Analyzing the future of technology and society

Scania and the case of the Russian fuel market

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Abstract

Title: Analyzing the future of technology and society
- Scania and the case of the Russian fuel market

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Issue of study: The development of technology and society is closely linked. Mutual dependency and complex interrelationships make straightforward analysis of issues regarding the future of technology and society hard to perform. Therefore, the study addresses the question of how organizations should describe and analyze the interactions of technology and society in order to gain a better understanding of what the future may bring.

Purpose:

- To develop a method for analysis of the future course of issues regarding technology and society in interaction.
- To apply and test the developed method through a case study, where it is used to analyze the future of the Russian fuel market.

Method: In the study, a holistic systems approach is applied. Through combining theory about socio-technical systems with elements from scenario-based techniques, the FUTSTEPS method is developed. The socio-technical systems theory is used to understand and structure the complex interactions of technology and society. The scenario-based techniques form the basis of the developed FUTSTEPS method, which enables a systematic description, analysis, and presentation of empirical data in relevant issues regarding the future of technology and society. The FUTSTEPS method is applied and tested in a case study of the Russian fuel market.

Conclusions: The FUTSTEPS method is a tool for finding the most important factors determining an issue involving technology and society. The developed theoretical framework connects socio-technical systems to scenario-based techniques, thus filling the latter with structured content. The FUTSTEPS method allows for a more formalized and rigorous step-by-step construction of scenarios for issues regarding the future of technology and society than previous techniques. It can be used for analysis of a range of complex multiparty issues.

The case study showed that the four most important fuels for the future in Russia are CNG, diesel, DME, and E-fuels. The constructed extreme scenarios connected each fuel to a certain development of society. Among the identified key factors, the development in the European Union and Asian countries, together with the level of Russian protectionism, were found to have the largest impact on the future course. In order to anticipate what the future will bring, Scania should monitor five of the key factors and conduct additional research in five key areas of knowledge.

Keywords: Technology and society, Socio-technical systems, Scenario-based techniques, MICMAC method, FUTSTEPS method, Russia, Scania, Fuel

Acknowledgements

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A special thanks goes to our tutors at Scania: Jonas Holmborn and Håkan Jyde. Jonas we especially thank for his steady support and encouragement, as well as for the trouble-free administration of our work at Scania in Södertälje. To Håkan we are hugely grateful for clearing the way for and arranging our stay in Moscow. The output from our interviews there has been of great importance for our thesis. We would also like to thank our reference group at Scania Södertälje, where especially Per Holmgren through his everlasting patience with our questions and enormous depth of knowledge of everything from engine technology to where to find good lunch, made our search of information both easy and pleasant. Also, we would like to thank the personnel at Scania's Advanced Combustion department for giving us support and valuable input to our work. Particularly we would like to mention Olof Erlandsson and his remarkable crash-course in combustion engine technology.

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Lund, May 2008

Camilla Andersson Andreas Jensen

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Abbreviations and frequently used terms

1st-generation biofuels	Biofuels made from sugar, starch, or oil crops using conventional technology
2nd-generation biofuels	Biofuels made from ligno-cellulosic biomass, e.g. grasses, wood, or special energy crops using new processes
Cetane number	Measure of quality for diesel-type fuels, which are combusted in compression ignition internal combustion engines
Energy density	Energy per volume unit of fuel
FUTSTEPS method	Future of Society and Technology, Presented in Scenarios. A step-by-step method for describing, analyzing, and presenting issues regarding the future of technology and society in interaction, which is developed in this thesis
GDP	Gross Domestic Product. A measure of national income and output for a country's economy, defined as the "value of all goods and services produced in a country in one year"
GNP	Gross National Product. A measure of national income and output for a country's economy, defined as the "value of all goods and services produced in a country in one year, plus income earned by its citizens abroad, minus income earned by foreigners in the country"
MICMAC analysis	A quantitative analysis method. The abbreviation MICMAC stands for *Matrice d'Impacts Croisés – Multiplication Appliquée à un Classement*
RON	Research Octane Number, also called octane number. A measure of quality for petrol-type fuels, which are combusted in spark-ignition internal combustion engines
Socio-technical system	A system theory covering the physical technology of a system's societal rules and stakeholders, which all interact with each other. The system consists of human, organizational, economic, and legal aspects of operation.

1 Introduction

In the initial chapter, a basic background, a problem description, and the purpose, as well as an overview of delimitations and intended readers, are presented. A general outline of the disposition is also included.

1.1 Background

Today's businesses face serious challenges trying to understand what the future society and its associated technology may look like. When formulating problems like "How will people communicate in 30 years time?" or "What will be the dominating house building material in Northern Europe 20 years into the future?", the inquirer encounters enormous complexity. This makes straightforward analysis difficult and also creates problems in simply knowing where to start the investigation. A number of ways of trying to address this problem and predict or picture the future, for example by creating scenarios, have been proposed, but there is still much room for improvement of the methods used.

Technological innovation is more rapid than ever. It is influenced by trends such as global warming, fast economic growth in developing countries, and increasing globalization. In this context, it is crucial for companies to understand how the interaction between technology and society works in order to understand what the future may bring. Thereby, they can find appropriate innovation strategies, which ensure their success in situations very different from today. The interaction between technology and society is addressed in theories about *socio-technical systems*, which try to capture the close relationship between technologies themselves, actors, and societal "rules" for interaction, e.g. laws and norms.

A concrete example of a problem connected to the future of technology and society is the heavy-vehicle fuel market in Russia, which is of big interest for the Swedish truck and bus manufacturer Scania. The outcomes of issues such as new production processes for alternative fuels, competitors' technological preferences, as well as the general economic development in Russia, will affect the company's desired future product portfolio on the market. This in turn requires an appropriate R&D configuration already today, from which arises the question about which fuels and engines they should put their money and effort in.

1.2 Issue of study

With the above-described background in mind, the aim of this thesis is to address the following question:

How should organizations describe and analyze the interactions of technology and society in order to gain a better understanding of what the future may bring?

1.3 Purpose

The purpose of this thesis is twofold:

- To develop a method for analysis of the future course of issues regarding technology and society in interaction.
- To apply and test the developed method through a case study, where it is used to analyze the future of the Russian fuel market.

1.4 Delimitations

The study is limited to *describing*, *analyzing*, and *presenting* possible futures for, technology and society. It will therefore not address questions about which strategies are suitable for the future, or how companies should react to the information obtained. Also, it is important to note that the focus is on creating a "usable" method, which means that it inevitably contains simplifications and does not capture all elements of reality.

The empirical testing of the developed method is limited to one case: Scania and the future of the Russian fuel market. This was done due to Scania being the study's sponsor and because of the four month time frame.

1.5 Target audience

The target audience for the thesis consists mainly of academics within the futures research or societal and technological development fields, and business people in R&D or strategic planning functions. The case study is especially aimed at people interested in environmental or technical questions regarding Russia's transport sector, and Scania personnel involved in R&D or strategic planning. Additionally, other corporations, scholars or students may find inspiration for further investigations of other important parts of our technological and societal future.

1.6 Outline and disposition

The thesis is divided into the following sections:

Chapter 2: *Methodology*
The chapter presents the working process and methodology used in this thesis.

Chapter 3: *Theoretical framework*
Chapter 3 provide basic theory about socio-technical systems. The theory is improved by adding other relevant aspects and is thereafter connected to scenario-based techniques. The chapter ends with a description of the quantitative MICMAC analysis method.

Chapter 4: *The FUTSTEPS method*
In this chapter, the FUTSTEPS analysis method is presented step-by-step. The description aims to be a clear and simple user's guide.

