Master Thesis

Trend Analysis and Establishment of an Industry Roadmap for CNG-Systems in the Automotive Industry

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Statutory Declaration

I declare that I have authored this thesis independently, that I have not used other than the declared sources / resources, and that I have explicitly marked all material which has been quoted either literally or by content from the used sources.

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Abstract

Beside stricter legislation on emissions due to increasing environmental pollution, also rising energy prices are a reason for the industry to count more and more on alternative propulsion systems. Several different concepts, such as electric-, hybrid-, hydrogen-, and natural gas vehicles are increasingly gaining importance. Manufacturers and suppliers are therefore required to respond to these changes and to extend its portfolio accordingly. Magna International, one of the world’s leading automotive suppliers is interested in the market development of alternative propulsion systems. One of these concepts are natural gas vehicles and Magna expects a great chance for these vehicles to gain market share in the coming years.

In the context of this master thesis the future development of natural gas vehicles and the related technology is determined based on an analysis of the current market situation and rising trends. Since Magna still has less experience with components of natural gas systems, a market entry does not only offer new chances but also risks and dangers.

The elaboration of this thesis aims to identify and evaluate the main developments, events and trends that may affect the market position and technology of natural gas vehicles in the next five to seven years, and illustrate them in form of an industry roadmap. At the beginning of this thesis a detailed literature review provides the necessary knowledge to carry out the investigations. This research includes the topics of market and trend analysis, integrated roadmapping and general information about natural gas as a fuel for vehicles.

The practical studies provide information about the opportunities of natural gas systems in different regions. Attention is paid not only to the market development but also on technology trends. The potential of natural gas vehicles compared to conventional vehicles is central to this work. Furthermore, drivers and blockers of natural gas vehicles are investigated. All information collected is evaluated and incorporated into the Industry Roadmap. The roadmap serves as a decision support for the Magna management, which must decide on further steps in the field of alternative drives.

Kurzfassung

Die Anforderungen der Gesellschaft an das Automobil haben sich in den letzten Jahren geändert. Hohe Treibstoffpreise und der Trend hin zum Klimaschutz zwingen die Automobilhersteller ihr Portfolio zu überdenken und vermehrt auf alternative Antriebe zu setzen. Eine vielversprechende Möglichkeit stellen erdgasbetriebene Fahrzeuge dar. Für den international agierenden Automobilzulieferer Magna stellt sich nun die Frage, ob das Konzept des Erdgasantriebes in Zukunft einen bedeutenden Marktanteil erringen kann, und sich somit ein Entwicklungsengagement diesen Bereich lohnen würde.

Basierend auf einer ausführlichen Analyse der momentanen Marktsituation von Fahrzeugen mit Erdgassystemen (CNG Systemen) soll auf zukünftige Trends geschossen werden. Dabei sollen Einflussfaktoren für die Markt- und Technologieentwicklung gefunden und bewertet werden. Die gewonnenen Erkenntnisse werden in einer Industry Roadmap illustriert, welche die Entwicklung des jeweiligen Produktes und der dahinterstehenden Technologie über einen Zeitraum von fünf bis sieben Jahren für verschiedene Regionen darstellt. Das Ergebnis der Masterarbeit soll als grundlegende Entscheidungshilfe für das operative Management dienen, das weitere Schritte des Unternehmens im Bereich alternative Antriebssysteme festlegen wird.

Am Beginn der Arbeit steht eine eingehende Literaturrecherche, um das Hintergrundwissen zu schaffen, welches für die praktische Ausarbeitung der Industry Roadmap notwendig ist. Der Fokus dabei liegt auf den Methoden der Informationsgewinnung und Technology Roadmapping.

Im praktischen Abschnitt der Arbeit werden bereits vorhandenen Informationen gegebenfalls aktualisiert und ergänzt. Bisher unberücksichtigte Einflussfaktoren müssen identifiziert und in die Untersuchung miteinbezogen werden. Dazu ist eine enge Zusammenarbeit mit Vertretern von Magna Standorten in den jeweiligen Regionen notwendig. Nachdem alle relevanten Faktoren ermittelt wurden, werden die gewonnenen Erkenntnisse in die Maske der Industry Roadmap eingearbeitet, um so eine übersichtliche Darstellung der Markt- und Technologieentwicklung über die nächsten Jahre zu erhalten.

Acknowledgement

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Heartfelt thanks to my parents, my family and friends who have supported me mentally during the preparation of the thesis. The patience and good winning bids, which they have applied, has given me enough motivation to carry out the work.

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Very special thanks to my supervisor at Magna, Gerhard Krachler, who always supported me with great knowledge and patience. He has played a major role in ensuring that the work could be completed successfully. I would also like to thank my supervisors at the university Verena Kriegl (PSM) and Hans Peter Schnöll (IBL) for their support. They have shown me the right way to achieve my goal quickly and effectively.

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1. Introduction

The requirements of society on the automobile have changed in recent years. High fuel prices and the trend towards climate protection are forcing car manufacturers to rethink their portfolio and to increasingly rely on alternative drives. Different concepts such as electric, hybrid, hydrogen and natural gas vehicles are currently the most promising alternatives to conventional gasoline and diesel vehicles. So far, none of these concepts was able to substantially prevail against the others. Magna, as an automotive supplier must closely observe and react to the market development as well as to technology improvements in order to secure a competitive advantage over the contenders.

1.1 Objectives

Magna suspects great potential in natural gas vehicles sector and therefore considers supplying OEMs with components for natural gas systems. Before enter the business a reflection of the market is necessary to identify any risks and opportunities. The goal of this thesis is to generate an impression of the development of natural gas systems as an automotive drive system over the next five to seven years. Based on an analysis of the situation, future trends are identified and evaluated. The results are presented in an Industry Roadmap that incorporates all the relevant factors for the development of the product “natural gas vehicle” and the technology behind it. The Industry Roadmap represents a statement about the future development of natural gas systems and is used as a decision support for the upper management.

1.2 Magna International – A brief company introduction

Magna describes itself as one of the leading global automotive suppliers with 308 manufacturing operations and 88 product development, engineering and sales centres in 27 countries. About 117,000 people are employed in the global operations of Magna, making it one of the largest companies in the automotive industry, supplying the most important car manufacturers in the world with products and services.[1]

[1] cf. Magna Intranet (2013), access date 03.01.2013

The company's history dates back to the 50s. In 1957, the Austro-Canadian entrepreneur Frank Stronach founded a tool company in Canada, called Multimatic Investments Limited, which subsequently expanded into the production of automotive parts. In 1969, Multimatic Investments Limited merged with the Canadian Magna Electronics Corporation Limited. From that date, the company was operating under the name Magna International. This was followed by an expansion of the product portfolio and related revenue increases. Magna International could initiate numerous innovations and was able to steadily increase its market success. Through strategic acquisitions of competitors, Magna was able to quickly develop into an internationally successful company.[2]

Magna International is known for the active involvement of employees in company decisions. The so-called Magna Charta provides a fairness-based work environment, which is characteristic of the corporate culture. It predetermines the annual percentage of profits shared between employees, management, investors and society.[3] Figure 1 shows the global operations of Magna with a representation of the number of production and service facilities and the number of employees.

Figure 1: Global operations of Magna[4]

Today, Magna is represented on five continents and supplies automotive manufacturers and suppliers with components and engineering services. The red numbers provide information about the amount of manufacturing and assembly sites,

[2] cf. Magna (2013), http://www.magna.com, access date 03.01.2013
[3] ibd.
[4] ibd.

whereas the blue numbers provide information about engineering, service and sales sites. The grey numbers represent the amount of the respective employees.[5]

Magna's product capabilities include body, chassis, interiors, exteriors, seating, powertrain, electronics, mirrors, closures and roof systems and modules, as well as complete vehicle engineering and contract manufacturing. The company is structured in the divisions:

- Magna Seating
- Magna Exteriors and Interiors
- Magna Mirrors and Magna Closures
- Cosma International
- Magna Powertrain and Magna Electronics
- Magna Steyr

In 2011, Magna generated revenues of US $ 28.7 Billion. The total net income in 2011 was US $ 1.018 Million and the total assets US $ 14.7 Billion. Furthermore, Magna is listed in the Toronto Stock Exchange and the New York Stock Exchange.[6]

1.3 Approach

This thesis consists of two parts. First, the elaboration of a theory part is intended to provide knowledge about the methodology for developing the practical task. Basic knowledge about market and trend research and the methodology to create an Industry Roadmap is created. The theoretical part is complemented with a brief description of Compressed Natural Gas (CNG) systems in general.
The practical elaboration starts with the determination of the initial situation, and the targets. Existing information is assessed and supplemented by new ones. The study aims to gather all necessary information to establish the Industry Roadmap. Therefore a close cooperation with working groups of Magna North America and Magna Steyr is needed. The structured results of the investigation provide an impact of upcoming events and trends that can influence the market and technology development.

[5] cf. Magna Intranet (2013), access date 03.01.2013
[6] ibd.

2. Market and Trend Analysis

Market and trend analysis is the basis of any market research. The content of this chapter should provide a basic understanding of the key terms, structures and practices of market research, which are necessary for carrying out studies for the creation of an Industry Roadmap effectively. Starting with the explanation of the marketing management process (which is considered as a fundamental process for decision making by the company management) the context of market research and trend analysis is described. The aim is to convey how the market research "tool" can be used to investigate current market situations and future trends.

2.1 Marketing Management Process

The marketing management process specifies the sequence of operations to achieve the corporate objective. The four main stages of this process are analysis, design, implementation and control. The process is shown in figure 2.[7]

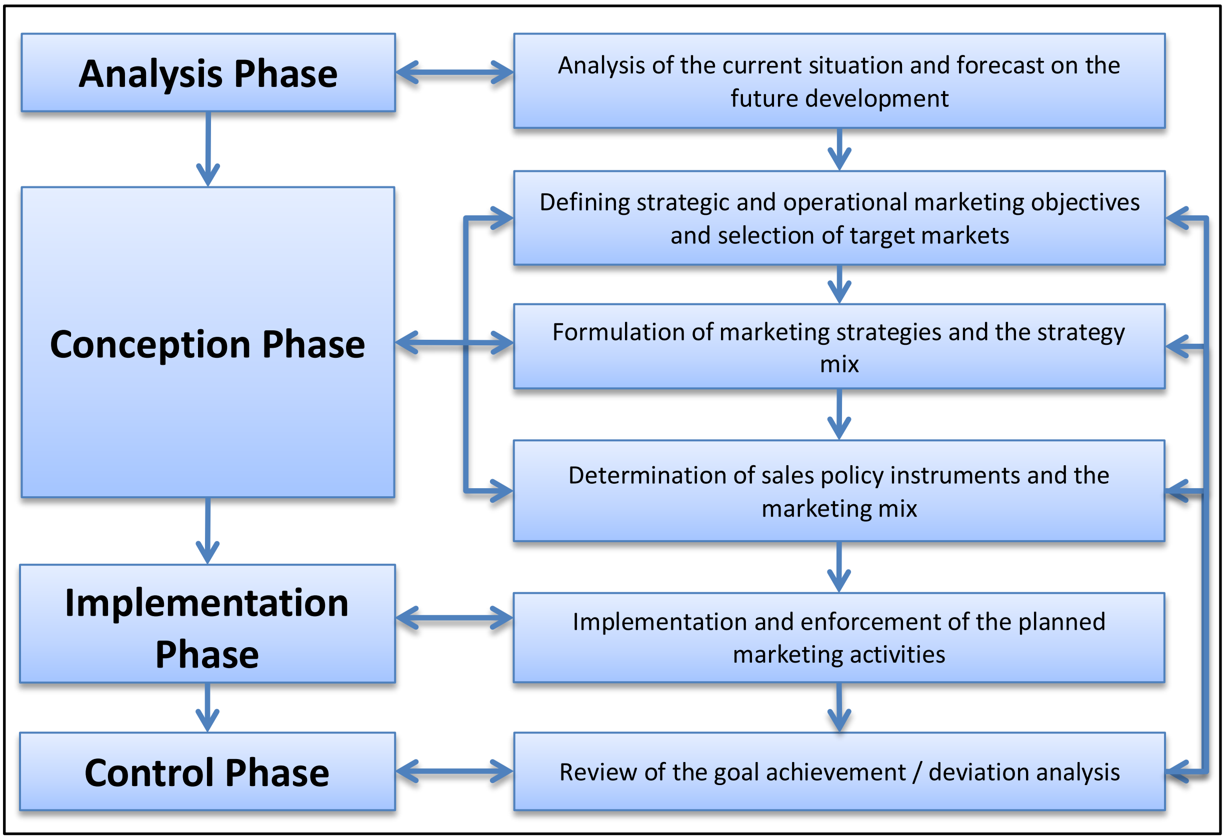

Figure 2: Management-decision process[8]

[7] cf. Koch, J.(1999): p.30
[8] own representation based on Koch, J. (1999), p.30

2.1.1 Analysis Phase

The analysis phase includes the acquisition of relevant information about the company external and internal baseline. With this information, strategic and operational decisions were made. Chances and risks for a company can be discovered during this phase. These chances and risks must then be compared with the company's opportunities and weaknesses. The so called SWOT Analysis is a common tool for analysing the current situation.[9]

Within the analysis phase, the prognosis is dealing with the research of relevant future market and social influence factors. The forecasting activity involves the study of trends in demand patterns and competition behaviour in the environment. Hence a prediction of market and sales trends should be gained.[10]

2.1.2 Conception Phase

The conception phase can be divided into the strategic and the operational marketing planning. In strategic marketing planning, first the marketing goals that are the overall company goals are defined. Here, both economic and environmental objectives are taken into account. The marketing objectives serve as the basis for subsequently deriving the marketing strategies. The strategy serves as a long-term and comprehensive behaviour plan that will ensure the achievement of objectives. It also indicates the way a company should behave in the market. The marketing strategy is concerned with the selection of the market segments, the decision on the market development strategy and the use of marketing tools.[11]

The operational marketing planning builds on the strategic marketing planning and pushes the implementation of marketing tools. Marketing tools are used to control the implementation of the marketing strategy. The marketing tools are composed into the so called marketing mix within the marketing planning. The four main components are Product, Price, Place and Promotion. Marketing tools for a specific point in time can be determined by using the marketing mix elements. The content of all components of the marketing mix must be analysed in every stage of the product life cycle. A method that is recommended for this is the PDCA (Plan, Do, Check, Act) cycle by DEMING (figure 3). The intent of this field of operative marketing planning is that the process gets planned, executed, assessed and adjusted in every stage taking into account the influence factors of the marketing mix components.[12]

[9] cf. Meffert, H. et al. (2009), p. 3
[10] ibd.
[11] cf. Meffert, H. et al. (2009), pp. 3-4
[12] cf. Ebel, B. (2004), p. 179

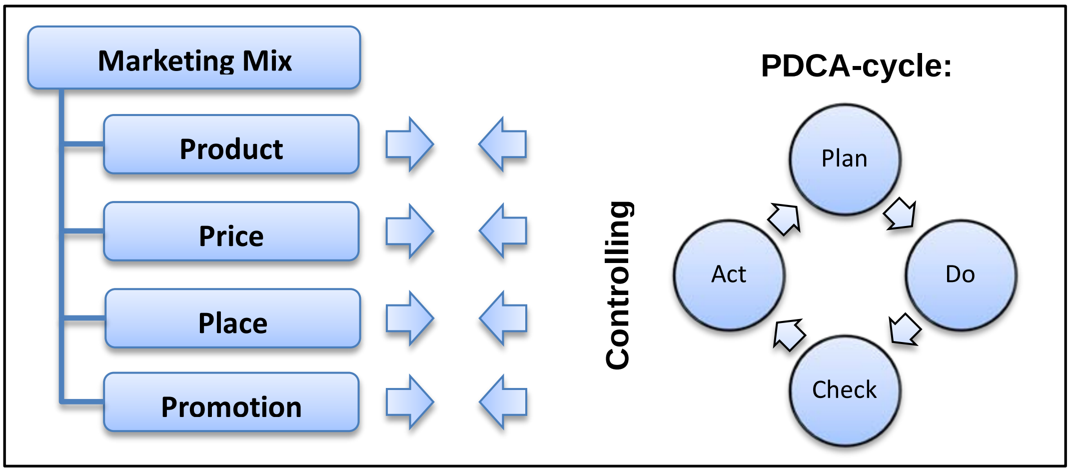

Figure 3: Marketing Mix and PDCA-cycle[13]

The four Marketing Mix Elements:[14]

Product: Product policy is about making the offered services market-driven and customer-oriented. Innovation management, market research, developing product range, and product profitability are activities that are covered in this chapter.
Price: The pricing policy concerns the design of the price range of products and services. Thereby, the entire life cycle is taken into consideration.
Place: The distribution policy aims to provide the target market with a company's products and services. The requirement is to provide the products and services completely, in time and at agreed prices.
Promotion: This marketing mix instrument deals with the supply of information about the company, to the market. Here, the focus is on topics such as branding, advertising, sales promotion, press releases and public relations.

In some business areas, such as in the service sector, the marketing mix can be extended to seven points. Here, also the instruments People, Processes and Physical Facilities can be taken into consideration. Which instruments of the marketing mix must be considered is dependent on the business field and must be decided specifically for each company.[15]

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[13] own representation based on Ebel, B. (2004), p.179
[14] cf. Ebel, B. (2004), p. 180
[15] cf. Meffert, H. et al. (2009): p. 5

2.1.3 Realisation Phase

The findings from the design phase will be implemented in the realisation phase. The implementation requires considerations of efficient process- and procedure-organisation. Furthermore, appropriate responsibilities, leadership concepts and budgets must be determined. Inter-departmental processes require precise coordination of accountability and a thoughtful distribution of tasks among the various departments.[16]

2.1.4 Control Phase

Whether the objectives have been achieved, or if there where deviations is checked. If necessary, an adjustment is carried out for all phases of the planning process for improvement and in order to comply with the provisions accurately. Within this phase, what went wrong and how improvements can be achieved should be evaluated.[17]

2.2 Assessment of the market situation

The first step in the management decision process is the analysis of the market situation. According to LYNDON O. BROWN (1937), a reflection of the industry, the competition and the own company is necessary for the analysis of the current market situation.[18]

2.2.1 Assessment of the industry

To be successful as a company, it is essential to know the structure and conditions of the industry in which one wants to position their products or services. MICHAEL PORTER's "Competitive Strategy" (1980) and "Competitive Advantage" (1985) books deal extensively with the analysis of industry structure and competition. Even today, his theories are still relevant and serve as a valuable reference for managers. This chapter will provide a basic overview of the structure of industries and general competitive strategies.

Industry structure directly influences the rules of competition and the strategies that are potentially available to a company. Porter's concept of the five competitive forces

[16] cf. Meffert, H. et al. (2009), p. 5
[17] ibd.
[18] cf. Brown, L. O. (1943), p. 149

contains five factors that are essential for the intensity of competition in an industry. The Porter model is shown in figure 4.[19]

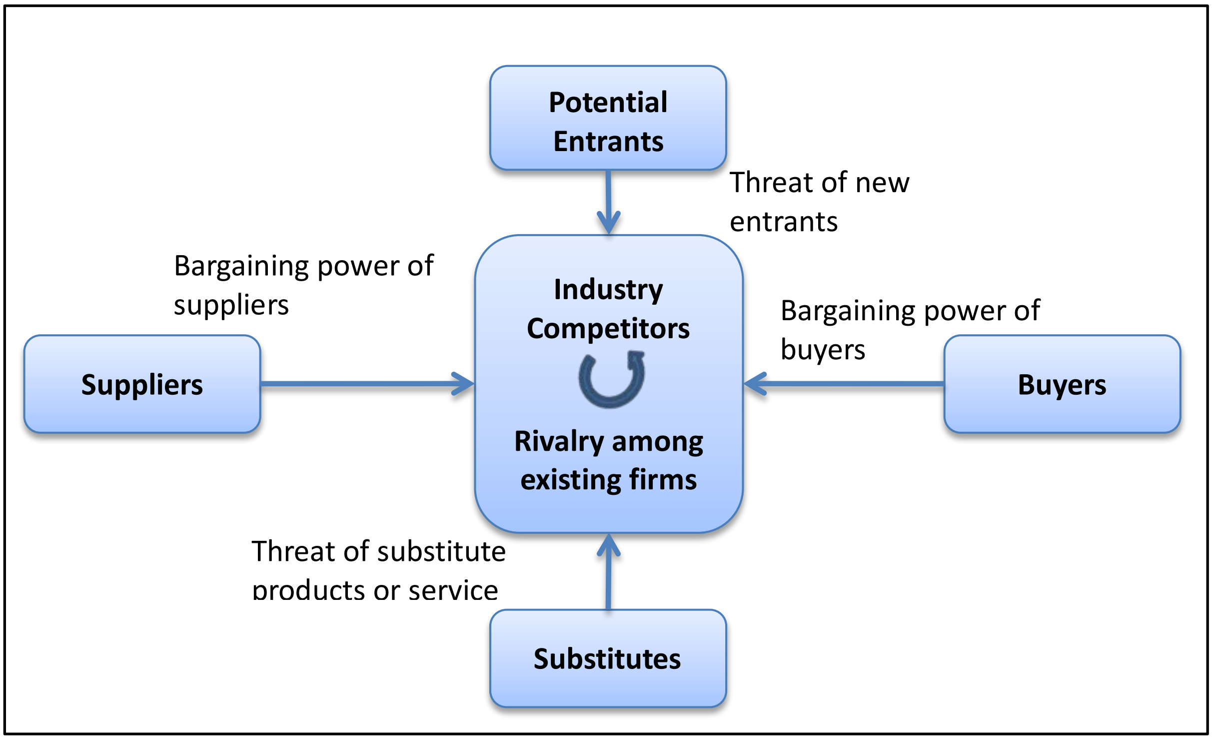

Figure 4: Five Forces for industry competition according to Porter[20]

The key structural features of industries determine the strength of the influencing factors and hence industry profitability. A business's competitive strategy is successful if a position within the industry is found, in which a company is able to defend itself best against these competitive forces or even influence them in its favour.[21]

2.2.1.1 Rivalry among existing competitors

The intensity of competition is determined by various factors. For example, if the industry is characterised by strong market growth, then all competitors can develop freely, without the need to attack each other. If the capacities are not fully utilised, the competition is determined by the price. With capacity utilization, the fixed costs are covered. Therefore, prices can be fixed, which do not contribute to covering the fixed costs, but help to increase the capacity. The impact of the price decreases if a

[19] cf. Camphausen, B. (2007), pp. 37-38
[20] Porter, M. E.(1999), p. 36
[21] cf. Camphausen, B. (2007), pp. 37-38

company can manage to differ from others in points like functionality, service, quality, etc. The number of competitors is indicative of the intensity of rivalry. A high number of competitors is an indication that competition is increasing, as is the unbalanced strength of competitors. Stronger companies will try to push out weaker ones. [22]

2.2.1.2 Threat of potential entrants

New entrants bring new capacity and often substantial resources into an industry. An occurrence of a new competitor on the market will reduce profits for the existing competitors. For the level of demand, there is a greater supply. The likelihood of the entry of a competitor depends on:[23]

- The expected competitor's reactions
- The entry barriers of the market

2.2.1.3 Threat of substitute products

A substitution refers to a product that serves the same purpose as the original product. Substitutes can reduce the demand for a particular product class, if consumers switch to alternatives. Existing substitute products often force a company to adapt its pricing policy. A competing product that features a better price-performance ratio calls for countermeasures in form of a price reduction or performance improvement. The customer must then recognise an improvement in the product offered. This may be a better price performance ratio, improved quality, or better service and availability.[24]

2.2.1.4 Bargaining power of buyers

Customers seek to purchase a product of the highest possible quality and service, at the best price. Therefore, they play competitors off against each other, which leads to a reduction of profitability for the industry. The level of influence of the industry´s buyer groups depends on some characteristics of its market situation and on the purchase proportion compared to the sale of the entire industry. For example, the bargaining power of the buyer is large when the quantity of products purchased is also large.[25]

[22] cf. Camphausen, B. (2007), pp. 38-39
[23] cf. Wallentowitz, H. et al. (2009), p. 120
[24] cf. Johnson G. et al. (2011), p. 88
[25] cf. Porter, M. E. (2004), pp. 24-25

2.2.1.5 Bargaining power of suppliers

In bargaining, suppliers can exert pressure by threatening to raise prices or reduce the quality. For companies that operate in industries where it is not possible to hand a price increase to the end-customer, it means a restriction of profitability. There are some conditions under which suppliers can influence the strategy of companies significantly. Suppliers must absorb this increased competitive pressure. In general, this means the need for lower purchase prices and optimized procurement processes. The supplied companies benefit from greater options for action.[26]

2.2.2 Competitive analysis

Broadly speaking, if a company wants to remain competitive, it needs to know a lot about the position and strategy of competitors in their respective industry. The consideration of the competition must not be based on guesswork or intuition but on information, which has to be collected, analysed and evaluated.[27] This subsection will describe the structure of the competitive analysis and briefly discuss each item.

A structured analysis of the competition can be divided into four diagnostic components: future goals, current strategy, assumptions and capabilities. Figure 5 shows the four basic elements that together, all have an influence on the response profile of the competitor. The elements on the left describe the understanding that drives a competitor’s behaviour. In reality, it is very tough to investigate these subjects because obtaining information concerning future goals and assumptions is extremely difficult. The current strategies and capabilities of competitors are topics, which are easier to investigate. For each element, there is a catalogue of questions that can be processed to obtain a statement about the competitor's strategy and market position. All these approaches can be useful, not only for the analysis of the competition but also as a framework for self-analysis of a company.[28]

Competitors that must be analysed are mostly companies that operate in the same industry and offer the same or similar products and services. It should be noted, however, that in addition to the significant existing competitors, potential competitors that could come on the scene, also have to be considered.[29]

[26] cf. Appenfeller, W.; Buchholz, W. (2011), p. 67
[27] cf. Porter, M. E. (2004), p. 47
[28] cf. Porter, M. E. (2004), pp. 47-49
[29] cf. Porter, M. E. (2004), pp. 49-50

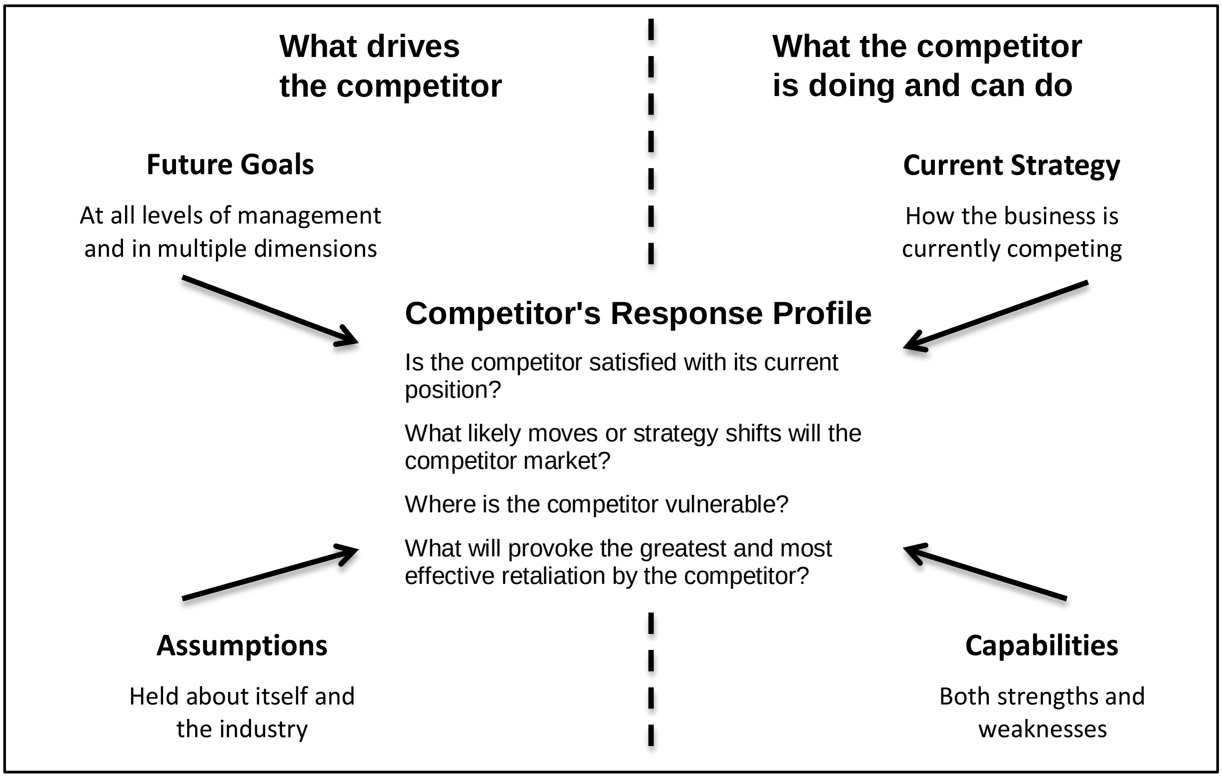

Figure 5: Components of a Competitor Analysis[30]

2.2.2.1 Future Goals

By knowing competitor's goals, statements can be made that allow an insight into the competitive strategy. An identification of the competitor's market share, profitability and organizational performance can help to understand where a competitor is headed. Depending on a company's primary goals, it will react differently to changes in the market. Therefore, knowing a competitor's goals can help to predict response to strategic changes.[31]

Once the goals are identified, they can be compared to the current situation and thus statements can be made, on whether the competitor is satisfied with the current situation. If the current situation is satisfactory, then a change of strategy is not in sight. To determine the competition's future goals, some fundamental questions that are dealing with various strategic positions of competitors, must be answered.[32]

[30] Porter, M. E. (2004), p. 47
[31] cf. Bensoussan, B.; Fleisher C. (2009), p. 46
[32] cf. Camphausen, B. (2007), p. 52

An overview of the factors that might influence the objectives of a company is given below: [33]

- Values and corporate policy of the competitor
- Risk attitude of the competitor
- Financial goals of the competitor (short and long term)
- Structure and organisation of the competitor
- Salary system of the competitor (performance fees, long term incentive plan, stock options)
- Accounting, controlling and reporting system of the competitor
- The competitor’s Supervisory Board and Advisory Board

When a company knows the competitor’s targets, a direct exchange of blows may be prevented. A competitor will defend his strategic objectives, as soon as he sees these threatened. With known targets, positioning in the market will be possible, which can help prevent or at least calm a direct confrontation.[34]

2.2.2.2 Assumptions

Identifying the competitor’s assumptions is the second component in competitor analysis. It can be divided two main categories:[35]

- The competitor’s own assumptions about himself
- The competitor’s assumptions about the industry and the other companies in it

The operation of a company is highly dependent on its assumptions. They are closely related to the objectives and provide the basis for the chosen strategy. Just as companies make assumptions about themselves, they also try to assess their industry and competitors.[36]
If assumptions are made incorrectly, it can result in a significant advantage for competitors. On the other hand, incorrect assumptions of competition can also lead to benefits for the own company. A close examination of the assumptions can reveal whether a competitor may assess the situation incorrectly and thus will misinterpret the importance of certain events or react too slowly to market changes. A

[33] cf. Camphausen, B. (2007), p. 52
[34] ibd.
[35] cf. Deltl, J. (2011), p. 80
[36] ibd.

competitor's assumptions can often be derived from actions that have been made in the recent past.[37]

2.2.2.3 Current Strategy

The examination of the current strategy of competitors is the next item in the competitor analysis. The strategies of the competitors are in close relationship to their goals and assumptions. Competitor strategies are crucial for the development of the market and can be regarded as a combination of the characteristics of its respective value chains. A successful competitive analysis requires knowledge about the strategy of competition.[38]

2.2.2.4 Capabilities

The final component of the competitive analysis is to consider the capabilities. Whether a competitor is able to realise its objectives, assumptions and strategies also depends on its strengths and weaknesses. Several key areas of the business must be examined for strengths and weaknesses.[39]
Different capabilities can be interesting for corporate observation, such as the analysis of core capabilities. Also the ability to grow in business and to adapt to change are factors of the competitive analysis. Furthermore, it is important that a competitor can react quickly to the movements of others and that he has the power to take on a battle for market share.[40]

2.2.2.5 Competitor Response Profile

A response profile can be created from the four basic elements of competition analysis. First, a company's strategic steps are to be identified, and then all possible changes in the environment should be determined.[41]

[37] cf. Camphausen, B. (2007), p. 53
[38] cf. Deltl, J. (2011), p. 80
[39] cf. Porter, M. E. (2004), pp. 63-67
[40] ibd.
[41] cf. Camphausen, B. (2007), p. 53

The reaction profile of competitors helps to answer the following key questions:[42]

Which strategic steps or environmental changes…

- … surprise the competition most?
- … provoke the competition most?
- … suppress the goals, strategies and capabilities of competition best?

2.2.3 Company analysis

The company analysis completes the analysis of the current situation. The aim is to identify any strengths and weaknesses of a company in order to find a suitable business strategy. Depending on the company profile and set targets, an appropriate strategy should be chosen so that the company's success can be achieved. There are several methods of analysis for the identification of strengths and weaknesses and external factors such as potential external threats or opportunities. The so-called SWOT Analysis is one of the most applied methods.[43]

2.2.3.1 Competitive Strategies

A company may pursue different strategies to position its products and services in the market. It is crucial for the competitive strategy, which position within an industry a company has. According to a theory developed by MICHAEL PORTER, three different generic strategies can be distinguished:[44]

- Overall Cost Leadership
- Differentiation
- Focus

Usually, a company applies one of these strategy types, but it is also possible to use more than one strategy. The implementation of a strategy requires full commitment and efficient organisation. The aim should be to use the advantages of the business's own strengths to outperform other competitors. A graphical representation of Porter's competitive strategy is given in figure 6.[45]

[42] cf. Camphausen, B. (2007), p. 53
[43] cf. Zdromyslav, N. (2002), pp. 18-19
[44] cf. Porter, M. E. (2004). pp. 34-35
[45] ibd.

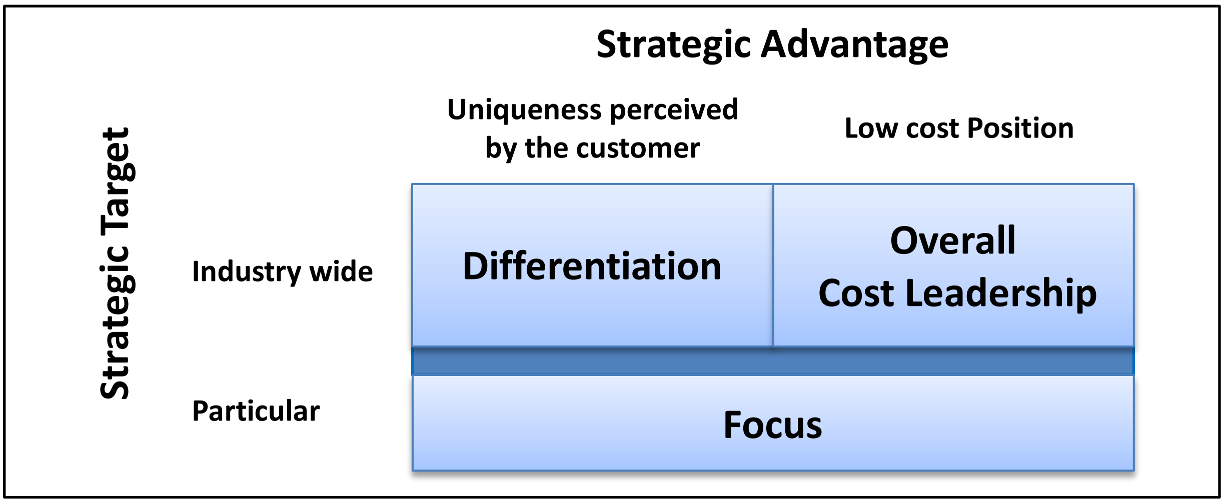

Figure 6: Generic strategies according to M. E. Porter[46]

The core of any strategy is the creation of competitive advantages. This requires a decision of company management. If a company wants to create a competitive advantage, it must choose a field. Working with several strategies usually leads to below average performance and a low or even no competitive advantage.[47]

Overall Cost Leadership:
This strategy has the aim of being the cost leader within the industry. Such a cost position opens the seller a great scope in shaping the prices. The industry structure sets out the conditions for the successful implementation of this strategy. Thus companies using this strategy usually concentrate on standard products and do not have any luxury products in their portfolio. The cost leader must identify all sources of cost advantages and use them in an efficient way. If a company has adopted cost leadership, it can achieve superior results if it is able to enforce prices at the level of the industry average.[48]
For example, one company which use the overall cost leadership strategy is RyanAir, a low cost airline. The customers receive cheap offers that meet the basic purpose, entirely without luxury.[49]

Differentiation:
With this strategy, a company aims to differentiate its products or services from others and therefore tries to become unique in its industry. The differentiation strategy is aimed at performance-based superiority of the company. Typical characteristics of a differentiation strategy are an intensive care brand, a permanent

[46] own representation based on Porter, M. E. (2004), p. 34
[47] cf. Porter, M. E. (2010). p. 38
[48] cf. Runia, P. et al. (2011), p. 132
[49] cf. Hoskisson, R. E. et al. (2008), p. 135

optimization of the performance of the products, a medium to upper price level and intensive communication.[50]

There are numerous approaches for differentiations like brand image, technology, features, service or dealer network. Ideally, a company differentiates itself in more than one dimension. The company Caterpillar, for example, offers high quality products but is also known for its dealer network and its unique spare parts availability in the industry.[51]

Focus:

The strategy of focusing should help to generate a competitive advantage in niche markets. There is a concentration on certain customer groups, a particular product group and a specific geographic market. Focusing can be done in two ways. First, the focus can be on cost. Here the company is targeting a cost advantage. The second variant is focusing on differentiation.[52]

2.2.3.2 Methods for company analyses

Before starting innovation projects, the strategic orientation of the company has to be determined.[53] There are various tools for strategic planning and evaluation. To mention all methods would go too much into detail, so here, the SWOT Analysis and Benchmarking will be briefly described as they are of importance for the practical task.

