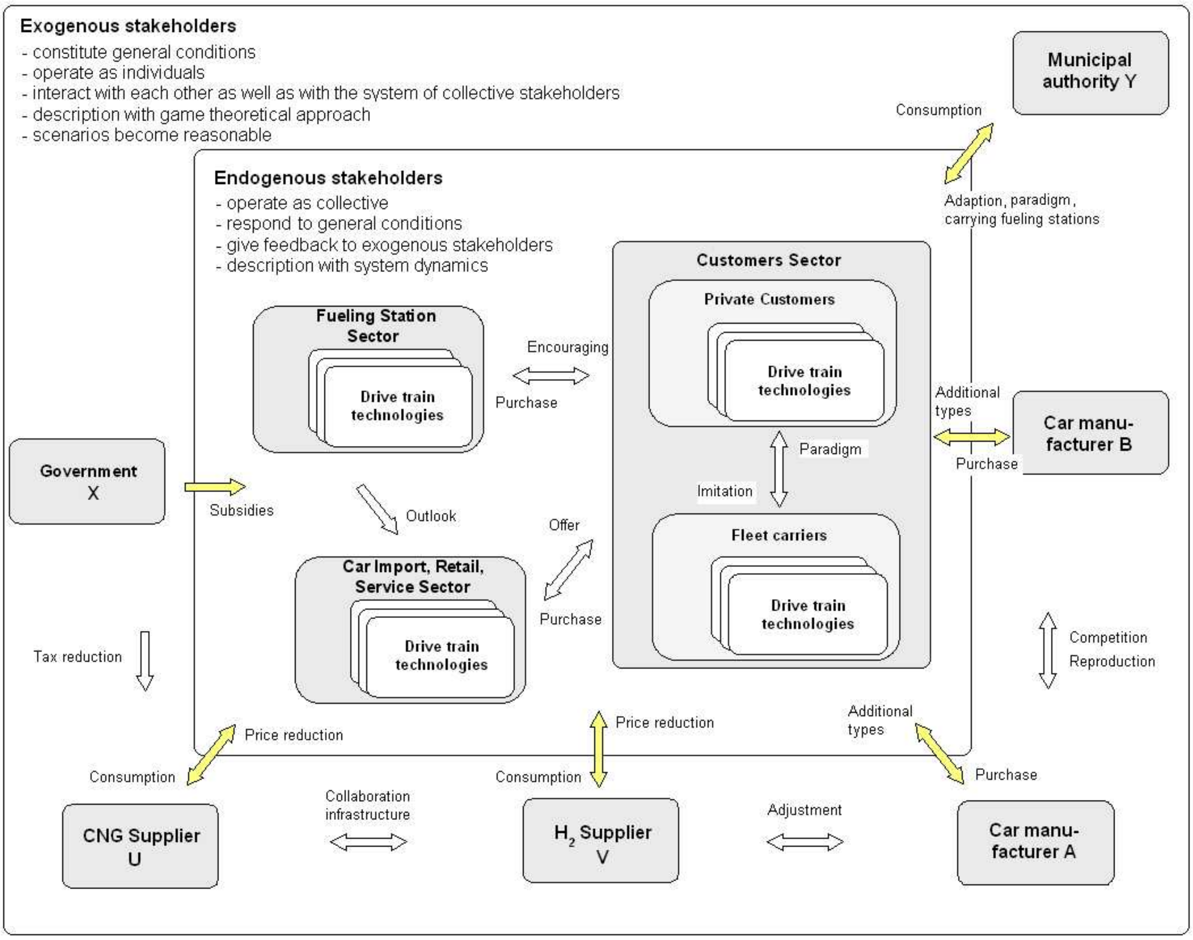


Figure 5: Box diagram, showing the final model structure, including all constitutional extensions: This hybrid model would have an exchange between the endogenous, system dynamic and the exogenous, game theoretical submodels.

5 Model description

This section descibes the model developed so far. The different possible technology paths and the related question of more than one alternative fuel manifests in the dynamic hypothesis of the model. Figure 6 shows the interlinkage of the different layers, i.e. drive train technologies, on the level of cars. We have considered conventional internal combustion engine vehicles (ICE), natural gas vehicles (NGV), hybrid vehicles (hybrid) and H_2 fuel cell vehicles (FCV) as competing technologies.