Chapter 5: *Case study: Russian fuel futures*
A background to the case study and some basic technical data for investigated fuels are given. Additionally, the fuels chosen for further investigation are presented.

Chapter 6: *Case Study: Analysis with the FUTSTEPS method*
This chapter presents and analyzes the empirical findings made during the authors' work together with Scania. The FUTSTEPS method is tested by applying it to the future of the Russian heavy-vehicle fuel market.

Chapter 7: *Discussion*
In this chapter, a discussion regarding the study's academic relevance, methodology, and theoretical contribution is conducted.

Chapter 8: *Conclusion*
Finally, conclusions drawn from the work both on the development of the method and the case study are clearly presented.

2 Methodology

The methodology chapter gives an understanding of the way the study has been conducted. The first part aims to clarify the working process, while the theoretical framework is presented in part two. The third part motivates our choices in the case study and describes how and why we have chosen to work with the collected data. Finally, we will describe the way we have chosen to approach our study.

2.1 Working process

This study had its origin in the automotive industry's challenges in meeting an increased awareness of environmental issues, which creates tougher demands on vehicle emissions and engine technology. Initially, it asked the question about whether Russia would follow a development path similar to Europe's in this aspect. Along the way however, the thesis slowly changed direction towards finding a general answer on how to describe and analyze future changes involving technology and society. Even though the general direction of the study was quite clear from the beginning, we early on decided that an iterative process was necessary in order to not miss out on important aspects in any of the different parts.

Even though the working process was largely iterative, it can be divided into distinct sections: theoretical search, empirical pre-investigation, fuel selection, theoretical framework development, method development, empirical research, analysis, and finally recommendations to Scania (figure 1). Initially, we started off with a solid search of theories, combined with an initial gathering of basic empirical data, both at Lund University and at Scania in Södertälje. In parallel, we performed a fuel selection in order to select the most relevant fuels in a Russian context. These investigations resulted in the development of a comprehensive theoretical framework. The framework was in turn used to develop a method for describing, analyzing, and presenting empirical data in issues involving technology and society. During a two-week stay in Moscow, we thereafter performed a more thorough empirical research in the form of a case study with the goal of acquiring a deep knowledge and understanding of the investigated issue. The developed theoretical framework and method served as a guiding framework for our research questions. Once back in Lund, the analysis and presentation of the empirical findings from the case study were done by applying the method step by step. As mentioned, the empirical findings lead us to make some small changes to the method, which also affected the theoretical framework. From the final results we at last specified recommendations to Scania, which are presented in the thesis' conclusion chapter.

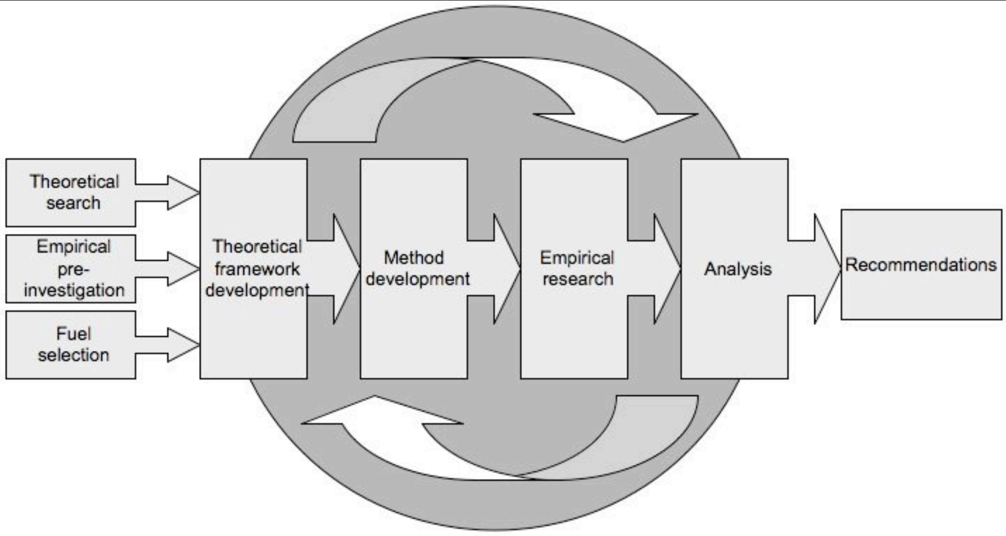

Figure 1 – Illustration of the study's working process. Theory, methodology, and empirical findings were used in an iterative process in order to enhance the quality of the study.

The intention of the study was to find a way to determine factors, trends, and patterns of the present development, combine it with some knowledge of the past in, and then analyze possible future developments in order to find the key factors impacting the future of the Russian fuel market. To do this in a satisfying way, the empirical findings are analyzed through the step-by-step creation of scenarios, which are an essential part of the developed analysis method. We designed the steps in the method to suit issues involving technology and society in interaction and the great complexity associated therewith. By constructing a method to perform a structured analysis and clear presentation of the data, we tried to generate a way to create order out of confusion in questions regarding the future.

2.2 Theoretical process

Having found that the study should address more general questions about the future of technology and society in interaction, we concluded that one way of analysing such complex issues was through applying a systems approach[1]. Hence, our study is best described as being focused on systems analysis, where we try to describe and analyze the existing technical system itself and its complex interaction with other elements, such as the economic and legal framework surrounding it and the actors that regulate it[2]. The way we apply systems analysis in our study agrees well with the definition given by Miser and Quade:

[1] Bjerke (1981), pp. 7-8
[2] Ericsson (2006), p. 5

> Systems analysis […], is not a method or a technique, nor is it a set of techniques; rather it is an approach, a way of looking at a problem and bringing scientific knowledge and thought to bear on it. […][3]

The theoretical framework we developed with basis in this approach is divided into two parts. The first consists of an explanation of theories concerning socio-technical systems. To the socio-technical system theory we added other significant theories and hypotheses to ease analysis and increase understanding of certain aspects, see figure 2. Taken together, these give the possibility to investigate the most important factors affecting issues regarding technology and society in interaction. Theory about *technology lock-in*[4] effects was used to explain why a system might get stuck in a certain technology or infrastructure, and the cost of changing it. *Standard setting*[5] theory was used to improve the understanding of how standards often shape the technological progress in an area, which in turn affects what designs are likely to be dominant in the future. *The Environmental Kuznets Curve (EKC)*[6] hypothesis was helpful in understanding how economical progress in an economy correlates with environmental impact as a result of pollution. *Technology diffusion*[7] theory increased our understanding of why and how technology spreads from one area to another. *Stakeholder analysis*[8] was of interest since it is a systematic method for analyzing the importance of stakeholders and their potential to affect a system.

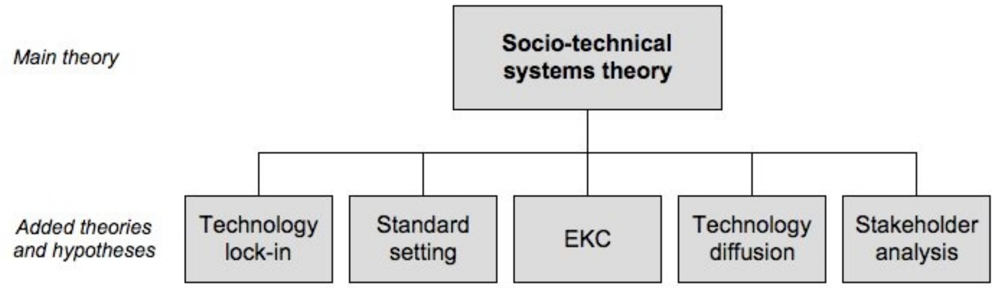

Figure 2 – The socio-technical systems theory forms the basis of the theoretical framework. Other theories were added to enhance the understanding of the issue we studied.