<u>SWOT-Analysis:</u>

The term SWOT derives from the words Strength, Weaknesses, Opportunities and Threats. The method serves as a direct derivation of strategies from the previously identified strengths and weaknesses. The results of a previously conducted strengths and weaknesses analysis are entered in list-like form in a four-field matrix. In the second dimension of the matrix, the results of the analysis of opportunities and risks are listed. The SWOT-Analysis scheme is illustrated in figure 7.[54]

[50] cf. Runia, P. et al. (2011), p. 132
[51] cf. Porter, M. E. (2004), p. 63
[52] cf. Runia, P. et al. (2011), p. 132
[53] cf. Gelbmann, U. et al. (2003), p. 12
[54] cf. Gelbmann, U. et al. (2003), pp. 12-13

	List of weaknesses	List of strengths
List of opportunities	**Strategy: Catch up**	**Strategy: Push**
List of risks	**Strategy: Avoid**	**Strategy: Secure**

Figure 7: Systematics of the SWOT-Analysis[55]

The resulting strategies can be characterised as follows:[56]

- **Opportunities-Strength-Strategies:** This area contains the greatest competitive advantages. Therefore, companies must focus on activities in this area.
- **Opportunities-Weaknesses-Strategies:** Deficits over the competition must be minimised, in order not to miss possible opportunities.
- **Risks-Strength-Strategies:** Defending achievements, in order to hold the current position.
- **Risk-Weaknesses-Strategies:** Forcing an avoidance of the particular areas in order to avoid potential hazards.

<u>Benchmarking:</u>

Benchmarking is defined as the ongoing process of a company striving for improvement in its performance and competitive advantage by orientation towards the best performances in the industry or other reference performances.[57]

By using benchmarking, a company is able to discover opportunities to usually improve its own performance or even to become the best in its industry. The best solutions do not only refer to the solutions of competitors. Also, the performance of suppliers and other partners, as well as suggestions, complaints or requests from customers, can be used as a reference for benchmarking.[58]

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[55] own representation based on Gelbmann, U. et al. (2003), p.13
[56] cf. Gelbmann, U. et al. (2003), p. 13
[57] Sabisch, H.; Tintenlot, C. (1997), p. 12
[58] cf. Sabisch, H.; Tintenlot, C. (1997), p. 12

In benchmarking, first of all, the company's goals must be set. An improvement in business processes can only be carried out if the strategies and processes of the company are known accurately enough. After a critical review of the company's strategy, any weak points can be tackled. Usually, after successful application of benchmarking, the position on the market can be significantly improved.[59]

2.3 Management of market and technology trends

A trend is defined as the recognizable direction of a development.[60]

In the innovation process, the timely detection of new trends is a key factor for success. Companies that want to remain competitive are obliged to identify new trends early and respond to them. Therefore, trend analysis is an appropriate tool for preparing for all kinds of future developments.[61]

2.3.1 Trend research for identification of future developments

Trend research or management is about identifying and evaluating company relevant trends in order to take appropriate measures for their handling or further observation.[62]

Changes of development directions can occur at different levels, so the trend term is very diverse. Trends are dependent on the level that is considered. The time frame in which one can observe the evolution of trends defines these levels:[63]

- **Fashions** describe individual trends and socio-cultural effects. This term is limited to market and consumer research.
- **General Tends** denote the summarised fashions and effects. Depending on the type of business, consumer trends can be spoken of.
- At the third level, trends are merged into **Megatrends**. They represent a development, which is valid over many years.
- **Metatrends** describe overarching and fundamental trends.

[59] cf. Jochem, R. et al. (2010), p. 129
[60] Fink, A.; Siebe, A. (2006), p. 124
[61] cf. Herrmann, A.; Huber, F. (2009), p. 149
[62] Fink, A.; Siebe, A. (2006), p. 127
[63] cf. Fink, A.; Siebe, A. (2006), pp. 128-129

Which trend term is interesting for an investigation depends on the respective company and its industry. Trend research can be executed for all levels by following a specific process model, which is described in the following chapter.

2.3.2 Process model of trend management

Figure 8 shows a process model of trend management, which can be used for identifying and evaluating different trends.

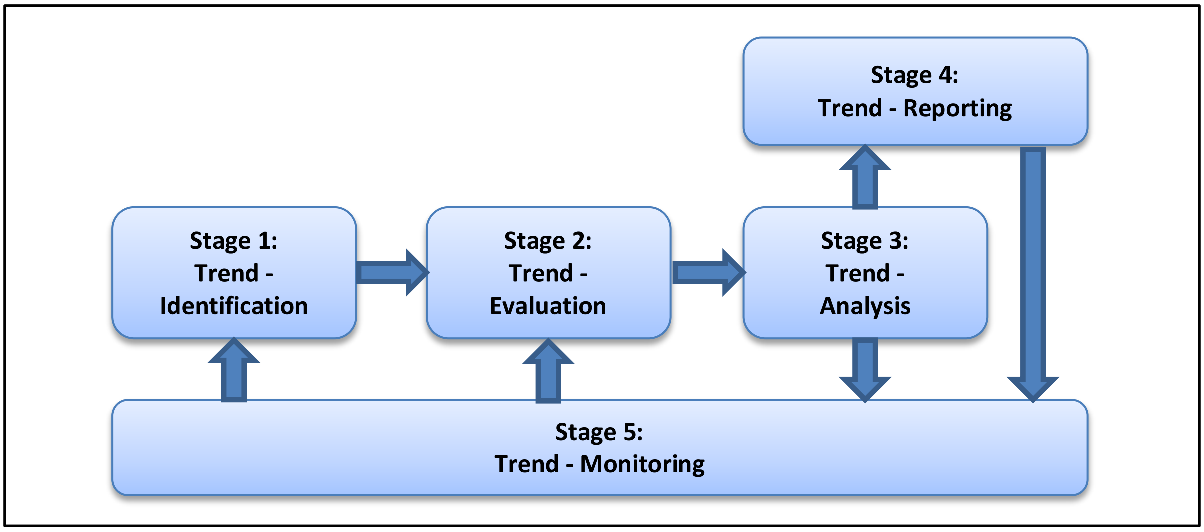

Figure 8: Process model of trend management[64]

2.3.2.1 Trend Identification

The starting point of each trend management process is the trend identification. The design of the trend identification strongly depends on the industry sector and the application background. MATTHIAS HORX, a German futurologist, specifies four steps for trend identification: [65]

- **Semiotics:** significant change patterns in society are detected in the specific area of consideration.
- **Evidence:** Statistical and other sociological facts must be found to substantiate the identified trends.
- **Economic matching:** This step is to determine for which industries or consumer groups the trends are of relevance.
- **Naming:** In the final step, the identified trends are named.

[64] own representation based on Fink, A.; Siebe, A. (2006), p. 130
[65] cf. Fink, A.; Siebe, A. (2006), pp. 130-132

2.3.2.2 Trend Evaluation

An evaluation of trends only makes sense after all relevant information is gathered and prepared. The identification follows an assessment of the various trends based on different criteria:[66]

- the trend's impact strength on the company
- section or department that is impacted within the company
- probability of the trend occurring at a certain time
- uncertainty of the trend

2.3.2.3 Trend Analysis

Trend analysis involves creating a trend portfolio, which demonstrates the probability of occurrence and the degree of impact of trends on the company. A trend portfolio is illustrated in figure 9.

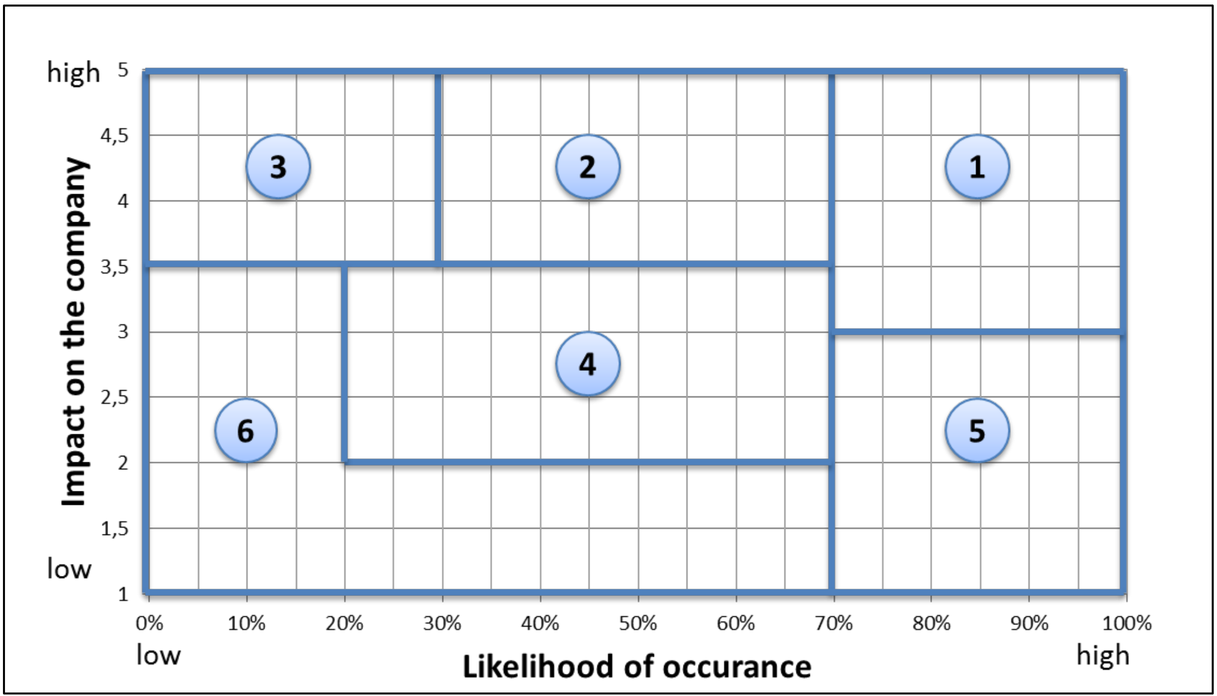

Figure 9: Trend portfolio[67]

[66] cf. Fink, A.; Siebe, A. (2006), p. 133
[67] own representation based on Fink, A.; Siebe, A. (2006), p. 134

Six areas can be distinguished and each of them requires different actions: [68]

(1) React to trends immediately: Trends in this area are of high importance for the company and there is a great likelihood that they will occur with. Chances must be taken and risks must be avoided.
(2) Proactively take on trends: These trends are of great importance for the company but it is not clear whether they will really occur. The company should act upon these trends, monitor the development and if possible, even influence it.
(3) Be prepared for surprising trends: Likelihood of occurrence is rather low but the impact on the company is high. Preparing contingency plans will help in taking chances and avoiding risks in case the trend occurs anyway.
(4) Observe trends: These trends are currently not in the centre point but they can develop in all directions. They should be watched very closely.
(5) Observe and integrate trends: Respective trends only have a low impact on the company. Nevertheless, they should be observed and integrated in the company strategy planning.
(6) Avoid using unnecessary resources: These trends should not be the focus of planning.

2.3.2.4 Trend Reporting

Information needs are assessed so that a suitable way can be found to communicate the relevant information. It must be clarified, whether the information is reported frequently or depending on the situation. To ensure excellent communication between the research team and management, it is necessary that communication between the two groups is "short track".[69]

2.3.2.5 Trend Monitoring

In Trend Monitoring, previously known and particularly important trends and their influencing factors are observed continuously. Observers can be internal team members as well as external persons with appropriate expertise. The results of the observation flow back to the trend-management coordinating research team. The gained knowledge can then be used to improve the findings.[70]

[68] cf. Fink, A.; Siebe, A. (2006), pp. 133-134
[69] cf. Fink, A.; Siebe, A. (2006), pp. 135-137
[70] ibd.

2.4 Market research for analysing markets and trends

This chapter contains the basic procedures for the identification and assessment of data and information in the market and trend analyses.

2.4.1 Importance of information in market analyses

Information is data that gains meaning through context and further can be transformed into knowledge by experience. A decision based on information is the selection of alternatives of several possible options for action. Information serves to identify, evaluate and solve problems.[71]

2.4.1.1 Information in market research

Information is the basis for all decision-making processes that are necessary for the control of corporate activity. The corporate activity is made up of a variety of actions, which are crucial for the company's success. This includes the marketing process. Economic decision-making involves the consideration of relevant information in order to achieve the specified corporate goals. It follows that corporate governance can be seen as a continuous decision making.[72]

2.4.1.2 Evaluation criteria for information

Information is tied to specific requirements to ensure that they are useful. Information must provide new knowledge to the user while meeting the following preconditions:[73]

- **Relevance:** Information must be relevant to the decision-making event.
- **Completeness:** Information should be recorded as accurately and completely as possible.
- **Actuality:** Outdated information, which can lead to wrong decisions in the planning process, must be avoided.
- **Objectivity:** Collection, analysis and interpretation of information requires objectivity. Meaning that there must be unaffected and neutral conductors of investigation.

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[71] cf. Koch, J. (2009), p. 16
[72] cf. Berekoven, L. et al. (2009), p. 19
[73] cf. Koch, J. (2009), p. 21

- **Security:** Information should help to reduce the uncertainty of decisions. The use of certain information should ensure a high probability of the predicted occurrence.
- **Utility:** Information is useful if the costs for its acquisition are lower than the income from its use. A cost / benefit analysis can be performed easily and provides a statement on the usefulness of information.

2.4.1.3 Institutions of information gathering

Market research for analysing markets can be performed by different bodies. In principle, it is possible to distinguish between self and external market research. Most market research is provided internally. Specialised market research departments are tasked with this function. In larger companies there is a specific group within the marketing department which undertakes market research. Certain very large organisations even have a separate market research department.[74]
External providers of market research are specialised in collecting and evaluating data and information. They focus on a few highly specific market research techniques and are able to investigate certain problems more objective. Such institutions are independent commercial enterprises, which mainly focus on market research. The surveys are conducted autonomously and generally without help.[75]

2.4.2 Aims of market research

The aim of market research is the timely presentation of decision-relevant information to decision makers, taking into account financial, staff, time and legal restrictions.[76]

Market research is performed to provide a meaningful analysis and forecast of the desired division. The main objectives of market research are listed below:[77]

- Early detection of trends
- Identification of customer needs and expectations
- Findings on the benefit assessment and willingness to pay of the consumer
- Increasing predictability of product innovation
- Generation of independent market opinions

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[74] cf. Mooi, E.; Sarstedt, M. (2011), p. 5
[75] cf. Mooi, E.; Sarstedt, M. (2011), pp. 5-7
[76] Fantapié Altobelli, C. (2011), p. 6
[77] cf. Ebel, B. (2004), p. 178

- Dialog and information exchange with shareholders

The findings from the market research act as a basis for the conception phase in the management decision process. The results of the analysis phase are essential for the further decision-making and therefore have to be carefully worked out.[78]

2.5 Process of market research

In order to analyse a market correctly, the instrument "market research" is used. A systematic and planned approach is the basic requirement for successful market research. The process of market research consists of the sections planning, implementation and control. The section “planning” can be divided into three steps.[79] Figure 10 shows the various stages of the research process.

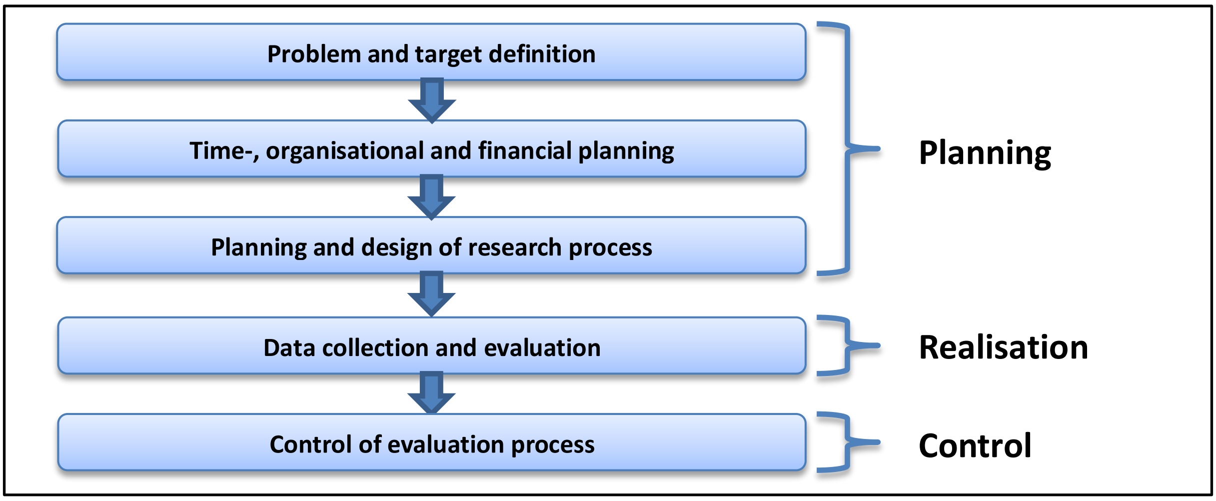

Figure 10: Market research process[80]

2.5.1 Definition of problem and target

At the beginning of the process is the definition and formulation of research problems and research objectives. The required information needs to be defined precisely so that the investigation target can be derived. Creating a problem catalogue facilitates the classification of problems according to their type and scope.[81]

[78] cf. Ebel, B. (2004), p. 178
[79] cf. Fantapié Altobelli, C. (2011), p. 16
[80] own representation based on Fantapié Altobelli, C. (2011), p. 16
[81] cf. Berekoven, L. et al. (2009), pp. 31-32

Hypotheses that describe problems and questions are often created. After an extensive investigation, these hypotheses can then be confirmed or rejected.[82]

2.5.2 Time-, organisational- and financial- planning

After problem and target definition the time-, organisational-, and financial planning follows. Within this phase, a time frame should be drawn up indicating which period is interesting for the investigation.[83]
An estimation of the time required should make clear from the start, how long the investigation will take, and which milestones could be set. The established schedule is largely determined by the size of the task and the resources used. So it is important to estimate the expense and the available staff for the project.[84]
In order to stay true to the timetable, sufficient organisational planning is essential. This planning section aims to determine all involved parties. It is also determined, who will carry out the market research. Possibilities are internal and external parties. In case of internal market research, the team must be put together.[85]
Furthermore, all prerequisites must be clarified. If there is already information that might be helpful for conducting the market analysis, it must be provided. Firstly, it should be considered which information can be procured internally and which externally. Furthermore it must be defined, in which form the result should be present and how it should be documented. This includes whether the results will be public or only the concerned department will be able to access them.[86]
Finally, the available budget is set. In principle, at this stage, all costs incurred for the acquisition of information are reported. This includes the cost of employees, equipment and all other expenses incurred in carrying out the market analysis.[87]

A checklist of the main points in this planning phase is given below:[88]

- Define target market and target group for research
- Define required information by type, extent and quality
- Which information can be gathered internally and which externally?
- Which external information can be obtained through primary research and which through secondary research?

[82] cf. Koch, J. (2009), p. 22
[83] cf. Fantapié Altobelli, C. (2011), p. 17
[84] cf. Heche, D. (2004), p. 45
[85] cf. Fantapié Altobelli, C. (2011), p. 17
[86] cf. Heche, D. (2004), pp. 42-48
[87] cf. Koch, J. (2009), p. 23
[88] ibd.

- When should the required information be available?
- Which budget is available for information gathering?

After clarifying the organisational issues, the planning of the study design is the next step.

2.5.3 Planning and design of research process

The phase planning and design of research process serves for content planning and concretisation of the survey. It is defined which method is the best for collecting data and information. The method can be derived from information, which emerged in the financial-, organisational-, and budgeted planning. In a final step, the survey framework has to be determined before the data collection can begin.[89]

2.5.3.1 Selection of research approach

The determination of the basic research approach is the first step in planning the survey. It can be distinguished between explorative, descriptive and causal studies. The differences between the various approaches are described below.

Explorative studies:
This approach is used to obtain initial insights into the current research problems. It is applicable to complex issues for which there is still little knowledge. They are used to develop a basic understanding of the study subject. With explorative studies subsequent investigations can be controlled better and thus financial resources can be saved. A high degree of flexibility and creativity is required for the research team as the level of knowledge is still very low at the beginning of the research. It may be necessary to change the research approach over the course of the investigation in order to adapt to the changing level of information.[90]
Data collection methods for exploratory studies are typically secondary research and interviews and observations (see 2.5.3.2). By doing secondary research, data and information already collected may be used for its own purpose. Observations and interviews can be targeted to provide better insight for the problem. Two very popular methods in explorative studies are "case studies", which concentrate on the more

[89] cf. Fantapié Altobelli, C. (2011), p. 17
[90] cf. Kollmann, T.; Freiling J. (2008), p. 365

detailed analysis of specific cases in the field of investigation, and “benchmarking”, in which the application of comparison should lead to new findings.[91]

Descriptive studies:

In descriptive studies, it is usually important to make accurate statements. This can relate to the size of the market, the characteristics of customer groups or the growth of markets. Often, it is conducted as the next step after the exploratory study. Descriptive studies deal with the characterisation of markets and market segments, the analysis of correlations of variables and forecasts. Therefore, the descriptive research approach is also often used for predictive analytics, such as forecasting. [92]
More objectivity is required than in the exploratory method here. The study is based on a well-defined research objective and a concrete defined demand of information. Typical methods include observation and questioning of persons who can provide information to solve the task. This can be potential clients but also experts in the relevant field.[93]

Causal or experimental studies:

This method deals with the analysis of cause-effect relationships. Important goals of causal studies are performance control and the prognosis of market development. For example, an exploration of the success / failure of success of already implemented measures is a causal investigation. Experiments are a typical method for gaining information in causal studies.[94]

2.5.3.2 Selection of information sources and survey methods

The choice of survey method is done to define the research method and the approach for information gathering or processing. The survey method is greatly influenced by the information amount to be determined and the information already available. In terms of information sources, in principle, primary research and secondary research can be distinguished between.[95]

Secondary research is defined as the collection and analysis of data gathered at an earlier date, possibly also collected for another purpose.[96]

[91] cf. Fantapié Altobelli, C. (2011), pp. 21-22
[92] cf. Kuß, A. (2012), p. 38
[93] cf. Fantapié Altobelli, C. (2011), pp. 22-23
[94] cf. Hohn, S. (2008), p. 59
[95] cf. Kuß, A. (2012), p. 42
[96] Fantapié Altobelli, C. (2011), p. 23

Secondary research is also known as desk research. In contrast to primary research, the data is already collected but needs to be analysed. This is much cheaper and less time consuming than collecting data itself. Desk research must not be underrated because it often provides enough information for decision making. In an ideal research process, first secondary research should be run and then the missing information is determined by primary research.[97]
Secondary data can be obtained from both internal and external sources. Internal data sources might include sales statistics, cost accounting, sales reports and marketing information systems. External data sources include all data from various external statistics and scientific literature, business publications, back-data from market research companies and external databases. Secondary data can be stored in archives but can also be available through online databases and the internet.[98]

If there is insufficient information content from secondary research, the necessary information is collected through primary research. Another term used for primary research is field research.
The primary research is referred to the new data collection for an upcoming investigation problem.[99]

This method of obtaining information requires a thoughtful approach so that the information can be collected efficiently, in an uncomplicated manner, cheaply and with a high degree of truth. Typically, within primary research, information is obtained by three different methods: questioning, observations and experiments.[100]

Questioning belongs to that kind of survey, where test persons comment on the survey subject.[101]

Within primary research, questioning is the most important method for gaining information. The goal is to obtain the desired information from a target group by means of oral and/or written questioning. The methodology of questioning can give the investigative body a lot of freedom. Questions can be adjusted very precisely to the problem but this also means that it must be carefully considered, who, how and what will be asked. So the choice of questioning instruments for determining how the communication with the test persons works is very important. For qualitative exploratory research, in-depth interviews, qualitative open interviews and group

[97] cf. Koch, J. (2009), p. 46
[98] cf. Koch, J. (2009), pp. 42-45
[99] Kuß, A. (2012), p. 42
[100] cf. Fantapié Altobelli, C. (2011), p. 26
[101] Grunwald, G.; Hempelmann, B. (2012), p. 46

discussions are popular methods. Here, the respondents answer completely freely and are able to contribute their own views. This type of qualitative questioning is for building a foundation of knowledge, which can be discussed in more depth later.[102]
The qualitative descriptive questioning is more target-oriented. The text and structure of the questions are precisely defined, which facilitates the interviewee with a lower degree of freedom but leads to more accurate results. Methods which come into consideration are, for example, structured interviews, written surveys, telephone interviews and computer-based surveys such as online surveys.[103]

Observations are the second method for gaining information in primary research. With observations the searched information is not obtained from the statement of the respondent, but from itself or its behaviour.[104]
The observer behaves passively and keeps trying to acquire an unclouded image of the current situation. The objectivity of the results of observations is much higher than that in questioning. Observations differ in transparency, structure and degree of participation of the observer. An observation may be open or covered, which means the observed is unaware of the investigation. Typical areas of application for the method of observation can be found in trade and consumer behaviour research. Sales figures, for example, can be monitored easily and provide an objective insight about customer interest in a product.[105]

The third method of data collection is the experiment. Experiments are made up of the elements of questioning and observation and differ mainly in the specific experimental arrangement. With experiments, the connection between two or more factors is determined. Different variables have a correspondingly varying impact on test units. With experiments, the effect of an independent variable on a dependent variable can be determined. An example is the effect of the change in price (independent variable) on the sales of a product (dependent variable).[106]

2.5.3.3 Selection of observation unit

Before starting the realisation phase, the survey unit must still be determined. It can be distinguished between full sample survey and partial sample survey.

[102] cf. Koch, J. (2009), pp. 48-52
[103] cf. Koch, J. (2009), p.49
[104] cf. Hüttner, M.; Schwarting, U. (2002), p. 158
[105] cf. Koch, J. (2009), pp. 69-71
[106] cf. Pfaff, D. (2004), pp. 38-39

Within the full sample survey, all eligible units of investigation are included. This type of investigation is rarely in the field of market research because often, it is not possible to collect the information in this extensive way due to time and cost reasons. When the population of the information providers is limited in numbers, for example, in dealer surveys, this method can lead to economically feasible success. However, the partial sample survey finds use in market analyses more often.[107]

Within the partial survey, only a section of the population will be considered for the investigation. Samples are examined, which should reflect the characteristics of the population. Partial sample surveys have reduced effort required to time and cost compared to full sample surveys. Due to the limited scope of investigation, a more exact result can be expected. If survey units must be destroyed during the study, like in quality tests, a partial sample survey is the only possible way.[108]

2.5.4 Data collection end evaluation

After detailed planning of the study design, the implementation phase can start. The correct implementation of field work is just as important as planning.

2.5.4.1 Data collection and processing

It is essential that the data collection is sufficiently well prepared. The questions may be formulated only by persons with enough background knowledge. The information is collected, for example, by means of questionnaires. The setup of the questions is essential. In interviews, it must be ensured that the answers are properly registered. The answers must be recorded verbatim, as well as with additional notes and comments. At the same time, the researcher must check whether the temporal, financial and physical aspects are observed. [109]

After the data collection is completed, the data material is on hand, dependent on the prior survey method, in the form of completed questionnaires, observation records, audio or video tapes, etc. So that the data can be analysed, they must be processed next. Errors must be detected and eliminated. Data and responses can be incomplete, illegible or unintelligible. In a further process all usable data and information is digitized and sorted categorically.[110]

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[107] cf. Fantapié Altobelli, C. (2011), p. 183
[108] ibd.
[109] cf. Koch, J. (2009), pp. 211-215
[110] ibd.

This further processing of data must always be made in primary research. In secondary research data processing is almost never necessary because in most cases the data is in a form in which the evaluation and analysis can begin immediately.[111]

2.5.4.2 Data analysis

The purpose of the data analysis is to organise, consolidate and clearly display the collected data. Qualitative information collected may already have a clear statement, such as an answer to a specific interview question. Quantitative data still needs to be further processed in an appropriate manner in order to obtain information that can be used for decision making. Depending on whether it is qualitative or quantitative data, various analytical methods have to be applied.[112]

Statistical methods are suitable for the analysis of quantitative data. There are various criteria according to which the process can be divided. An example for such a criterion is the number of data-variables considered. Depending on the relation of the variables to each other, it can be distinguished between univariate, bivariate and multivariate methods. Each of these methods, in turn, offers statistical approaches that can be used for data analysis.[113]

The results of qualitative surveys are usually soft data, which cannot be evaluated using quantitative methods. In qualitative content analysis, all types of audio-visual recordings were examined. Sometimes the results can be directly derived from the records or interviews. Usually a qualitative study delivers a wealth of audio visual and textual material which must be transcribed, organized and evaluated.[114]
After the transcription, the data is available in written form. In the next step, the content is analysed according to certain rules in order to interpret the data in such a way that a comprehensible statement can be made. Out of the statements, generalised results have to be derived in order to complete the data analysis.[115]

[111] cf. Koch, J. (2009), pp. 211-215
[112] cf. Fantapié Altobelli, C. (2011), p. 220
[113] cf. Reiter, G.; Wolf, G. M. (2000), p. 70
[114] cf. Fantapié Altobelli, C. (2011), pp. 343-344
[115] cf. Fantapié Altobelli, C. (2011), p. 344

2.5.4.3 Documentation and presentation of the results

The implementation phase is completed by the interpretation and presentation of results. The outcome must be reproduced as clearly, comprehensibly and user-optimised as possible. For that, the possibilities of an oral or written presentation are available. The presentation of the results often includes a final discussion. In the context of this discussion it must be clarified if the results contribute to the solution of the problem or if an additional investigation must be carried out to compensate the lack of information.[116]

A market research report in written form is used by default to document the results. Thereby, some formal and substantive aspects must be considered. The market research report should include:[117]

- Content
- Tasks and objectives
- Structure of the Study
- Survey method of investigation
- Evaluation procedures
- Presentation of results with tables and graphs
- Summary of key findings
- Conclusions and recommendations
- Appendix table
- Statistical tables

With regard to the former aspects, it should be noted that the scope of the report is limited to a minimum, but still contains all the important statements. It is important that the results can be easily understood. This means that the report should not be too complicated and statements made should, if possible, be accompanied with pictorial representations and tables. The charts and graphs should be designed in a consistent format. They should be clear, well-structured and replicable.[118]
In addition to market research report, an oral presentation of the results can be held. This offers the advantage of communicating directly with the people involved, which means the ability to eliminate any confusion in a discussion immediately. Thorough preparation of the presentation is important so that the results of the research can be conveyed as credible. It is important that the presentation is designed concisely

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[116] cf. Reiter, G.; Wolf, G. M. (2000), p. 265
[117] cf. Koch, J. (2009), pp. 253-255
[118] ibd.

graphically but clearly and simply so that the audience is not overwhelmed and can remember the key points. The same applies for written reports as for presentations: keep it short but incorporate all the important points.[119]

2.5.5 Control of evaluation process

The control of survey planning and survey implementation is a process that must be carried out by market researchers to determine if the research objectives have been met or not. It can be checked whether all listed points in the task were completed. It must also be checked if the schedule, the budget and organisational requirements have been met. Only if all the points were properly observed, the project has been successful. Responsible persons must also constantly monitor the status of the project and initiate corrective actions in case of non-conformity.[120]

[119] cf. Koch, J. (2009), pp. 253-255
[120] cf. Fantapié Altobelli, C. (2011), p. 20

3. Integrated Roadmapping in Innovation Processes

Markets are increasingly exposed to more complex and dynamic business processes. This has the consequence that early recognition and monitoring of technological, market, political and social development is becoming increasingly important in order to be economically successful.[121] The early identification of innovation opportunities and risks, new business areas and markets, requires the answering of some core questions:[122]

- Which changes can be expected (trends, scenarios)?
- Which opportunities and challenges will these produce?
- Which future is desirable?
- Which disruptive events could occur?
- Which successful future strategies can be derived from this?

The creation of integrated roadmaps is an effective method for answering these core questions. This chapter discusses the main characteristics of roadmaps, their application and the procedure for developing.

3.1 Roadmapping - a tool in innovation processes

The idea of the roadmap concept originated in the 80s in the United States and is used increasingly as a strategic tool in business planning. Just like a roadmap that is used for orientation in road traffic, the integrated roadmap should provide companies with a basic understanding of their location and the desired (or possible) movement by using an easily, understandable and clear graphical representation. Essentially, this means that different objects of interest, their relationships, and influencing factors are listed on a timeline in a way that one or more development paths can be identified.[123]

A precise definition for integrated roadmaps is difficult to determine, since many factors influence the characteristics. A general definition for roadmaps is: [124]

[121] cf. Popp, R.; Schüll, E. (2009), p. 255
[122] Popp, R.; Schüll, E. (2009), p. 255
[123] cf. Fink, A.; Siebe, A (2006), p. 196
[124] cf. Popp, R.; Schüll, E. (2009), p. 257

Roadmapping constitutes a search process that provides representations of the status of products or technologies in an innovation context at a given time and under consideration of type, speed and direction of possible research and technology developments. Furthermore Roadmaps bundle potential challenges and transfer them into activities, requirements and milestones.

3.1.1 Classification and application of roadmaps

In general four different types of road-mapping can be defined (figure 11).[125]

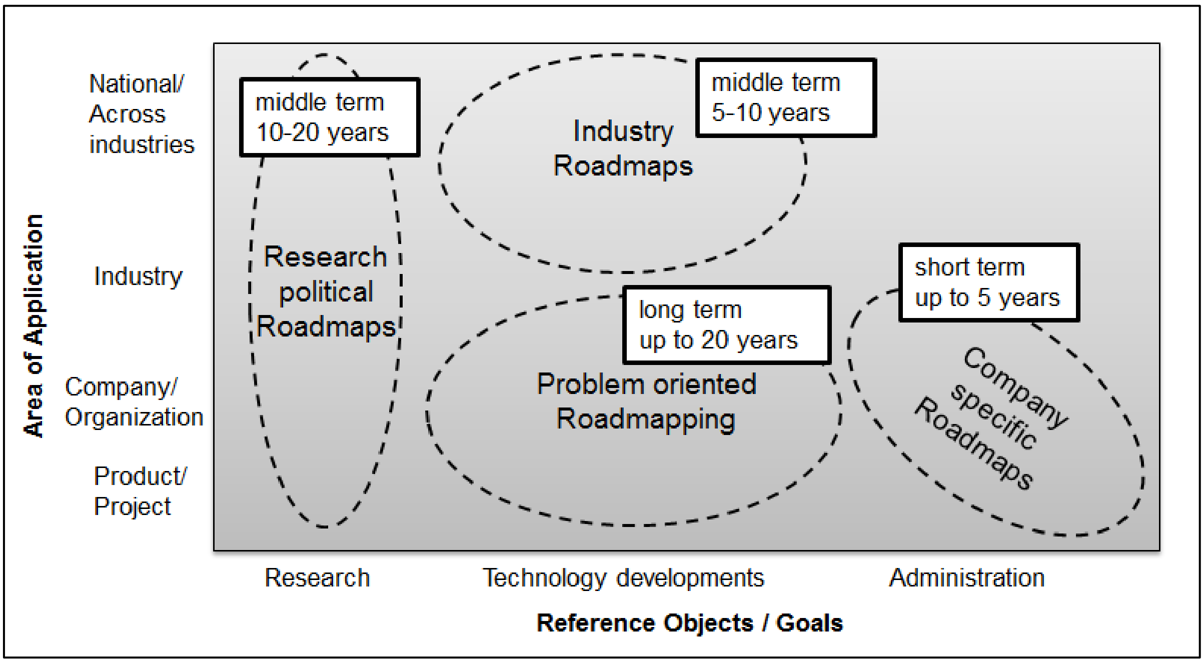

Figure 11: Types of roadmaps by area of application[126]

In essence, the types differ based on following aspects:[127]

- Subject and scope of the investigated area
- Implementation of roadmapping
- Target group and users of the roadmap
- Goals that should be reached with roadmapping
- Methods for identifying, analysing and evaluation of development processes
- Orientation logic: technology or problem-oriented
- Investigated period between the status quo and the underlying visions

[125] cf. Popp, R.; Schüll, E. (2009), p. 258
[126] own representation based on Popp, R.; Schüll, E. (2009), p. 258
[127] Popp, R.; Schüll, E. (2009), p. 257

The four basic types of Roadmapping define themselves primarily through the objective and the field of application. The basic characteristics are explained below.

Company-specific Roadmaps

These roadmaps are used to identify technological options for meeting specific product and technology requirements. Company-specific roadmaps are representations of the future of products, product lines and technologies, taking into account economics, technological expertise and business objectives. The observation period for the investigation is two to four years. This is comparatively short and usually there is little consideration of scenarios for the future. Due to the short time period, a perspective using exploration of current trends is allowed in order to obtain a reasonable result. Publication of the results is often not intended, the roadmaps are typically used only within the company. A typical implementation is company marketing for finding out future technologies.[128]

Industry Roadmaps

Industry roadmaps are created to identify trends across an entire industry. Thus, long-term competitiveness of individual companies within a sector should be ensured. It is appropriate that such roadmaps are created together by several companies of an industry or by several departments of a large company. Industry roadmaps serve as an information and strategic planning tool for the development, organisation and presentation of information on requirements, challenges and milestones, along one or more technological development paths. The development of these roadmaps is very complex and expensive, so the creation is usually carried out together by several companies within an industry. Here, not the competitive rivalry is in the focus but the creation of a mission statement, showing the development of the entire industry, which creates an advantage for all parties involved. In contrast to the Company-specific Roadmaps, the observation period for the Industry Roadmaps is about five to ten years.[129]

Problem-oriented Roadmaps

The use of problem-based roadmaps will enable an organization to identify cross-technology problems or challenges and their consequences. The procedure to development such a roadmap is different from the others, because the goal is defined at the start and the main effort lies in identifying and tracing back the different development paths. Goals can be objects or applications (e.g. touchscreen for smartphone), functional goals (e.g. emission reduction of cars) or competitive goals

[128] cf. Siebenhüner, B. (2006), pp. 399-400
[129] cf. Siebenhüner, B. (2006), p. 400

(e.g. market share). Problem-oriented roadmaps can cover periods of up to twenty years.[130]

Research and development roadmaps for politics
The concept of roadmapping can also be implemented for structuring and directing research and technology policies. The aim is to place technological developments in context of political, social and economic challenges. This should lead to the identification of long-term research needs in order to derive priorities out of that. The observation period of these roadmaps is medium term with ten to twenty years depending on the industry.[131]

3.1.2 Basic concept for Integrated Roadmaps

The object of this study calls for the establishment of an industry roadmap to display the current market situation and future developments. There is a general concept for roadmapping, which can be utilised for elaboration of technology or industry roadmaps.