The structure basically allows possible conversions among all stocks. However, all the flows back to conventional ICEs are to decrease over time due to the assumption, that petrol and diesel will decline with the future lack of crude oil resources. This is included in the model by given external functions of time, which are also used to simulate the emerging possibility of H_2 FCVs not being available in the beginning of the model's run time. Still an open question at the moment is the potential of replacements for liquid fossil fuels, like for example biodiesel as a replacement for diesel, but this could be incorporated into the model in a similar way like the reduction of crude oil availability. Therefore, and since the environmental impact of such substitutions is not yet accessed, no additional stock for liquid bio-fuels in internal combustion engines is needed at this time.

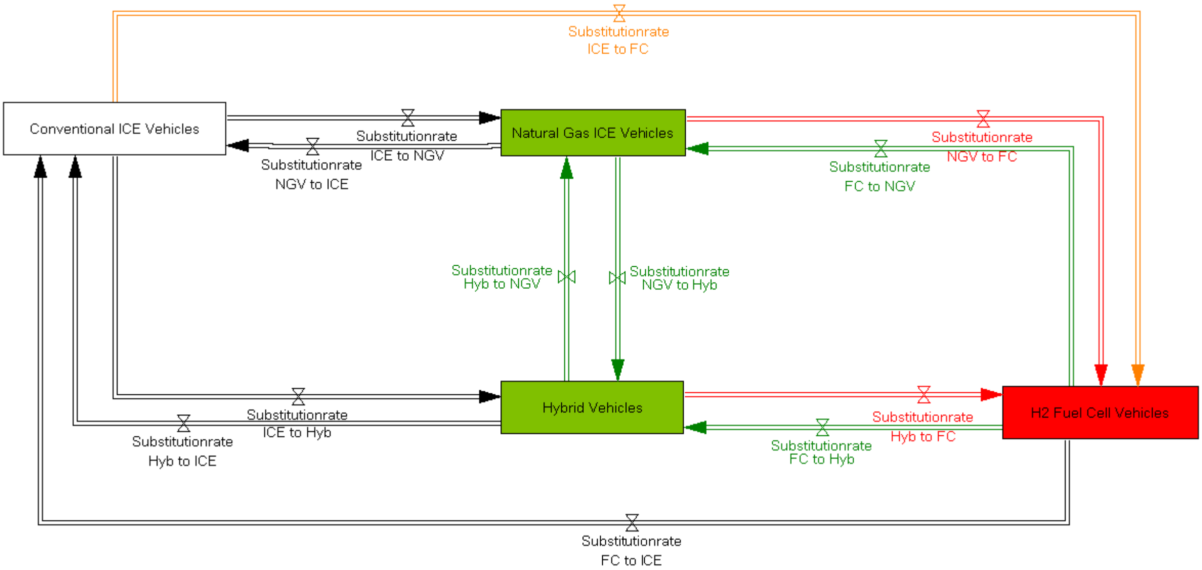


Figure 6: Stock and flow diagram, showing the basic model structure for the different car stocks. The classification “conventional“ comprises petrol as well as diesel and does not distinguish between them.

Figure 7 shows the general formation of the substitution rates, except the rates back to the stock of conventional ICEs, which are treated below.

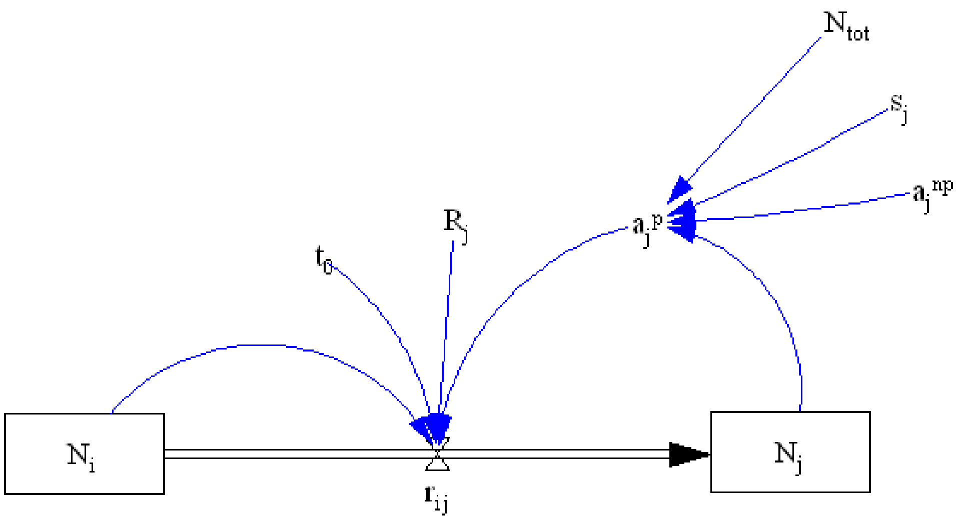


Figure 7: General structure for a flow rate. All rates in the model, excepted the flows back to conventional ICE vehicles, are built with this structure.