The second part of the theoretical framework deals with the scenario-based methods chosen to present and analyse the empirical findings. With basis in these we developed the FUTSTEPS method, which is an especially adapted technique for analysis and presentation of any system where technology and society interact (figure 3). The method is in most parts based on the qualitative *Intuitive logics model*[9], but also contains a distinct quantitative feature from *La Prospective*[10] in the form of MICMAC analysis, described in section 3.10.

[3] Miser & Quade (1985), p. 30
[4] Arthur (1989)
[5] Arthur (1988)
[6] Huang et al. (2008)
[7] Grübler (1998)
[8] Grimble & Wellard (1996)
[9] Schoemaker (1995); O'Brien (2004)
[10] Godet (1986)

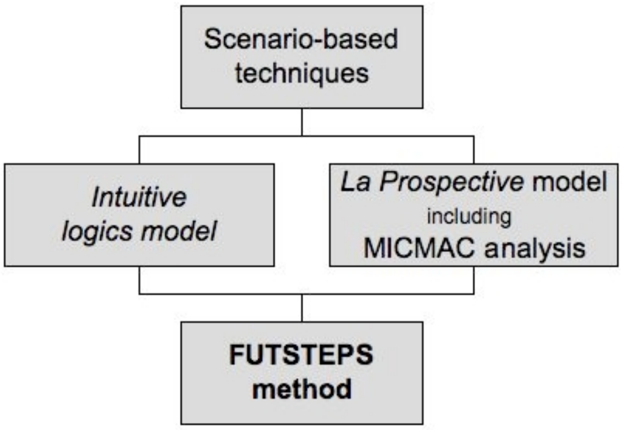

Figure 3 – The developed FUTSTEPS method was inspired by scenario-building techniques such as the intuitive logics model and the *La Prospective* model. MICMAC analysis, which is a part of *La Prospective*, plays a vital role in the FUTSTEPS method.

2.2.1 Theoretical contribution

A central part of this master thesis was to provide an academical contribution to the field. Through our study we found that there was no established way of describing, analysing, and presenting the interaction between society and technology in order to understand the possible future developments of an issue. By combining socio-technical systems theory with scenario-based techniques we filled this methodological gap. The socio-technical systems theory enables a structured description and analysis of the present, while scenario-based techniques allows a vivid presentation of future possibilities. The developed method was named FUTSTEPS, which stands for Future of Society and Technology, Presented in Scenarios. Our main contribution to the academic world is thus the FUTSTEPS method, which is a structured way of gaining understanding of what the future may bring.

2.3 Case study

Through the performed case study[11] of the Russian fuel market, we had the possibility to reframe our earlier conceptions of the theory. The study consisted of a comprehensive investigation of one single issue, limited in time and space[12], namely the technological and societal environment in Russia associated to the fuel market. The case was analysed in-depth through applying the FUTSTEPS method and served as the basis for giving general recommendations regarding the Russian fuel market to Scania.

The case study served as a testing ground for the FUTSTEPS method. Thus, it allowed us to identify areas for improvement, which eventually made the method more solid. At the same time, the case study was also the reason for Scania's

[11] Eisenhardt (1989), pp. 546-548
[12] Bryman & Bell (2005), p. 71

sponsorship, which made it important for us to secure high quality and relevance for Scania in all parts.

2.3.1 Investigated fuels

The choice of which fuels to include in the empirical investigation was made at an early point. The main reason was that we in the beginning of the study had the possibility to interview experts at Scania in Södertälje. Moreover, we wanted to focus our interviews in Moscow at a few specific fuels.

To identify which fuels to investigate further and include in the case study, a fuel selection was performed through a screening. The screening process consisted of two basic information-gathering methods: interviews and a synoptic literature survey. The screening questionnaire template we used is found in Appendix I. The investigation, which was performed fuel by fuel, concentrated on four areas of interest, of which the latter three focused specifically on Russia:

- Technology
- Production potential
- Infrastructure
- Research & general interest

The information in the screening was collected during extensive interviews with Per Holmgren and Olof Erlandsson from Scania, Lars Mårtensson from Volvo Trucks, and, for details about the Russian market, Sergey Lebedev of Scania Russia. Production potential was mainly estimated from literature sources. In some cases, literature and Internet searches were also used to get a wider picture and to check fact consistency. Additionally, some pieces of anecdotal information, caught during the four weeks we spent at Scania in Södertälje, were used as input.

When the four most important fuels had been identified, they became the focus of more intensive information gathering. This included extensive research of the status of the fuels on the Russian market as part of the empirical investigation in Moscow. During this work, we as a bonus received valuable input on the general conditions on the Russian fuel market, which was essential when performing the complete analysis with the FUTSTEPS method.

2.3.2 Interviews

To begin with, we held numerous interviews at our sponsor company, i.e. Scania. Qualitative interviews with employees from mainly R&D, market, and strategy functions provided fundamental insights into the company's products and strategies in the Russian market, as well as into the problems associated to the current fast development of new fuels. Thereafter, we held more specific interviews with external experts on both Russia in general and the Russian fuel market in specific, but also with key personnel at Scania in Moscow.

Data was gathered via formal meetings, seminars, and interviews both face-to-face and by telephone both in Sweden and Russia. The interviews were open and semi-structured in order to obtain a broader perspective and not to influence the interview object. They were usually performed with primarily predetermined subjects and themes, which were derived from the theoretical framework. Informality and openness were prioritized. Additionally, informal interviews were conducted with available Scania personnel as questions emerged. The personal interviews constituted the most important part of the gathering of empirical data for this study since they opened up for personal opinions and thoughts from experts from widely different areas of knowledge.

Ahead of some of the interviews, questions were sent in advance to enable the interview object to prepare and reflect on the topic in advance. Difficulties in speaking to and understanding Russian interview objects were eluded as one of the authors is fluent in the Russian language, and in some cases an interpreter was present. The data gathered during the interviews were structured and rewritten shortly after the interviews to increase the validity and reliability[13] of the study, but also to avoid misunderstandings and loss of information. By documenting the interviews separately and thereafter merge them to one single document the objectivity in the study was strengthened.

The analysis required interpretations of the substance in the collected data. The interviews and data acquired from experts in different fields were sometimes more or less subjective, and a need of converting the data to a more objective picture therefore arose. As a consequence, our study is characterised by a hermeneutic approach[14]. In a hermeneutic approach, a pre-understanding of the verbal and cultural community is of importance when analysing and interpreting the qualitative data. In our study, this was made possible thanks to one of the authors having a history of contact with the Russian business environment and society.

Interviews were conducted with Scania personnel both in Södertälje and Moscow, but also with experts not connected to Scania and, in some cases, not directly involved in the heavy-vehicle industry. With many sources of information, important contrasts were captured. This gave us the possibility to compare primary data from different sources. We are aware of the possibility to having received subjective information from Scania personnel. However, the interviews at Scania were mainly fact-based. To further increase the reliability of the study, key factors, market trends and patterns, which are more subjective by definition, were constructed from external sources' information. In order to achieve a higher degree of validity, we also tried to triangulate[15] empirical data through confirming findings from several different sources. For example, we strived to arrange meetings and in different contexts and with people from various fields, e.g. private companies, research institutions, private equity firms, and interest organizations. Additionally, we tried to confirm oral

[13] Jacobsen (2002), pp. 21-22
[14] Lundahl & Skärvad (1999b), pp. 42-45
[15] Bell (1995), p. 62

information in written sources. Although we did not always managed to find more than one source for key facts, we feel that the study's overall reliability is clearly acceptable.