Although the concept of roadmapping has become increasingly popular since the mid-90s, a well formalised methodology structure hardly exists. A few general steps can be applied in all types of roadmaps but in general there are application-specific solutions for the creation of every type of roadmap.[132]
This chapter will give an impression of a general concept for integrated roadmaps which is valid for all kinds of technology roadmaps. The basic concept can be seen in figure 12.

The graphical representation shows how the initial situation is influenced by various factors. Present-day influencing factors such as society, economy, politics, environment and technology determine business-related variables such as products, market and industry. By extrapolation and retropolation potentials for change, challenges can be found. First, existing trends are projected into the future. After that, possible developments which go beyond these trends are pointed out by application of scenario planning. Selected scenarios then get projected back into the present. In this way, approaches can be found that show how to respond to the requirements of any future markets and customers.[133]

[130] cf. Behrendt, S. (2006), p. 18
[131] cf. Siebenhüner, B. (2006), pp. 398-399
[132] cf. Behrendt, S. (2006), p. 18
[133] cf. Behrendt, S. (2007), p. 5

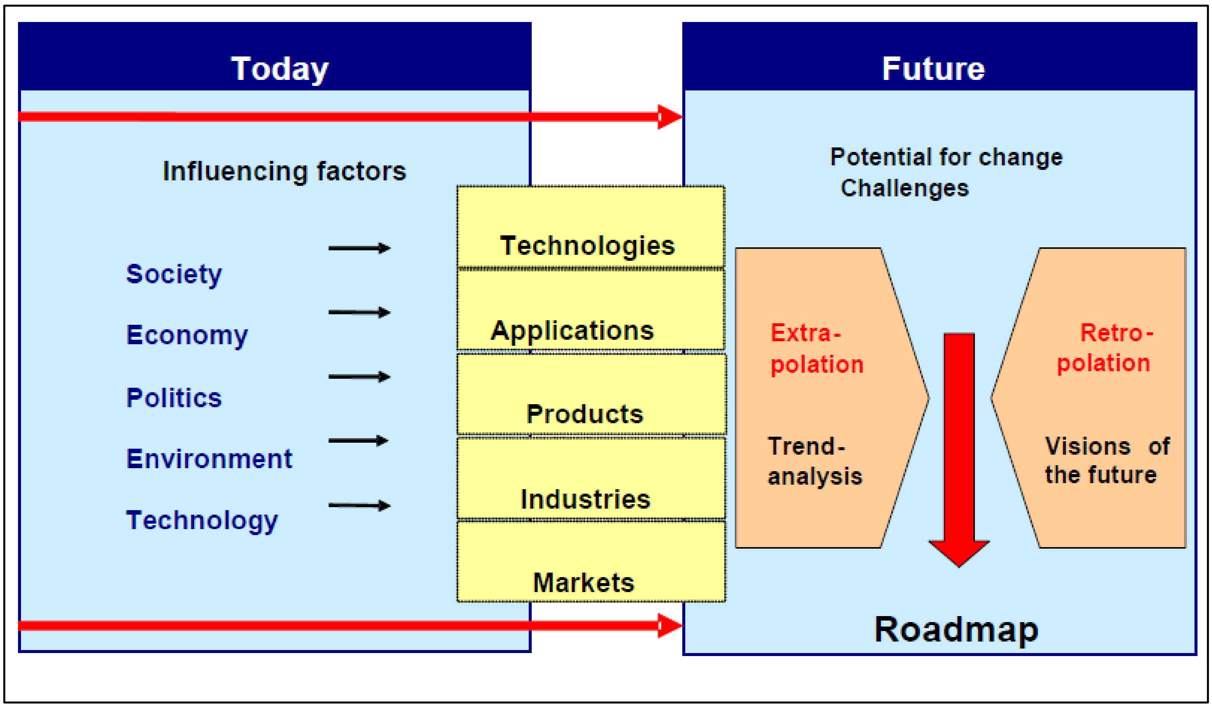

Figure 12: Basic concept for the integrated roadmap[134]

Extrapolation and retropolation complement each other. The trend analysis projects known trends into the future, whereas future scenarios serve to identify tasks and problems related to today's innovation planning. Roadmaps are representations of activities, requirements and milestones. The concept of combining trend analysis (forecasting) and visions of the future (backcasting) deliver insights which are necessary to create the roadmap.[135]

3.1.3 Requirements on Integrated Roadmaps

In order to obtain the highest possible consideration of all factors, a roadmap has to meet various requirements:[136]

- Firstly, the circumference of the considered areas has to be large enough to accommodate the complexity of the overall trends and developments. The dynamics of change in markets and technologies can be very strong, so it may be difficult to describe all correlations needed for generating roadmaps. Therefore a roadmap must provide a sufficient frame which covers all influencing factors.

[134] Behrendt, S. (2007), p. 5
[135] cf. Behrendt, S. (2007), pp. 5-6
[136] cf. Siebenhüner, B. (2006), p. 406

- Secondly, the complexity of the environment and the uncertainty of the trend statements require focusing on priorities so that a concrete insight can be gained. All available resources must be concentrated on these priorities in order to establish concrete results.
- Thirdly, when creating roadmaps it must be considered that conflicts between economic, environmental and social objectives can occur. The difficulty in creating roadmaps is to derive concrete activities from conditions of high uncertainty. The application of strategies such as interviews with experts (company, customers, and science) and scenario modelling techniques is recommended in order to identify future scenarios of possible developments.
- Fourthly, with the integration of customers and other stakeholders, future requirements and needs are revealed. Roadmapping requires good communication between the parties concerned.
- Fifthly, a roadmap must be created in a way that the immediate and future benefits can be communicated clearly and in step with actual praxis. Roadmaps must discover concrete new business opportunities. It's about figuring out which innovations have the potential to gain a key position in the future market.

3.2 Five steps of Integrated Roadmapping

Although roadmap-processes may differ in their field of application, certain basic steps can be recognised that stand behind all roadmaps. The methodology for the establishment of industry roadmaps is inspired by the practice with respect to technology roadmaps. The multi-step process of creating a roadmap begins with the determination of the search area and ends with the target group-specific transferring of the results.[137]

The five steps that are necessary to create the roadmap are shown in figure 13.

[137] cf. Behrendt, S. (2007) , p. 7

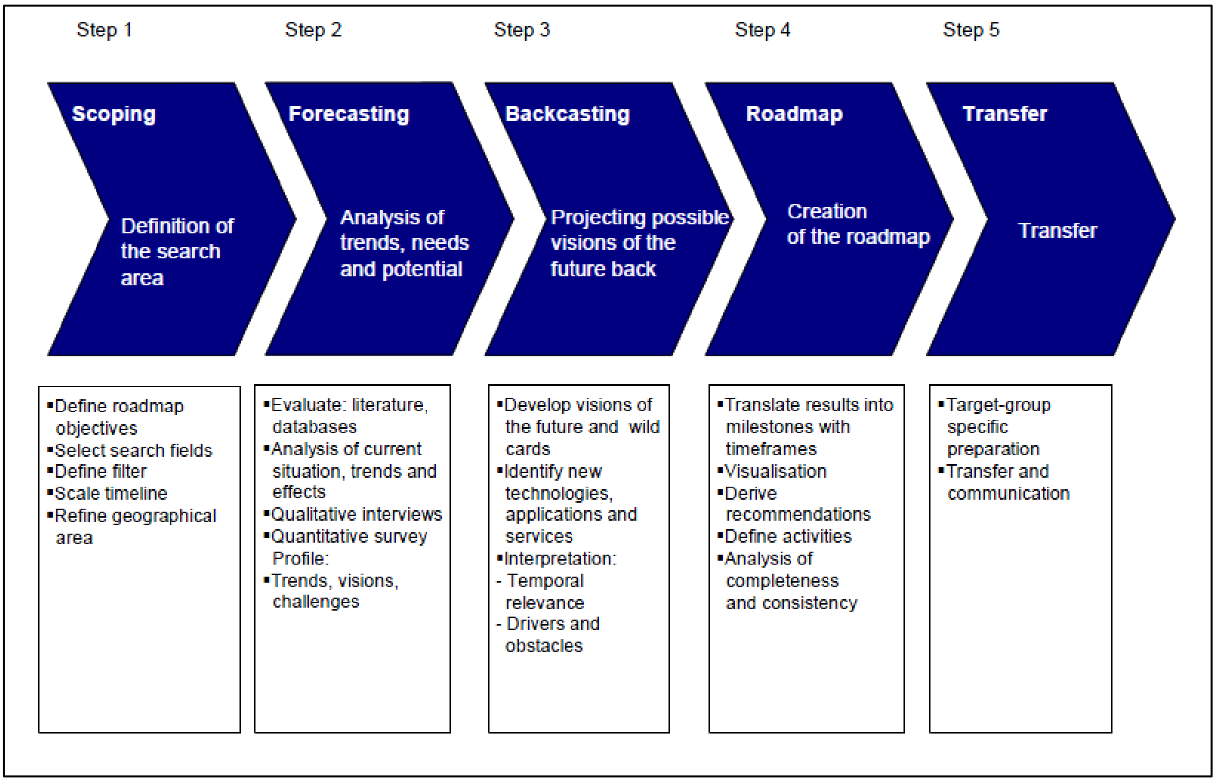

Figure 13: Steps for creating an integrated technology roadmap[138]

The individual steps of the process are explained briefly below.

3.2.1 Scoping

Scoping involves the restriction of the search area to a reasonable size. This means that points of reference which are needed for the evaluation of innovation trends and technologies have to be determined. Once the tasks and objectives of the roadmap are defined search field can be considered. The definition of a filter can be helpful to hide non-relevant fields and parameters. Setting further parameters regarding temporal perspective, technological range, geographical reference areas and market segments is applied to limit the investigation frame.[139]

To be able to keep roadmaps very narrow in space, concentrating on a target corresponding timeframe, individual technologies or market segments is recommended. Depending on the area of application, there are several possibilities for roadmap scopes. An optimum search area refinement cannot be defined, since there is no general scope for roadmaps. The optimum scope must be found under

[138] Behrendt, S. (2007), p. 7
[139] cf. Popp, R; Schüll, E (2009), p. 264

consideration of the objectives set and the capabilities and resources available. It is absolutely necessary to define the following parameters:[140]

- Timeframe: short, medium or long-term perspective
- Geographical reference areas: e.g. Austria, Europe, other regions, worldwide
- Technological range: individual technology, technology fields
- Market segments: present-day market relevance, potential future markets, lead markets and niche markets, areas with strong or little consumer contact, technological trailblazers and stragglers, heavily and loosely regulated markets, areas with short and long investment cycles

Search area refinement is also characterised by identifying and evaluating the need for new technologies and further to assess the potentials they offer. For identifying requirements regarding needs, market analyses can be conducted while potential for change (trends) are detected by analysing research and development.[141]

3.2.2 Forecasting

Forecasting includes trends, needs and potential analyses. The aim is to identify relevant potential for change. It requires more than just an analysis and further updating of trends to identify potentials for change. The simple updating of trends may not provide adequate detection of new challenges and possibilities in technology and product development. Meaningful results can only be obtained if methods are employed and combined, which allow the following:[142]

1. Analysis of the starting conditions,
2. identification of relevant trends and their effectiveness over time, and
3. exploration of potential for change.

To meet these requirements, there is no nostrum. Much more useful is a multi-stage procedure with a combination of methods, which must be adapted to the specific requirements of the roadmap, depending on each individual situation. Such methods can be, for example, interviews with experts, online manufacturer and user surveys, and Delphi expert surveys. In this phase of roadmap generation the involvement of experts, customers and other stakeholders is essential.[143]

[140] Behrendt, S. (2007), pp. 7-8
[141] cf. Behrendt, S. (2007), p. 8
[142] Popp, R; Schüll, E (2009), p. 264
[143] cf. Behrendt, S. (2007), p. 8

The practical elaboration usually starts with the evaluation of literature and databases. The existing data and information serve as a basis for subsequent market, trend and impact analyses. The acquisition of information for the analysis has to be performed in addition to the literature search, by carrying out qualitative interviews and quantitative surveys. If all relevant information is interpreted correctly, the estimation of potential for changes in the market is possible.[144]

3.2.3 Backcasting

By projecting possible visions of the future back to the present, new technologies, applications, and markets can be found. Unlike forecasting, where known developments were projected into the future, backcasting enables one to identify possible future market and customer requirements by projecting back various future visions into the present.[145]

In order to be able to detect new opportunities or challenges for the company, it is essential to generate different visions of the future. Based on demand and potential analyses, such visions can be created. Visions are a representation of coherently bundled trends and models. In the field of futurology, visions are an established tool and are often described by scenarios.[146]

Within this process step, the examination of so called "wild cards" is common. Wild card is an expression for a seriously disruptive event which can upset structured plans and everyday routines. Usually, the occurrence of such events is highly unlikely, but if they occur, it can have a widespread impact on the development of company-relevant markets. An example therefore would be the appearance of the global economic crisis in 2007. Hardly any company was prepared for such a crisis, which has brought many of them into trouble.[147]

Depending on the task, formulations of possible, desirable but also undesirable visions of the future have to be carried out. For instance, an investigation for social challenges and needs, like the need for climate and resource protection or the demand for medical services, requires a projection of the desired situation of the future back to the present, rather than a forecasting to detect possible developments. In order to achieve goals, it is more useful to set the visions from beginning and

[144] cf. Behrendt, S. (2007), p. 8
[145] cf. Siebenhüner, B. (2006), p. 410
[146] cf. Behrendt, S. (2006), p. 41
[147] cf. Behrendt, S. (2007), p. 9

search for a way to reach them. By setting target determinants in alternative scenarios, a development of visions of the future is possible. The performance of the different tasks can be carried out best by clarifying the risks and opportunities separately for each scenario.[148]

As in step forecasting, the involvement of relevant players is also crucial here to identify the challenges which are relevant in practice. Those players, such as customers or experts of the field, should contribute to execute an impact analysis on visions of the future, wildcards and scenarios. Therefore the enforcement of group-based methods such as future-, user-, or expert-workshops is recommended. The application of such workshops for more effective communication and better exchange of information leads to results that are more meaningful than ones that are based on simple technology forecasts or market signals.[149]

3.2.4 Creation of the roadmap

The fourth step of the roadmap process is the visualisation of the findings. A roadmap must illustrate all opportunities and risks which can occur along with the future development of the industry, a technology or a product. This is done by transferring the acquired results of the forecasting and backcasting steps into milestones, activities and recommendations. The development of the reflection objects is then applied over a time line.[150]
A review of the process is performed after the roadmap containing all relevant relationships has been generated. The review has the following purpose:[151]

- Control whether all of the relevant developments were taken into account.
- Establish whether the assessment of technologies and future markets is plausible from a factual and temporal point of view.
- Assess whether statements made regarding trends stand up to scrutiny.
- Make assumptions and evaluations transparent and understandable for internal and external users of the roadmap.

During the review, uncertainties can be detected and eliminated. As a last step, the quality of the data and the informational value of the results have to be checked. This is to prevent any inaccuracy of the future prognoses and also to protect the roadmap

[148] cf. Behrendt, S. (2007), p. 9
[149] cf. Behrendt, S. (2006), p. 41
[150] cf. Popp, R; Schüll, E (2009), p. 264
[151] Behrendt, S. (2007), pp. 9-10

from losing its credibility.[152] An example for an illustrated Roadmap is given in figure 14.

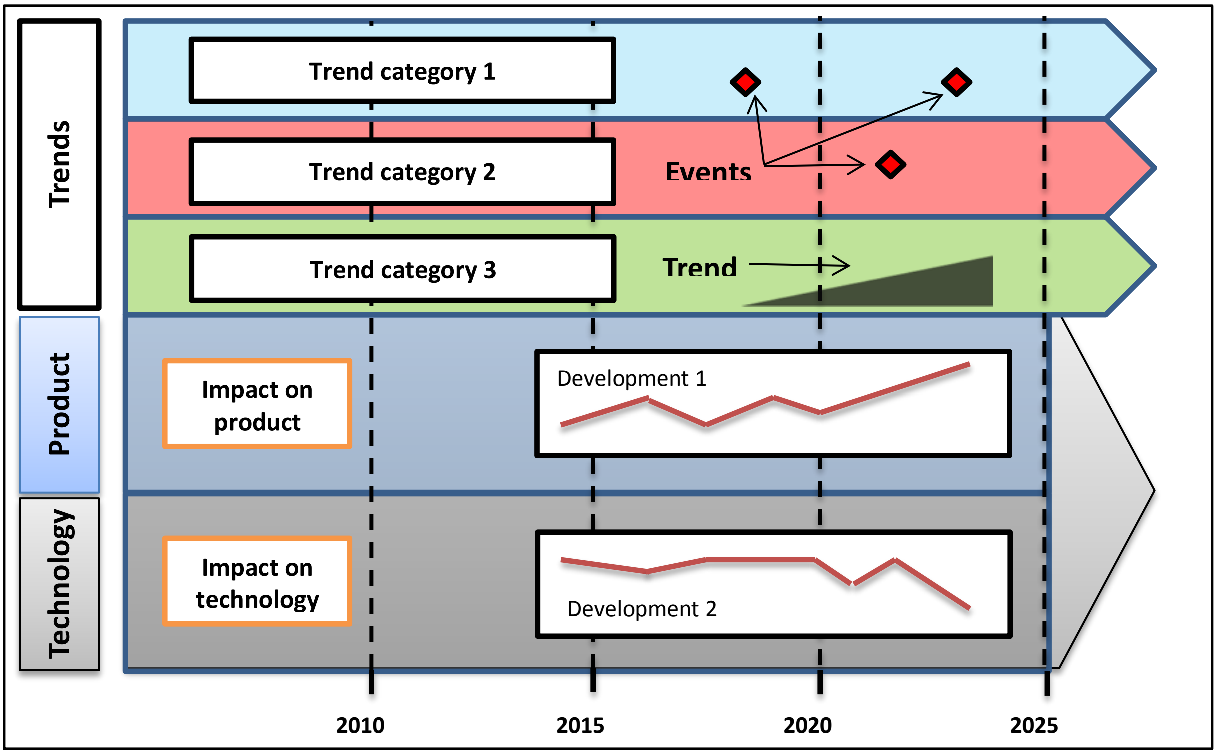

Figure 14: Example for an Industry Roadmap[153]

3.2.5 Transfer

To use the roadmaps to their full potential, it is necessary to use them early in research processes in order to support the early monitoring of social, economic and technological developments. Roadmaps can have a valuable impact on the design of the corporate strategy if given enough attention. This requires a targeted group-specific preparation. Roadmaps have to be linked to operative activities in order to have an impact on innovation policy and management. By using special transfer activities, the roadmap can be delivered to specific target groups which can act on the basis of the acquired results.[154]

[152] cf. Behrendt, S. (2007), p. 10
[153] own representation based on Magna (2012a), p. 51
[154] cf. Behrendt, S. (2007), p. 10

4. CNG systems in the automotive industry

Natural gas is the fastest growing primary energy source in recent years. Experts predict that natural gas consumption will nearly double between 2001 and 2025. The various possibilities of application make natural gas a popular energy source. Also, the automotive industry discovered this trend and therefore offers natural gas driven vehicles. This chapter will provide some basics about the properties of natural gas and natural gas vehicles.[155]

4.1 Fundamentals of natural gas

The energy source natural gas occurs in many variants and is used for different fields of application. Experts predict natural gas to play a major role in the future energy market. It is a versatile energy carrier which has, in comparison to other energy sources, some decisive advantages.[156]

4.1.1 Definition of natural gas

Natural gas is a fossil energy source which is usually produced from underground deposits. Like all other fossil fuels, the resources of natural gas are finite. It can occur together with crude oil or on its own. Natural gas is non-toxic, flammable, odourless, and in comparison to air it is lighter.[157]

Natural gas consists mainly of methane (approx. 70-95% CH_4). Other components are ethane, propane, butane, hydrocarbon compounds, nitrogen and carbon dioxide. The exact composition varies according to the location of production. It can be distinguished between high calorific gas (H-gas) with a higher methane share (86 - 98%) and low calorific gas (L-gas) with a maximum methane share of 85%. H-gas has a higher energy value and therefore a higher energy conversion is possible. Furthermore, it can be distinguished between:[158]

- Liquefied natural gas (LNG)
- Compressed natural gas (CNG)
- Synthetic natural gas (SNG)

[155] cf. Demirbas, A. (2010), p. 57
[156] cf. Geitmann, S. (2010), p. 112
[157] cf. Demirbas, A. (2010), p. 60
[158] cf. Ströbele, W. et al. (2012), pp. 141-142

In order to transport natural gas more easily it can be liquefied. LNG has a much lower transportation cost. Natural gas liquefies at about -164°C. If the gas cannot be transported by pipeline but by ship, it is liquefied. To store natural gas it is usually compressed to a higher pressure. The height of the pressure depends on the further application. CNG as fuel for cars, for example, is stored in cylinders with 200 bar (in Europe). In contrast to LNG and CNG, SNG results from splitting of liquid hydrocarbons. SNG can also be produced from coal.[159]

Table 1 shows the composition of H-gases and L-gases in European regions. The quality of natural gas depends mainly on the methane content. High methane content inhibits the annealing and pre-ignition propensity in combustion engines. Compared to gasoline engines, a higher compression ratio is possible for natural gas engines. This leads to, with proper adjustment to natural gas, an increase of the inner degree of efficiency, and thus to a reduction in fuel consumption.[160]

Properties	H2 - Gas	H1 - Gas	L - Gas
	(North Sea)	(FSU)	(German Verbund)
Calorific value HU [kJ/kg]	46.778	49.149	40.665
Mass density [kg/m^3]	0,84	0,73	0,82
Octane number RON [-]	126	132	130
Stoichiometric air requirement [-]	16,01	16,88	13,93
Ignition limit [Lambda]	0,7 - 2,1	0,7 - 2,1	0,7 - 2,1
Methane CH_4 [Vol%]	86,5	98,3	84,8

Table 1: Composition of various types of natural gas[161]

By means of combustion of methane, energy is released, which then, usually, is converted into mechanical energy and heat. The stoichiometric combustion of methane can be seen in formula 4-1.[162]

$$CH_4 + 2O_2 = CO_2 + 2H_2O \quad \text{(Formula 4-1)}$$

Conventional natural gas must not be confused with LPG (liquefied petroleum gas). LPG is a by-product of petroleum refinement and has different properties to natural gas. It has far higher ratios of propane and butane, in contrast to CNG and LNG.[163]

159 cf. Ströbele, W. et al. (2012), pp. 141-142
160 cf. Eifler W. et al. (2009), p. 261
161 own representation based on Eifler W. et al. (2009), p. 261
162 cf. Joos, L. (2002), p. 31
163 cf. Geitmann, S. (2010), pp. 88-89

4.1.2 Natural gas origin

Natural gas has emerged over millions of years from residuals of organic matter from plants and animals. These organic substances were decomposed by putrefaction processes and converted to carbon dioxide and water. If this process was inhibited by lack of oxygen, the organic residuals penetrated deep into the earth. Over millions of years, they went through a process of change due to high temperatures, pressure and the absence of oxygen. Precondition for the development of oil and gas is the presence of carbon-rich rocks. An essential step in the development of fossil fuels is the splitting of the organic material into simple organic-chemical compounds such as methane and benzene.[164]

Natural gas can also originate from unconventional sources. It can be produced by the decay of dead plant matter in rice fields. Animals, such as cattle, produce large quantities of natural gas as a by-product of digestion but these sources cannot be trapped for energy use. Other sources, such as landfills, manure digesters, and wastewater treatment plants are able to produce enough natural gas for a meaningful energy use.[165]

4.1.3 Utilization of natural gas

Natural gas was mainly applied towards streetlamp lighting and heating in buildings at the start of its commercial use. Today, natural gas is one of the biggest energy sources. The operational area of natural gas is very diverse and covers industrial fields, residential use, commercial use, electricity generation and transport. Figure 15 shows the use of natural gas in Europe by sector.[166]

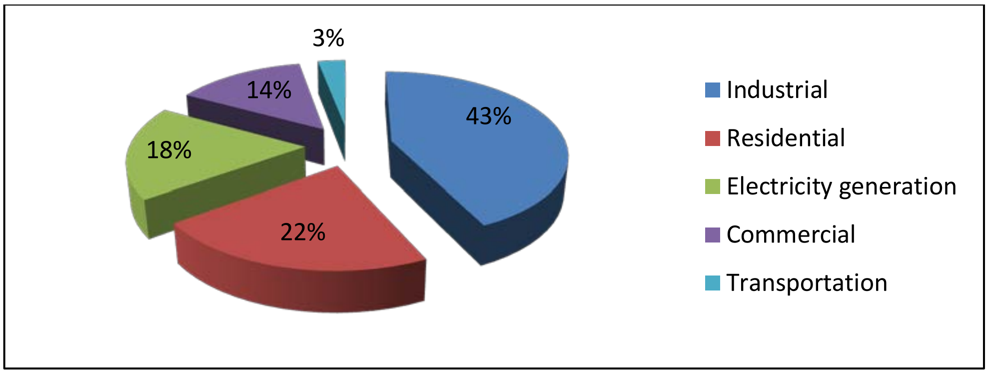

Figure 15: Use of natural gas in Europe by sector[167]

164 cf. Demirbas, A. (2010), p. 60
165 cf. Demirbas, A. (2010), p. 61
166 cf. Demirbas, A. (2010), pp. 68-72
167 own representation based on Demirbas, A. (2010): p. 69

Industry is the largest consumer of natural gas. Natural gas is the second most used form of energy in the industry, after electricity. The most important application for natural gas in the industry is lighting. Other fields of application are waste treatment and incineration, preheating of metals, drying and fuelling industrial boilers.[168] An explanation of the main areas of application is given below:[169]

- Natural gas is one of the most popular energy sources for residential use. Due to the fact that gas is up to 70% cheaper than electricity it is often used for heating and cooking. Its main advantage is the efficiency and cost effectiveness. Natural gas is also used for clothes dryers, fireplaces, garage heaters and outdoor lights.
- Gas can also be used for electricity generation. Since the gas combustion has relatively low emissions, it has great potential to take over a bigger part in electricity generation in the future. For 2030, experts predict that electricity generation will account for 35% of the world's total natural gas consumption. A very common example for the use of natural gas for electricity generation is the operation of gas-powered combined heat and power units (CHP). The overall efficiency of such systems can be up to 90%.
- The use of natural gas in the commercial sector includes applications which are similar to the residential field. Commercial sector means public and private enterprises like office buildings, schools, churches, hotels, etc. The consumption of natural gas in this sector mainly refers to lighting, heating, cooling, cooking, and drying.
- With approximately 3% of the total natural gas consumption, transportation represents the smallest part of all consumers. Although the first vehicles were gas driven about 130 years ago, natural gas as a fuel for vehicles wasn't able to become established. Now more and more vehicle manufacturers offer cars with natural gas systems. Compressed natural gas- driven vehicles have similar characteristics to gasoline cars, but they are much cheaper in use. Another advantage is that natural gas vehicles have lower emissions compared to gasoline and diesel vehicles.

4.2 Natural gas as a fuel for combustion engines

Natural gas has similar combustion properties to gasoline. Calorific value and air requirement are almost identical and therefore it is easily possible to modify a conventional gasoline vehicle into a natural gas vehicle. Basically, it is also possible

[168] cf. Demirbas, A. (2010), p. 68
[169] cf. Demirbas, A. (2010), pp. 68-72

to run a vehicle using both fuels. Diesel engines generally cannot be operated with natural gas. Therefore a significant modification is necessary. There are several research groups that deal with technologies with the aim to enable the operation of diesel engines on gas.[170]

4.2.1 Properties of CNG

Compared to gasoline, the energy density per volume is much smaller, so natural gas has to be stored in cylinders under high pressure (200 bar in Europe). In this form the fuel is called "Compressed Natural Gas" (CNG). The technical requirements for the CNG storage system are very high. Gas tanks must ensure a high level of security and are designed accordingly. The extra weight of the tank affects the fuel consumption and driving dynamics.[171]

A great advantage of CNG is that it has, compared to other fuels, a very high octane number. The octane number is a measure for the anti-knock properties of a gasoline fuel. The higher the octane number, the better the combustion properties of the fuel. The efficiency of the engine and the fuel consumption depends on the possible compression ratio. With a high octane number, a high compression ratio can be achieved, which leads to good engine performance.[172]
The most important octane numbers of prevalent fuels are listed in table 2.

Fuel	Octane number
Gasoline/Super	95 RON
LPG	103 - 111 RON
E85	104 RON
CNG	120 - 130 RON

RON… Reactive Octane Number
LPG… Liquefied Petroleum Gas
E85… Ethanol Fuel
CNG… Compressed Natural Gas

Table 2: Octane number of different fuels [173]

Converting the energy content that is contained in 1 kg of natural gas to the equivalent amount of gasoline and diesel fuel, it can be seen that 1 kg of natural gas corresponds to 1.5 litres of gasoline and 1.33 litres of diesel (table 3).

[170] cf. Dudenhöffer, F. (2011), p. 6
[171] ibd.
[172] ibd.
[173] as cited in Dudenhöffer, F. (2011), p.6

Fuel	Gasoline	Diesel
1 kg CNG (H-Gas)	1.50 l	1.33 l
1 kg CNG (L-Gas)	1.30 l	1.10 l

H-Gas… High Caloric Gas
L-Gas… Low Caloric Gas
CNG… Compressed Natural Gas

Table 3: Conversion of energy content[174]

High quality H-gas (high caloric gas) contains more methane than L-gas (low caloric gas). Therefore, the range of vehicles that are fuelled with H-gas is correspondingly higher.[175]

4.2.2 Types of CNG-Vehicles

The natural gas solutions offered to the customer are various in terms of technology properties and price. In the area of passenger cars and light transport vehicles, some manufacturers already offer cars produced in series. If it is desired to retrofit a gasoline vehicle into a natural gas vehicle, there is the possibility for modification in one of the numerous car workshops, which are specialised in that area.[176]

4.2.2.1 Aftermarket

A conventional gasoline car can be modified to a NGV by subsequently implementing a gas system. The main purpose of such a reconstruction is to become independent of the usually much more expensive fuel, gasoline. After the conversion, commonly an optional operation of gasoline and CNG is possible. The intervention has consequences to the driving characteristics, fuel consumption and thus emissions behaviour. Although the combustion properties of gasoline and CNG are similar, the combustion process with CNG operation is not as smooth as with gasoline. The entire engine management is tuned to gasoline, and remains mostly unchanged after the conversion.[177]

The existing vehicle geometry is not designed for a modification. An underfloor installation of the CNG-cylinders is not possible, thus the tanks are usually mounted in the trunk. This results in a significant loss of space. A typical solution for the placement of CNG tanks in After Sales changeovers can be seen in figure 16.[178]

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174 own representation based on Geitmann, S. (2010), p. 112
175 cf. Geitmann, S. (2010), p. 112
176 cf. Dingel, O. et al. (2004), pp. 4-5
177 cf. Dingel, O. et al. (2004), p. 8
178 cf. Gas24 (2012a), http://www.gas24.de, access date 27.09.2012

Figure 16: CNG tanks installed in the trunk [179]

Normally Aftermarket vehicles also have weaker emission behaviour, as they influence gasoline operations negatively. Retrofitting is only recommended for older vehicles (e.g. emission standard Euro II). New engines with modern engine management can be very sensitive to a modification. After-sales solutions are particularly popular in developing countries such as Argentina, Brazil, Pakistan, and Iran. In Europe, the market share dwindles more and more in favour of OEM production models.[180]

4.2.2.2 Qualified Vehicle Manufacturer (QVM)

This variant represents a kind of interim solution in which the OEM-produced car is brought directly from the factory to a specialist. Collaboration between automobile manufacturers and retrofitters is required. The integration of a natural gas system starts in the engineering office of the manufacturer. The vehicle is designed in a way that a subsequent installation of a gas system is facilitated. For example, the vehicle body can be adapted for additional gas tanks and the vehicle electronics can be prepared for an expansion of gas system electronics. The quality of such solutions is quite high, and comes very close to those of mass-produced vehicles. In contrast to pure after-sales solutions, complex tests are done to ensure quality, crash safety, emission stability, etc. Since the experimental procedure is laid-out for only small quantities, it is not quite as elaborate as for production cars. QVMs are charged for units of up to 2000 vehicles. At higher volumes a production by the OEM or a subsidiary makes sense.[181]

[179] Focus Online (2013) , http://www.focus.de, access date 12.01.2013
[180] cf. Dingel, O. et al. (2004), p. 8
[181] cf. Dingel, O. et al. (2004), pp. 8-9

4.2.2.3 OEM – series production

Many car manufacturers offer CNG-variants in their product range. Particularly in the area of fleet vehicles, manufacturers have taken a CNG- vehicle in their product portfolio to test whether there is a ready market for NGVs. As with conventional drive systems, the NGV is going through all steps of development. This includes preliminary investigation, concept and system definition, design, analysis, simulation, prototyping, assembly, testing, application and approval. The development process takes at least two years and the costs are similar to those of petrol and diesel vehicles.[182]

OEMs offer both monovalent and bivalent vehicles (explanation in chapter 4.2.3.1). The additional required components for gas operation are integrated in the vehicle in a way that the customer recognises no discernible difference to petrol or diesel vehicles. The gas tanks are almost exclusively fitted underfloor, which means that there is no loss of space in other areas. The system architecture guarantees that the highest safety standards are met.[183]

4.2.3 CNG-vehicle technology

CNG vehicles differ in their operating strategy. Depending on whether the vehicle is tuned to pure natural gas operation or may be operated on gasoline as well, it has different properties. Range and engine performance are just two examples. Because of its similarity to gasoline vehicles, a CNG vehicle is relatively easy to modify. The additional components are almost limited only to the tank system and its wiring.[184]

4.2.3.1 Operating mode on CNG

The following considerations relate on multi-track road vehicles. The currently available engine concepts for CNG vehicles can be divided into two basic concepts: monovalent and bivalent. The difference is in the operating strategy.