The calculation performed for the flowrate of stock N_i to stock N_j reads as follows:

$$r_{ij}(t) = \frac{N_i(t)}{t_0} \cdot a_j^p(t) \cdot R_j \tag{1}$$

with

$$a_j^p(t) = \frac{1}{2}\Big(\frac{N_j(t)}{N_{tot}} \cdot s_j(t) + a_j^{np}(t)\Big) \tag{2}$$

where

$r_{ij}(t)$	:	substitution rate	N_{tot}	:	total number of vehicles on road
$N_i(t)$	:	stock i	$N_j(t)$	:	stock j
t_0	:	car lifetime	t	:	time
$a_j^p(t)$	:	perceived attractiveness	$a_j^{np}(t)$	:	normal perceived attractiveness
$s_j(t)$	:	supply of needs	R_j	:	retarding factor

Let us first consider equation (1). The fraction $\frac{N_i(t)}{t_0}$ on the right hand is the average number of cars with technology i that are replaced per time unit, because they reach the end of their lifetime, t_0. This fraction is multiplied with a technology-specific "perceived attractiveness" a_j^p (c.f. equation (2)) which is explained below and can take values from 0 to 1. This attractiveness of technology j is interpreted as the percentage of cars that are substituted by this technology. Since it's value is limited to 1 the maximum conversion rate yields up to the number of cars that are replaced. The final factor R_j is also a limiting factor with the range of 0 to 1. It represents the fact that a substitution will not take place instantly, because there may be a delay for several reasons, like delivery problems for instance.
In equation (2) it can be seen that the perceived attractiveness is determined by two different summands: The first term in brackets is a product of the "supply of needs" s_j with the fraction of cars belonging to technology j as a weighting factor. s_j is a perceived quantity in relation to todays standard technology's supply of needs – of ICEs in our case – which is assumed to be the maximum. The car fraction $\frac{N_j(t)}{N_{tot}}$ describes the measure of perception. The product cannot exceed the value of 1. The second summand $a_j^{np}(t)$ represents a given perception-independent attractiveness of technology j, but is also time dependent and limited to a value of 1. The sum in brackets can thus take a maximum of 2, why it is normalised with a factor of $\frac{1}{2}$ and consequently bounded to 1.
Matters stand a bit different for the flow rates back to the ICEs. Figure 8 shows the formation of such a rate.

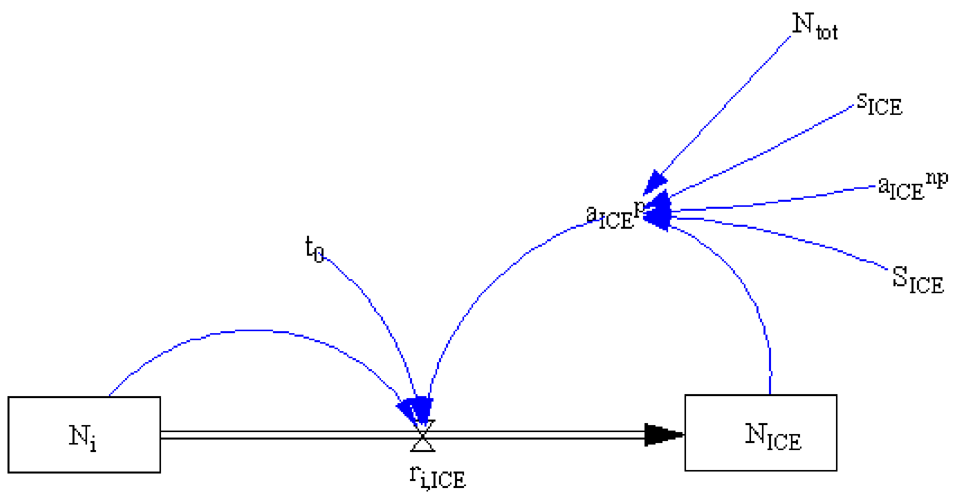


Figure 8: Structure for a rate of a flow back to conventional ICE vehicles. The retarding factor R_j is set to 1, according to its definition (see below). However, there is an additional factor S_{ICE} appearing in the definition of the perceived attractiveness, describing the decreasing availability of crude oil.