2.3.3 Literature

The literature studies gave a broad and deep pre-understanding of the investigated market, as well as served as a complement to the collected empirical data. It also laid the ground for the theoretical framework. The data were collected from industry-related webpages, business reports, articles, scientific publications, textbooks and newspapers, which were found in libraries at Lund University, at Scania, and in Lund University's web-based article search tool. By using the Internet and helping recommendations from Scania employees and external interview objects, access to the most recent reports and prognoses became possible during the study. In some cases literature sources were used to acquire a deeper understanding of the collected data or vice versa, but also to build up the theoretical framework.

The published data were collected from several different sources, which we to increase the reliability strived to find as updated versions as possible of. We broadened the information gathering to include sources in Swedish, English and Russian in order to not miss out on any valuable information and avoid lack of relevant sources. In as high extent as possible the original source was used in the study to avoid misinterpretation. We checked logical coherence and accordance with primary data and vice versa and strived for using sources written at a "higher level" than the study we conducted ourselves.

2.4 Theory vs. reality

A combination of the two main types of reasoning – induction and deduction[16] – was used during the thesis work. This means that our working process and general work direction were affected by the empirical findings from the case (induction) as well as by input from the theories we used (deduction). Initially, deductive reasoning was used in order to secure that the theoretical framework allowed for our research to cover the issue of study. The inductive approach also was important since we needed openness in interviews, without prejudices, to gather personal views and opinions. The interaction between theory and empirical data in the study was necessary to enhance the overall understanding of interaction between technology and society. We used the theoretical framework and initial findings as guidance for the empirical research and thereafter applied the information from the investigation to improve the framework, which is called an abductive approach[17].

In the case study, the abductive reasoning was combined with a holistic[18], largely qualitative[19], approach in order to get a thorough understanding and deeper knowledge

[16] Jacobsen (2002), pp. 36-37
[17] Alvesson & Sköldberg (1994), pp. 41-42
[18] Jacobsen (2002), pp. 35-36
[19] Lundahl & Skärvad, (1999), p. 101

of the system and its components. Additionally, our need for time for reflection and understanding of the development in Russia, which made complementary post-interview questions inevitable, rendered the qualitative view very suitable. An important part of this qualitative study was to be able to describe, analyze, and understand stakeholders and other parts of the system with a starting point in the object interviewed. The questions were therefore personalised according to the interview objects' background and expertise area.

To achieve the above-mentioned holistic view of the system we had to investigate the components extensively. Due to the large amounts of information thus gathered, only a fraction of it is presented to the reader. Because parts of the data were not relevant enough to warrant space being put aside for it, but still was necessary for us to obtain an understanding of the system, it had to be excluded. This approach is very typical for a holistic system view, where the understanding of a system cannot be obtained without a thorough investigation of the components[20]. As described in Andersen (1998), there cannot be a holistic understanding without knowing the components, and there cannot be a reasonable component analysis without having a holistic understanding[21].

There is a risk that the conclusions drawn from the case study may have been affected by our preconceptions of the Russian market. This might have been accentuated by our decisions to exclude parts of the gathered information, which we deemed irrelevant. However, we believe that the interaction between theory and empirical data helped us create an analysis method, which lets us objectively illustrate the reality of the studied issue. Although there is a risk that we have tried to include too many aspects into the empirical investigation, thus creating a risk that the method lacks the desired simplicity, we wanted to follow through our holistic approach. Also, the case study allowed for the developed FUTSTEPS method to be applied to a real case. It should thereby have increased its validity.

[20] Andersen (1998), p. 187
[21] Ibid., p. 186

3 Theoretical framework

In this chapter, the theories applied in the study are presented. A solid theoretical framework enables a correct treatment and analysis of empirical data, which in turn is a prerequisite for meaningful explanations of the findings. Firstly, socio-technical systems theory, which suits the systems analysis approach, is presented. This is followed by an overview of scenario-based techniques, which in combination with the MICMAC method are introduced as useful means of analyzing socio-technical systems.

3.1 Introduction to socio-technical systems

The future of a large and complex system – such as the vehicle fuel system in Russia, which is presented in chapters 5 and 6 – is a difficult issue to examine. During the study, we found that in order to explain what may in the future happen in purely technical terms, i.e. which fuel(s) will be available at the filling station, we also had to take into account what happens in other aspects such as social, environmental, policy, and legal questions.

There are several theories where emphasis is put either on the purely physical parts of the system, or on the social actors and agents involved in its creation and utilisation. Examples include theories about *Large Technical Systems* (LTS), *systems of innovation*, and *technological systems*.[22] A theory that also includes the sought-after "soft" aspects is the *socio-technical systems* theory as proposed in a number of articles, mainly written by Geels[23]. The theory covers not only the physical technology, but also the system's human, organizational, economic, and legal aspects of operation. This met the study's needs, especially since the socio-technical view enabled the treatment of the system as a "result of a meeting of technology and society"[24]. Additionally, the theory had earlier been used to explain similar situations[25].

A socio-technical system can, according to the theory, be separated into three interrelated analytical dimensions, which are all connected and therefore affect each other's state. *Tangible technologies* (for example artefacts, devices, and infrastructure) are the material elements needed to fulfil the system's societal functions. *Actors and social groups* develop, use, maintain and regulate the system's

[22] Geels (2004), pp. 897-898

[23] See for example Geels (2002, 2004, 2005, 2007), Geels & Kemp (2007)

[24] Kaijser et al. (1991), pp. 20-21

[25] The socio-technical approach has earlier been used to explain and illustrate fundamental technical system changes in various areas, such as ships (sailing to steam-) (Geels (2002), pp. 1263-1272); highways (Geels (2007), pp. 134-146); wastewater treatment and waste management (Geels & Kemp (2007), pp. 446-453); and land-based transportation (from horse-drawn carriages to automobiles) (Geels (2005), pp. 453-473).

technologies. *Socio-technical regimes*, or sets of rules, in turn give guidance to and orient the activities and perceptions of the actors and social groups.[26,27]

In the following, we choose to concretize the concepts of tangible technologies, actors and social groups, and socio-technical regimes by concentrating on the elements included in them. Therefore, we hereafter will label them *technology and infrastructure*, *stakeholders*, and *societal rules* (figure 4). Further explanations for this choice are given in respective section. Also, we will explain two other important concepts to take into consideration when analyzing a socio-technical system; the *macro landscape* and *innovation phenomena*.

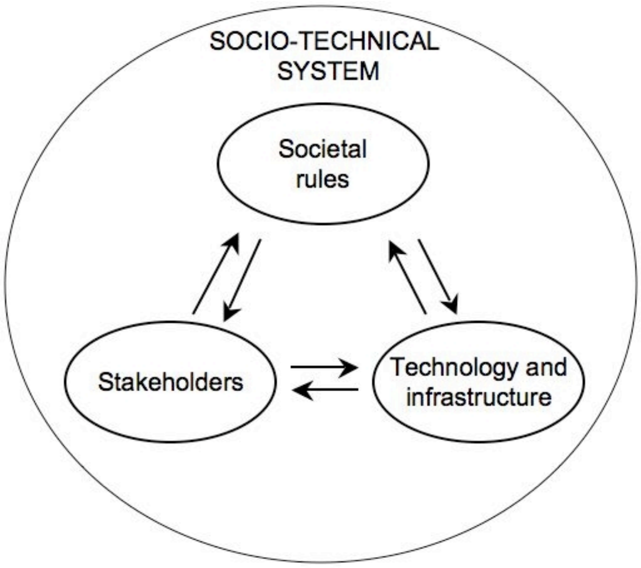

Figure 4 – The three interrelated analytical dimensions of socio-technical systems.[28]

3.2 Overview of the socio-technical systems framework

Building on the above-described components of socio-technical systems, we created the full theoretical framework used in the study. The framework in a clear way captures all the relevant aspects to consider when analysing both the present state of, and possible change in, socio-technical systems. An overview is visible in figure 5.