A monovalent vehicle is designed to run only on natural gas, which means that the entire vehicle is matched to the CNG-operation. The engine is optimised for CNG and therefore, the combustion properties are better than that of a comparable bivalent vehicle. A vehicle may also be designated as monovalent if an additional gasoline tank is present but this tank has no volume that is greater than 15l. The extra fuel tank serves only as an emergency tank. A switch to gasoline operation is not possible

[182] cf. Dingel, O.et.al (2004), p. 8
[183] ibd.
[184] cf. erdgasfahren.ch (2013), http://www.erdgasfahren.ch, access date 09.01.2013

if natural gas is still available. Table 4 gives an overview of advantages and disadvantages of monovalent vehicles compared to bivalent ones.[185]

Advantages	Disadvantages
• better engine performance • better pollutant reduction • lower fuel consumption	• small or no gasoline tank • shorter range • sometimes problems with engine lubrication

Table 4: Advantages and disadvantages of monovalent vehicles[186]

Bivalent vehicles have two separate fuelling systems that enable them to run on either natural gas or gasoline. The primary mode is natural gas and this can be switched to gasoline if necessary. The range of these vehicles is accordingly high. The engine settings for bivalent vehicles are typically optimised for petrol operation, so normally there is little power loss in case of CNG operation. This type is currently well received, as in many regions, the gas filling station infrastructure is not sufficient. Since monovalent vehicles usually offer a range of about 400 km, customers are afraid of getting into trouble by driving longer distances. The bivalent method provides approximately twice the range, due to an additional gasoline tank. Table 5 shows the advantages and disadvantages of bivalent vehicles compared to monovalent ones.[187]

Advantages	Disadvantages
• higher range due to additional gasoline tank • independence from gas filling station network • anytime switch between gasoline and CNG possible • higher product variety than monovalent vehicles	• possibility of guarantee limitation if vehicle was retrofitted • engine management is a compromise for two fuels: power loss and slight emission increase • retrofits can cause loss of space (trunk)

Table 5: Advantages and disadvantages of bivalent vehicles[188]

185 cf. Gas24 (2012b), http://www.gas24.de, access date 27.09.2012
186 own representation based on Gas24 (2012b), http://www.gas24.de, access date 27.09.2012
187 cf. Gas24 (2012a), http://www.gas24.de, access date 27.09.2012
188 own representation based on Gas24 (2012a), http://www.gas24.de, access date 27.09.2012

In addition to these two basic concepts, there are other technologies that are in development and will soon be ready for series production. One promising method in the commercial vehicle sector is the Dual-Fuel Technology. Here, heavy duty applications have fuel systems that run on natural gas and use diesel fuel for ignition assistance.[189]
The operation of a natural gas vehicle is very similar to the operation of a gasoline vehicle. The combustion of the mixture takes place in a conventional Otto-engine, which is, depending on the operating strategy, normally optimised for natural gas operation. In most natural gas engines, the gas is injected into the intake manifold, similar to gasoline systems. The extremely high knock resistance of natural gas allows a higher compression ratio of the engine and is ideal for supercharging.[190]

4.2.3.2 System components and function

In order to operate a vehicle with natural gas, some additional components are required. Essentially, these are the fuel system including supply lines and components for engine management. The additional components can be seen in figure 17.[191]

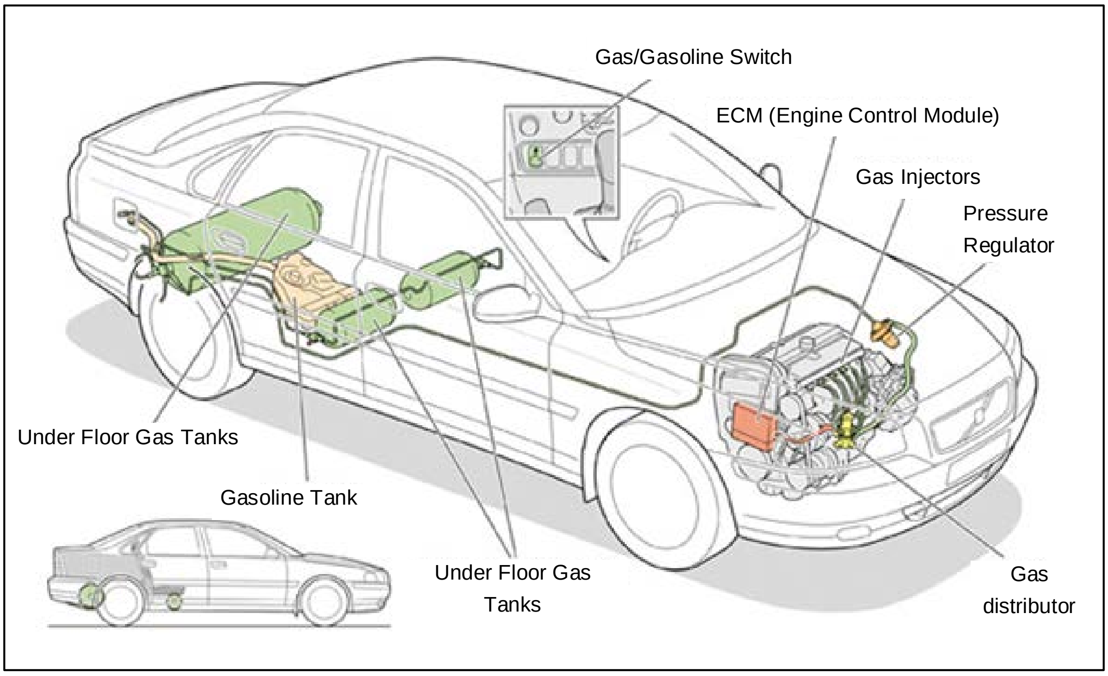

Figure 17: System components of a NG vehicle[192]

[189] cf. Dudenhöffer, F. (2011), p. 19
[190] cf. Reif, K. (2011). pp. 596-598
[191] cf. Gibgas (2013), http://www.gibgas.de, access date 09.01.2013
[192] Autogush (2013), http://www.autogush.com, access date 08.01.2013

Figure 18 illustrates the main parts of a CNG-System in a function scheme. The gas is stored in one or more tanks under 200 bar (Europe) pressure. Each tank is equipped with a safety valve that discharges the gas in case of too high a pressure, which can occur, for example, in case of accidents or fires. With the refuelling system, all existing tanks are filled in parallel until a pressure of 200 bar is achieved. Via the pipe system, the gas is directed into the engine compartment into a pressure regulator, which reduces the gas pressure to 6-8 bar. The ECU (Electronic Control Unit) controls the gas distribution system, which is responsible for the multi-point injection.[193]

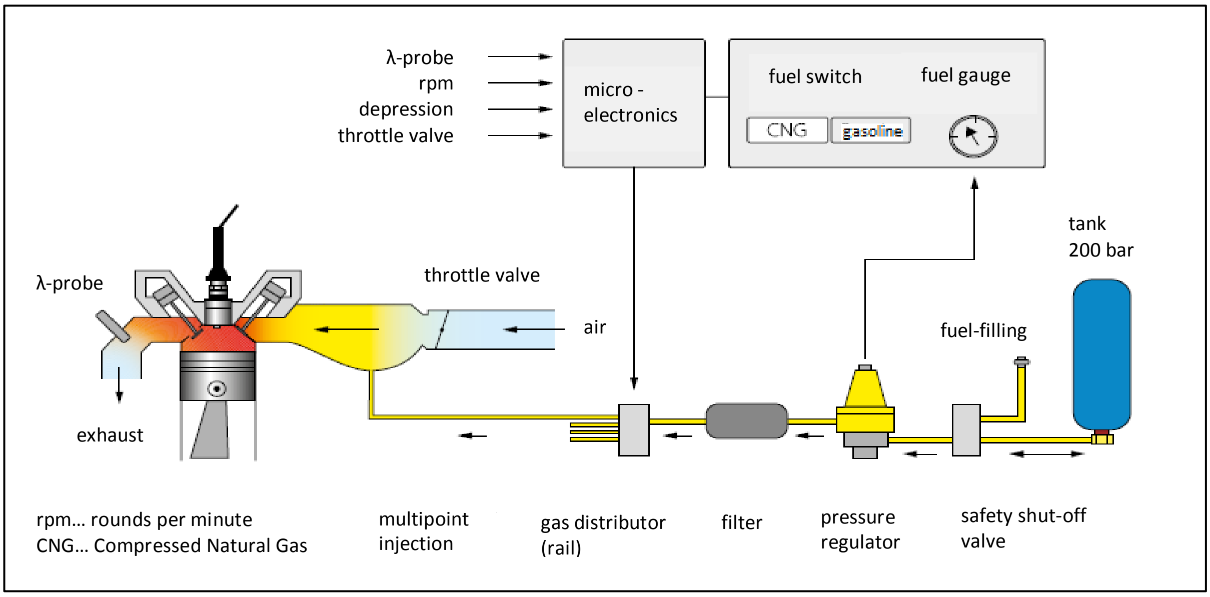

Figure 18: CNG-System function scheme[194]

[193] cf. FGW (2011), p. 29
[194] own representation based on FGW (2011), p. 29

5. Determination of initial situation and targets

The creation of the roadmap consists of a multi-step process that begins with defining the search field. The investigation of all market-relevant factors that may influence the development of the industry is necessary for a comprehensive and successful planning of the company strategy.
The process explained in detail in chapter 3.2 provides the basis for the creation of the Industry Roadmap.

5.1 Scoping – Definition of the search area

Magna is currently not active as a supplier of CNG systems. However, there are some possibilities for the company to enter the CNG market. Before such a step is taken, it is necessary to determine whether an entry is worthwhile, and if so, under which conditions. The first step in practical elaboration aims to outline the objectives and scope of the investigation which are of interest for Magna. The search field must be limited to the requirements demanded by the company. Therefore, the selection of the search field and the definition of crucial parameters are applied to limit the investigation frame. The most important conditions which are essential for the creation of the roadmap are clarified.

5.1.1 Time frame

Usually, the time frame concerning foresight in Industry Roadmaps lies between five and ten years (figure 11). A prediction about the development of a market becomes more uncertain the larger the time frame is set.[195]
To obtain the most credible and reliable statement about the development of natural gas vehicles, it makes sense to keep the time frame short. Industry analyses with a look ahead for less than five years are very accurate in most cases but they don't meet the requirements for the preparation of the corporate strategy.[196] A consideration of the industry development for a period of longer than seven years is associated with too many uncertainties. Different influences from business, politics and society don't allow a far-reaching forecast of the development. Therefore, the investigation of the industry development over the next five to seven years is the

[195] cf. Popp, R.; Schüll, E. (2009), p. 258
[196] ibd.

most appropriate solution. A foresight to the year 2025 rounds off the investigation and generates an estimation of further developments.

5.1.2 Technological range

The technology for natural gas vehicles is mainly mature. Since the operation of a vehicle driven by natural gas is very similar to the operation of a gasoline vehicle, the implementation of a CNG-system is not that big challenge. The components that distinguish a natural gas vehicle from a conventional gasoline vehicle can be seen in figure 17.

The illustration shows a bivalent vehicle, which has a petrol tank installed in addition to natural gas tanks. The natural gas system consists of the components:[197]

- Refuelling system
- CNG tanks
- Gas pipe system
- Pressure regulator
- Gas distributor
- ECU (Electronic Control Unit)
- Gas injector
- Additional: Gas/Petrol switch

Out of all these components, Magna is most interested in the production of CNG tanks. Magna has already done research in the area of hydrogen storage systems. The generated know-how can be adapted for CNG research. The technology investigation should therefore be limited to the natural gas tank system.

The comparison of natural gas vehicles to conventional gasoline and diesel vehicles is of special interest. Only when gas vehicles have significant advantages compared to gasoline and diesel vehicles, they would be capable of taking over market share. The comparison between the various vehicles with different fuel types must also respond to Total Cost of Ownership and emissions.

[197] Autogush (2013), http://www.autogush.com, access date 08.01.2013

5.1.3 Geographical reference areas

A limitation of the geographical research field is provided to identify the relevant factors for Magna more precisely and in a more targeted way. Magna is not present in the CNG market yet, therefore the potential markets have to be analysed first. This involves identification of markets depending on the region as well as the analysis of customers and competitors in the respective areas.
The current CNG market is composed of NGVs, which in most cases are equipped either with steel tanks or with tanks made of composite material. Magna has special interest in producing composite tanks, which is why regions where composite tanks are popular in particular must be investigated in more detail. The industry roadmap must focus on the regions of Europe and North America where the chances for composite tanks are greatest. All other regions are insignificant for the first analysis and are therefore not included in the investigation. NGVs enjoy great popularity in the Middle East and South America. Here, almost all vehicles are aftermarket solutions with steel tanks so these regions are only covered briefly.

5.1.4 Market segments

Although CNG can be used as fuel for almost all means of transportation, natural gas systems differ significantly according to their field of appliance. Magna, as an international supplier to the automotive industry, is specialised in developing and producing vehicle components for OEMs as well as for other suppliers of the automotive industry. Magna therefore is interested in producing components for CNG systems and delivering them to OEMs and aftermarket enterprises.

As already mentioned, the investigation focusses on the tanks in which the CNG is stored. Currently, predominantly steel tanks are integrated in NGVs. Due to steadily increasing customer demands requirements for manufacturers are also growing. NG-systems with composite tanks are expected to gain in importance in future.[198] If the demand for composite tanks rises in the future, then new opportunities for manufacturers will also open up. The investigation aims to identify opportunities for Magna as a supplier to automotive manufacturers and retrofitters. Potential customers are OEMs, but so too are retrofit companies such as qualified vehicle manufacturers (QVM) or automotive workshops.

[198] Interview with Dr. Uwe Thien (Project Manager Natural Gas Storage Systems, Magna Steyr) conducted on 30.01.2013

It is planned that the products that will be offered are high-pressure gas storage tanks. The examination of trends should show whether an entry into this market segment would be worthwhile or not.

5.2 Selection of research fields

The assessment of the current situation and trends must point out the general development of the CNG market and technology. One possibility is the development of composite tanks. However, a collaboration or acquisition with/of manufacturers of steel tanks is also a possible opportunity for entering the market. The drafting of the situation and trend analysis requires the contemplation of several relevant topics:

- Technology standards for CNG systems
- Assessment of the industry and market
- Competitive and Company analysis
- Trend detection, description and evaluation
- CNG Potential compared to other fossil fuels
- Drivers and blockers of NGVs
- NGV sales prediction 2010-2020

An extensive and accurate investigation of these focal points will provide the information necessary for creating the industry roadmap. A reappraisal of these topics in the forecasting and backcasting stages will provide information about the market and technological development of natural gas systems in the coming years.

5.3 Market research process – planning the investigation

Before starting with data collection and evaluation, it is essential to establish a planning of the procedure. The market research process is used for information gathering and processing, which is described in chapter 2.5.

5.3.1 Problem and target definition

The objective of market and trend analysis is the extraction of data and information that are needed to complete the Industry Roadmap. Since the objectives and research areas are already described in detail, they are not discussed further.

5.3.2 Time-, organisational-, and financial planning

The time frame for the study is attached from August 2012 until February 2013. However, some information was already collected in previous projects and can be adopted for this study. Involved parties are the departments of Innovation and Technology and Fuel Storage Systems at the Magna plant in Graz and a project group from Magna Canada which is concerned with the situation in North America. Therefore, a close cooperation with the appropriate people in Canada is intended.
The focus of the research is exclusively the market and trend development of CNG systems in the automotive industry. The focus is on passenger cars and light commercial vehicles. After the evaluation of information already available, additional information must be collected through primary and secondary research.

5.3.3 Planning and design of research process

The first choice that has to be made is the selection of the research process. Due to the fact that many assumptions concerning the development of the CNG market were already made company intern as well as by external parties, there is some information on the topic. The aim of the investigation should be a statement about future developments. The demand of information and the research objective is well defined, so a descriptive study is recommended. Nevertheless, there are also circumstances which are not considered or detected so far. There are some issues for which there is still little knowledge, so there must be also an explorative research approach for setting up hypotheses to gain new insight.

Secondary research will be applied primarily for data collection due to information about market and technology trends that is available through various sources. To round off the acquisition of information, interviews with experts will supplement the needed knowledge. Observations and experiments are not appropriate for the task and therefore only questioning in the form of interviews will be conducted in primary data collection.
Due to time and cost reasons only a section of the subject will be considered for the investigation. For example, for the comparison of natural gas vehicles with conventional vehicles, only a particular model is used, which is representative for all other vehicle models, to provide a statement.

5.3.4 Data collection, evaluation and control

The process step of data collection and evaluation is performed by elaborating the phases forecasting and backcasting of the roadmap process. The control of the evaluation process is included in the roadmap creation itself.

6. Forecasting - Trends, needs and potential analysis

The "Forecasting" process step includes a detailed analysis of the situation, trends and potential for change. Data and information are collected, which are necessary to create the Industry Roadmap. The task is fulfilled when all factors and issues that were listed in the previous section have been assessed. In order to identify factors that can influence the development of natural gas systems in the automotive industry, following an analysis of the current situation, the development of trends and the potential for change are carried out.

6.1 Consideration of the current market situation

In order to adequately investigate the development of vehicles powered by natural gas, a listing and weighting of factors that influence this development is conducted. Figure 19 shows the main market influencing factors that are relevant for the investigation.

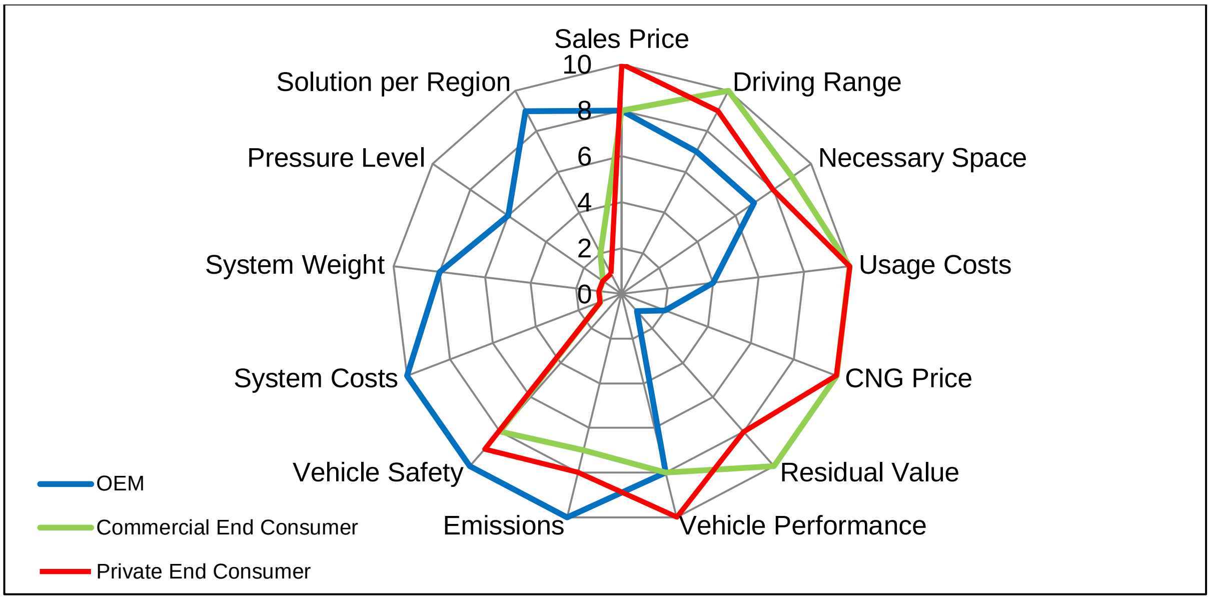

Figure 19: Importance of influencing factors on natural gas systems[199]

Figure 19 illustrates the importance of various influencing factors that are relevant for the research. The representation of the importance distinguishes between OEM, Commercial End Consumer like taxi driver and logistics companies and Private End

[199] own representation based on interviews with Dr. Max Lang (Department Head of Vehicle Technology, Transportation & Consumer Protection , ÖAMTC) and Prof. Dr. Erich Pucher (Head of the Institute for Vehicle Drives and Automotive Engineering, TU Wien) conducted on 01.10.2012

Consumer. It is noticeable that, for the OEM, the technology is of decisive interest, while private and commercial end consumers pay special attention to low purchase and operating costs. As the costs also depend largely on the technology, it is indispensable to carry out a holistic approach, starting with the technology, up to the economic situation. Vehicles powered by natural gas can therefore only be successful if the OEM and thus the suppliers manage to equip vehicles with adequate technology, which subsequently keeps the costs low for the end consumer.
Key factors in this diagram that can be influenced by the car manufacturers are: system costs, vehicle safety, emissions, performance, usage costs, necessary space and sales price.

6.1.1 Technology standards for Compressed Natural Gas Systems

An examination of currently available system technology and an investigation of production costs and the value distribution of system components provide the basis for discussing opportunities for entering the market. The technological consideration is completed by the comparison of possibilities of the geometrical integration in the vehicle.

6.1.1.1 Tank system design and technology properties

In Europe CNG tanks are cylinders in which the gas is stored at 200 bar pressure. In the North American region, the common cylinder pressure is between 3000 psi and 3600 psi, which equals about 206 bar to 248 bar.[200]
Depending on the materials used and the method of manufacturing four different tank types can be distinguished. Due to different materials, the tanks have respective properties, which affect the whole system in terms of price and weight. Also physical properties such as durability and safety in case of an accident vary by type of tank.[201]
Magna sets ambitions in developing Type IV composite tanks, which is why particularly technology and potential markets of tanks out of composite materials must be considered. Figure 20 shows a representation of the tanks with the materials and the coarse construction.

For storing CNG, Type I Tanks out of steel and Type IV Tanks out of carbon fibre are mainly used. The steel tank is the cheapest one in production and therefore the most

[200] cf. Sweet, D. (2012), p. 63
[201] cf. Wallenberger, F.; Bingham, P. (2010), p. 222

popular storage system at the moment.[202] CNG vessels out of carbon fibre (Type IV) provide highest weight reduction potential but the production costs are significantly higher than for steel cylinders. The production method for steel cylinders is drawing, whereas the plastic liners are wrapped in carbon fibre. Moreover, steel is much cheaper to procure than carbon fibre.[203]

Type II and Type III vessels combine characteristics of the other two types of cylinders. However, they are not as light as the pure plastic liner and due to the more complicated production method also not competitive in comparison with steel cylinders in terms of costs. Type II and III cylinders need to be drawn and wrapped, which makes the production process expensive.[204]

All types of cylinders must meet the same safety standards. Depending on the region, there are different requirements. The most common standards are the European ECE-R110 and R115 standard and the North American US-NVG2 standard. Most regions (about 52 countries) follow the ECE-R110 standard, only a few of them follow the US-NGV2 for the use of NG in vehicles. Functional and safety problems with low technologies in some countries are still existent and prohibit the introduction of Type IV systems because Type IV cylinders are still new and are preparing for volume entrance to the market.[205]

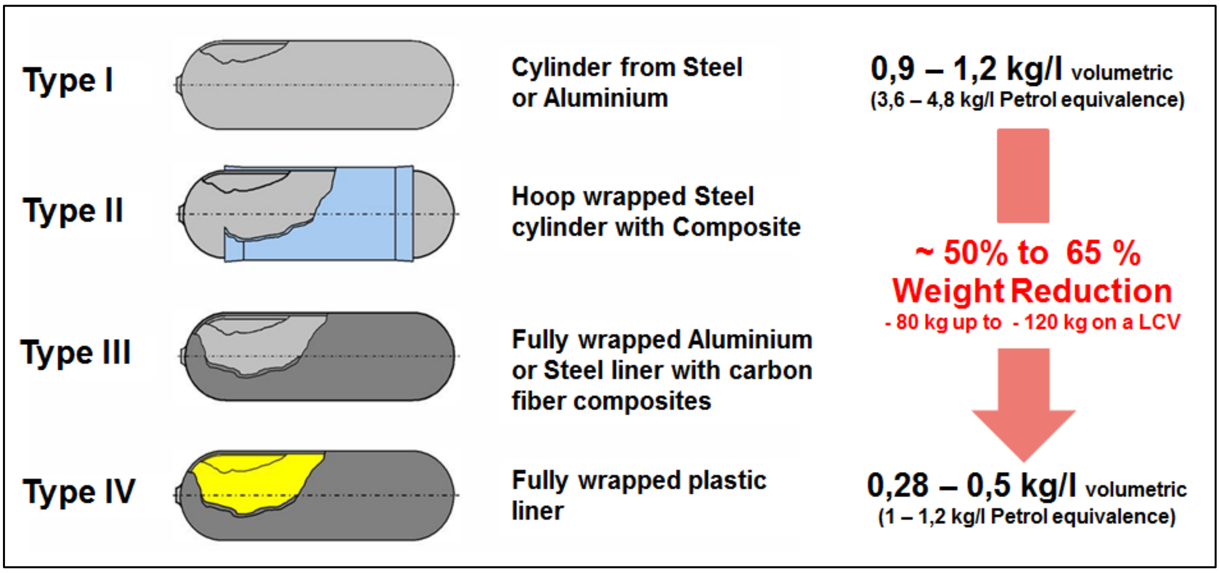

Figure 20: Differentiation of the four cylinder types[206]

[202] Interview with Dr. Uwe Thien (Project Manager Natural Gas Storage Systems, Magna Steyr) conducted on 30.01.2013
[203] ibd.
[204] Thien, U (2012), p. 22
[205] Interview with Dr. Uwe Thien (Project Manager Natural Gas Storage Systems, Magna Steyr) conducted on 30.01.2013
[206] Thien, U (2012), p. 22

In summary, it can be stated that due to the low price steel tanks are most in use. Type II and III are currently barely in use because the price performance ratio here is not convincing. Type IV tanks have a good chance of gaining a larger market share, as the weight reduction is a major factor for many manufacturers. Both driving dynamics and fuel consumption can be positively influenced by implementing lighter tank systems. Whether it will be possible to minimize the production cost range between Type I and Type IV is crucial.

6.1.1.2 Value distribution in the tank module system

Magna has already performed studies where the exact cost structure of a CNG-system module was determined. An Opel Zafira with a built-in Type IV tank module serves as a reference model. The tank module consists of the main parts: filling system, connection blocks, Type IV cylinders (4 x 37l) and gas handling units. The composition of the manufacturing costs of a Type IV tank module is shown in figure 21.

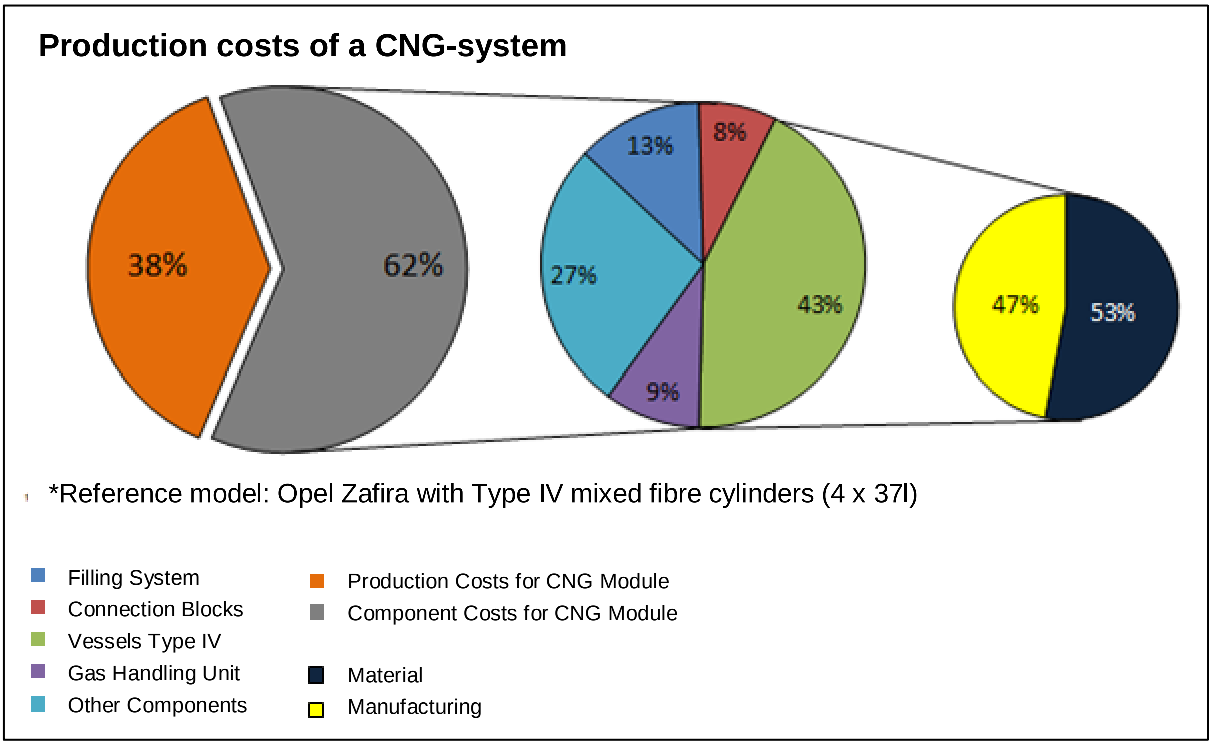

Figure 21: Production cost share of a CNG-System Module with Type IV tanks[207]

[207] own representation based on Steiner, M. J. (2012), p. 21

The overall costs are divided into production costs and costs for the component groups. The share of the component costs is divided again. The costs of the entire tank module amount to € 2.619. Of these, about € 1.624 are component costs. The costs for the CNG cylinders are € 700, whereby about half is obtained for material and the other half for the manufacturing process.[208]

The distribution of costs for a tank module with steel cylinders is determined based on the values and results of the reference model with Type IV tanks. The result can be seen in figure 22. The costs of the entire system amount to € 2.425. As in the division of manufacturing costs for a Type IV Tank module, in the Type I module, the cylinders also make up the greatest part of the material costs. Overall material costs make up € 1.425 of which € 506 are the costs for steel cylinders. The steel cylinders are therefore about 28% cheaper than the composite tanks. A major difference arises when considering the cost-sharing of the cylinder itself. The material costs are much lower than for the Type IV module. The production cost for the cylinder makes up the largest share.

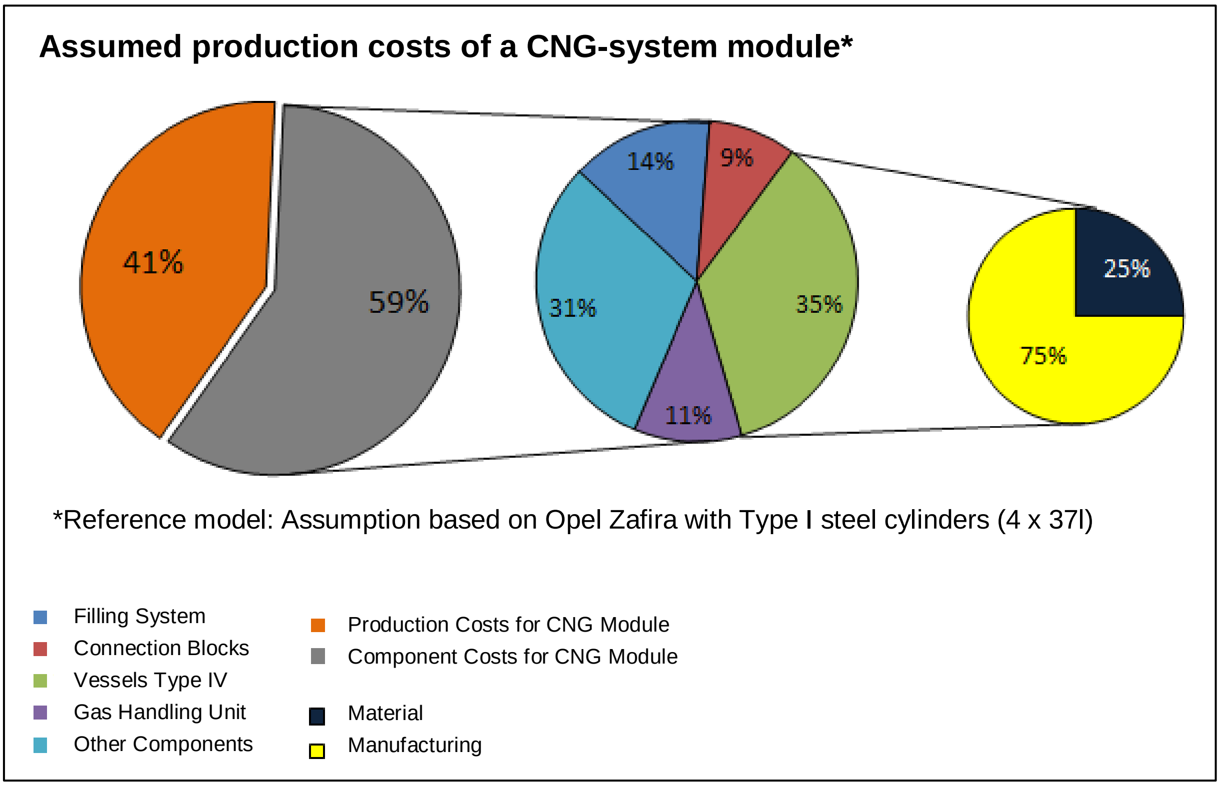

Figure 22: Manufacturing costs of a CNG-System Module with Type I tanks[209]

[208] cf. Steiner, M. J. (2012), p. 21
[209] own representation based on Steiner, M. (2012) and an interview with Dr. Uwe Thien (Project Manager Natural Gas Storage Systems, Magna Steyr) conducted on 09.11.2012

The comparison shows that tank modules with steel cylinders are about 8% cheaper than a comparable system with Type IV tanks. The main difference results from the price gap of the tanks. The additional components cost roughly the same. In contrast, there is a weight saving of about 80 kg (Opel Zafira) compared to the heavier Type I steel tanks. The allocation of production and material costs is significantly different. For the Type IV tank, the material is much more expensive, while the absolute manufacturing costs of the two tank types do not differ significantly. Therefore, the material costs of the CNG tanks are crucial for the total module costs. Magna cannot affect material prices but they can break new ground in terms of material composition. A promising way to reduce the cost difference between the two modules is the production of Type IV tanks made of mixed fibres. Previously, Type IV tanks are usually only wrapped in carbon fibre composites. But there is also the possibility of partly wrapping them in carbon fibre and partly in glass fibre. This issue will be discussed more in detail in chapter 7.2.

6.1.1.3 Geometrical and functional vehicle integration

In order to set development accents, Magna needs information about the system properties of OEM and after-market CNG systems. Therefore, advantages and disadvantages of both variants are highlighted.

Key facts of **Aftermarket solutions** are:[210]

- Conventional gasoline vehicles are retrofitted to CNG operation
- Almost all after-market solutions are bivalent
- Integration of CNG tanks in the trunk or in loading platforms
- Engine control unit has to be modified for bivalent operation
- Aftermarket CNG vehicles are typically equipped with Type I tanks

The main advantage is that nearly every CNG conventional gasoline vehicle can be modified to CNG operation. The conversion is not complicated because few parts have to be installed or replaced. The modification is performed by a professional workshop and costs between € 2000 and € 3800 depending on vehicle model and the desired tank volume. The end consumer benefit is lower operation costs than with gasoline. Payback can usually be achieved after about two to three years with a yearly mileage of 20.000 km.[211]

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[210] cf. Magna Steyr (2012a), p. 1
[211] cf. Hydrogeit (2012), http://www.hydrogeit.de, access date 06.12.2012

In contrast, there are also some disadvantages: Since gasoline vehicles are not designed for a CNG retrofit, the tanks must be installed in places that are normally used to load passengers or cargo goods. So there is a significant loss of space. Additional system parts also entail bad weight distribution in the vehicle, which leads to an impact on driving dynamic properties. A modification can also result in power loss of the engine because the engine management system is not optimised for CNG operation.[212]

Another decisive problem that especially occurs in emerging countries is that some modifications are not performed by professional workshops, which do not respect the laws and standards for NGV design. This leads to many accidents due to insufficient safety measures.

Key facts of **highly integrated CNG Systems (OEM)** are:[213]

- Bivalent and monovalent operation is common
- Usually tank module is installed under floor
- Tank type used is dependent on OEM and vehicle segment
- CNG operation is considered in the vehicle design from the very beginning
- Engine management system is optimised for gasoline and CNG

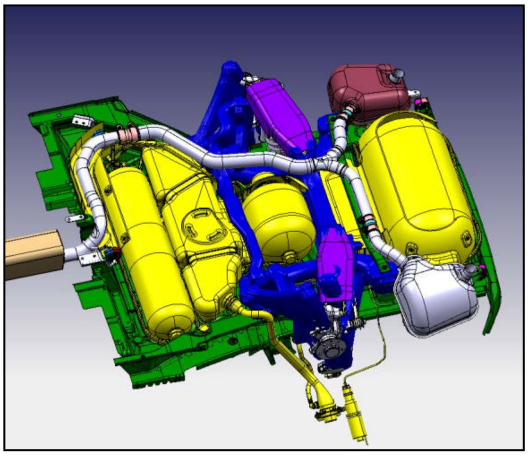

Figure 23: Highly integrated CNG System[214]

The functional and geometric integration in the vehicle offers several advantages. The effects on the new weight distribution are minimal. The CNG tank module is embedded in a special frame and is installed under the floor (figure 23). The

[212] Interview with Dr. Max Lang (Department Head of Vehicle Technology, Transportation & Consumer Protection , ÖAMTC) conducted on 01.10.2012

[213] Magna Steyr (2012a), p. 1

[214] ibd.

customer almost does not recognise additional parts, and there is no significant loss of space. The integration in the under floor frame also provides a better protection of the tanks in case of an accident.

A highly integrated CNG system only requires minimal platform modifications but offers an optimised operating strategy of bivalent solutions in focus consumption and drivability. A functional integration concept avoids power loss of the engine by adjusting operation on CNG or switchable operation on CNG and gasoline.

The only disadvantage of highly integrated CNG Systems is the additional effort for the design of the system module. Currently, natural gas vehicles of OEMs are not sold in high volumes. The market still starts to grow and therefore the investment in the development of integrated systems is also risk associated.

The outcome of the investigation shows that at the moment after-market solutions are very popular, especially in regions where there is a lack of OEM offer. Nevertheless, a look at the system properties shows that high vehicle integration provides decisive advantages compared to after-market solutions. The complete tank system can be delivered as a module and be integrated in the vehicle at the OEM’s plant. Due to the resulting development effort, it is necessary to sell high volumes to pay off such solutions. Therefore, the logical conclusion is that specific OEM systems with high integration level are of interest, especially in the European region and occasionally in North America, where they are already widespread. Aftermarket solutions will keep their market share in emerging countries, where OEMs still don´t offer an acceptable variety of NGVs.

6.1.2 Assessment of the industry and market

A number of factors have a major impact on the development of the industry and the market. As is well known, the operating costs play a major role in the battle for market share in the automotive sector. Hence, the evolution of the natural gas price and the effort in the creation of the necessary infrastructure for NGVs will be crucial. The price of natural gas is highly dependent on available resources and reserves. A trend for market development for NGV can also be inferred from the sales figures from recent years.

6.1.2.1 Global crude oil and natural gas reserves and resources

Success in achieving the breakthrough of NGVs is also critically dependent on the price development of fuels. A decisive advantage can occur when natural gas compared to gasoline and diesel remains cheaper or the price gap even increases. In addition to the various economic and political scenarios that play a role, the current and future resources are substantially involved in the development of fuel prices. Many experts have tried to analyse the availability of raw materials, which is why opinions vary. The German Mineral Resources Agency (DERA) published statements concerning oil and gas availability.

For **crude oil**, which is needed for further processing of gasoline and diesel, the key facts are:[215]

- From a geological point of view, security of supply can be guaranteed over the next years, assuming a moderate increase in oil consumption but not over a prolonged period.
- Crude oil will remain one of the world's most important energy sources.
- The share of crude oil from the OPEC countries is already at nearly 40% and will increase further in the future.
- The price of oil is very difficult to predict. There are numerous factors in the production of oil, which are impossible or very difficult to assess, for example politics, global economy and technology.
- Crude Oil is the only non-renewable energy source that cannot cover demand in the coming decades.