The appropriate calculation for the flow rate N_i to stock N_{ICE} reads as follows:

$$r_{i,ICE}(t) = \frac{N_i(t)}{t_0} \cdot a^p_{ICE}(t) \tag{3}$$

with

$$a^p_{ICE}(t) = \frac{N_{ICE}(t)}{N_{tot}} \cdot s_{ICE}(t) + a^{np}_{ICE}(t) \cdot S_{ICE}(t) \tag{4}$$

where

$$S_j(t) \;:\; \text{shortage of resources}$$

The other variables and parameters are equally defined as in equations (1) and (2).

The difference to the two above equations ist twofold:
First, the equation for the rate has no factor R_{ICE}, because all retarding effects in the model are considered comparatively to those of the ICE vehicles and their industry. It is not likely that alternative technologies would have better retail and service attributes etc. than ICEs, and therfore we have $R_j = 1$, and consequently can omit it in this case. Secondly, there is an additional factor $S_{ICE}(t)$ in equation (4), that represents the possible disappearence of fossil fuelled drive train technologies due to decreasing resources. This would cause a general loss of attractiveness, although the corresponding drive trains could still be technologically attractive. For this reason the given, time dependent factor "shortage of resources" $S_{ICE}(t)$ has been added.

5.1 Modelling of given functions

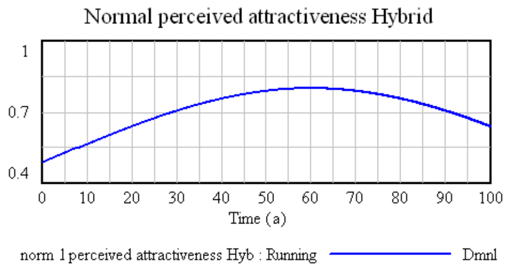
As aforementioned, given external functions of time are used to describe the normal perceived attractiveness and the shortage of resources. This could be done with look-up tables, defined differently for each scenario. However, this would need a big effort of changing every lookup function while performing different tests with the model, like for example extreme value tests, or just "playing" around to get a feeling for the possible behaviours. This effort can be minimised by using for example gaussian or sigmoid functions that can be handled with a few parameters. Of course these simple functions are incapable of reproducing complicated and detailed look-up curves, but on the model's level of aggregation they are adequate to investigate the most important and characteristic behaviours. Two examples illustrate the simplicity of this approach:
The normal perceived attractiveness of hybrid vehicles a^{np}_{Hyb} might grow in the near future, because they become more economic and ecologic than conventional ICEs. However, since they still need liquid or gaseous fuels for their combustion engine in addition to the electric power train, their a^{np}_{Hyb} might peak after a certain time and eventually decrease again with the shortage of fossil resources. This behaviour can qualitatively be reproduced by the following gaussian function

$$a^{np}_{Hyp}(t) = c_{max} \cdot e^{-\frac{(t-\mu)^2}{2\sigma^2}} \tag{5}$$

where

c_{max}	:	determines the maximum value achieved
μ	:	denotes the point in time where c_{max} is taken (mean value)
σ	:	is the standard deviation

The shape of the curve can easily be determined by adjusting these three paramters. Figur 9 shows a numerical sample.



with parameter setting:

$$\begin{array}{lcl} c_{max} & : & 0.8 \\ \mu & : & 60 \text{ a} \\ \sigma & : & 60 \text{ a} \end{array}$$

Figure 9: Numeric example of the gaussian function (5) used for the qualitative behaviour of the normal perceived attractiveness of hybrid vehicles.