[26] Geels (2007), p. 127
[27] Geels & Kemp (2007), p. 442
[28] Adapted from Geels (2007), p. 127

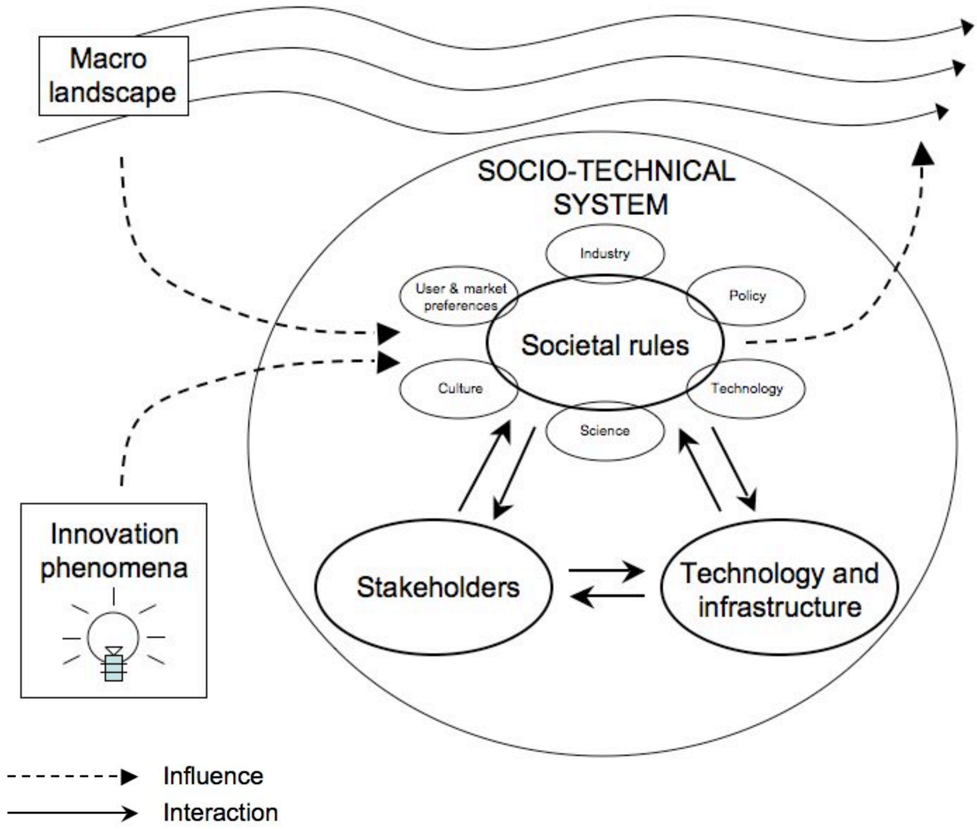

Figure 5 – The theoretical framework used in this thesis. The socio-technical system consists of societal rules, stakeholders, and technology and infrastructure, which all interact with each other. Societal rules are the centre of change processes, which are caused by influence from the macro landscape and/or innovation phenomena. Changed societal rules may in the long run also cause changes in the macro landscape.[29]

3.3 Technology and infrastructure

Technology and infrastructure includes, for example, artefacts, devices and infrastructure[30], which essentially constitute the "hardware" of a socio-technical system. Therefore, an example of technology and infrastructure from a system for car-based transportation would include the automobile (artefact); fuel infrastructure (oil companies, gas stations); maintenance and distribution networks (repair shops, dealers); road infrastructure and traffic system (lights, signs) etc.[31] Essentially, we in this study interpreted technology and society as everything that is possible to see, touch, and feel when you examine a socio-technical system.

[29] Adapted from Geels & Kemp (2007), p. 444
[30] Geels (2007), p. 127
[31] Geels (2005), p. 446

All technology and infrastructure in use represents sunk investments in the form of machines, buildings, roads etc. Together with economics of use and scale these material aspects contribute to the stability of an existing socio-technical system. When technology and infrastructure is in place, it almost "acquires a logic of its own", which discourages change and adds to the stability of the existing system.[32] This is an example of the *technology lock-in* concept, which is explained further below.

3.3.1 Technology lock-in

Technology lock-in usually occurs due to network externalities, which increase the chance of individual users adopting a technology the more it has already been adopted. Also, random events cause a path dependency in the technology's development, which may create an insurmountable advantage. From this follows that one technology eventually reaches a 100 percent market share, which locks the market to that solution and effectively hinders a change to another technological system due to the resulting "inflexibility".[33]

In socio-technical systems this means that the existing technology and infrastructure may be very hard to change. Even for a superior technological alternative it may be impossible to gain a foothold on the market[34]. From this we may conclude that it is important to know the degree to which there is a lock-in situation in order to determine the magnitude of what is needed to change the system. If a significant lock-in situation is at hand, it may be very costly for society to exit from the adopted technology. Also, it is very important that the alternative is not ecologically harmful or economically unviable.[35]

3.4 Societal rules

The actions of the socio-technical system's stakeholders are governed by "semi-coherent sets of rules, which are linked together"[36]. These societal rules, which affect the stakeholders' behaviour in a number of ways, can be classified into three different groups: *regulative*, *normative*, and *cognitive*. The rules within one set are internally aligned, which in effect makes it difficult to change one rule without altering also the others.[37]

The societal rules can additionally be divided into six separate dimensions, in which there are separate rules. According to Geels & Kemp[38] the dimensions include markets and user preferences; industry; policy; technology; science; and culture (figure 6). We found that this division was useful when trying to classify rules into different areas of jurisdiction and therefore decided to use it in this thesis.

[32] Geels & Kemp (2007), p. 443
[33] Arthur (1989), p. 116-117
[34] Ibid., p. 123
[35] England (1994), p. 755-760
[36] Geels (2004), p. 904
[37] Ibid., pp. 904-905
[38] Geels & Kemp (2007), p. 444

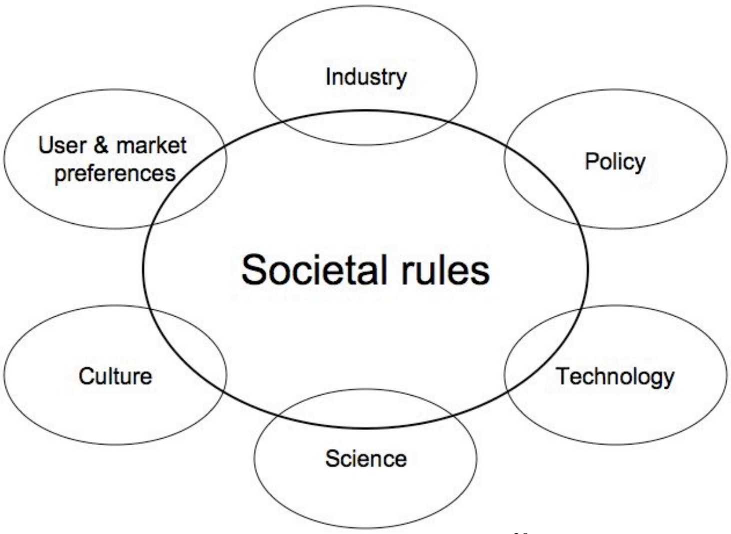

Figure 6 – The six dimensions of societal rules.[39]

In each of the six dimensions there is, as mentioned above, a separate subset of rules. The individual subsets are connected to each other in many ways, but there are still parts of them that are separated from the others. Thereby, the subsets of rules are in some aspects also autonomous.[40] This means that, for example, some of the rules that govern the behaviour of industry belong to the societal rules for land-based transport (biofuel), whereas other rules in the same industry subset belong to other systems, such as for nutrition (food). The societal rules concept is in our view a very good way to capture all the invisible aspects of society that govern our behaviour. However, it is important to understand the meaning of the word "rules" in the way it is used in this thesis.