The result of the study indicates that crude oil will remain the most important energy source of fuels in the coming years. The production will continue to rise and dependency on the OPEC countries will increase even more. Due to the rapidly increasing global demand for energy, oil will be the first fossil resource that will not be able to keep pace with rising demand. A severe price increase over the next few years is expected.[216]

[215] cf. DERA (2011), p. 22
[216] cf. DERA (2011), p. 33

The natural gas resource is characterised by the following aspects:[217]

- From the geological perspective natural gas is available in very large quantities.
- Gas production in Europe has already exceeded its maximum. With further decreasing domestic production, the dependence on gas imports from the CIS (Commonwealth of Independent States), Africa and the Middle East will increase.
- Past achievements in the development of unconventional gas resources (e.g. shale gas) have improved the global supply situation. Also in Europe, cautious use of these resources may help to increase security of supply.
- The production of synthetic fuels from natural gas (Gas to Liquid) is increasing. This could affect the natural gas market in the future.

Unlike crude oil, energy production from natural gas will not be limited in case of increasing demand in the following decades. The European market is in a comfortable position due to good connections to the CIS States, North Africa and the Middle East. Europe and North America will benefit from the growing supply. Figure 24 shows the supply situation in 2010.[218]

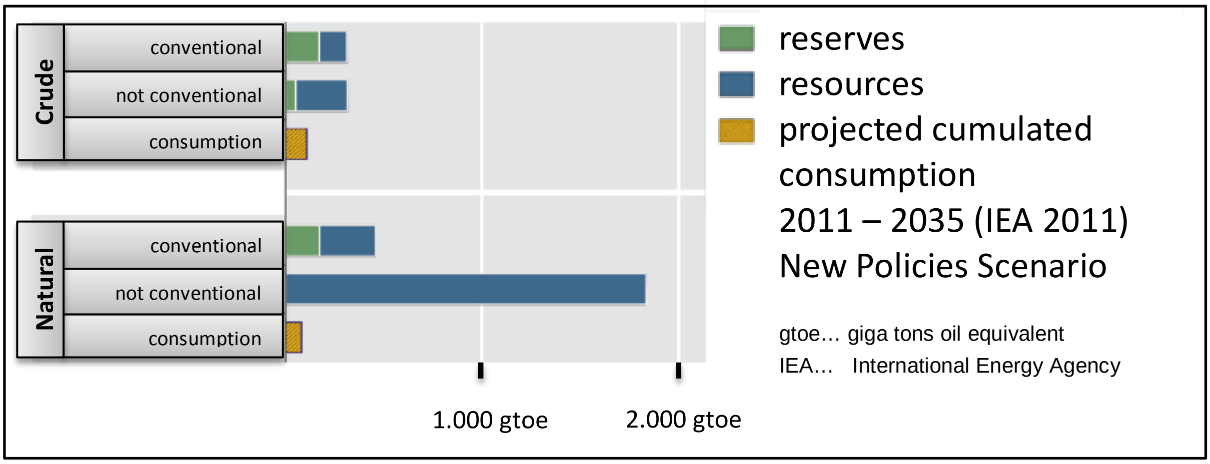

Figure 24: Supply situation of crude oil and natural gas in late 2010[219]

The chart points out the availability of crude oil and natural gas expressed in giga tons oil equivalent (gtoe). The consumption of oil is high in relation to the available resources and reserves. The non-conventional gas resources ensure supply safety for many decades.[220]

[217] cf. DERA (2011), p. 25
[218] cf. DERA (2011), p. 33
[219] on representation based on DERA (2011), p. 32
[220] cf. DERA (2011), p. 32

From the graph, it can be deduced that the security of supply of natural gas is much higher than for crude oil and therefore for gasoline and diesel. Thus, one condition is fulfilled that the natural gas fuel could remain cheaper than gasoline and diesel in the future.

6.1.2.2 Natural gas supply infrastructure

End customers place great value on the fuelling station infrastructure. Only if sufficient facilities are available to refuel the vehicle, can natural gas vehicles compete in the market.[221] Therefore, the current possibilities of natural gas refuelling must be considered. Conventional public gas stations can also easily provide natural gas in addition to petrol and diesel after installing a gas filling unit. Another possibility for fuelling a NG vehicle is the use of Home Refuelling Applications (HRA). These devices are mounted either at home or at the workplace and are connected to the conventional gas network.[222] Whether such HRAs are a meaningful alternative is also being investigated.

The global number of natural gas filling stations has increased a lot in recent years. However, the development of infrastructure in the highest degree depends on the region. Examples from Europe show that occasionally there is already a very good filling station network. In other regions, however, there are only a small number or even no gas filling stations for natural gas.
The development of the number of global natural gas filling stations reveals an interesting trend (figure 25). The total number of natural gas filling stations is steadily increasing, while the annual number of newly built stations decreases. This can be explained by the fact that energy suppliers have invested heavily in natural gas stations, in individual regions and thus have created a sufficient infrastructure. Energy suppliers are now hoping for a breakthrough of NGVs in the automotive market that their investment will pay off. As other regions often do not have a sufficient filling station network, many customers are still not convinced and decide against NGVs. Specifically, customers who wish to travel longer distances are often not convinced by the filling station network. Therefore, the number of natural gas vehicles increases rather slowly, especially in Europe. This in turn provides the

[221] cf. Dudenhöffer, F. (2011): p. 23
[222] Interview with Heimo-Thomas Blattner (Project Manager Alternative Drives, Energie Steiermark) conducted on 28.09.2012

energy companies with an argument for discontinuing investment in expanding infrastructure. The market therefore faces a kind of “chicken-and-egg” problem.[223]

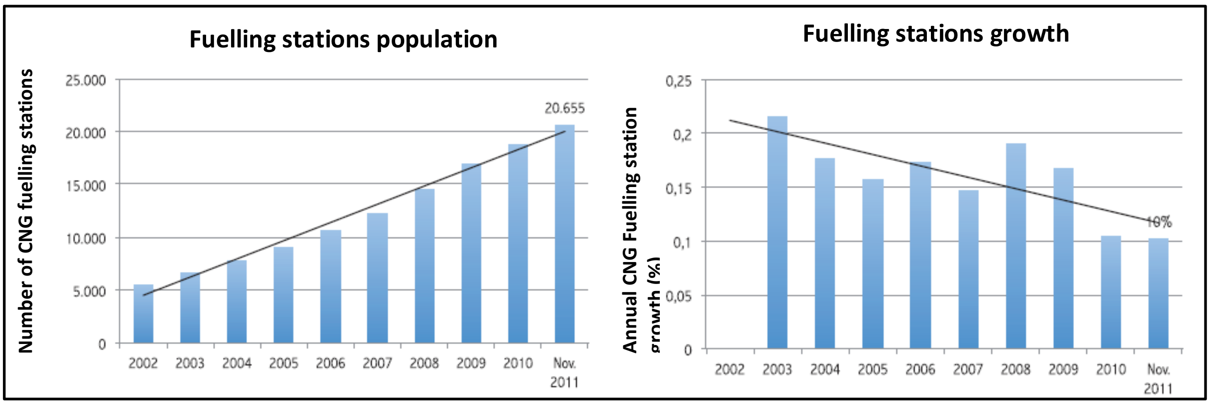

Figure 25: CNG fuelling stations population and growth 2002-2011[224]

A closer look at the major regions of Europe and North America confirms this assumption. In Europe, the situation varies from country to country and no consistency has been recognisable until now. Italy and Germany hold a leading role in terms of natural gas filling station networks in Europe. So both Italy and Germany are leaders in Europe, with slightly more than 900 CNG filling stations. The distribution within the countries is uniform and extensive. Thus, it can be noted that the necessary basic infrastructure is available for refuelling a vehicle within reasonable distance. Also in Austria, the infrastructure of 200 refuelling stations is quite acceptable considering the area of the country. Sweden and France are countries which already have a very high number of registered natural gas vehicles but the infrastructure, each with less than 200 filling stations, is very weak and usually only concentrated on some regions. Slovenia, Denmark and Bosnia & Herzegovina can be indicated as bad examples for the promotion of natural gas vehicles in Europe. These countries have very few or no opportunities for refuelling the vehicles.[225] A detailed list of fuelling stations in each country is given in the appendix.

Figure 26 shows two examples of filling station networks. On the left there is the excellently developed network in Germany and on the right the less developed network in the United States. To date, there are only 1035 CNG filling stations in the United States, of which only about half are publicly available. Furthermore, it can be

[223] Interview with Dr. Max Lang (Department Head of Vehicle Technology, Transportation & Consumer Protection , ÖAMTC) conducted on 01.10.2012
[224] own representation based on GVR (2012), p.33
[225] cf. GVR 135 (2013), p. 24

seen very clearly in the illustration that in the U.S. natural gas infrastructure is limited to individual regions. These are the regions where natural gas is produced. The situation in Canada is even worse. By the end of 2011, only 83 refuelling stations were located in Canada. These stations are almost all located in cities.[226]

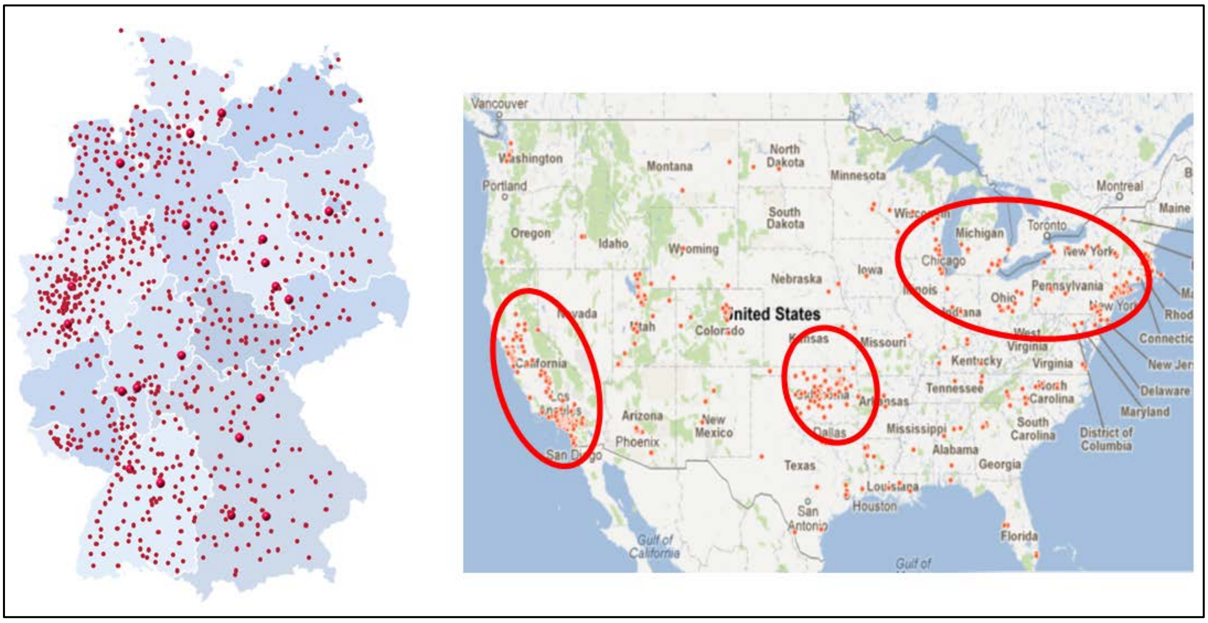

Figure 26: Natural gas filling station network in Germany and the USA (2012)[227]

The infrastructure situation in the examined regions of Europe and North America is regionally very different. Very few countries have a sufficiently well-developed network of filling stations. For vehicle buyers, this is crucial. Since most vehicles work in bivalent mode anyway, bridging of short distances is possible. Problems can occur in regions where there is hardly a way to refuel. Here NGVs don't have a good chance of gaining market share.[228]

It is also possible to refuel the vehicle at home. By installing Home Refuelling Applications, the refuelling process can be done at home or at the workplace. These devices are connected to the natural gas network and compress the gas to the required pressure. An HRA can be used as an alternative in regions with weak infrastructure. Currently, these devices are particularly well received in the United

[226] cf. GVR 135 (2013), p. 25
[227] own representation based on Gas24 (2012c), http://www.gas24.de and CNG NOW! (2012), http://www.cngnow.com (2012), access date 18.11.2012
[228] Interview with Heimo-Thomas Blattner (Project Manager Alternative Drives, Energie Steiermark) conducted on 28.09.2012

States. Table 7 indicates a cost comparison for the refuelling of ten kg of natural gas with the HRA "Phill P30" from BRC Fuelmaker and a public gas station.[229]

	Home Refuelling Application	Public Refuelling Station
ø price for CNG inc. Tax:	0,96 €/kg	1,10 €/kg
Mass:	10 kg	10 kg
Costs CNG:	9,60 €	11,00 €
Costs electricity for compressing 10kg CNG:	1,31 €	---
Total costs:	**10,91 €**	**11,00 €**
Refill time:	**~ 9 h**	**~ 3 min**
CNG... Compressed Natural Gas Fuel and electricity prices in Austria in November 2012		

Table 6: Cost comparison of HRA "Phill P30" and Public Refuelling Station[230]

The cost comparison indicates that, although the natural gas from the regional network is cheaper than at the gas station, the total costs are approximately equal. The energy costs for the compression of the gas with the HRA must be taken into account as well. The extremely long filling time of about nine hours for ten kg, is a major disadvantage. The vehicle must be refuelled overnight and even in this period, a full refuelling is not possible. The acquisition cost of about 3.500 € is not even considered in the calculation. Thus, HRAs are not a cost-effective alternative to public filling stations. A useful application can only be found in regions with a very poor fuelling station infrastructure. An acquisition is not recommended for private customers. For commercial customers, like shipping companies, it may be possible to supply their vehicles with natural gas, which is in fact cheaper than running them with gasoline or diesel.[231]

6.1.2.3 Gas vehicle population and target segment per region

A key point for to assessing the further development of NGVs is to study the sales from recent years. The development over ten years starting from 2002 is described in figure 27.

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[229] ibd.
[230] own calculation based on datasheet (BRC FuelMaker), fuel and electricity prices in Austria in November 2012
[231] Interview with Heimo-Thomas Blattner (Project Manager Alternative Drives, Energie Steiermark) conducted on 28.09.2012

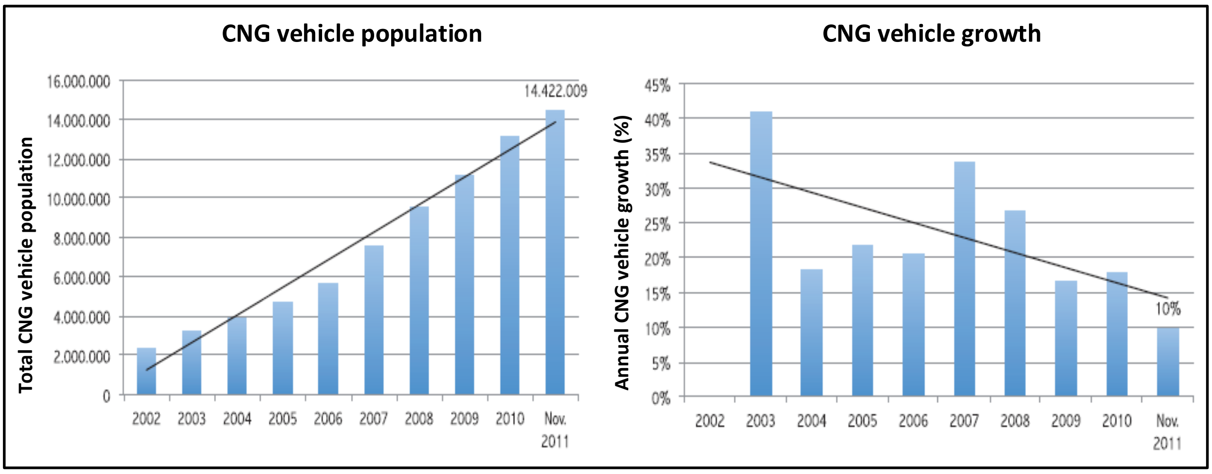


Figure 27: CNG vehicle population and growth 2002-2011[232]

As can be seen, the development of the NGV number is analogous to the number of natural gas filling stations. The popularity of NGVs depends very strongly on the region. Markets that offer good conditions for natural gas vehicles are gradually saturated, which is why annual growth declines. The regions with the most natural gas vehicles are the Middle East and South America. Iran is the world leader, with 3.3 million registered NGVs. This corresponds to about 19% of global NGV fleet. Pakistan follows with 3.1 million or 18 %. Subsequently Argentina follows with about 2.2 million (13%) and Brazil with 1.7 million (10%). On the streets of India and China, there are 1.5 million (9%) gas vehicles on the road. In these named six countries, over 75% of the global NGV is on the move.[233]

Of the natural gas vehicles in the Middle East, about half are provided by OEMs and the rest are converted in workshops. In South America, natural gas vehicles are almost exclusively converted gasoline vehicles. Only a very small share is delivered by the OEMs. In both regions, the operating mode is mostly bivalent, which also means that gasoline combustion is possible. NGV in these regions are passenger cars as well as light duty vehicles (LDV). Vehicle segments where natural gas is used as fuel are A (micro car), B (subcompact car), C (compact car), and LDV. For the storage of natural gas, almost all used tanks are Type I out of steel.[234]

Within the European region, Italy is the absolute leader with 746.000 registered NGV. But this only represents about 4.3% of the global NGV population. Further down the list there is the Ukraine, with 388.000 and Armenia, with 244.000 NGVs. Germany follows far behind at the fourth place, with about 95.000 vehicles. If all NGVs are

[232] own representation based on GVR 127 (2012), p.33
[233] cf. GVR 135 (2013), p. 25
[234] cf. Magna Steyr (2012b), p. 3

counted together, then exactly 10 % of the global NGV population is registered in Europe.[235]

The market in Europe is mainly driven by the Total Cost of Ownership (TCO). The majority of the vehicles work in bivalent mode, which is also due to the unequal and regional dependent gas supply infrastructure. Unlike in emerging countries, mainly OEM delivered vehicles are in use in Europe, only a few customers trust in Aftermarket solutions. Vehicle segments in Europe are A, B, C and LDV. Today, for the CNG storage, mostly Type I steel tanks are applied. There are also OEM vehicles that are equipped with Type IV tanks. There is potential for Type IV tanks in Europe because most premium manufacturers rely on lightweight construction.[236]

The situation in North America differs in many ways to the situation in Europe. In the U.S., only about 112,000 natural gas vehicles are in use. This corresponds to about 0,65% of the total CNG vehicle population. In Canada, there are actually only 14.200 vehicles (0,08% of total CNG vehicle population). Measured against the total volume of the North American market, these numbers are infinitesimally small.[237]

The NGV in this region are mainly retrofitted gasoline cars. In North America, the price for gasoline and diesel is rather low and this circumstance reduces the profitability of NGVs compared to conventionally fuelled cars. Unlike in Europe, here the proportion of monovalent vehicles is already at about 50%, as a large number of commercial and municipal vehicles are present. SUVs are still very popular in North America. In North America, the highest potential lies in the transportation sector and not in passenger cars. School busses and shipping vehicles with CNG systems are promoted by the governments. These vehicles are almost all equipped with Type IV or Type III tanks.[238] A list of the exact numeric values for all countries can be found in the appendix.

By means of research and interviews with automotive manufacturers and suppliers, Magna was able to create an overview, which indicates the potential of the tank systems in individual regions. Figure 28 illustrates global CNG markets and an accentuation of regions for which there is a good chance that Type IV tanks systems will penetrate the market. Type I tanks are currently most widespread. Its decisive advantage over the composite tanks is the lower cost of production. Nevertheless, due to some characteristics of Type IV tanks, they may gain momentum in the future.

[235] cf. GVR 135 (2013), p. 24
[236] cf. Magna Steyr (2012b), p. 4
[237] cf. GVR 135 (2013): p. 25
[238] cf. Magna Steyr (2012b), p. 4

The most interesting regions for Magna are North America and Central Europe. Here, the potential for composite tanks is particularly high.[239]

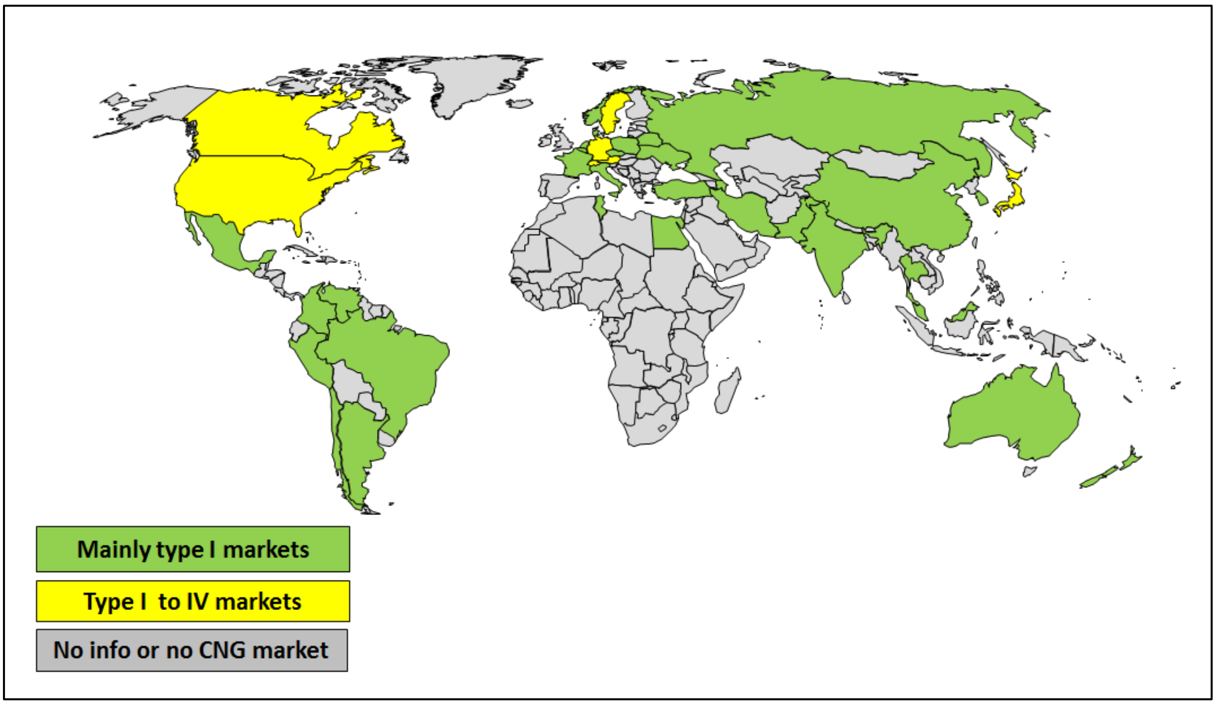


Figure 28: Current markets by vessel type[240]

6.1.3 Competitive analysis

The planning of the opportunities and risks of market entry requires consideration of the competition. This includes listing the competitors currently leading in the market and an assessment of their skills. A comparison across different categories, with the expertise of Magna, then cites company strengths and weaknesses compared to the competition.

A comprehensive competitive analysis is associated with a lot of time and effort and is not the focus of this work, which is why only the result of an investigation carried out by Magna Steyr is briefly explained. Table 8 indicates the result of this investigation. The market leading suppliers of all currently available natural gas storage systems (Tank Types I, III, and IV) have been evaluated according to different criteria.

[239] Interview with Dr. Uwe Thien (Project Manager Natural Gas Storage Systems, Magna Steyr) conducted on 30.01.2013
[240] Magna Steyr (2012b), p. 40

	Supplier	Industrial Ex-perience	Technics	Patents	Weight	Price	Volumes		Product range			Σ
							Auto-motive	Non-Auto-motive	Cylin-der	Module	Vehicle Enginee-ring	
Type I	FABER (DALMINE, WORTHINGTON, WITKOVICE, EKC, RAMA)	+ +	o	o	- -	+ +	+ +	+ +	+ +	o	- -	6
Type IV	RAGASCO	+ +	+ +	o	+	+ +	+	+ +	+	o	- -	9
	ULLIT	+ +	+	o	+	+	+	o	+	o	- -	5
	XPERION	o	+ +	o	+	+	o	+ +	+	o	- -	5
Type III	DYNETEC	+ +	+	o	o	-	+	o	+ +	+	- -	4
	LUXFER	+ +	+ +	o	o	o	o	+ +	+ +	o	- -	6
Type IV	MAGNA	o	+ +	o	+	+	o	-	+	+ +	o	6

Table 7: Competitor strength and Chances for Magna (red arrows: potential for improvement, blue circles: leaders in important business fields)[241]

A rating of Magna in the categories Industrial Experience, Technics, Patent, Weight, Price, Volume and Product Range gives the total score 6. A “+” stands for a positive point and a “-“ for a negative point. Ragasco, in the field of Type IV tank systems and Faber, in the field of Type I steel tank systems are identified as the main competitors of Magna. The highest economy of scale is achieved by Faber, Ragasco and Luxfer, which score with especially high volumes in the non-automotive sector. Although Magna has comparatively little experience with natural gas filling systems, the company has the best experience as an automotive supplier. Magna’s contacts and good reputation as a reliable supplier over several years is an enormous advantage. Furthermore, no company yet has been able to create a Unique Selling Proposition (patents), which would mean a distinct advantage over the competition. Areas where Magna still has potential for improvement are marked with red arrows. If Magna is able to improve in these areas, it would be quite competitive in case of market entry.[242]

[241] cf. Magna Steyr (2012b), p. 24
[242] ibd.

6.1.4 Company analysis

Just as the competitive analysis, the company analysis is also part of the market analysis and is therefore briefly described here. The results serve as support for the management in decision making, as well as the Industry Roadmap. Also in this area, Magna has put a lot of effort into researching the company's characteristics and potentials. Subsequently, the main findings of the investigation are described.

6.1.4.1 Strength-Weaknesses-Threats-Opportunities (SWOT) Analysis

A SWOT Analysis is conducted in order to gain a good overview of the business relevant factors, which may have an impact on Magna. The investigation is primarily done to find out which chances and risks Magna must face, in case of market entry. The results are intended to not only contribute to the strategic decision making but also to indicate some development directions for the Industry Roadmap. Table 9 contains the main factors of the categories strengths, weaknesses, threats and opportunities.

Looking at the results, it can be seen that opportunities and risks are fairly balanced. So it is foreseeable, that a careful consideration of all arguments, which speak for and against a market entry, is required. A closer examination of all the arguments for and against a market entry is the task of the strategic management and is not treated here anymore. A more detailed list of chances and risks for Magna is shown in the appendix.

Strengths	Weaknesses
- Technical competence in fuel systems - Past experience OEM acceptance of Magna - Financial strength - Magna "brand" precence - OEM can leverage Magna - Governments affairs support	- No US presence for CNG - Techn. eyperience only in Europe - Only Type IV tank experience - Strategy for Type IV tank only - Unknown in the compressed natural gas market - Competitors heavily invested
Opportunities	**Threats**
- Federal targets for low CO_2 - Massive gas reserves in the US (shale gas) - Grants and incentives for use of CNG - Growth in truck and car use with < 2 year payback - 10- 15 % market growth p.a. through 2019	- Lack of refueling infrastructure in short term - Demand icludes most types of tanks - Exposure to price of carbon (Type IV) - Liabilities for supply to OEMs (Warrenty, etc.) - Future imports form Asia - Stability of CNG price s long term (taxes)

SWOT Analysis

Table 8: SWOT Analysis: Main points concerning Magna (CNG: compressed natural gas, OEM: official equipment manufacturer, US: United States)[243]

6.1.4.2 Potential customers and market entry strategies

To complete the market analysis potential, customers and entry strategies are briefly discussed. Magna enforces development in the field of Type IV composite tanks which is the target segment. This means that OEMs and fuel system manufacturers using carbon fibre tanks or those planning to work with them in future are potential customers.

Market analyses and discussions with company representatives have revealed that in the United States, there is a very high interest in working together with Magna. OEMs, such as Honda U.S., Chrysler, Nissan U.S., Ford and GM have been identified as potential customers. These manufacturers already work together with suppliers and sell cars powered by natural gas. The preferred tank systems in North America are Type IV carbon fibre tanks.[244]

243 own representation based on Magna Steyr (2012c), p. 28
244 cf. Magna Steyr (2012c), p. 17

In Europe, there are also potential customers. In addition to VW / Audi, Opel, Fiat and Daimler, which already have natural gas vehicles on offer, Ford is also starting to introduce its model Focus in a CNG version. Type IV tanks in Europe are not as popular as type I steel tanks but the trend is towards lightweight and thus the carbon fibre tanks.[245]

The market in Asia is not as well studied. OEMs have very few natural gas vehicles and if they do, then usually only vans, buses and trucks. Potential customers in Asia are only Honda, Mazda and Toyota. The need is also greatly reduced to steel tanks. In Japan, only Type IV tanks are relevant.[246] A review of potential customers in Europe and the United States can be seen in the appendix.

Magna has two entry options for becoming a new market player for CNG. One possibility is entering into a partnership with a company that has maintained the market and is ready to start cooperation. Magna can use, buy or participate existent facilities and acquire additional volumes. Both Magna and the partner company could benefit substantially from cooperation. Magna could save on development costs and production costs and the cooperating company would benefit from Magna’s contacts and business partners.[247]

The second possibility is to acquire an OEM production contract. An acquisition is very expensive but also brings independence. The existing know-how and corporate contracts could be adopted. Calculations have proven that an acquisition would only be profitable at a yearly CNG tank production of about 40.000. Whether such a need will exist is highly questionable and thus a company takeover is linked with an extremely high risk.[248]

6.2 Identification of relevant trends

An essential step in creating the Industry Roadmap is to identify trends that may contribute to a positive or negative development of the NGV market. Besides the identification, an evaluation is also conducted in order to determine the relevance to the company. Trends with very high likelihood of occurrence and significant impact on business success have to be considered with special care.

[245] cf. Magna Steyr (2012c), pp. 18-19
[246] cf. Magna Steyr (2012c), pp. 21-22
[247] cf. Magna Steyr (2012c), p. 25
[248] ibd.

6.2.1 Trend detection and evaluation

By conducting an environmental analysis of the natural gas vehicle market a total of eight different trends, which are of importance for the development of the market and technology are being recognised. For the investigation, the Trend Portfolio model is used and is explained in chapter 2.3.2.3. The result of the analysis is shown in figure 29.

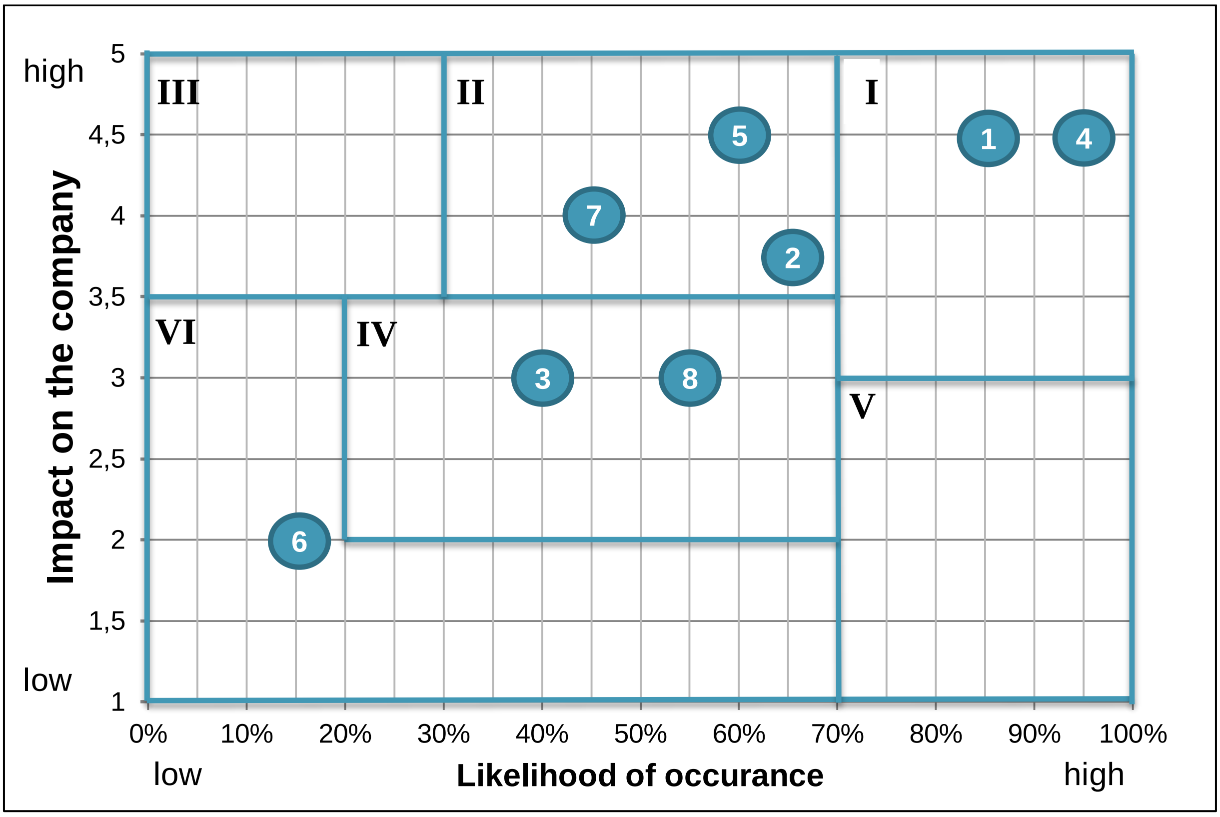


Figure 29: Trend Portfolio with CNG market relevant Trends[249]

From the eight trends found, five are of very high importance for Magna. Especially trends which are located in the fields I and II in the Trend Portfolio require increased attention. The two trends that are in the field IV should be kept in mind. The likelihood of these occurring is difficult to predict and the grade of influence on the company is in the middle range. The probability that trends in field VI will gain in importance is very low and the impact on the company's strategy is low too. This trend should not be given too much attention. The detected trends are described in the next chapter.[250]

[249] own representation based on Fink, A.; Siebe, A. (2006), p. 134
[250] cf. Fink, A.; Siebe, A. (2006), p. 134

6.2.2 Trend description

A brief description of trends gives an impression of their importance for the development of the market over the next few years.

6.2.2.1 Trend 1: Growing NG vehicle offer

A large selection of vehicle models is of particular importance for car buyers. For this reason, car manufacturers have put a lot of effort into expanding their range of vehicles on offer over the next few years. High volume models like the VW Golf will be offered as a CNG version in 2013. The VW Group recently introduced the new manufacturing strategy "Modular Transverse Matrix" (MQB). This system offers the possibility of installing alternative drive systems such as hybrid, electric and NG systems in an identical position to conventional internal combustion engines.[251]
The selection of fleet models will grow significantly from 2013 to 2014. Thus NG vehicles will be a serious alternative to conventional gasoline and diesel vehicles. In Germany, seven new models will be released in 2013. Examples are: VW Golf, Audi A3, Skoda Octavia and Seat Leon. The current model initiative signalises the commitment of OEMs in establishing NGVs on the market and increase sales.[252]

This trend is of highest importance to Magna. An increased vehicle offer will also have a positive impact on sales and this will please suppliers of natural gas fuel systems.

6.2.2.2 Trend 2: Shale gas production in the United States

With new hydraulic fracturing technology, additional natural gas reserves have come online. Shale deposits hold a large amount of gas around the world, especially in North America. A quote from the U.S. President Obama's State of the Union address in January 2012:

"We have a supply of natural gas that can last America nearly 100 years. And my administration will take every possible action to safely develop this energy." [253]

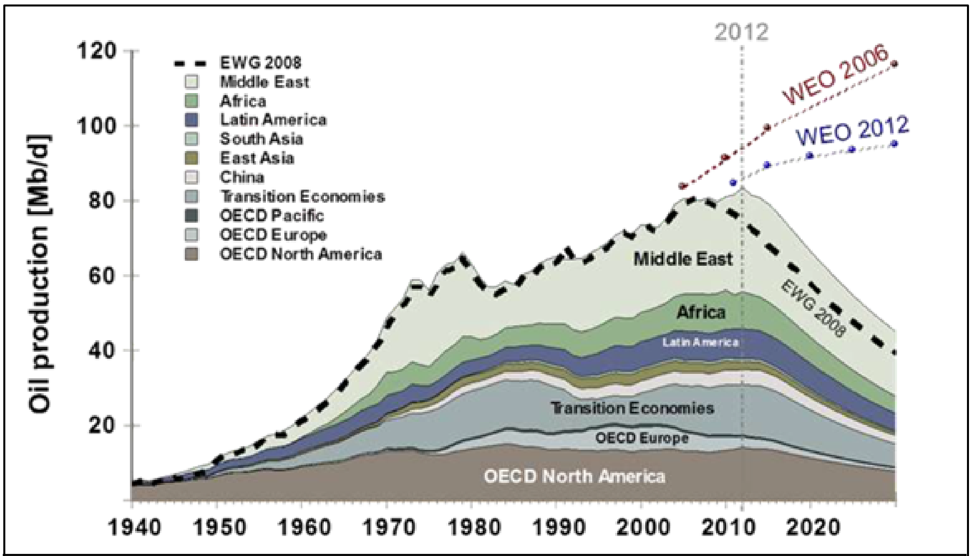
In 2035 shale gas accounts for 49% of total U.S. natural gas production, which is more than double its 23% share in 2010. Thus, the world's energy market will change

[251] cf. ooegw.at (2013), http://www.ooegw.at, access date 22.01.2012
[252] cf. erdgasautos.de (2012), http://www.erdgasautos.de, access date 16.12.2012
[253] White House statement (2012), http://www.whitehouse.gov, access date 24.01.2012

and gas will become an increasingly important source of energy. Due to new sources of natural gas, it can be assumed that gas prices will not rise as much in the next few years, as it has been assumed in previous studies.[254]
The newly opened natural gas sources will definitely affect the price of gas. If natural gas prices remain well below the price of crude oil, NGVs then will be in a better position than a similar vehicle, fuelled with gasoline or diesel. This is due to lower operating costs. The trend of opening shale gas wells is therefore positive for the development of natural gas vehicle market share.[255]

6.2.2.3 Trend 3: Oil Peak and price increase of fossil fuels

The world oil production has plateaued since about 2005. Conventional oil production has been in decline since 2008. Figure 30 displays the so called Oil Peak and the expected declining oil production over the coming years. The oil industry tries to hold this plateau as long as possible but they have to struggle with a growing decline of production in ageing fields. Compensation by developing new fields is becoming more difficult because new fields are becoming harder to find, are smaller and of poorer quality.[256]



WEO… World Energy Organisation
EWG… European Economic Community
OECD… Organisation for Economic Co-operation and Development

Figure 30: World oil production in million barrels per day (Mb/d)[257]

[254] cf. U.S. Energy Information Administration (2012), pp. 92-93
[255] Interview with Heimo-Thomas Blattner (Project Manager Alternative Drives, Energie Steiermark) conducted on 28.09.2012
[256] cf. Zitterl, W. et al. (2013): pp. 7-8
[257] Zitterl, W. et al. (2013), p. 10

While the world energy demand rises sharply, oil production declines. This has the consequence that oil prices will continue to rise and oil is being replaced as the second most important energy source, behind coal, in the foreseeable future. Due to this fact, the price of gasoline and diesel will also continue to rise. The operating costs of vehicles with conventional fuels are increasing and eventually they will reach a level that is no longer acceptable for customers. The simultaneously increasing production from natural gas due to newly developed shale gas wells has the consequence that the probability is high that NG will stay the cheapest fuel in future and the price gap between CNG and gasoline and diesel will increase. This fact makes CNG vehicles more attractive to cost-conscious customers.[258]

6.2.2.4 Trend 4: Legislation for emissions reduction

The increasing environmental pollution resulting from emissions is forcing governments to act. There are several approaches for handling the rising emissions. One way to make the purchase of a NGV more attractive is to offer subsidies. Especially in Europe, states are trying to obtain the purchase of NGVs with bonuses. These mostly come from the governments or energy companies and are paid in the form of discounts on the purchase or fuel vouchers. Furthermore, the tax on CNG is restricted in countries like Germany, Austria, Italy and Switzerland. This ensures that CNG is significantly cheaper than diesel and gasoline at the filling stations.[259]

Besides the governmental support measures in several states, a law adopted by the EU Commission will be valid form 2012. This law stipulates to gradually limit the average emissions of new registered cars to 95 g CO_2/km by 2020. If they exceed the emission limits, OEMs are obliged to pay penalty fees. By introducing this law, vehicles with low CO_2 emissions are promoted. NGV have lower CO_2 emission rates than comparable gasoline and diesel vehicles and will therefore profit from this law.[260]

In the USA there is also a law that limits emissions in the future. This trend is very important and will be discussed again in more detail in chapter 6.3.