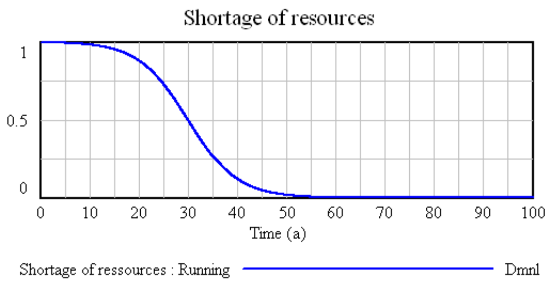
As another example we consider the shortage of resources. In one possible scenario fossil resources deplete within several decades. This can be seen as a declining s-shape curve behaviour, represented by an analogon of the Fermi-Dirac distribution

$$s_{ICE}(t) = \frac{1}{e^{m(t-t_0)} + 1} \tag{6}$$

where

$$\begin{array}{lcl} m & : & \text{determines the gradient of the curve} \\ t_0 & : & \text{denotes the point in time where the inflexion occurs} \end{array}$$

One could add a third, multiplicative parameter to dilute the curve and affect the maximum value, which is set to 1 in this version. Again, adjusting at most three paramters is enough to handle the shape. Figure 10 shows a numerical sample.



with parameter setting:

$$\begin{array}{lcl} m & : & 0.2 \text{ a}^{-1} \\ t_0 & : & 30 \text{ a} \end{array}$$

Figure 10: Numeric example of the function (6) used for the qualitative behaviour of the normal perceived attractiveness of hybrid vehicles.

6 First results

The rather simple model structure described in the last section already shows an interesting behaviour. As an example we will focus on three interrelated preliminary results, which underline the role of the normbuilding processes in the model.
All three following graphs base on model runs with 1000 automobiles in total and a time horizon of 100 years. Our interest lies on the resulting characteristics of the NGV, hybrid

and FCV stocks. Figure 11 shows a very typical behaviour of the model. The parameter set is such that fuel cell vehicles have a high normal perceived attractiveness, but also a long delay. NGVs and hybrids are slightly less attractive, but have also much shorter delays. In relation to each other they are very close, while NGVs are less attractive but have a shorter delay than hybrids. The resulting development shows three slowly growing curves, with FCVs clearly far behind.

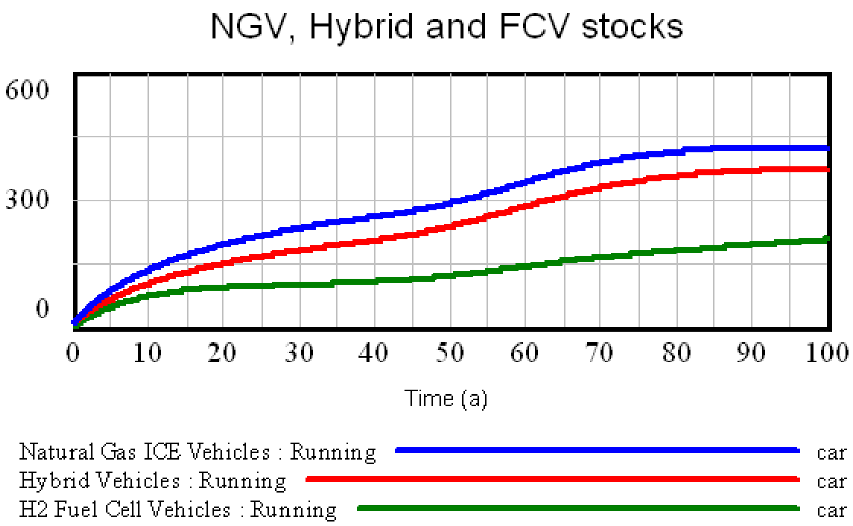


Figure 11: Development of the three stocks for NGVs, hybrids and FCVs, assumed a high normal perceived attractiveness but also a long delay for the latter.

If now the situation is changed in such a way that the normal perceived attractiveness of NGVs peaks after a short period and drops afterwards,