3.4.1 Types of rules

The six dimensions of the set of societal rules each contain specific regulative, normative and cognitive rules, which together create a "meta-coordination" of stakeholders' actions in the socio-technical system[41]. Below, the characteristics of each rule type are described. Examples of rules can be seen in table 1 below.

Regulative rules

Regulative rules include formal regulation such as laws, governance systems, technical standards etc. Their compliance is enforced through legally sanctioned force or punishments. Essentially, regulative rules create the formal "rules of the game".[42]

[39] Adapted from Geels (2004), p. 905 and Geels & Kemp (2007), p. 444
[40] Geels (2004), p. 905
[41] Ibid., pp. 905-906
[42] Ibid., p. 905

Normative rules

Normative rules are governed by moral. Examples include values, role expectations, codes of conduct etc. Normative rules are adhered to by following notions of social obligations, i.e what is "proper" to do. Social sanctions such as "shaming" constitute punishments for non-compliance.[43]

Cognitive rules

Cognitive rules govern humans' perceptions of the surrounding world. For example, they affect priorities, problem agendas and beliefs. Together, cognitive rules create a commonly shared world of collective ideas or concepts, which becomes an embedded part of the culture and is therefore automatically assumed to be correct. This may cause people to be "blind" to certain issues outside their focus.[44]

Table 1 – Examples of rules in the different subsets.[45]

Subset	***Regulative rules***	***Normative rules***	***Cognitive rules***
User and market preferences	- Product quality laws - Market subsidies - Safety requirements	- Interlocking role relationships between users and firms - Mutual perceptions and expectations	- User practices - User preferences - User competences
Industry	- Competition rules - Property rights - Liability rules	- Companies own sense of themselves (what company are we? What business are we in?)	- Beliefs about the efficiency of markets - Perceptions of what 'the market' wants
Policy	- Administrative regulations and procedures which structure the legislative process - Formal regulations of technology (e.g.) safety standards, emission norms)	- Policy goals - Interaction patterns between industry and government - Institutional commitment to existing systems - Role perceptions of government	- Ideas about the effectiveness of instruments - Guiding principles (e.g. liberalisation) - Problem agendas
Technology	- Technical standards - Product specifications (e.g. emissions, weight) - Functional requirements - Expected capital return rate for investments - R&D subsidies	- Authority structures in technical communities or firms - Testing procedures	- Routines - Guiding principles - Expectations - Technical problem agenda - Problem solving strategies
Science	- Formal research programmes - Professional boundaries - Rules for government subsidies	- Review procedures for publication - Norms for citation - Academic values and norms	- Paradigms - Exemplars - Criteria and methods of knowledge production
Culture	- Rules which structure the spread of information - Production of cultural symbols (e.g. media laws)	- Cultural values in society or sectors - Ways in which users interact with firms	- Symbolic meanings of technologies - Ideas about impacts - Cultural categories

[43] Geels (2004), pp. 905, 910

[44] Ibid., pp. 905, 910

[45] Adapted from Geels (2004), p. 906 and Geels & Kemp (2007), p. 444

3.5 Stakeholders

The set of societal rules is influenced by different groups of actors such as engineers, users, and policy makers[46]. We choose to depict them, together with countries, firms, and other organizations, as the socio-technical system's stakeholders (see explanation in section 3.5.1). The stakeholders within the same social group share a common set of societal rules, which guide their actions. Through the shared rule system, "patterns of activity" are generated by the collective actions of individuals.[47]

However, there are also private rule systems, which cause small differences in the way members of the same group act. The differing ways of acting are usually motivated by self-interest in the struggle for improvement of a person or organization's situation (e.g. market position or strategic situation) or control of resources (e.g. money).[48] Hence, many of the stakeholders' actions can in our view be related to the wish to gain more power. To understand the dynamics in a socio-technical system it is therefore necessary to identify the stakeholders with power to influence. One way to do this is by using *stakeholder theory*.

3.5.1 Stakeholder theory

A stakeholder is, according to the dictionary, someone who "is involved in a particular organization, project, system, etc., especially because they have invested money in it"[49]. Stakeholder analysis is in turn a methodology to acquire a better understanding of issues involving several stakeholders, such as environmental or development problems, or managerial business decisions. It also helps in gaining insight into the different perspectives and interests of stakeholders at different levels.[50] By asking three general questions, a good understanding of the stakeholder community can be developed: (1) Who are they? (2) What do they want? (3) How are they going to try to get it?[51] There is support in using stakeholder analysis as part of a systems analysis:

> It [stakeholder analysis] is an approach for understanding a system and changes in it, by identifying key actors or stakeholders and assessing their respective interests in that system.[52]

There are three key attributes of a stakeholder: urgency, legitimacy and power. In various combinations these attributes are indicators of the amount of attention a stakeholder should receive.[53] Most scholars agree that power is the most important attribute.[54] Power is here defined as:

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[46] Geels (2002), p. 1260
[47] Geels (2004), p. 907
[48] Ibid., p. 907
[49] Oxford Advanced Learner's Dictionary (2005), p. 1489
[50] Grimble & Wellard (1996), pp. 173-177
[51] Frooman (1999), p.191
[52] Grimble & Wellard (1996), p. 173
[53] Mitchell et al. (1997), p. 855
[54] Frooman (1999), pp. 193-194

> […] the ability of individuals or groups to persuade, induce or coerce others into following certain courses of action.[55]

Therefore, we will concentrate on trying to find the most powerful, and thereby most influential, stakeholders involved in the investigated socio-technical system. By asking the three simple questions mentioned above, a key part of the system can easily be identified.

3.6 The macro landscape

The "socio-technical landscape", which we choose to rather call the macro landscape, includes "aspects of the exogenous environment that are beyond the direct influence of actors"[56]. The landscape, which consists of a set of deep structural trends[57], covers all heterogeneous macro-economic factors such as economic growth, environmental problems, oil prices etc.[58,59,60] A landscape may change slowly as the result of changes in the societal rules[61].

As indicated above, economic growth and environmental problems are two of the most important factors in the macro landscape. The connection between general economic development and environmental impact is most visibly depicted in the *Environmental Kuznets Curve* hypothesis. Another important macro-economic factor is transfer of technology, which is a key factor for the economic development of countries and regions[62]. This and other related issues are covered under the general subject of *technology diffusion*.

3.6.1 The Environmental Kuznets Curve

The Environmental Kuznets Curve (EKC) hypothesis is the most frequently adopted methodology for analysis of whether economic development is detrimental or positive for the environment. EKC hypothesizes that in the beginning of a country's economic and industrial development, little or no focus is given to environmental concerns such as increased pollution. After a certain economic threshold, when basic physical needs have been met, interest in a clean environment eventually rises. This reverses the polluting trend since the society by then has the capital, and willingness, to spend to reduce pollution, which is illustrated in figure 7.[63] We believe that EKC is a useful theory to explain what may happen in terms of environmental consciousness as a macro landscape factor in a socio-technical system when there is general economic growth.