[258] Interview with Prof. Dr. Erich Pucher (Head of the Institute for Vehicle Drives and Automotive Engineering, TU Wien) conducted on 01.10.2012

[259] cf. Dudenhöffer, F. (2011), pp. 34-36

[260] cf. Dudenhöffer, F. (2011), p. 24

6.2.2.5 Trend 5: Growing NG refuelling station infrastructure

Accessibility to public filling stations is one of the main purchasing criteria for car buyers. In certain regions, energy companies have already invested well in the development of infrastructure (see 6.1.2.2). Those responsibilities are aware of the fact that a further improvement of gas station accessibility is necessary, especially in regions with a poor network.[261]

The poor CNG station network in North America prevents the success of NGVs. In North America, the focus is on the fleet market, with the expectation that the consumer will catch on once a sufficient number of stations are in place. This focus is expected to bring about 2000 refuelling stations online by 2016 at the main transport routes. Several programs are underway to build up the public network. The goal is to create refuelling stations along major truck routes, one region at a time, at a minimum of 250 miles apart. The overall growth of the number of filling stations is estimated at 25% annually.[262]

In Europe, a large-scale infrastructure development in the coming years is very closely connected with the development of sales of NGVs. Taking into account the recent development and the global NGV statistics, it is to be expected that, by 2017, there will be about 6.000 natural gas filling stations in Europe.

The European Union is also proving an official policy paper - including legislative proposal – which recommends extending the natural gas filling station network and greatly reducing the gap between natural gas fuelling stations in all EU member states to a maximum of 150 kilometres.[263]

6.2.2.6 Trend 6: Home Refuelling Applications

In North America, Home Refuelling Applications (HRAs) are offered in regions with weak infrastructure. These devices are very expensive to purchase and are not able to provide significant advantages over public filling stations. As is shown in table 7, no considerable cost saving is possible. HRAs are only interesting for customers who want to drive a NGV in a region with no other refuelling possibility. It is expected that in North America HRAs will come into use sporadically, at commercial customers, such as transport companies, whereas in Europe, these devices will not engage the market development of NGVs significantly.[264]

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[261] cf. DENA (2011), pp. 30-33
[262] cf. Magna Steyr (2012c), pp. 12-13
[263] cf. Erdgasmobilität (2013), http://www.erdgasmobilitaet.info, access date 10.03.2013
[264] Interview with Heimo-Thomas Blattner (Project Manager Alternative Drives, Energie Steiermark) conducted on 28.09.2012

6.2.2.7 Trend 7: Growing market share of alternative propulsion systems

Alternative drives will gain popularity in the coming years, not only because of their environmentally friendly operation but also because of steadily increasing fuel prices. Hybrid vehicles are already very popular and electric vehicles are more in use, particularly in urban areas. Customers are willing to pay a maximum of 2% surcharge for an economically friendlier car. The energy storage systems in electric cars are not yet fully developed. Expensive batteries and low ranges have prevented a market breakthrough so far. The purchase prices of electric vehicles are so high, that they are not competitive compared to vehicles with internal combustion engines. Customers for electric vehicles will be found sporadically in urban areas or will be those who have one as a second car.[265]

Also hydrogen cars will not play a significant role by 2020. There are almost no hydrogen filling stations and the production of hydrogen is quite expensive today. A promising future is reputed to hybrid vehicles. The concept of hybrid drive is very versatile. Mild hybrids use a braking energy recovery system to support the combustion engine with an electric motor. Full hybrids are capable of pure electric driving with an electric motor in addition to the combustion engine, which draws energy from a battery that is charged via regenerative breaking and the combustion engine. The battery of Plug-In Hybrids (PHEV) can be charged via an external power supply.[266]

An accurate prediction of the market share is difficult, even experts' opinions vary. Magna has conducted a study which uncovers how high the potential market share of alternative propulsion systems can be in the year 2020. The global market share of hybrid vehicles in 2020 is predicted to be 4%. Electric vehicles can have a market share of 0.85%. The market for hydrogen vehicles will be very low, at 0,15%. Thus, hybrid vehicles represent the biggest competition for NGVs in the coming years. Electric vehicles and hydrogen cars can match only partially due to the high purchase and operating costs.[267]

6.2.2.8 Trend 8: Green Mobility

A trend that has developed in recent years is the increased environmental awareness of society. Rising emission load, high fuel prices and stricter legislation have meant that the industry has specifically sought new ways of operating vehicles in a more

[265] Interview with Prof. Dr. Erich Pucher (Head of the Institute for Vehicle Drives and Automotive Engineering, TU Wien) conducted on 01.10.2012

[266] ibd.

[267] cf. Thien, U (2012), p. 30

environmentally friendly way. In addition to alternative drives, the focus was also on new fuel compositions and innovative ways of producing new fuels. Biofuels or synthetic fuels can replace fossil fuels like gasoline, diesel and natural gas or be added in certain amounts. This enables an extension of the duration of availability of fossil fuels and an improvement in the CO_2 balance. Natural gas can also be mixed up with bio-methane or synthetically produced methane. An EU Regulation proposes to raise the share of biofuels by the end of 2014 to 6.25%. The blending of fossil fuels with bio or synthetic gas not only has a positive impact on the CO_2 balance but also helps to keep the fuel price stable. In the long term, fuel price increases can be limited by the application of fuel admixtures.[268]

Not only do governments and energy suppliers insist on new fuels but also the automotive industry pays attention to this topic. In 2013, Audi AG starts their Wind Gas Project. Hydrogen is generated from surplus wind power and water and is subsequently converted, together with commodity CO_2 from industrial facilities, to methane gas. The resulting synthetic natural gas (SNG) is fed into the supply network and can be mixed with conventional natural gas. The gas is only produced from excess "clean" electricity, water and the waste product CO_2. [269]

New ways of producing automotive fuels promote the topic NGV and have a positive impact on an early market breakthrough.

6.3 Exploration of potential for change

The trends described in the previous chapter predominantly stand for good market opportunities for NGVs in the coming decade. The question that must be answered, however, is what drives the customer to buy a NG car or what prevents the customer from making a purchase. Therefore, first the CNG fuel properties are explained and advantages and disadvantages of natural gas compared to conventional fuels are exposed. The circumstances that have prevented a market breakthrough up until now are revealed next. This is followed by a selection of facts that stand for improvement or deterioration of the market conditions in the coming years. To illustrate the potential of natural gas vehicles, an economic analysis of three VW Passat models (gasoline, diesel and natural gas) is carried out. A prediction of sales of natural gas vehicles by 2020 concludes this chapter.

[268] cf. DENA (2012), pp. 4-8

[269] Interview Dr. Max Lang (Department Head of Vehicle Technology, Transportation & Consumer Protection , ÖAMTC) conducted on 01.10.2012

6.3.1 CNG potential

The comparison of natural gas with other fossil fuels provides information about the potential that is hidden in the NGV sector.

6.3.1.1 Energetic value of Compressed Natural Gas

As explained in chapter 4.2.1, the volumetric energy content of natural gas is much smaller than for gasoline and diesel. This is why natural gas is stored in tanks at 200 bar (in North America up to 250 bar). In order to be able to compare the fuels by their energy content, a recalculation to a certain amount of fuel is carried out. A comparison of the fuels shows that significantly more energy is stored in one kilogram of natural gas than in one litre of diesel, petrol or LPG. Based on the Energy content in kWh a cost comparison can also be established. Compared to the reference price of gasoline, the prices of diesel, LPG and CNG are cheaper. Gasoline is most expensive and CNG is by far the cheapest. The results of the calculation with the numerical values can be seen in figure 31.[270]

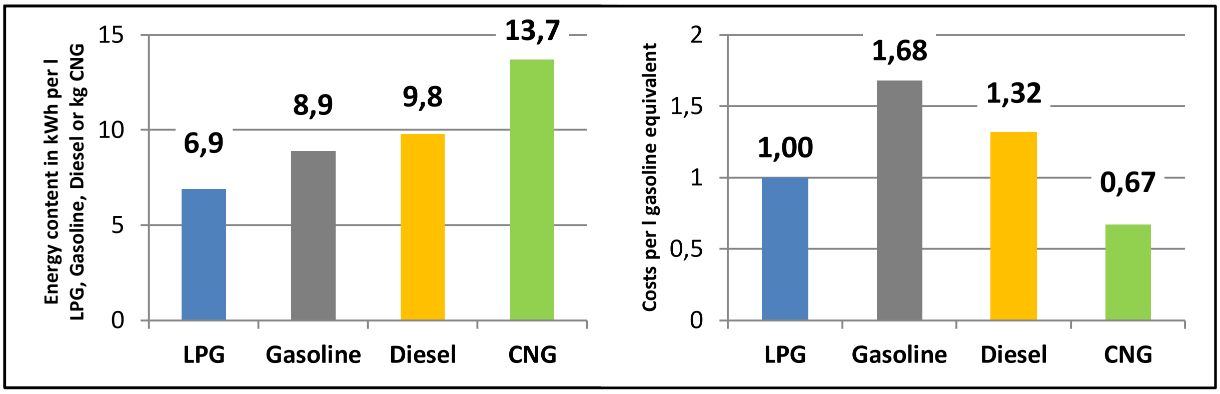

Figure 31: Energy content and energy related costs for different fuels[271]

The comparison of the most common fuels shows that natural gas is the cheapest fuel. CNG has the best energy content to price ratio and thus also the running costs of natural gas vehicles are the lowest. The huge price difference is not only caused by the better energy content of CNG but also by lower taxation of natural gas in many countries. At filling stations, the fuel prices are indicated in monetary unit per litre or kilogram. As a result, the price advantage of CNG appears much smaller than it is in

[270] cf. Volkswagen Group (2013), p. 6
[271] own representation based on Volkswagen Group (2013), p. 6

reality. An energy-based pricing would be more transparent and would highlight the cost advantage of CNG.[272]

6.3.1.2 Vehicle range and fuel cost comparison

End customers place particularly high emphasis on range and operation costs. The range of NGVs depends on the on-board tank capacity. Most NGVs on the market are bivalent and therefore have a gasoline tank in addition to the CNG tanks. The storable gas mass of OEM vehicles is dependent on the manufacturer and vehicle model and lies between 11 kg and 36 kg. Commercial vehicles are usually equipped with larger tanks.[273]
A comparison of the possible ranges of fully fuelled vehicles shows that diesel vehicles can reach the highest distance. A calculation of the range of VW Passat models showed that the fully fuelled diesel vehicle Passat 2.0 BlueTDI can theoretically reach 1521 km. The comparable gasoline vehicle Passat 1.4 TSI reaches theoretically 1076 km with a full tank. The fuel tank capacity of the two vehicles is 70 litres of diesel or gasoline. The bivalent NGV Passat 1.4 TSI EcoFuel theoretically achieves a range of 488 km with 17 kg natural gas. The extra 31 litre gasoline tank enables an additional 455 km. So the total distance is 943 km, which is only slightly less than the range of the gasoline vehicle.[274]

The extremely high energy content, based on 1 kg CNG and the high octane number, which enables a higher compression ratio in the engine and thus provides improved engine efficiency, facilitate an excellent cost-range ratio for NGVs. In comparison, the VW Passat models are used again in the variants gasoline, diesel and CNG. With a 10 € tank filling, the NG Passat can theoretically cover a distance of 211 km. The NG Passat drives more than twice as far as the comparison model with gasoline. Figure 32 illustrates theoretically reachable distances. All values are based on the consumption data of the manufacturer VW for combined traffic. Consumption values can be found in the appendix.[275]

[272] cf. Volkswagen Group (2013), p. 6
[273] cf. Abate, V. (2011), pp. 16-20
[274] own calculation based on consumption values specified by the VW group (Appendix), driving cycle: combined: VO (EG) 715/2007
[275] own calculation with consideration of the average Austrian fuel prices in November 2012

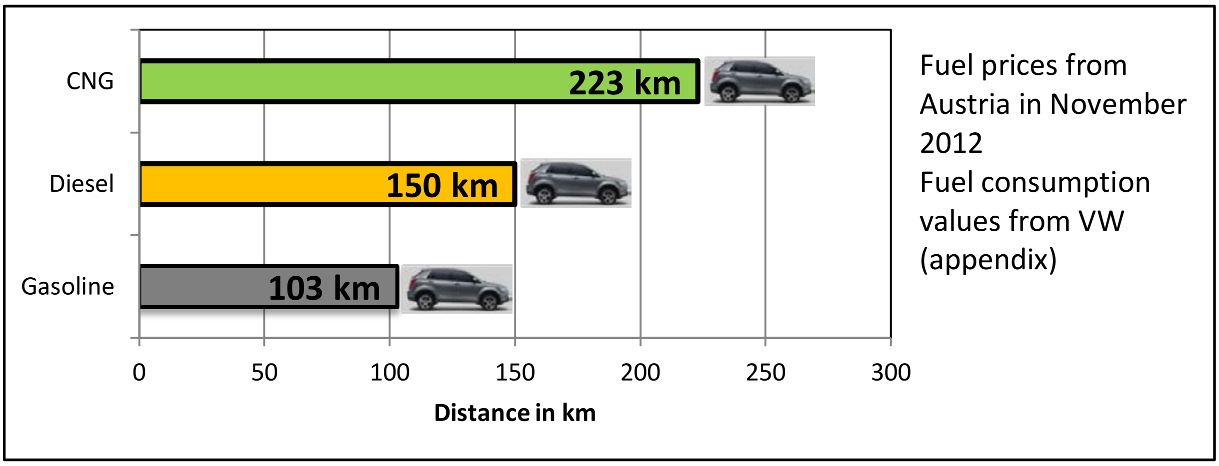

Figure 32: Vehicle range with 10€ tankful[276]

In summary, it can be stated that the vehicle range in the pure NG mode is significantly lower than for similar gasoline or diesel vehicles but with the additional gasoline tank, this disadvantage can be removed. More than 400 km of reach are enough to do every day rides without having to rely on the gasoline reserve. In regard to operating costs, the NGV is not beatable. The slightly higher purchase price is compensated in about two to four years at an average driving performance of approximately 20.000 km a year.

6.3.1.3 Greenhouse gas emission and air pollutant reduction potential

A comparison of NG, gasoline and diesel proves that NG has the greatest potential to reduce greenhouse gas (GHG) emissions within the group of fossil fuels. An investigation by the German Energy Agency (DENA) gives an impression of GHG emissions of different fuels. As a reference vehicle, a gasoline car with suction motor and a fuel consumption of 7 litres per 100 km was used. For setting up the GHG balance of a vehicle, the emissions of GHGs like methane or CO_2 are calculated from the source of the resources (well) to the drive of the car (wheel). Greenhouse gas emissions are then converted into CO_2 equivalents (CO_2eq).[277]
The GHG emission reduction potential for NG is 24% compared to gasoline, 21% compared to diesel and 14% compared to LPG. More significant CO_2 emission reductions can be achieved by the addition of biogas into the existing natural gas network. The result of the investigation with the absolute values in g CO_2eq/km is shown in figure 33.[278]

[276] own illustration based on calculation with average Austrian fuel prices in November 2012
[277] cf. DENA (2011), p. 10
[278] cf. OVGW (2011), pp. 58-59

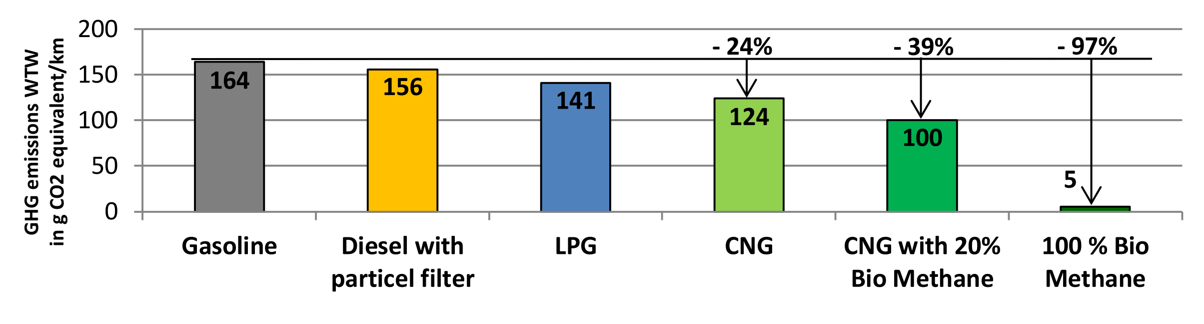

Figure 33: GHG emission reduction potential for different fuels[279]

Furthermore, NG as a fuel for combustion engines can reduce other harmful air pollutants as it is shown in figure 34. The comparison is based on gasoline and diesel vehicles running in compliance with the European exhaust emission standard EURO 4. The diesel vehicle is equipped with a diesel particle filter.[280]

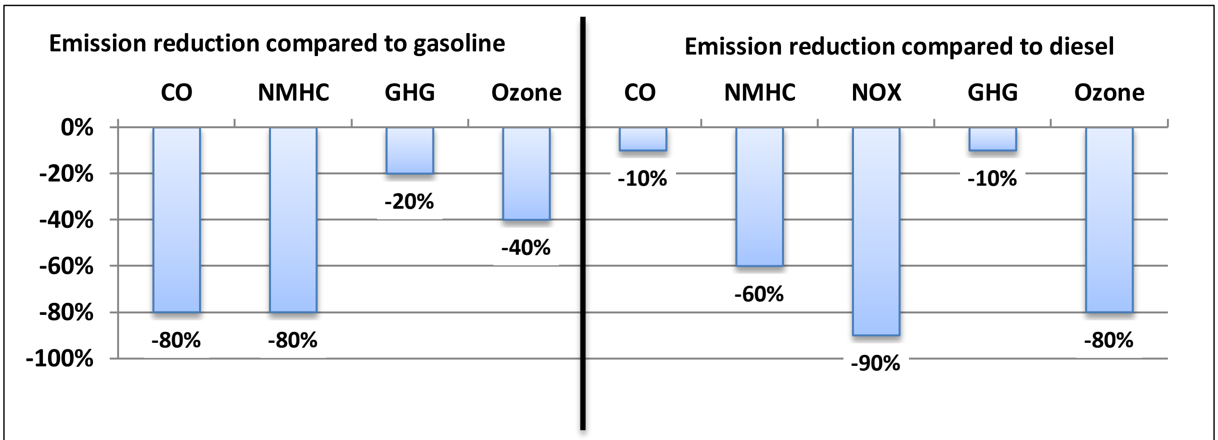

Figure 34: Air pollutant reduction potential of NG compared to gasoline and diesel[281]

As can be seen in the results of the investigations, the fuel NG offers outstanding properties for reducing emissions. This can be a benefit, especially for end customers in urban areas, since in some cities environmental green zones have been introduced, which do not allow the driving of high emission vehicles. The comparatively low GHG emissions (primarily CO_2) are of utmost importance for vehicle manufacturers. The introduction of tougher laws in the coming years will limit CO_2 emissions. Both in Europe and the USA, these legislative proposals have already been drafted and start in 2012. OEMs are forced to produce low emission vehicles otherwise they have to pay sensitive fees. These penalties would be applied to the purchase price of the cars, which negatively affects the competitive ability of

[279] own representation based on DENA (2011), p. 10
[280] cf. OVGW (2011), p. 59
[281] own representation based on OVWG (2011), p. 59

OEMs. Therefore, the production of NGVs is a good opportunity for supplying the market with low emission vehicles, which can be produced with little technical effort. Legislation and their impact on the market will be discussed in chapter 6.3.2.3.[282]

6.3.2 Drivers and blockers of natural gas vehicles

To assess the development of the NGV market over the next few years, it is essential to determine the circumstances which have prevented a market breakthrough so far and the efforts being made to enable an imminent market breakthrough. The most important reasons for lack of success and potential market drivers are described below.

6.3.2.1 Reasons for the low market share of natural gas vehicles

Worldwide, there are about 17 million natural gas vehicles on the roads.[283] Measured by the total number of vehicles, that is a very small percentage. A market breakthrough has not succeeded so far. Essentially there can be nine main reasons for the low proportion of NGV on the market identified.[284]

1. Purchase and amortization costs of NGV

The incentive to purchase a NGV is low because the cost is higher compared to gasoline and diesel vehicles. The fact that the higher purchase cost is easily amortizable by driving average distances is not taken into account by many customers.[285]

2. Fuelling station infrastructure

Neither in Europe nor in North America there is a consistent fuelling station network. Some regions or countries like Italy, Germany and Austria already have a good network of filling stations but in other regions it is often impossible to refuel a car within reasonable distances. An expansion of refuelling infrastructure is urgently needed to increase the attractiveness of NGVs.[286]

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282 cf. OVGW (2011), p. 59
283 cf. GVR 135 (2013), p. 25
284 cf. Dudenhöffer, F. (2011), p. 23
285 ibd.
286 Interview with Dr. Max Lang (Department Head of Vehicle Technology, Transportation & Consumer Protection , ÖAMTC) conducted on 01.10.2012

3. Ignorance of NG technology

Most car buyers are not aware about the benefits of natural gas as an automotive fuel. The broad community does not know about the environmental friendliness and cost effectiveness of NG vehicles. Another problem is that people often confuse the fuel LPG with CNG. Customers are not aware of the properties of CNG and often also think that gaseous fuels implicate an increased safety risk, which is not true.[287]

4. Marketing of NGVs

The ignorance of NG technology not only affects the end consumer but often also car dealers, which inhibit sales of NGVs through their lack of knowledge. In certain cases, dealers are not motivated to sell a NGV due to an insufficient commission model from the manufacturer, which puts NGVs at a disadvantage. Generally, demonstration vehicles, which might bring this technology closer to the customer, are also missing.[288]

5. Transparent indication of fuel prices at the fuel station

The prices at fuel stations refer to one litre gasoline and diesel or one kg CNG. The energy content remains completely ignored. Therefore, the cost advantage of CNG over other fuels is not displayed transparently. A price indication in € gasoline equivalent would be purposeful and would help to explain to the public that CNG is the cheapest fuel.[289]

6. Lack of NG powered series-production vehicles

A versatile vehicle offer is an almost equally important criterion as the purchase price for car buyers. The model selection of NGVs has been very low up to now. Most OEMs have few NGVs in their product range to test the market and to evaluate whether these vehicles can find their buyers. Very popular high volume models like the VW Golf or the Opel Astra are not available as a CNG version. The demand would rise significantly if such models were available with a NG system.[290]

7. Taxation of NG

Although, natural gas is less heavily taxed than gasoline and diesel in many countries, there are some disadvantages. In some countries for example, the energy tax on CNG is higher than on LPG, although the NG vehicle operation is much more environmentally friendly than those with LPG. In Germany and Switzerland there are

[287] cf. DENA (2011), p. 19
[288] cf. DENA (2011), pp. 19-20
[289] cf. Dudenhöffer, F. (2011). p. 23
[290] Interview with Dr. Max Lang (Department Head of Vehicle Technology, Transportation & Consumer Protection , ÖAMTC) conducted on 01.10.2012

favourable tax arrangements for CNG, which are valid until 2018. An extension of these regulations to 2025 is currently discussed. A uniform and permanent tax credit for CNG would give all parties security for long term planning.[291]

8. No uniform system of subsidies

There are no standard measures to encourage the purchase of NGVs. In some European countries such as Italy, Sweden and Austria, the purchase or operation of NGV is funded, in others it is not.[292]

9. Unknown residual value of NGVs

Primarily commercial customers, such as delivery companies, buy vehicles that operate them for some time and then sell them again. In Central Europe, the fleet vehicles will mostly be sold to Eastern Europe. But lack of refuelling infrastructure provokes the fear that used NGVs will find no takers in these countries.[293]

6.3.2.2 General measures for NGV market improvement

Looking at all the obstacles of the breakthrough of NGVs in the market, it is clear that there is still a very strong need for action but some steps have already been taken to improve the situation. One important step is the increased expansion of refuelling infrastructure, especially in areas with poor networks such as in North America. Energy companies are planning the expansion of the main traffic routes in cooperation with political support.[294]

Also, a larger variety of NGVs shows that the OEMs are willing to establish the NGV on the market. The intensified development effort also suggests that manufacturers will increase their effort in marketing. The development costs have to be recouped and that is just possible with high sales.[295]

Politics promote the sale of NGVs in an active and passive way. Support measures are adopted or extended. Promoting the purchase of natural gas vehicles is on the rise. Thus, the higher purchase price of NGV can often be compensated. The lower taxation of NG is continuously discussed and general emission limits are introduced. Also the extension of green zones in cities promotes the purchase of NGVs. A range of support measures undertaken by countries in Europe and the USA can be found in

[291] cf. Dudenhöffer, F. (2011), p. 23
[292] ibd.
[293] Interview with Dr. Max Lang (Department Head of Vehicle Technology, Transportation & Consumer Protection , ÖAMTC) conducted on 01.10.2012
[294] cf. Magna Steyr (2012c), pp. 12-13
[295] cf. DENA (2011), p.32

the appendix. The topic of legislation concerning emission reduction is critical and is therefore covered in more detail in the following chapter.[296]

Even energy suppliers are participating in the improvement of the market situation. In addition to the development of infrastructure, energy companies often offer bonuses for the purchase of NGVs. Thus, in Switzerland, for example, fuel vouchers of up to CHF 1.000 are granted for the purchase of a new vehicle (appendix). Energy companies put considerable research effort into the field of biofuels. Together with industrial partners (e.g. Audi AG) they are working on new concepts for NG production. The potential of biofuel and synthetic natural gas is also discussed in a separate chapter (6.3.2.4).[297]

6.3.2.3 Legislation affecting the automotive market

Both in Europe and North America, draft laws have been passed for the limitation of CO_2 emissions. Since natural gas vehicles emit fewer pollutants and the greenhouse gas potential is significantly lower than for gasoline and diesel vehicles, a tightening of emissions laws is beneficial. The key facts of the coming laws in Europe and the United States are listed below.

<u>Europe:</u> EU regulation for the reduction of CO_2 for 2012-2020:[298]

- Target: There is a CO_2 - emissions average for all newly registered passenger cars of 130 g CO_2/km, measured according to Regulation (EC) No 715/2007 and its implementing regulations.
- Limit curve: The Commission proposed curve, which is corrected from 2016 by a weight gain factor. That means, the permissible specific CO_2 – emissions (in g/km) for each new passenger car is set according to the formulas in table 10.

Period	from 2012-2019	From 2020 - ?
Specific CO_2 emissions	130 + a * ($M-M_0$)	95 + a * ($M-M_0$)
Reference mass M_0	1372,0 kg	1372,0 kg
Mass of vehicle M	depends on vehicle	depends on vehicle
Factor a	Variant 1: 0,0457 Variant 2: 0,0333	Variant 1: 0,0457 Variant 2: 0,0333

Table 9: Specific CO2 emissions from 2012-2015 and from 2016 to 2019[299]

[296] cf. Dudenhöffer, F. (2011), p. 35
[297] cf. DENA (2011), p. 32
[298] cf. BMU (2012), http://www.bmu.de, access date 28.10.2012
[299] own representation based on BMU (2012), http://www.bmu.de, access date 28.10.2012

- "Phase in": The average specific CO_2 emissions of the manufacturer are determined from 2012 to 2015: Every year, only a certain part of the new passenger cars must comply with the respective target values. The share of produced cars that must meet the requirements is in 2012 65%, 2013 75%, 2014 80% and in 2015 all new vehicles.
- Target for 2020: A target value of 95 g CO_2/km is set valid from 2020
- Penalty fees for exceeding the target values:
  From 2019 there is the full penalty of 95 € per g CO_2/km. From 2012 to 2018 there is a graded penalty height for the first 3 g exceeded:
    - Transgression from 0 to 1 g/km : 5 € per g/km
    - Transgression form 1 to 2 g/km: 15 € per g/km
    - Transgression from 2 to 3 g/km: 25 € per g/km
    - Transgression over 3 g/km: 95 € per g/km
- If a car model has an emissivity value below the required limit, the difference will be credited for other models of the manufacturer. OEM target must be: The CO_2 footprint of all vehicles in their fleet together must be below the limit.

A concrete example demonstrates the tremendous impact of regulation. The gasoline car VW Passat 1.4 TSI model year (MY) 2012 is used as an example. Table 11 shows the theoretic penalty fees for 2015 and 2020.

Passat	1.4 TSI 2015	1.4 TSI 2020
Weight	1483 kg	1483 kg
CO_2 emissions	149 g/km	149 g/km
CO_2 allowed	135 g/km	100 g/km
Penalty	1.090 €	4.655 €

Table 10: Penalty fees for target exceeding[300]

If VW produces this Passat model in 2015, they would have to pay a penalty fee of € 1.090. In 2020, it would be even higher, at € 4.655. These sums are not acceptable for a company that wants to stay competitive, so they will have to react and produce low emission vehicles.

300 own representation, values from VW group (appendix) and BMU (2012), http://www.bmu.de, access date 28.10.2012

<u>USA:</u> Corporate Average Fuel Economy (CAFE) and CO_2 emission reduction:[301]

- The Corporate Average Fuel Economy (CAFE) is a regulation in the U.S. intended to improve the average fuel economy of cars and light trucks. The regulation sets a minimal value, which explains how far a vehicle must come with one gallon of gasoline.
- For CNG vehicles, there is a special treatment for the calculation of the fuel economy rate: Only 15% of the fuel use of the vehicle will be counted towards CAFE.
- According to the AMFA (Alternative Motors Fuel Act), passed by the U.S. Congress in 1988, 100 standard cubic feet of Natural gas is considered to be equal to 0.823 gallons of gasoline. For example, a vehicle which can travel 25 miles on 100 ft^3 of natural gas would, according to CAFE rules, have a fuel economy rating of 202.5 miles per gallon (mpg).

$$Fuel\ Economy = \left(\frac{25\ miles}{100 ft^3 of\ NG}\right) \times \left(\frac{100 ft^3 of\ NG}{0{,}823 gallons}\right) \times \left(\frac{1}{0{,}15}\right) = 202{,}5 mpg \qquad \text{(Formula 6-1)}$$

- The CAFE calculation is for a dedicated natural gas vehicle. For dual fuelled vehicles, it is assumed that they will operate 50% of the time on gasoline and 50% on natural gas. The harmonic mean is used to calculate fuel economy for a given vehicle, for including in the CAFE calculation. For example, using the above 202.5 mpg on natural gas and 30 mpg on gasoline results in a rating of 52 mpg.

$$Fuel\ Economy = \frac{1}{\left(\frac{0{,}5}{202{,}5 mpg} + \frac{0{,}5}{30 mpg}\right)} = 52 mpg \qquad \text{(Formula 6-2)}$$

- Depending on the vehicle footprint, a certain distance must be reached with one gallon gasoline (or the equivalent amount of NG). The value increases every model year. There is also a distinction between passenger cars and trucks.
- Regulated fuel economy rates for the year 2025:
  - Passenger car standards range from 45.6 mpg for the largest footprint to 61.1 mpg for the smallest
  - Light truck standards range from 30.2 mpg to 50.4 mpg
  - Combined passenger car and light truck fleet projected CAFE standard is 48.7 mpg

[301] cf. Barnhard, D. (2013), pp. 4-10

- The penalty for failing to meet the CAFE requirements is $5.50 per every 0.1 mpg below the limit.

In addition to the CAFE regulation, there is also a law for the reduction of CO_2 emissions. The allowed CO_2 emissions from cars and trucks are lowered annually and ignoring the limits may result in the restriction of vehicles needing to be recalled or fines of up to $ 37,500 per vehicle.[302]

6.3.2.4 Biofuel and Wind Gas – Alternative gas production

In order to meet the trend of Green Mobility and to be able to drive vehicles in the most environmentally friendly way possible manufacturers and energy suppliers focus on research methods for producing fuels in an alternative way. Two alternative approaches to produce natural gas are the generation of bio-methane and the production of synthetic natural gas by chemical reactions.

<u>Bio Methane:</u>
Bio methane is a renewable energy source that has the same quality as the fossil natural gas. It has excellent characteristics concerning environmental protection and energy efficiency. Bio methane is produced in special processing plants and is then fed into the natural gas network. For the production of bio methane, different resources are needed. These are, for example, energy crops such as maize, sugar beet, cereals, grassland growth and residues such as the excrements of livestock, organic waste and industrial waste. In the processing plant, the biogas is cleaned and adjusted to the required network quality. The bio methane can be used for the generation of electricity, heating and as fuel. The bio methane production process is illustrated in figure 35.[303]
Bio methane can be used in pure form or added (as a certain percentage) to conventional fossil NG. The German “Initiative Natural Gas Mobility” is committed to ensuring that by 2015, the NG fuel must contain at least 20% bio methane. The environmental benefits would be significant, as the representation of the Greenhouse gas emission reduction potential in figure 33 shows. The well to wheel balance shows that with an addition of 20% bio methane, about 39% of GHG emissions can be saved. With 100% bio methane it would even be 97%. So there is basically no way to fuel a vehicle more cleanly at the moment.[304]

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[302] cf. Barnhard, D. (2013), p. 7
[303] cf. DENA (2011), pp. 15-16
[304] ibd.

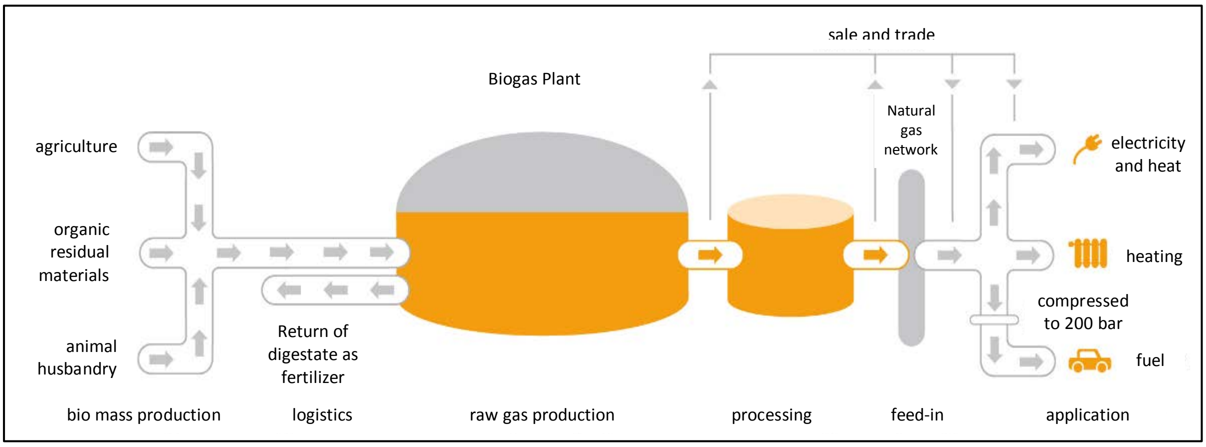

Figure 35: Bio methane production and value chain[305]

Wind Gas:

In the summer of 2013, the Audi AG will start up a facility in which electricity from wind energy is used to generate synthetic natural gas.[306] The process, starting at the wind turbine and ending at the gas station, is illustrated in figure 36.