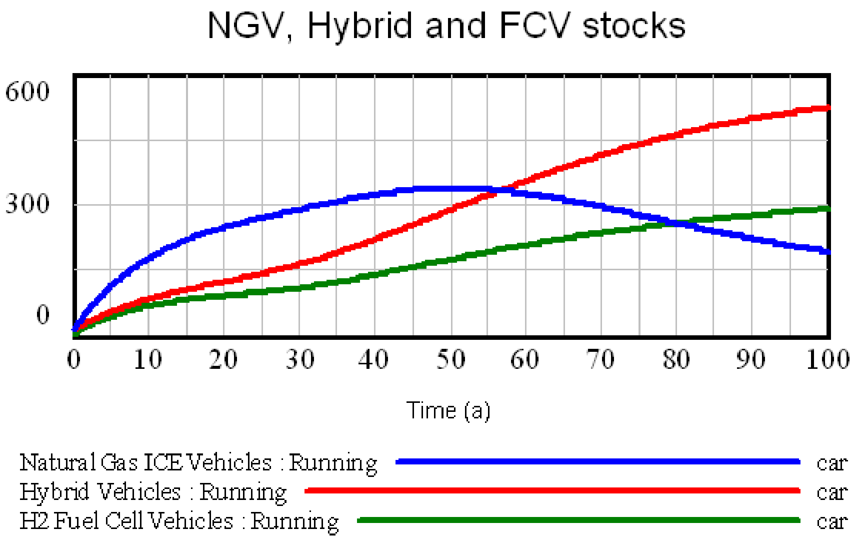


Figure 12: Same situation as before, but now with a peak for the normal perceived attractiveness in the beginning and a strong decline afterwards.

the number of NGVs also decreases. The development of the stock follows to a certain extent the shape of the normal perceived attractiveness as an external given function of

time. Hybrids and FCVs comparably profit by this development, and NGVs lose their domicance, as can be seen in figure 12.
In the next step we slightly change the attributes of the normal perceived attractiveness for NGVs. The peak is increased and broadened, and one could expect that the NGV stock would again follow the shape more or less, as it did in figure 12, but this is not the case. The development for NGVs is more successful than the new characteristics of their normal perceived attractiveness would imply. Another effect must be responsible for the behaviour shown in figure 13.

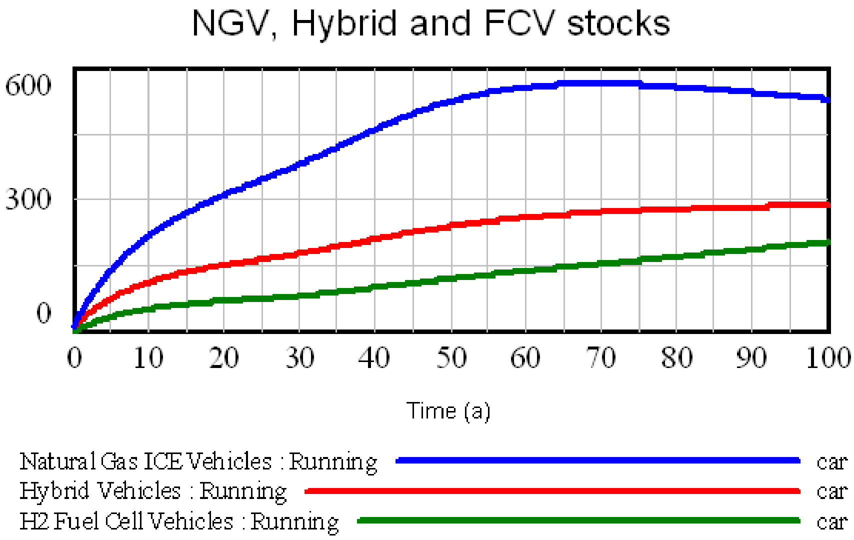


Figure 13: The peak in the normal perceived attractiveness for NGVs is higher and broader than before. This results in a different behaviour because of the normative effect.

Equation (2) shows that for small stocks, as it is the case in our example for NGVs for small t, the perceived attractiveness is almost fully determined by the normal perceived attractiveness. The term $\frac{N_{NGV}(t)}{N_{tot}}$ in a^{p}_{NGV} is too small during the whole run to have a substantial influence. Therefore, the stock of NGVs in our second case in- and decreases with a^{np}_{NGV}, the normal perceived attractiveness. However, in the third situation, the peak in a^{np}_{NGV} is high and broad enough to let the stock grow to a certain extent which enables $\frac{N_{NGV}(t)}{N_{tot}}$ to compensate the subsequent decrease of a^{np}_{NGV}. The normal perceived attractiveness in the beginning is high enough to tie down a critical mass of NGVs, making them self-sustaining and dominant, even if attractiveness later changes to their disfavours. This rather simple model thus shows a normative behaviour and the important competition between attractiveness and time aspects.

7 Outlook

The model extensions described above are not exhaustive. It is now essential to implement them gradually into the present model and to correct them as necessary. The stakeholder interviews will provide necessary information to build the right connections. Although the final model will still contain quantities which will have to be estimated and left constant over time, more exogenous parameters of the present model will become active parts of the development and contribute to reasonable scenarios, allowing to derive realistic policy recommendations.

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