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[55] Johnson et al. (2005), p. 185
[56] Geels & Kemp (2007), p. 443
[57] Geels (2002), p. 1260
[58] Geels (2007), p. 129
[59] Geels & Kemp (2007), p. 443
[60] Geels (2002), p. 1260
[61] Geels (2005), p. 452
[62] Perez & Soete (1988), p. 458
[63] Huang et al. (2008), pp. 239-241

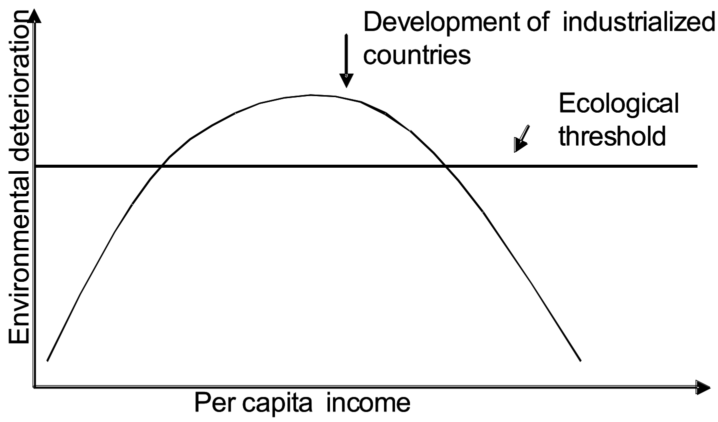

Figure *7* – The Environmental Kuznets Curve predicts that the ecological impact from economic development first increases past an ecologically sustainable threshold, then eventually decreases, with per capita income.[64]

3.6.2 Technology diffusion

An important part of the spreading of new technology is the *neighbourhood effect*, which stipulates that when the distance between the source of knowledge and the user increases, the degree of knowledge and technology transfer decreases[65]. Geographic space is thus a key factor in any explanation of the diffusion of novel innovations[66].

Diffusion can be seen as a widespread adoption of technologies over time between different social entities, which carries with it increased output and technological change, as well as improvements in economies, productivity and efficiency[67]. Technology diffusion follows a predefined pattern, even though the regularity and timing of the process vary greatly. Diffusion starts in innovation centres and spreads first within a core area and then via a hierarchy of subcentres to the periphery. The process tends to last longer in the region where the technology has its origin. Regions where diffusion begins later see a quicker diffusion process, as there is a "catch-up" with the innovation region. Quicker adoption of a technology, however, leads to a lower adoption rate. The extent of diffusion within a region tends to be highest in the innovation region.[68,69]

The timing of diffusion also sets the pace for the penetration of technological change. Other things being equal, the higher the perceived profitability and the lower the required investments, the faster diffusion moves forward. Diffusion proceeds faster if

[64] Huang et al. (2008), p. 240
[65] Coccia (2008), pp. 105-107
[66] Ibid., p. 106
[67] Grübler (1998), p. 28-60
[68] Ibid., pp. 5-6
[69] Ibid., pp. 58-69

network externalities, learning and knowledge requirements for producing the technique are known by the adopting part.[70,71]

We find that the concept of technology diffusion will help us explain why new technology spreads in a certain way within a socio-technical system. It also gives help in understanding why change may occur at different times in separate geographical areas of the system.

3.7 Innovation phenomena

Innovation phenomena occur in "technological niches"[72] on the micro-economic level. Through learning processes, where knowledge is gathered about technical specifications, user preferences, public policies etc., innovations are created. The innovations are protected from market selection in "protected spaces", which increases their chances of survival. The means of protection are often subsidies, public authority support or status as strategic investments within companies, e.g. skunkworks.[73] Innovation phenomena thereby include, for example, sheltered "incubation rooms"[74] for radical innovations and supporting social networks around the novelty, e.g. lobby groups, user associations and new industry networks.[75]

Innovations go through three general phases. In the first, ambiguity about their ultimate configuration is significant and actors improvise in order to find the best design and identify user needs. In the second phase, a dominant design emerges from the existing alternatives and enters a small initial market. In the third phase, the new technology enters into serious competition with the existing regime and experiences a wider breakthrough.[76] The road from a spectrum of competing disparate new technologies to the emergence of a competitive dominant design has been covered by a number of authors in the field of standard setting theory. Therefore, we choose to use elements of this theory to explain the mechanisms behind innovation phenomena.

3.7.1 Standard setting processes

Dominant designs may become de facto standards and therefore they are in many cases synonyms. Arthur explains the term "standard" with the following:

> The term 'standard' has two meanings in the technology literature: that of a convention or code of practice […] and that of the technology or method or code that comes to dominate – that becomes a 'standard'.[77]

[70] Grübler (1998), pp. 5-6
[71] Ibid., pp. 58-69
[72] Geels & Kemp (2007), p. 443
[73] Geels (2004), p. 912
[74] Ibid., p. 912
[75] Geels (2005), p. 450-451
[76] Ibid., p. 451
[77] Arthur (1988), p. 601

A dominant design may emerge in several ways, for example when users prefer one particular design or technology to others. The market demand is affected by a combination of technological possibilities, individual and organizational factors and government regulations. Governmental factors may force adoption of a certain standard, especially when the development is of national interest. An industry committee or a group of firms may also create a durable standard or form an alliance around a certain standard.[78] Standards often shape the technological progress in an area, which in turn enables and restricts which designs are likely to emerge in the future[79].

Adoption of a new technology or a standard often requires building an alliance, which might be slow if adoption is required from many different players.[80] Additionally, there are a number of other known effects that influence the development:

Learning curve
The more a technology is being used the more is learned about it, which in turn leads to development and improvement. As the usage increases the technology becomes part of an infrastructure enabling the technology to become even more dominant.[81]

Path dependency
Technologies improve as more people adopt them, since firms gain expertise and become more skilled with the technology[82]. If an event gives a technology an initial advantage in adoptions, it may benefit from learning curve effects or the development of complementary technologies.[83]

Network externalities
There are usually benefits to consumers and firms from standardisation of a product. There may be benefits in form of a direct network externality, meaning that a user's benefit from using a good, increases with the total number of users. In markets where network externalities are important, an organization's decision to switch to a new standard is partially dependent on who else also switches.[84]

Signalling effects and installed base
The size of a technology's installed base and the availability of complementary goods may be the most important factors determining its success or failure[85]. The size of the installed base may serve as an indicator of the quality and value of the technology. Moreover, a large installed base signals that others already have evaluated its performance and experienced it as favourable.[86]

[78] Anderson & Tushman (1990), pp. 615-616
[79] Schilling (1999), pp. 265-266
[80] Shapiro & Varian (1999), pp. 8-14
[81] Arthur (1988), pp. 591-601
[82] Anderson & Tushman (1990), pp. 613-614
[83] Schilling (2002), p. 387
[84] Farrell & Saloner (1985), p. 70-73
[85] Schilling (1999), pp. 265-266
[86] Shapiro & Varian (1999), p. 9

3.8 Change in socio-technical systems

Socio-technical systems are characterized by stability. An established system is stabilized by roles, routines, ways of thinking and doing, legally binding contracts, people having adapted their lifestyles, favourable institutional arrangements, formal regulation, infrastructure etc. Taken together, all these social and material elements lead to "technological momentum", which make existing systems hard to abandon once they are in place.[87]

System change does, however, occur. Simply put, the process starts in "technological niches"[88] outside or on the fringe of the existing set of societal rules, where innovation phenomena protect innovations from the market forces. Eventually, if any of the innovations becomes successful, the associated novelty causes change in the societal rules. The changed rules may thereafter in turn slowly affect the exogenous environment, i.e. the earlier described macro landscape.[89]

To visualise these relationships and understand change, the micro innovation phenomena must be linked with the macro landscape. In the selected theory about socio-technical systems, this is done through the introduction of the already described societal rules. The societal rules effectively constitute a bridge between innovation phenomena and the macro landscape.[90] However, it is important to note that "there is no simple 'cause' or driver" of change[91]. Change processes take place at multiple dimensions and levels simultaneously, i.e. they display "circular causality". Change occurs when the processes connect to and reinforce each other.[92] Since everything in the socio-technical system is interconnected, changes in one part of the system can trigger changes in other parts[93].