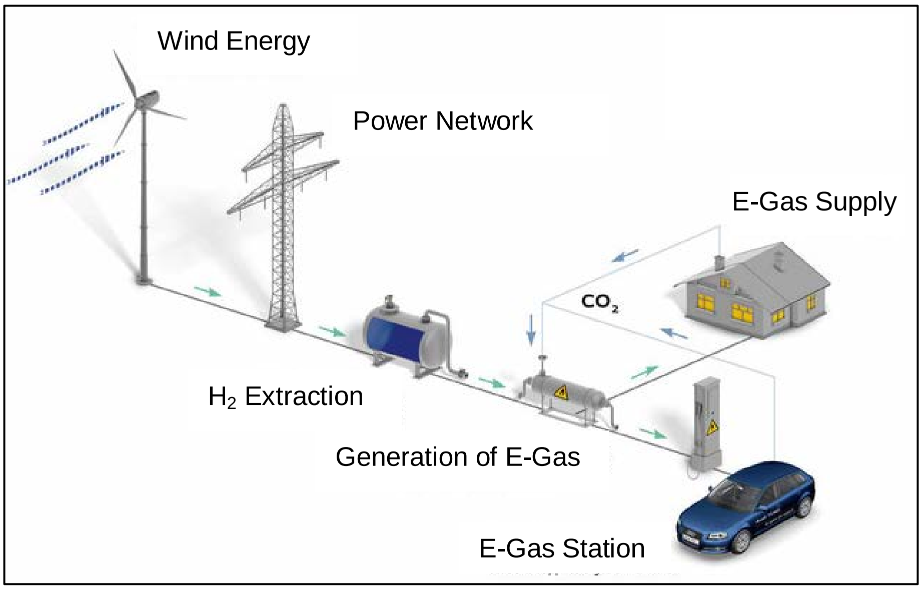

Figure 36: Audi E-Gas Project scheme[307]

The generation of methane takes place over several steps. Excess electricity from wind turbines is used to perform an electrolysis in which water is separated into dioxygen and hydrogen. In the next step, the synthetic natural gas (SNG) is

[305] own representation based on DENA (2011), p. 17
[306] Interview with Dr. Max Lang (Department Head of Vehicle Technology, Transportation & Consumer Protection , ÖAMTC) conducted on 01.10.2012
[307] Caricos (2013), http://www.caricos.com, access date 12.02.2013

generated by methanation, which joins the hydrogen with carbon dioxide into water and methane in a chemical reaction. Industrial plants emit huge amounts of carbon dioxide, which is responsible for the GHG effect. This CO_2 can be used for the methanation process. As a result, the carbon balance is very clean. The electricity is generated through wind power which is renewable. Additionally, CO_2 is used for the chemical reaction, which would otherwise be released into the environment. The only waste product is water. The recovered SNG can then be fed into the NG network.[308]

Besides the climate-friendly features of bio methane and wind gas, there are also disadvantages. The main problem is the production cost of the gas. Both methods are very cost intensive. The development of an effective infrastructure would take years and therefore only has limited influence on the sales numbers of NGVs. But NG fuel, with a certain percentage of renewable gas, can improve the image of NG as cleaner alternative to conventional fuels.[309]

6.3.3 Economic analysis: VW Passat Comfortline

To demonstrate the potential of NGVs compared to conventional vehicles, a cost analysis is established, which gives information about whether NGVs are cheaper in operation and thus fulfil the requirement of attracting customers. An amortization calculation shows after which driven distance the NGV pays off. All calculations are based on expenses that arise in Austria, except the purchase prices of the vehicles, which are from Germany.

6.3.3.1 Total Cost of Ownership (TCO)

The calculation compares four VW Passat models with each other. Volkswagen currently offers one NG version of its Passat model: VW Passat 1.4 TSI EcoFuel. This vehicle is equipped with a gas tank module with Type I steel cylinders. To get an idea of the costs of a comparable Passat model with type IV tanks, a fictitious Passat with these tanks is included in the comparison. The properties of this vehicle are determined in calculations and are based on information from former investigations by Magna Steyr. The competing vehicles are the gasoline version Passat 1.4 TSI and the diesel version Passat 2.0 BlueMotion TDI. All vehicles are built in 2012 and have comparable performance values. The calculation includes all costs incurred from the purchase of the car until the end of the 5th Year, with an annual mileage of 20,000

[308] cf. Caricos (2013), http://www.caricos.com, access date 12.02.2013
[309] ibd.

km. The vehicle characteristics and all incurred costs as well as the summarized total costs can be seen in a list in table 12.

	1.4 TSI Ecofuel Type I	1.4 TSI Ecofuel Type IV	2.0 BlueMotion TDI	1.4 TSI
Fuel	CNG	CNG	Diesel	Gasoline/Super
Cylinder capacity (cm^3)	1390	1390	1968	1390
Performance (kW/PS)	110/150	110/151	103/140	118/160
Fuel Consumption (Liter or kg / 100 km)	4,3	4,2	4,6	6,5
CO2 Emissions (g/km)	117	117	119	149
Weight (kg)	1598	1553	1532	1483
Fuel Costs (€/l or €/kg)	1,10	1,10	1,43	1,42
Fuel Consumption (Liter or kg / km)	0,043	0,042	0,046	0,065
Fuel Costs (€/km)	0,047	0,046	0,066	0,092
Spectated time (years)	5	5	5	5
Spectated distance (km)	20.000	20.000	20.000	20.000
Fuel Costs (€ for 20.000 km)	946,00	913,44	1.315,60	1.846,00
Vehicle Price (€)	32.775	33.217	30.925	30.050
Service Costs (+ repairs)	4.080	4.080	4.000	4.000
Insurance costs per year	540,95	540,95	540,95	540,95
Tax per year	567,60	567,60	521,40	620,40
Total costs for 5 years and 100.000 km				
Purchase costs in €	32.775	33.217	30.925	30.050
Fuel costs in €	4730	4567	6578	9230
Service and repair costs in €	4.080	4.080	4.000	4.000
Insurance in €	2.704,75	2.704,75	2.704,75	2.704,75
Tax in €	2.838,00	2.838,00	2.607,00	3.102,00
Total cost of ownership in €	47.128	47.407	46.815	49.087

Table 11: VW Passat properties and Total Cost of Ownership[310]

In addition to the purchase price, the fuel costs and the service and repair costs, the yearly insurance costs and the annual tax on motor vehicles are considered. The service and repair costs are assumed based on average values and are slightly higher for the NGVs. This is due to the costs for a visual inspection of the tanks, which has to be done every three years. Although many insurance companies offer favourable conditions for environmentally friendly vehicles, the cheapest offer from the insurance company VAV does not distinguish between the fuel types. The motor vehicle tax only depends on the performance in kW and therefore the gasoline Passat with 118 kW has the highest tax.

The result shows that the TCO for the diesel Passat are the lowest over the observed period. Close behind, the natural gas Passat follows with the steel tank system. The fictitious NG Passat with the Type IV tanks is about 280 € more expensive. The weight saving has been calculated with 55kg. The last place in the cost comparison

[310] own representation, values from VW group (appendix), calculation with average Austrian fuel prices in November 2012

goes to the gasoline Passat. With a TCO of € 49.087 it is almost € 2.000 more expensive than the original NG Passat. The results of the TCO comparison with all costs are depicted in figure 37.

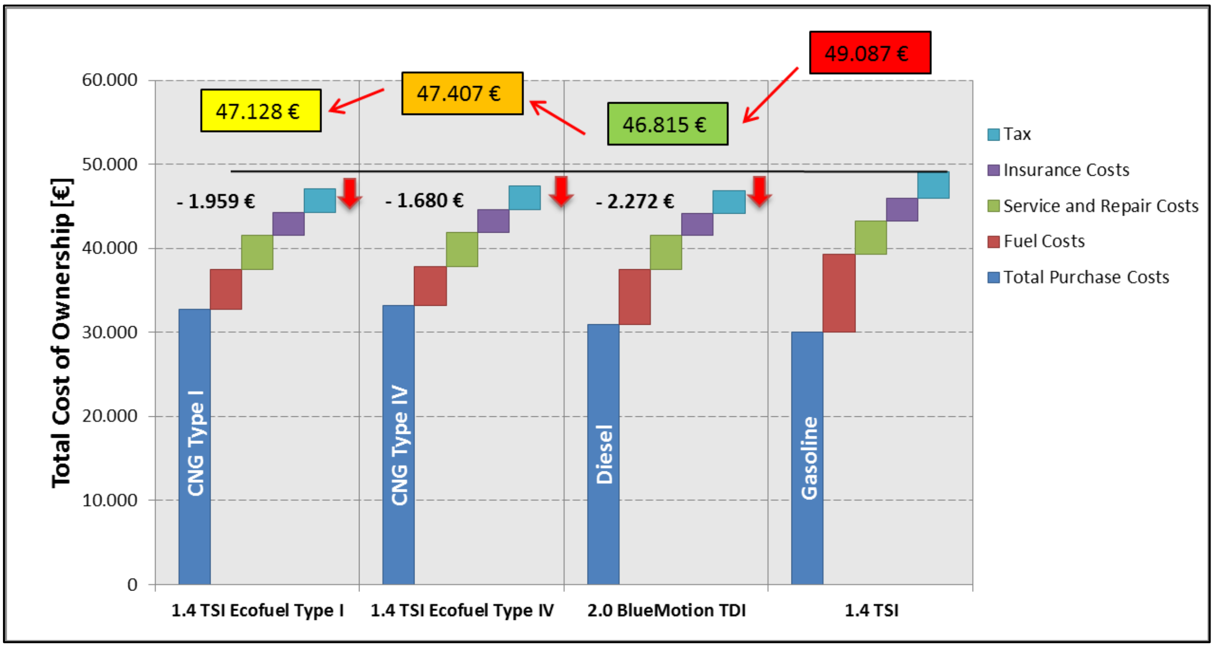

Figure 37: VW Passat Total Cost of Ownership comparison[311]

The tremendous savings of NGVs on fuel costs are striking. The fuel costs for the Passat 1.4 TSI EcoFuel are about 50% lower than the gasoline Passat and about 30% lower than for the diesel Passat.[312] Costs for service, repairs, and insurance are all at the same level. In taxation, the diesel vehicle can collect light plus points. The NGVs are exactly in the middle and the gasoline car is also in the most expensive category due to the highest vehicle performance. The main difference is in the acquisition costs. Here, the natural gas vehicles are the most expensive. The diesel vehicle offers the best mix of purchase price and fuel costs and is therefore the winner of the comparison. What is not taken into account in this calculation are the subsidies. Since in many countries subsidies for purchasing a NGV do not exist, they were not considered in order to keep the calculation neutral. In Austria, natural gas cars can be subsidised, by up to € 1.100.[313] Subtracting this amount from the purchase price, then the natural gas Passat would be the clear winner. It is also noticeable that the Passat with the carbon fibre tank achieves no significant fuel savings and thus its higher purchase price cannot be justified in terms of costs.

[311] own representation, all cost values for Austria
[312] fuel prices: average values from Austria in November 2012
[313] cf. Erdgasautos, http://www.erdgasautos.at, access date 12.11.2012

6.3.3.2 Payback Period

Due to the higher purchasing price NGVs have a certain initial disadvantage over the conventional vehicles. After a certain mileage, this cost difference is caught by lower operating costs. Inserting the current fuel prices, the purchase prices and the fuel consumption of the vehicles into a linear equation leads to straight lines, which intersect each other at certain distances. Thus it can be seen after which distance a vehicle is profitable over another. The result of the calculation is presented in figure 38.

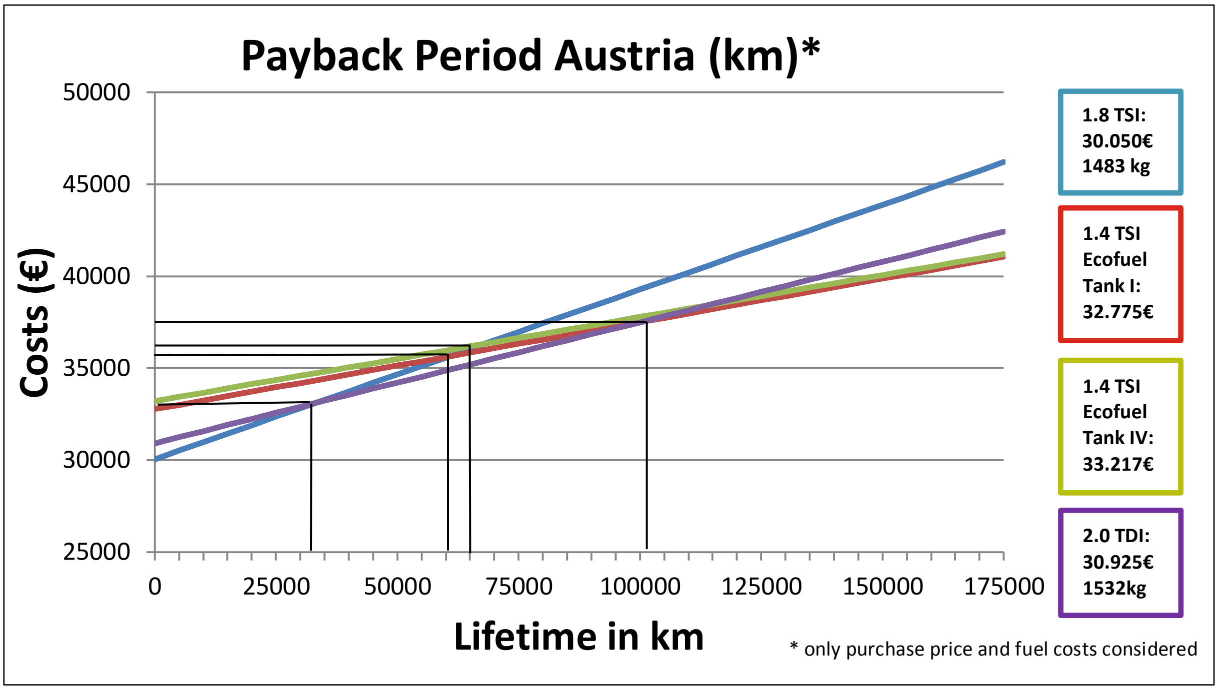

Figure 38: Payback distance of NGVs to conventional fuels[314]

The amortization calculation takes into account only the purchase prices and fuel costs. Subsidies, insurance, taxes and service and repair costs are not included. The diesel vehicle pays off compared to the gasoline vehicle after about 38,000 km. The CNG Passat with type I tanks is cheaper than the gasoline version after about 60.000 km. The Passat with the Type IV cylinders follows with about 5.000km further. After a bit more than 100.000km the NG Passat is profitable over the diesel Passat. It is also remarkable that the Passat with the Type IV tanks compared to the Passat with the steel tank is not profitable within a reasonable distance.

This makes it clear that the NGVs are competitive to gasoline cars but the diesel car is still cheaper up to a distance of 100.000km. Only with meaningful subsidies that

[314] own representation, values from VW group (appendix), calculation with average Austrian fuel prices in November 2012

reduce the acquisition price, does the ratio shift for the benefit of NGVs. The same calculation was also performed for the United States. Here the situation is even worse for NGVs, as the price difference between natural gas and gasoline/diesel there is even lower than in Europe. The NGVs are profitable there over the gasoline vehicle after about 115.000km (type I tank) and 128.000km (type IV tank). The diesel vehicle is more expensive after about 155.000km (type I tank).[315]
The purchase price of NGVs must be reduced approximately to the level of diesel vehicles to prevail against the diesel cars. OEMs or subsidies from energy suppliers and governments can lower the purchase price. NGVs are most favourable for customers who drive long distances.

6.3.4 Natural Gas Vehicle sales prediction 2010-2020

An estimation of total vehicle sales by 2020 gives a real impression of what market potential NGVs have. In this regard, Magna has elaborated a study based on data and information of HIS Consulting and Frost&Sullivan.

6.3.4.1 Sales prediction Western and Eastern Europe

In Europe, the market varies widely between countries. Today, the Ukraine and Italy are the largest NGV markets. In 2012, the share of OEM vehicles is 78%, only 22% of the European NGVs are Aftermarket solutions. In 2020 the share of original NGVs is assumed with 81%. So a slight increase in the share of OEM vehicles is expected. Top Markets Sales for 2020 are expected in Italy, Germany, Sweden and the Ukraine. Leading OEMs on the NGV market will be Fiat with > 65% and VW with > 20% share. The total OEM market share, measured on all cars newly registered in Europe, will be approximately 0.7% by 2020. The European market is mainly driven by TCO. Therefore, funding and incentives are an important factor for the market development and drives the European NGV market. The applied tank types are Type I and Type IV tanks where the share of Type IV tanks is expected to increase. By 2020, the proportion of Type IV tanks in OEM vehicles could rise up to 50% in the best case, whereas most converted cars will be equipped with steel tanks. A graphical representation of the expected annual sales of NGVs with the division in aftermarket and OEM can be seen in figure 39.[316]

[315] calculation with average fuel prices in the U.S. in November 2012, Magna North America
[316] cf. Magna Steyr (2012b), p. 4

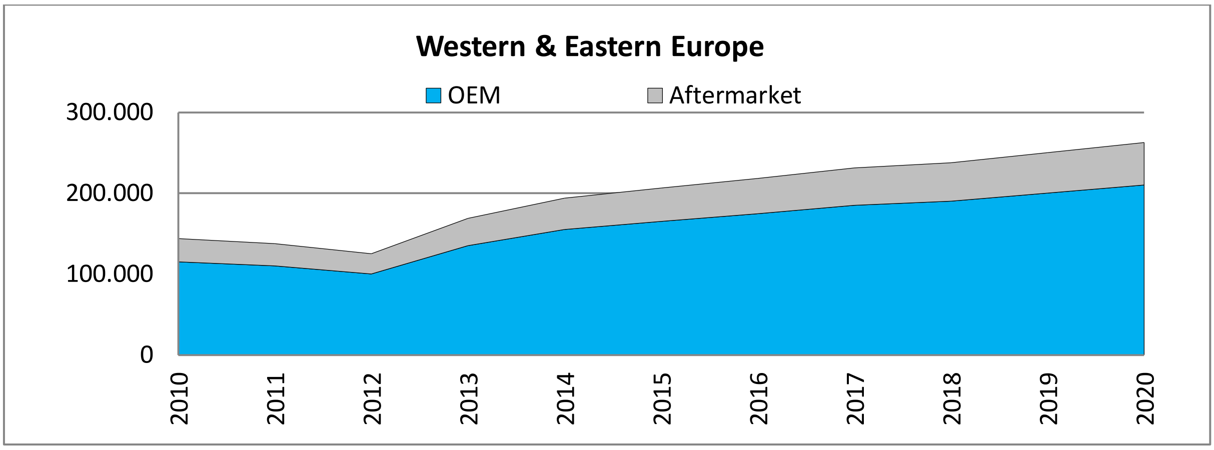

Figure 39: NGV sales prediction for Europe 2010-2020[317]

6.3.4.2 Sales prediction North American Free Trade Agreement (NAFTA)

The North American market largely consists of fleet purchasers rather than individual customers. Honda is currently the only OEM to manufacture a NG passenger car for the North American market. Most NGVs are vehicles with CNG equipment installed by suppliers after the OEM delivered them with some engine upgrades. The aftermarket share in North America is currently 95%. The development by 2020 will not lead to a big change. In 2020, approximately 8% of all sold NGVs will be delivered by OEMs. General Motors (GM) is expected to enter the market and will be market leader together with Honda. Although there is a weak CNG-availability (fuelling stations) there is a strong push from the governmental side. The potential of Type IV cylinders is higher than in Europe, since today, Type III and Type IV cylinders are already mainly in use. The shale gas production and the governmental support will drive the NGV sales in the coming two years. From 2014, the sales numbers will not change substantially. A view of estimated sales for the North American market over the next few years is given in figure 40.[318]

[317] Magna Steyr (2012b), p. 4
[318] cf. Magna Steyr (2012b), p. 4

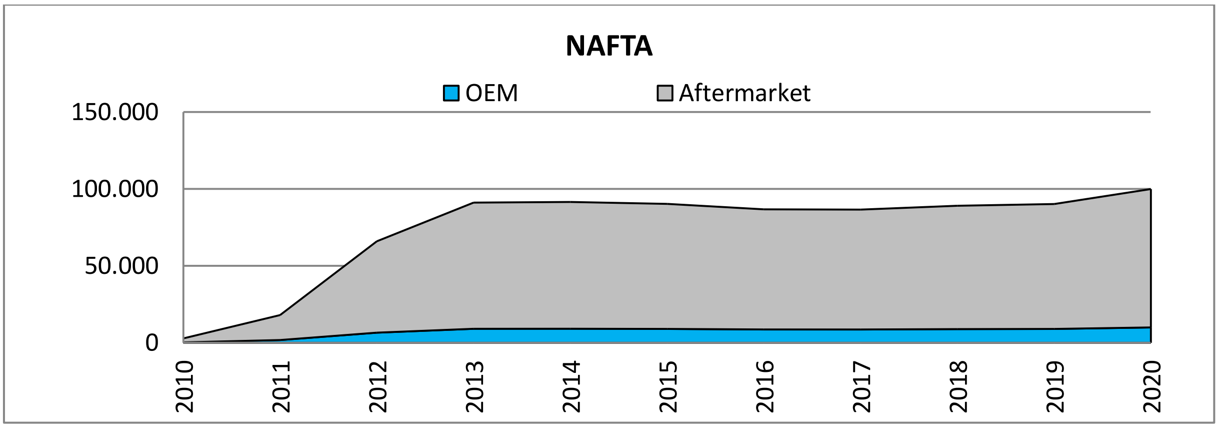

Figure 40: NGV sales prediction for North America 2010-2020[319]

[319] Magna Steyr (2012b), p. 4

7. Backcasting – Projecting visions of the future back

This chapter includes the consideration of possible future situations and their impact on the development of today to some point in the future. Two factors are examined, which may have a decisive influence on a positive development of the NGV market. The legislative changes will have an impact on the OEMs and therefore also on Magna as a supplier. One vision of Magna is to decrease production costs for Type IV cylinders. If Magna could provide light Type IV cylinders at a lower price than the competition, a market entry would have good chances of being successful.

7.1 Effect of the legislation on the automotive market

As explained in 6.3.2.3 new legislations will be introduced in Europe and North America in order to limit the CO_2 emissions of motor vehicles. Thus, OEMs are forced to avoid the emissions of their newly developed vehicles to reduce sensitive penalties. An impact study of the European legislation on three different VW Passat models demonstrates why OEMs will have to improve the emission behaviour of their vehicles.

The vision of the European Commission is to reduce CO_2 emissions to 130 g/km for an average passenger car by 2019 and afterwards to 95 g/km. The allowed emissions are determined by a formula which also considers vehicle weight.[320]
Current emission values of the Passat 1.4 TSI (gasoline) and the Passat 1.4 TSI EcoFuel (CNG) are indicated in figure 41. To demonstrate the possible penalty savings of a lighter NGV with composite tanks, the fictive Passat with Type IV tanks is considered again. Three lines are drawn on the diagram, and each of them represents the limit curve for the allowed CO_2 emissions. The red line indicates the allowed emissions from 2015 to 2019. According to the formula in table 10 a vehicle with a mass of 1372 kg is allowed to emit exactly 130 g CO2/km, heavier vehicles are allowed to emit respectively more and lighter less. The blue line represents the limit from 2019, which had been established by the EU commission. The green curve is a stricter version of the regulations from 2019, which is currently being discussed by the EU Commission.

[320] cf. BMU (2012), http://www.bmu.de, access date 28.10.2012

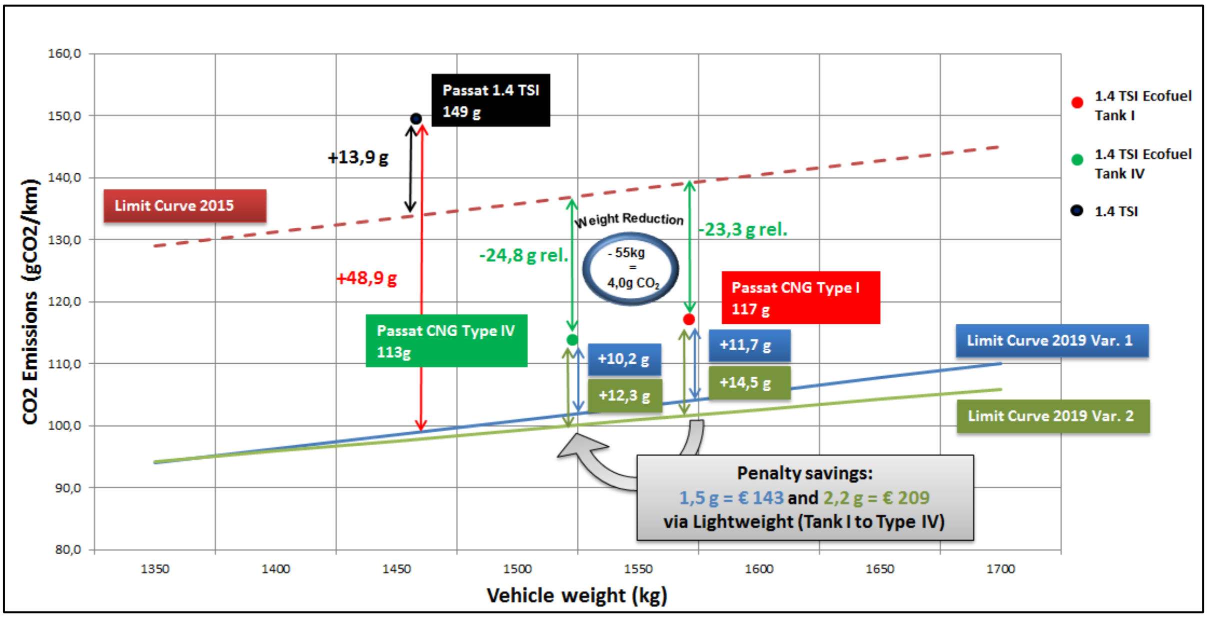

Figure 41: Impact of European Emission regulation on VW Passat models[321]

The comparison shows that both NG Passats are already more than 20 g CO2/km below the limit of 2015 to 2019. The gasoline version emits 149 g/km which is 13,9 g/km over the limit. In 2015 this would lead to a penalty fee of € 1.083. If VW produces the same vehicles in 2019, the two NGVs would also be over the limit. The penalty fee for the gasoline Passat measured by the Limit Curve 2019 var.1 is € 4648 for an exceeding of 48,9 g/km. In case of the Limit Curve var.2 the fee is € 4.778. The penalty fee for the standard CNG Passat in 2019 is € 1.108 in var.1 and € 1.375 in var.2. The Passat with Type IV tanks is lighter but must therefore emit less CO_2. The penalty for excess emissions is € 965 in var.1 and € 1.166 in var.2. A particularly interesting finding is obtained when comparing the two NG Passats. Due to the lower vehicle weight of the Passat with Type IV tanks, the fuel consumption and therefore the emissions are reduced. For var.1 of the Limit Curve difference is 1,5 g/km, which means a penalty saving of € 143. For var.2, the savings are € 209 for a difference of 2,2 g/km.

The result of the investigation shows that without a reduction in emissions, the manufacturers will not remain competitive. In order to achieve the EU targets, OEMs must reduce the emissions of their new cars. NGVs offer themselves as an attractive solution, since their emissions are already today just barely above the 2019 requirements. Due to the lighter Type IV tanks, an even higher penalty can be avoided. The additional costs for Type IV tanks compared to Type I tanks can

[321] own representation

therefore be more easily justified. It is assumed that the stricter legislation will be one of the main drivers for NGVs in the coming years.

7.2 Potential of technology improvement

Since Magna decided to focus on Type IV tank systems, the potential hidden in an improved technology is demonstrated. The low production costs are responsible for the dominance of Type I tank systems in the NGV industry. The weight advantage was so far not able to convince manufacturers to equip their vehicles with Type IV cylinders. The vision of Magna is to generate a Unique Selling Proposition in order to beat competitors in case of a market entry. In order to convince OEMs of Type IV systems, the price spread to the steel tanks needs to be smaller. Existing Type IV tanks are made of pure carbon fibres (CF). The idea is to replace a certain proportion of carbon fibres with glass fibres (GF) which are much cheaper.
The material price for carbon fibre is currently between 22 and 26 €/kg. For one kg glass fibre the price is between 2,2 and 4,4 €/kg. Due to the material properties, it is not possible to produce pure glass fibre cylinders. Due to the fact that GF is slightly heavier than carbon fibre, the ratio of CF is crucial to maintain the weight advantage over the steel cylinder. Research by the Magna Department of Fuel Storage Systems lead to the following values for the specific tank mass of Type IV cylinders:[322]

- 100% carbon fibre: m_{spec} = 0,28 kg/l
- Carbon fibre and glass fibre mix: m_{spec} = 0,32 to 0,48 kg/l

For a 120 litre tank system consisting of four cylinders including valves the following costs may be applied:

- Type I steel: 4,5 €/l x 120 l = 540 €
- Type IV CF: 8,0 €/l x 120 l = 960 €
- Type IV MF: 6,2 €/l x 120 l = 750 €

The calculation reveals that the Type IV cylinder out of MF is about 22% cheaper than the Type IV cylinder out of pure CF. In contrast there is only an increase in weight by about 14 kg. An illustration of the cost comparison can be seen in figure 42.

[322] Interview with Dr. Uwe Thien (Project Manager Natural Gas Storage Systems, Magna Steyr) conducted on 13.09.2012

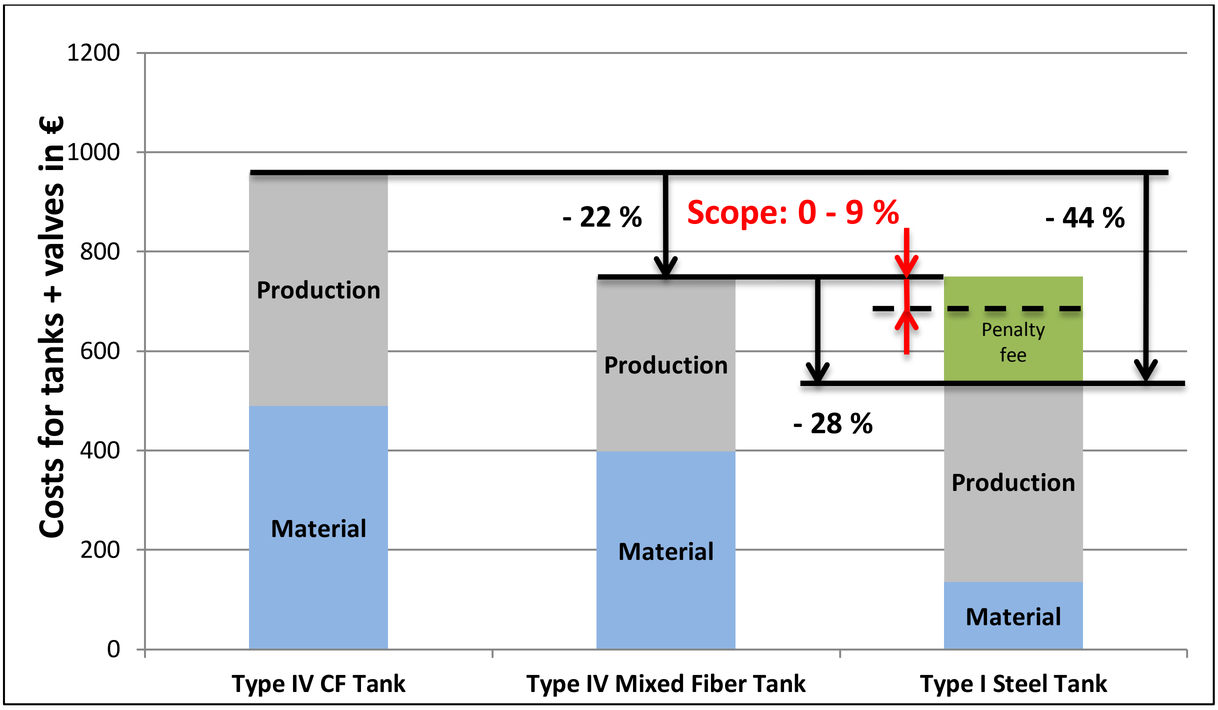

Figure 42: Manufacturing cost reduction potential of Type IV mixed fibre tank[323]

The Type I tanks made out of 34CrMo4 are about 44% cheaper than the CF tanks. The price advantage over the MF tanks is about 28%. The low material costs are responsible for this. As explained in the previous chapter, the European legislation can result in penalties for the OEMs in case of emission limit exceeding. When using the heavy steel tanks, higher penalties would occur than with the lighter MF tanks. The difference of the penalty fees can be added to the total costs of the steel tanks to justify the MF tanks. Depending on which formula is valid in 2019 (variant 1 or 2) the relative cost difference is between 0 % and 9 %. If variant 1 is valid, the steel tank is only 9 % cheaper and in case variant 2 is valid the steel tanks would cost exactly the same as the MF tanks. Thus MF tanks provide an excellent opportunity for closing the gap between steel tanks and CF tanks, which will be essential to react on future technology requirements.

[323] own representation based on calculation with values from Dr. Uwe Thien (Project Manager Natural Gas Storage Systems, Magna Steyr)

8. Industry Roadmap

The aim of this work is to identify and evaluate the key factors that have an impact on the NGV market and technology development in the coming years. Results are to be summarized in form of an Industry Roadmap, which indicates the influencing factors on the product NGV and the respective technology in a timeline.
The main events that occur in between 2010 and 2020 are included in the Industry Roadmap. A foresight to the year 2020 serves as an additional support for the Magna Management in decision making. The roadmap consists of two main areas. In the upper area, trends and events are indicated in chronological order. The development of the market (product NGV) and the technology can be seen below.

The events and trends have a significant influence on the development of product and technology. In essence, these events can be divided into three main groups: legislation, end consumer and energy industry. In the field of legislation, all political and governmental activities are included, which may have an impact on the automotive industry in the foreseeable future. The end consumer section includes trends that will mean positive and negative influences for NGV popularity and sales numbers. The energy industry is responsible for natural gas supply, which is one of the most important factors for the market success of NGVs. Their actions in the coming years complete the trend chart.
The area of product illustrates the expected sales figures of NGVs including a subdivision into OEM and after-market vehicles. Furthermore, there is an estimation of tank types which will be used in the respective vehicles.
The section technology provides an impression of what operating mode will be used to run a NGV. Finally, there is a chart that shows what material will be used to manufacture the tank Type I and IV.
The Industry Roadmap provides an overview of the main influencing factors and the subsequent development of the product NGV and the technology behind it.

8.1 Industry Roadmap Europe

In Europe, NGVs are already quite popular but in certain regions, there is only a weak or even no presence. Basically, there are certain measures of politics, OEMs and the Energy Industry to promote NGVs in Europe.[324]

[324] cf. Dudenhöffer, F. (2011), p. 35

By introducing a CO_2 emission reduction, the EU Commission has initiated the most important step to pave the way for low-emission vehicles. Starting from 2012, low-emission vehicles will gain on market share in order to prevent OEMs of possible fines. Manufacturers are increasingly forced to rely on alternative drives such as CNG. Also, governments of individual states offer more and more incentives for clean vehicles.[325]
From 2013, OEMs offer their customers a larger NGV portfolio, which also means increasing popularity. Due to higher costs for gasoline and diesel, NGV are expected to gain market share. After 2020 Hybrid cars will be the biggest competitor for NGVs.
The Energy industry will provide more than 6000 fuelling stations by 2017. The success of NGVs in Europe mainly depends on CNG availability. The US shale gas production will influence the global gas market in a positive way. Audis Wind Gas project strengthens the image of the clean fuel CNG.[326]

The numbers of NGVs sold yearly will almost double the next ten years. The distribution of OEM and Aftermarket vehicles will stay constant with light increase in OEM NGVs. A strong increase in sales is expected in 2013, from then on, NGV sales will increase steadily. It is expected that OEMs will equip up to 50% of their NGVs with Type IV tanks by 2020. After-market will still mainly be equipped with steel tanks.[327]

Today, the majority of NGVs is operated bivalent. Due to lack of infrastructure, the principle of bivalent operation will be standard even in 2020. Only the share of monovalent commercial vehicles will increase slightly. Steel tanks will also be produced out of High Strength Steels like 34CrMo4 in future. MF tanks will replace the conventional tanks of pure carbon fibre more and more in the category of Type IV tanks. An accurate representation of the industry map of Europe can be seen in figure 43.[328]

[325] Interview with Prof. Dr. Erich Pucher (Head of the Institute for Vehicle Drives and Automotive Engineering, TU Wien) conducted on 01.10.2012
[326] ibd.
[327] cf. Magna Steyr (2012b), p. 4
[328] Interview with Dr. Uwe Thien (Project Manager Natural Gas Storage Systems, Magna Steyr) conducted on 13.09.2012

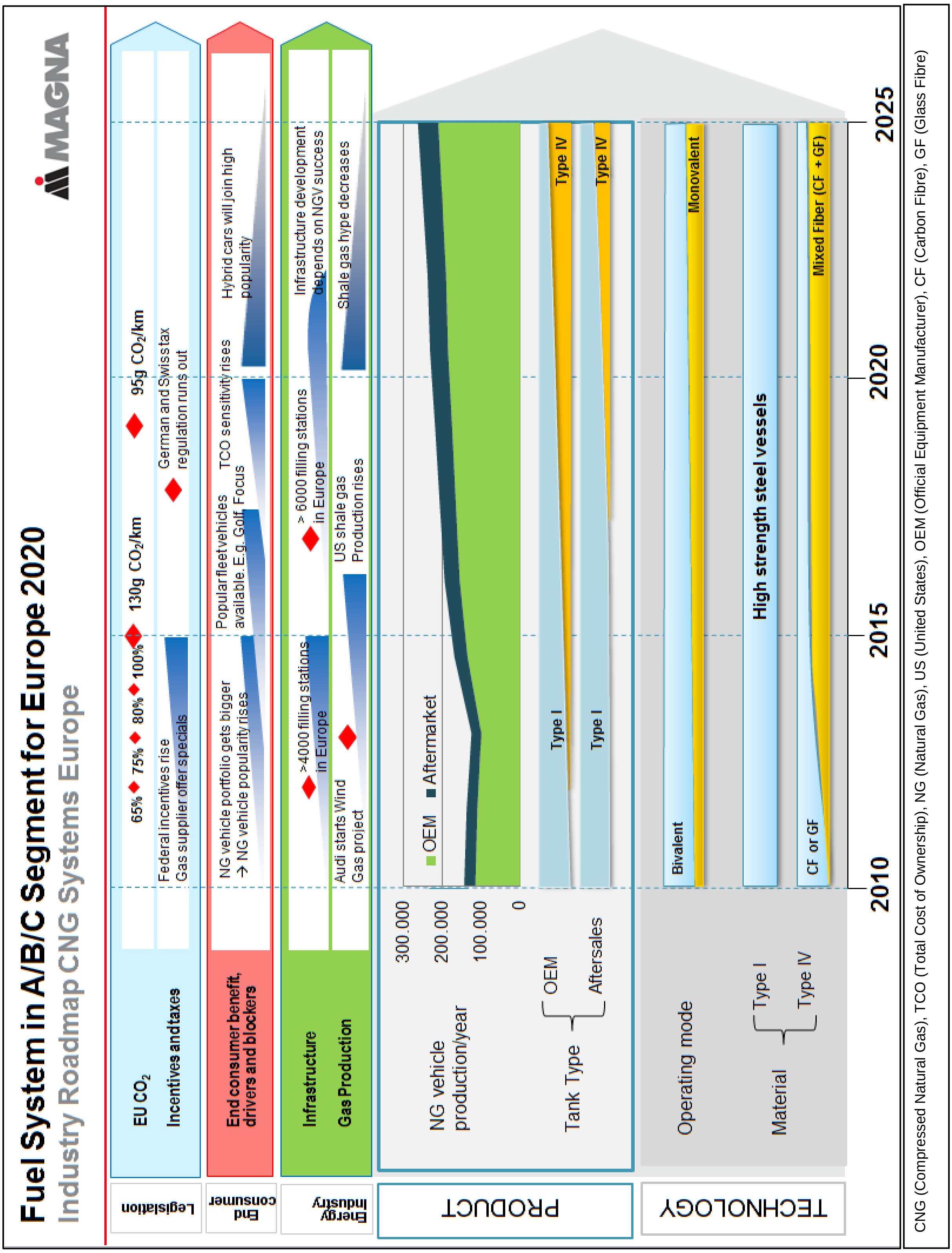

Figure 43: Industry Roadmap Europe[329]

[329] own representation based on Magna (2012a), p. 51

8.2 Industry Roadmap North America

The NGV situation in North America is different to Europe. Although, also in North America, all parties are willing to drive the topic NGV, there is great need for action. Especially in terms of infrastructure and OEM offer improvements are still needed.[330]

As is the case in Europe, NGVs in North America will also benefit from the legislation. Due to the regulations, OEMs are forced to reduce their emissions but there is still a lot of potential for emission reduction in conventional engines.[331]
In America, OEMs want to sell NGVs as a green alternative. OEM offer will rise but sale numbers are not expected to grow significantly. The main NGV market is seen in the after-market business and in commercial vehicles like shipping trucks.[332]
The energy industry in North America has a significant influence on the development of natural gas fleet. An annual growth of NG stations of about 25% is expected, however, only concentrated on certain regions. HRAs find their utility in commercial customers. In North America the shale gas production will cause a buzz around NG. This hype can flatten out again after about 10 years.[333]

NG sales have been increasing strongly since 2011. Especially after-market vehicles from QVMs are on the rise. The proportion of OEM vehicles will remain insignificantly small. OEMs are already using mostly Type III and IV tanks. This trend is still continuing. By 2020, about half of the installed tanks in aftermarket vehicles will be made from composite materials.[334]

In the field of technology, compared to Europe there are only differences in the operating mode. The NGVs in North America are mainly monovalent special vehicles. Transport companies or municipal facilities convert their fleets to NG in regions where the availability of CNG is acceptable. The share of these vehicles is expected to grow. Concerning tank material, there will be no improvement for Type I steel tanks. The share of MF tanks in the area of Type IV tanks will grow like in Europe. The industry roadmap for North America with all trends, events and results is shown in figure 44.[335]

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[330] Interview with Dr. Uwe Thien (Project Manager Natural Gas Storage Systems, Magna Steyr) conducted on 13.09.2012
[331] cf. Barnhard, D. (2013), p. 4
[332] cf. Magna Steyr (2012b), p. 4
[333] Interview with Heimo-Thomas Blattner (Project Manager Alternative Drives, Energie Steiermark) conducted on 28.09.2012
[334] cf. Magna Steyr (2012b), p. 4
[335] Interview with Dr. Uwe Thien (Project Manager Natural Gas Storage Systems, Magna Steyr) conducted on 13.09.2012

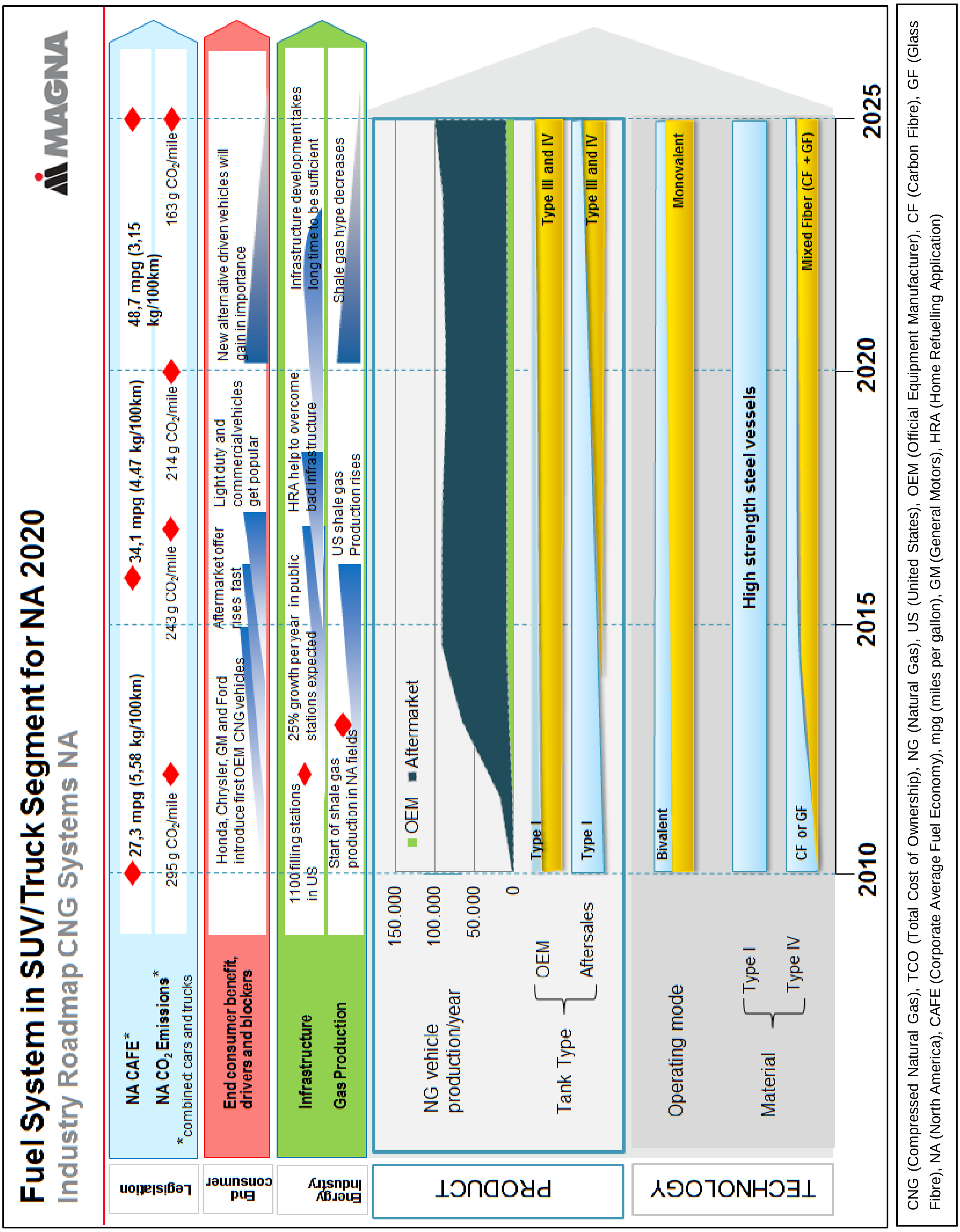

Figure 44: Industry Roadmap North America[336]

336 own representation based on Magna (2012a), p. 51

9. Transfer and conclusion

The aim of this thesis was to collect comprehensive information on the current market situation for vehicles that are operated with the fuel natural gas and furthermore, to generate an assessment of market success and technology development by means of identification and evaluation of relevant trends that will affect the development of these vehicles in the coming years. The results of the study are clearly represented in Industry Roadmaps for the investigated regions of Europe and North America. These regions are expected to be the main markets for Magna. The Industry Roadmaps serve as one of the building blocks of information that are necessary to facilitate Magna's management decision of whether to enter the NGV market or not. The most important findings of this study are summarised below.

The analysis of the current market situation has revealed in which regions NGVs are particularly widespread and what conditions are necessary for market success. The main purchasing argument for NGVs is the low running cost due to the price gap between CNG and gasoline or diesel. In all examined regions, CNG is the cheapest fuel. The main focus of the investigation is on Europe and North America. Average fuel savings of 50% compared to gasoline and 30% compared to diesel are common. This price advantage can also be traced back to the favourable tax treatment of CNG in certain countries. A comparison of the break-even for vehicles with CNG, gasoline and diesel fuel showed that the main competitor of the NGV is the diesel vehicle. Without subsidies for the purchase of NGVs the higher purchase price is difficult to make up, even with lower fuel costs. The diesel vehicle is also the winner of the TCO comparison.

The distribution of NGVs strongly depends on the region and the effort which is put into the infrastructure in the form of NG refuelling stations. Past sales figures point out that NGV sales grow with the number of refuelling stations. Customers only buy NGVs in regions where a refuelling possibility is nearby. While in North America, the infrastructure situation of about 1.000 stations is miserable, the refuelling station network in some countries in Europe is already acceptable. Italy, Germany and Austria are good examples of improved filling station availability. In other countries, such as Slovenia or Ireland, there is hardly any infrastructure. The inconstancy of the station network especially worries customers who want to drive longer distances. Energy Industry has provided a sufficient network in selected regions and now waits to see whether NGVs will penetrate the market. In contrast, customers are not satisfied with the current infrastructure situation and wait for a further improvement. This leads to a kind of "chicken and egg" problem. The annual number of newly built stations decreases and therefore also the number of newly registered NGVs. The

success of NGVs is highly dependent on the will of the energy suppliers to continue to expand their network, particularly in regions where there is a weak availability so far.
Costs and CNG availability are main factors for end customers. Magna also needs information about current products and technology. Basically, NGVs can be built directly by OEMs or be converted form gasoline to CNG operation in qualified workshops. The proportion of aftermarket vehicles in Europe is only 22%. In North America, however, 95% of NGVs have been retrofitted. The reason is that the North American infrastructure is so poor that there is only a need for NGVs in some regions. The low number of NGVs is not worth OEMs investing in R&D. In Europe, NGVs are encouraged by the EU and governments, which is why OEMs put more effort into development. The ratio between OEM and after-market will not change significantly either in America or in Europe.
NGVs can be operated in bivalent or monovalent mode. The range of bivalent vehicles is much higher as for monovalent. This property is a major advantage in the instantaneous CNG supply structure. In Europe, therefore, almost all vehicles are operated in bivalent mode. Exceptions are usually only special vehicles of municipal enterprises. In North America, the share of monovalent vehicles is much larger. Transport companies and communal holdings often have their own gas stations on site operate their vehicles on CNG.
An analysis of the current NG system technology demonstrates that there are only a few additional components necessary in order to run a gasoline car on CNG. The focus of the investigation is set on the CNG storage components. Magna is interested in producing Type IV tanks which are lighter and more expensive than Type I tanks out of steel. In Europe, Type I steel cylinders are mainly in use. The market for Type IV cylinders is bigger in North America. Currently, Type IV cylinders are no real alternative to the steel cylinders because the higher prices cannot be justified with the lower weight but changes in legislation will promote lighter tank systems.

The analysis of the situation has shown where NGVs are present. Also, the circumstances have been identified, which are responsible for a positive and negative market performance. To get an idea of how market and technology is developing, trends and the potential for change are investigated.

The identification and assessment of trends has essentially revealed two very important developments. One is the stringent legislation in Europe and the U.S. and the other is the increasing range of OEM NGVs on offer. The latter is directly linked to the legislation trend. The introduction of a CO_2 emission cap including penalties for non-compliance with the limit forces manufacturers to develop vehicles with lower

emissions. CNG is the cheapest alternative for OEMs to provide vehicles with good emissions performance and low development effort. This will lead to increased sales of NGVs in Europe and thus to widespread customer performance and in the best case scenario to a market breakthrough.
The excellent emission values of NGVs are giving CNG a clean image. Campaigns such as the introduction of a bio methane share in CNG and the production of SNG from wind energy, water and CO_2 support this image. Short and medium term, the admixture of bio methane and SNG cannot bring economic benefit. The production is too expensive so far.
A tank property and cost analysis shows that Type IV tanks can be competitive to Type I tanks if the weight reduction is high enough to save penalty fees for exceeding emissions. In the VW Passat example, the Passat with Type IV tanks emits 5 g CO_2/km less than the respective model with Type I tanks due to lower fuel consumption. The penalty savings can be up to € 209. Thus, higher material costs can be justified. The production of mixed fibre type IV tanks offers the possibility of reducing the cost by about 22%. Thereby the tanks would only be slightly heavier. The composite tank system costs would then be almost the same as for a steel tank system.

Natural gas is the only low tech and low cost alternative vehicle solution that is currently available for broad market application and the market is expected to grow. Government subsidies can rapidly expand or shrink local markets when they are applied or removed. Regardless of the government subsidies the low prices of NG, which are expected to stay low compared to oil, will continue to drive this market. For Magna, both the market for original vehicles and the after-sales vehicles may be interesting, if the company wants to specialise in tank production. There are different vessel technologies per region, which requires different solutions for every region. As the market in North America consists almost exclusively of after-sales solutions, a supply of tanks would be a possibility for Magna to get into the business. In Europe, mainly OEM vehicles are on the roads. Here, Magna can generate a unique selling proposition with the geometric integration process during the concept phase. Due to good reputation and Magna's contacts, there are good chances of an OEM contract for delivering highly integrated tank modules.
The Industry Roadmaps show that a lot of factors drive the NGV market. In contrast, there are also some uncertainties, such as the development of fuel prices, material prices or the efforts of governments and energy suppliers to keep or improve the natural gas subsidies. Magna has no influence over these factors, so a market entry would be associated with very high risk. The year 2013 is very indicative in terms of development of NGVs worldwide. It is therefore recommended to keep a close eye

on the market trends. Whether a market entry can be profitable or not, still requires further investigation with respect to production costs, competition and potential customers. Although natural gas as a fossil fuel cannot be a permanent solution because sooner or later even these resources will run out but they offer a cost effective and technically simple solution to bridge other drive systems, such as hydrogen or electric vehicles, which still need time to reach a competitive level.

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List of Abbreviations

AMFA	Alternative Motors Fuel Act
CAFE	Corporate Average Fuel Economy
CF	Carbon Fibre
CHP	Combined Heat and Power Units
CIS	Commonwealth of Independent States
CNG	Compressed Natural Gas
ECU	Electronic Control Unit
EU	European Union
g	Gram
GF	Glass Fibre
GHG	Greenhouse Gas
H-gas	High Caloric Gas
HRA	Home Refuelling Applications
IEA	International Energy Agency
kg	Kilograms
km	Kilometres
l	Litre
LDV	Light Duty Vehicle
L-gas	Low Caloric Gas
LNG	Liquefied Natural GAs
Mb/d	Million Barrels per Day
MBQ	Modular Transverse Matrix
MF	Mixed Fibre
mpg	Miles per Gallon
m_{spec}	Specific Mass
NA	North America
NAFTA	North American Free Trade Agreement
NG	Natural Gas
NGV	Natural Gas Vehicle
NMHC	Non Methane Hydro Carbon
OEM	Official Equipment Manufacturer
OECD	Organisation for Economic Co-operation and Development
OPEC	Organisation of Petrol Exporting Countries
PDCA	Plan Do Check Act
PHEV	Plug –In Hybrid Vehicle
psi	Pound-force per Square Inch
QVM	Qualified Vehicle Manufacturer
RON	Reactive Octane Number
rpm	Rounds per Minute
SNG	Synthetic Natural Gas
SWOT	Strength Weaknesses Opportunities Threats
TCO	Total Cost of Ownership
US	United States
WTW	Well to Wheel

Appendix

Regional safety standards for Europe, U.S. and other regions:

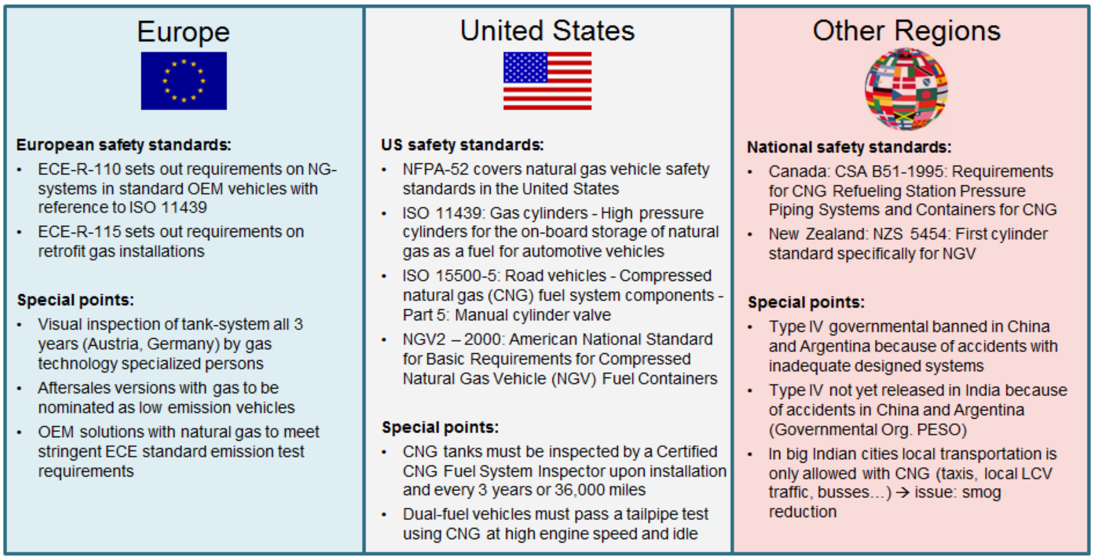

Figure 45: Safety standards for CNG use as automotive fuel[337]

List of Chances and Risk in case of a market entry:

Chances	Risks
Yearly vehicle market growth of gaseous vehicle between 10% and 15%	Remaining in cheap and flexible aftermarket supply
Steady growing petrol prices and steady lower gas prices (taxation) make CNG vehicles attractive for people with low income per capita (money savings)	More than one cylinder technology for expanded driving distance does not meet the lowest price requirement of the customer
Governmental dircetives to drive CNG for taxis and local transportation in e.g. India to reduce smog (particulate matter, others) in big cities and to improve air quality	Rethinking on air quality and green technology remains attractive only for transport sector in big cities, infrastructure remains untouched in the countryside
Taxation of Natural Gas (and therefore gas price -50%) will remain lower than for petrol fuels because gas supply is by 75% connected to industrial business and energy management of buildings (taxation increase seems unattractive today)	Taxation will be adjusted by decision of governmental authorities
High OEM CNG technology with OEM guarantee on engine and lifetime to a real standard level of automotive products	Cheap technology with direct individual care and contacts remains high competitive by price and mentoring
US initiative to partly separate from raw oil import and oil policy	Yust used for industry requirements with existing gas pipeline net (trans continental pipelines)
Proposed natural gas business for industry and vehicles	Initiative does not succeed by missing fuelling stations, lower driving attractivity (small supercharged engines vs. Request for standard symbol vehicle types)
Cheapest alternative for vehicles technology (Mr. Winterkorn) and competitive bridge technology in direction of other alternatives (FC, PHEV, Full Hybrides,..)	Much more progressive vehicle technology will be bought by customer
Automotive lightweight storage systems satisfy customers requirement for curb weight savings in connection with payload, driveability and emissions (test weight class)	Level for lightweight does not yet meet low price requirments and low investments risks of low income per capita and price-consious customers Technology could reamin per mass in industrialized countries
Lightweight technology is quite new in the market for automobiles (buses earlier, passenger cars and light commercial vehicles later) and progressive	Not yet known long time experiences on vehicles on the road for passenger cars and light comercials
CNG technology used for vehicles since 70's and supposed to be equal in energy use like petrol fuel	Valve technology not yet stable especially for emerging markets with impurity on fuel received from gas fuel stations (polutions, water,…)
CNG technology and especially lightweight has still considerable improvement potential (a major entitlement of Magna when combining with best price strategy) on mechanical, functional and economical issues on the product	Cheap single cylinder steel technology (250km vehicle gas range) remains as the successfull competitor against lightweight (exceeding 500km vehicle gas range)

Figure 46: Chances and risks for Magna[338]

[337] interview with Dr. Uwe Thien (Magna Steyr) conducted on 30.01.2012
[338] Magna (2013), p. 37

Subsidies, Programs and Incentives in Europe and the USA:

Europe	
Country	Incentives
Austria 	• Companies and communities: funding is up to 30% of investment price for companies and up to 50% for communities. Fleet conversations are supported with 500€ for companies and 1000€ for communities. • Governmental funding is 500€ (subtracted from vehicle purchase tax) • Austrian federal land specific: up to 1000€ for purchasing a new car or gas vouchers for up to 1000 kg CNG. Taxi companies can get up to 3500€
Germany 	• Lower energy tax until 31.12.2018 (option for extension) • Additional subsidies from local gas suppliers (usually in the form of gas vouchers)
Italy 	• Governmental funding since 2006: 1500€ for purchase of new NGV • Tax advantages for CNG (Energy tax) • Additional 500€ for purchase of new car with CO2 emissions < 120g/km • Scrapping bonus: 800€ for vehicles with EU emission-standard 1 or weaker • Environmental and scrapping bonus: 700€ for purchasing a new NGV and scrapping of an at least 10 year old vehicle at the same time
Switzerland 	• Lower energy tax until 31.12.2018 (option for extension) • Additional subsidies from local gas suppliers up to 1000 CHF in different forms (vouchers or price reduction) • Some cantons offer an reduction of the vehicle tax (up to 50%) for NGV

Figure 47: Incentives in Europe

USA	
Policies and Programs	Outcome
General: • The incentive and law system for CNG in the U.S. is very complex. Currently there are 357 different clean transportation laws, regulations, and funding opportunities. • Federal incentives and programs are valid for all states. In addition there are individual incentives and restrictions in most of the states. • Because of the complexity of the funding system it is hardly possible to explain the governmental funding for CNG vehicles. Federal Incentives: • American Recovery & Reinvestment Act (ARRA): increases the credit value for purchasing equipment used to store and dispense qualified alternative fuels placed in service in 2009–10. Federal Programs: • Clean Cities: government-industry partnership sponsored by the DoE, which strives to reduce dependence on petroleum resources. NGV projects will be featured in 19 of 25 cost-share projects announced in the Clean Cities program that will be funded with approximately $300M from the ARRA. • ARRA provides funding to a variety of other programs that may benefit NGVs. State Programs: • State tax credits for fuels, vehicles, infrastructure, and business development exist in 25 states.	NGV strategy in the U.S. has generally focused on high-fuel-use, return-to-base fleets that operate in urban areas. Numerous programs and initiatives have been introduced at the federal and state levels over the last several decades; however, these efforts have not led to success in fostering a sustainable NGV market yet. Main NGV market in the U.S. are SUVs and Trucks. Vehicles that are used to drive long distances are preferred equipped with an CNG system. Reasons are the later Break-Even-Point compared to conventional vehicles in Europe. Further information: http://www.afdc.energy.gov/laws/matrix/tech http://www.ngvamerica.org/incentives/index.html

Figure 48: Policies and programs in the USA

Global Natural Gas Vehicle statistics:

Country	Natural Gas Vehicles					Refuelling stations				VRA	Monthly gas consumption (M Nm3)		
	Total	Cars/LDVs	MD/HD Buses	MD/HD Trucks	Others	Total	Public	Private	Planned		Average consumption (actual report)	The consumption in theory	Reported consumption
Iran	3.300.000	3.293.948	6.036	16		1.960	1.925	35	400		480,00	611,03	78,6%
Pakistan	3.100.000	2.919.500	500		180.000	3.330	3.330				245,75	536,01	45,8%
Argentina	2.172.768	2.172.768				1.920	1.920			32	231,12	391,10	59,1%
Brazil	1.730.223	1.730.223				1.796	1.796			7	163,33	311,44	52,4%
India	1.500.000	1.469.004	23.376	715	6.905	724	405	319			163,21	335,47	0,0%
China	1.500.000	1.089.070	299.025	61.905	50.000	2.800	2.600	200	400	9		1145,13	0,0%
Italy	746.470	742.970	2.300	1.200	0	909	862	47	38	199	72,50	141,59	51,2%
Ukraine	388.000	19.400	232.788	135.793	19	324	132	192	40	8	52,00	810,49	6,4%
Colombia	387.250	363.790	13.800	9.660		676	676			3	45,00	114,61	39,3%
Thailand	352.652	291.321	15.699	43.870	1.762	481	456	25		0	285,17	134,95	211,3%
Uzbekistan	310.000	310.000				175	175		50			55,80	0,0%
Armenia	244.000	192.000	17.300	34.700		345	9	336			26,52	114,22	23,2%
Bangladesh	200.000	137.000	10.000	27.000	26.000	600	600			13	91,55	77,56	118,0%
Egypt	178.000	176.354	1.299		347	160	156	4			38,00	35,66	106,6%
Bolivia	140.400	140.400				156	156			46	26,28	25,27	104,0%
Peru	136.662	136.651	11			189	189				18,56	24,63	75,4%
USA	112.000	96.500	13.000	2.500		1.035	535	500		4.747	77,52	58,37	132,8%
Venezuela	105.890	105.890				166	166		300	80	8,15	19,06	42,8%
Germany	95.162	93.454	1505	145	58	904	838	66	100	804	23,00	21,46	107,2%
Russia	86.012	55.002	12.900	18.060	50	250	210	40	15	4	30,40	63,06	48,2%
Bulgaria	61.256	61.000	236	20		103	102	1	6		15,00	11,70	128,2%
Malaysia	53.783	53.129	594		60	173	171	2		10	14,80	11,35	130,4%
Sweden	41.789	39.480	1.680	627	2	195	143	52	20	21	11,40	12,65	90,1%
Japan	41.463	16.102	1.542	22.015	1.804	329	287	42	2	612		25,23	0,0%
South Korea	35.872	3.049	31.833	980	10	190	185	5	2		93,00	96,83	96,0%
Myanmar	30.005	26.526	3.475	4		51	51					15,20	0,0%
Canada	14.205	11.800	199	6	2.200	83	80	3		500		2,84	0,0%
France	13.500	10.200	2.400	900		177	37	140	10	1.290	6,00	9,76	61,5%
Switzerland	11.500	11.191	166	83	60	166	133	33	1	117	1,61	2,58	62,4%
Tajikistan	10.600	10.600				53	53				4,13	1,91	216,5%
Chile	8.164	8.055	109			15	15		28	1	3,20	1,78	180,1%
Austria	7.065	6.900	150	15		203	173	30		12	13,50	1,70	792,3%
Kyrgyzstan	6.000	6.000				6	6				0,60	1,08	55,6%
Singapore	5.522	5.508	14			4	3	1			1,03	1,03344	99,7%
Indonesia	5.690	4.850	570	20	250	7	7		4			2,61	0,0%
Netherlands	5.202	4.277	707	216	2	153	85	68	40	558		3,06	0,0%
Mexico	2.600	2.569	31			8	8			22	1,37	0,56	246,7%
Belarus	4.600	4.600				42	42				1,03	0,83	124,4%
T. & Tobago	4.100	4.100				9	8	1			0,80	0,74	108,4%
Czech Republic	3.964	3.527	326	41	70	54	39	15	9	85	1,00	1,65	60,6%
Turkey	3.850	1.850	2.000			14	8	6		35	4,20	6,33	66,3%
Australia	3.500	100	1.700	950	750	51	4	47	39	130		5,92	0,0%
Spain	3.219	574	1.503	1.099	43	60	17	43	14	21	4,48	5,49	81,5%
Kazakhstan	3.200	3.000	200			2	2		90				
Georgia	3.000	3.000				50	50					0,54	0,0%
D. Republic	8.000	8.000				5	5		4		0,09	1,44	6,4%
Moldova	2.200	2.200				24	24				0,40	0,40	101,0%
Poland	2.094	1.502	288	4	300	47	33	14			0,76	1,15	65,9%
UAE	1.751	1.750	1			17	16	1	18	1		0,32	0,0%
Finland	1.172	1.065	70	15	22	18	17	1	4	10	0,40	0,41	96,4%
Slovakia	1.170	775	320	75		14	10	4		15	1,00	1,16	86,2%
Serbia	838	788	50	0	0	9	7	2	3	1	0,31	0,29	106,2%
Norway	908	353	514	9	32	26	22	4	7		16,40	1,61	1015,9%
Mozambique	661	500	150		11	2		2	2		0,24	0,54	44,4%
Portugal	586	46	354	86	100	5	1	4	1		1,16	1,14	101,4%
United Kingdom	559	20	3	496	40	22	5	17	5	10	3,00	0,41	729,2%
Greece	526	6	412	108	0	3		3	1			1,32	0,0%
Vietnam	462	400	50	12		7	7						
Hungary	372	300	70		2	17	3	14	5	14	0,15	0,26	56,8%
Belgium	355	335	3	9	8	15	10	5	10	15		0,08	0,0%
Nigeria	345	260		85		6	6					0,11	0,0%
Iceland	255	237	2	16		2	2		2		0,04	0,06	63,5%
Luxembourg	253	214	39			7	6	1	2	2	0,06	0,16	35,7%
New Zealand	201	19	61	84	37	14		14				0,26	0,0%
Estonia	191	170	18	3		4	2	2	3	1	0,02	0,09	23,0%
Lithuania	190	75	115			3	3		5	5	0,20	0,36	55,8%
Lichtenstein	143	64	61	18		2	1	1	1		0,10	0,21	47,9%
Croatia	143	64	61	18		1	1		1		0,08	0,21	38,3%
Algeria	125	115	10			3	3					0,05	0,0%
Philippines	71	11	60			3	1	2				0,18	0,0%
Macedonia	54	7	47			1		1	3		0,02	0,14	14,8%
Slovenia	41	21	20			6	1	5	1	4	0,008	0,06	12,5%
Ecuador	40	40				1	1					0,01	0,0%
Tunesia	34	32	2			1		1				0,01	0,0%
Tanzania	52	52				1	1		2			0,01	0,0%
South Africa	24	21	2		1	2	2		2			0,01	0,0%
Bosnia & Herzegovina	21	20	1			2	2			2		0,01	0,0%
Latvia	18	18				1	1				0,003	0,00	79,3%
Panama	15	15											
Denmark	14	14				1	1						
Ireland	1	1							1	1		0,00	0,0%
Turkmenistan						1	1						
Montenegro						1		1				0,00	
Afghanistan						1	1						
Total	**17.193.023**	**15.856.742**	**701.758**	**363.578**	**270.945**	**21.393**	**19.041**	**2.352**	**1.691**	**9.447**	**2.280**	**5.263**	**43%**

Figure 49: Global NGV Statistics[339]

[339] GVR 135 (2013), p.25

Product information and data VW Passat:

		118 kW (160 PS) TSI	BlueMotion Technology 103 kW (140 PS) TDI
Motor, Getriebe	Motor-Bauart/Ventile pro Zylinder	4-Zylinder-Ottomotor/4	4-Zylinder-Dieselmotor/4
	Einspritzung/ Aufladung	Direkteinspritzung/ Twincharger	Common Rail/ Abgasturbolader
	Hubraum, Liter/cm³	1,4/1.390	2,0/1.968
	max. Leistung, kW (PS) bei 1/min	118 (160)/5.500	103 (140)/4.200
	max. Drehmoment, Nm bei 1/min	240/1.500-4.500	320/1.750-2.500
	Emissionsklasse	Euro 5[7]	Euro 5[7]
	Getriebevariante	6-Gang-Schaltgetriebe	6-Gang-Schaltgetriebe, 6-Gang-Doppelkupplungs-getriebe DSG
Gewichte, kg[2]	Leergewicht[1]	1.483	1.532 (1.560)[10]
	zul. Gesamtgewicht	2.020	2.100 (2.130)[10]
	Zuladung[9]	612	643 (645)[10]
	zul. Achslast vorn/hinten	1.060/1.010	1.120/1.030 (1.150/1.030)[10]
	zul. Anhängelasten[3]: gebremst bei 12%/8% Steigung	1.500/1.700	1.800/2.000
	ungebremst	740	750
	zul. Stützlast/zul. Dachlast	90/100	90/100
Fahrleistungen	Höchstgeschwindigkeit, km/h	220	213 (211)[10]
	Beschleunigung von 0-80/0-100 km/h, s	6,0/8,5	6,8/9,8 (6,8/9,8)[10]
	Elastizität von 80-120 km/h im 4./5. Gang, s[11]	8,5/11,0	8,5/10,5
Kraftstoffverbrauch, l/100 km[4]	Kraftstoff	Superbenzin schwefelfrei, mind. 95 ROZ nach DIN EN 228[5]	Diesel schwefelfrei, mind. 51 CZ nach DIN EN 590/ DIN 51628[6]
	mit Schaltgetriebe innerorts/außerorts/kombiniert	8,5/5,2/6,5	5,6/4,0/4,6
	mit Doppelkupplungsgetriebe DSG innerorts/außerorts/kombiniert	-	6,3/4,5/5,2
CO_2-Emission kombiniert, g/km[4]	mit Schaltgetriebe	149	119
	mit Doppelkupplungsgetriebe DSG	-	135
Effizienzklasse[13]	mit Schaltgetriebe	C	A
	mit Doppelkupplungsgetriebe DSG	-	B
Ausstattungsversionen	erhältlich als	Comfortline, Highline, R-Line, „Exclusive"	Trendline, Comfortline, Highline, R-Line, „Exclusive"

Figure 50: VW Passat 1.4 TSI and VW Passat 1.8 BlueMotion TDI product information[340]

[340] Volkswagen (2012), http://www.volkswagen.de, excess date 26.10.2012

		EcoFuel 110 kW (150 PS) TSI
Motor, Getriebe	Motor-Bauart/Ventile pro Zylinder	4-Zylinder-Ottomotor/4
	Einspritzung/Aufladung	Direkteinspritzung/Twincharger
	Hubraum, Liter/cm³	1,4/1.390
	max. Leistung, kW (PS) bei 1/min	110 (150)/5.500
	max. Drehmoment, Nm bei 1/min	220/1.500-4.500
	Emissionsklasse	Euro 5[7)]
	Getriebevariante	6-Gang-Schaltgetriebe, 7-Gang-Doppelkupplungsgetriebe DSG
Gewichte, kg[2)]	Leergewicht[1)]	1.598 (1.619)[10)]
	zul. Gesamtgewicht	2.120 (2.140)[10)]
	Zuladung[9)]	597 (596)[10)]
	zul. Achslast vorn/hinten	1.060/1.110 (1.080/1.110)[10)]
	zul. Anhängelasten[3)] gebremst bei 12 %/8 % Steigung	1.500/1.700
	ungebremst	750
	zul. Stützlast/zul. Dachlast	90/100
Fahrleistungen	Höchstgeschwindigkeit, km/h	214 (214)[10)]
	Beschleunigung von 0-80/0-100 km/h, s	6,6/9,8 (6,6/9,8)[10)]
	Elastizität von 80-120 km/h im 4./5. Gang, s[11)]	10,0/12,5
Kraftstoffverbrauch[4) 8)]	Kraftstoff	Erdgas (CNG); Superbenzin schwefelfrei, mind. 95 ROZ nach DIN EN 228[5)]
	mit Schaltgetriebe im Erdgasbetrieb, m³ (kg)/100 km innerorts/außerorts/kombiniert	8,7 (5,7)/5,3 (3,5)/6,6 (4,3)
	mit Schaltgetriebe im Benzinbetrieb, l/100 km innerorts/außerorts/kombiniert	9,0/5,4/6,8
	mit Doppelkupplungsgetriebe DSG im Erdgasbetrieb, m³ (kg)/100 km innerorts/außerorts/kombiniert	8,8 (5,8)/5,4 (3,5)/6,6 (4,3)
	mit Doppelkupplungsgetriebe DSG im Benzinbetrieb, l/100 km innerorts/außerorts/kombiniert	8,8/5,6/6,8
CO_2-Emission kombiniert, g/km[4) 8)]	mit Schaltgetriebe im Erdgasbetrieb (im Benzinbetrieb)	117 (157)
	mit Doppelkupplungsgetriebe DSG im Erdgasbetrieb (im Benzinbetrieb)	119 (158)
Effizienzklasse[13)]	mit Schaltgetriebe im Erdgasbetrieb	A
	mit Doppelkupplungsgetriebe DSG im Erdgasbetrieb	A
Ausstattungsversionen	erhältlich als	Trendline, Comfortline, Highline, R-Line

Figure 51: VW Passat 1.4 TSI EcoFuel product information[341]

[341] Volkswagen (2012), http://www.volkswagen.de, excess date 26.10.2012