3.8.1 Types of change processes

As described above, change in socio-technical systems occurs through processes at the micro innovation phenomena, mesa societal rules, and macro landscape levels. Change is, however, not always uniform. Instead it is possible to distinguish three types of change processes: *reproduction*, *transformation*, and *transition*. The individual processes all involve different levels and have specific underlying mechanisms.[94]

Reproduction
Reproduction is the normal situation at the societal rules level, which is also the only level where there are dynamics in this case. There is no influence on or from the

[87] Geels & Kemp (2007), p. 443
[88] Ibid., p. 443-444
[89] Ibid., p. 443-444
[90] Ibid., p. 443
[91] Ibid., p. 444
[92] Geels (2005), p. 453
[93] Geels (2002), p. 1259
[94] Geels & Kemp (2007), pp. 444-445

macro landscape or innovation phenomena. What happens during reproduction is that incumbent stakeholders refine the socio-technical system through incremental innovations, which give continuous small improvements, i.e. there prevails a "dynamic stability".[95]

Transformation

In transformation processes the societal rules and the macro landscape interact, whereas innovation phenomena exert little influence. Pressure from changes at the landscape level causes a change in the societal rules, e.g. changes in technical problem agendas, goals and guiding principles, or regulations and perceptions of opportunities. Pressure from the public, changed regulations or the entry of new actors, help in challenging old assumptions. The survival of incumbent actors is not under threat since these outsiders do not develop competing technologies. Instead, "a new system may grow out of the old one".[96]

Transition

A transition occurs when there is a shift from one socio-technical system to another. It refers to a radical change of technological trajectory, such as going from horse-drawn carriages to automobiles in the transport system. A transition involves changes in technology and infrastructure, among stakeholders, and in the set of societal rules. In a transition process, dynamics between the macro landscape, societal rules, and innovation phenomena interact. Problems in the set of societal rules, caused by pressure from the macro landscape, create a window of opportunity for innovation phenomena. With the breakthrough of an innovation, a part of the old system is replaced through 'creative destruction'. From this follows the collapse of some of the incumbents, which is then followed by a new state of dynamic stability.[97]

3.9 Scenario-based techniques

Having developed a relevant theoretical framework for the study, a suiting way to combine it with a tool for structured analysis and presentation of empirical findings was needed. Socio-technical systems present a special challenge in this matter since they are complex and span over very different kinds of issues. The solution was found among scenario-based techniques, which, according to Rasmussen, are "ideal for involving people in exploring socio-technical system possibilities in complex environments"[98]. Examples of socio-technical systems that have earlier been the subjects of scenario-building include railway systems, air traffic controls, the Olympic games and military planning[99].

[95] Geels & Kemp (2007), p. 445
[96] Ibid., p. 445
[97] Ibid., p. 446
[98] Rasmussen (2005), p. 229
[99] Ibid., p. 229

Scenarios help the human mind understand how environmental changes may affect a certain issue when dealing with a complex future determined by a number of different factors with unknown values [100]. A scenario is here defined as:

> A description of a future situation and the course of events which allows one to move forward from the original situation to the future situation.[101]

Scenarios tell stories and weave together information about likely future events with imagination about the uncertain. This means that scenarios can provide holistic views of the future. Thereby, early signals about what may come can more easily be identified and, thus, reacted to.[102]

To create the scenario-based method used in this study (described in detail in chapter 4), inspiration was taken from two different schools[103] of futures studies; the Anglo-American *intuitive logics* and the French *La Prospective*.

3.9.1 The *Intuitive logics* model

The intuitive logics model is based on intuitive and logical thinking with a clear process orientation. The purpose is to either make sense of certain situations or to aid organizational learning. Work activities typically include brainstorming, macro environment analysis, research, and discussions with experts. The final output is descriptive or normative, always qualitative, and consists of a set of narrative scenarios with no probabilities attached. Instead, the scenarios are seen as equally plausible.[104]

In this study, the intuitive logics model was used to create the general framework for the building of scenarios in the model developed. Its approach in many aspects suits the generally qualitative empirical data that is gathered when investigating socio-technical systems.

3.9.2 The *La Prospective* model

The *La Prospective* model is more outcome-oriented than the intuitive logics model. It is built on intuitive thinking in combination with data processing. The purpose is to find effective policy or strategic decisions and tactical plans of action. Quantitative, computer-based data analysis tools are extensively used. The output is both quantitative and qualitative and, usually, descriptive.[105]

In this study, the main inspiration from the *La Prospective* model is the inclusion of the MICMAC analysis method (see section 3.10) into the developed model. Since socio-technical systems display complex interrelationships between its individual

[100] Walsh (2005), p. 116
[101] Godet & Roubelat (1996), p. 166
[102] Rasmussen (2005), pp. 229-230
[103] Bradfield et al. (2005), p. 807
[104] Ibid., pp. 807-808
[105] Ibid., pp. 807-808

components there is a need for a tool that can analyse feedback loops and indirect relationships. MICMAC analysis is very well suited for this.

3.10 MICMAC analysis

A system is built on a set of inter-connected elements or factors. When performing a systems analysis, the goal is to put a light on the relationships between these factors. After having found a presentation of the system, which is as thoroughly descriptive as possible, the MICMAC analysis helps to reduce the systemic complexity to the most important factors.[106]

There are two general kinds of factors to identify: *drivers*, which are the most influential and the determinants of the system, and *dependents*, which are the most sensitive to changes in the environment. They are found by looking at indirect influence and feedback loops (figure 8), which for the human brain are difficult to perceive.[107]

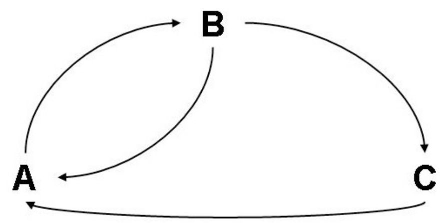

Figure 8 – An example of a feedback relationship between system factors, which is hard for the human mind to interpret intuitively. Factor *A* influences factor *B* with a direct relationship. However, *B* in turn influences *A* both directly and through factor *C*, creating a feedback loop.[108]

The MICMAC analysis creates a hierarchy among the factors. The driver power is measured by calculating how many paths and loops of length n that arise *from* each factor, whereas the degree of dependency is determined by looking at the number of paths and loops that lead *to* each factor.[109]

In the example in figure 8, factor *B* is intuitively the most powerful driver. This can be understood by considering figure 9 below, where the *structural analysis matrix* for the system is presented at the level $n = 1$, i.e. only intuitive, direct relationships are taken into account. In the matrix, which can be read either row-wise or column-wise, the number 1 means that there *is* a relationship, while 0 means that there is *no* relationship between the factors. If it is read row-wise, the value depicts the existence of a driving relationship on the factor in the corresponding column. If it instead is read column-wise, the value stands for the column factor's dependency on the factor

[106] Godet (1986), pp. 141-142
[107] Ibid., p. 147
[108] Ibid., p. 148
[109] Ibid., p. 147

in the corresponding row.[110] The row sum thereby depicts the factor's total "driver power", whereas the column sum is its "degree of dependency"[111].

$$M = \begin{array}{c} \\ A \\ B \\ C \\ \\ \end{array} \begin{array}{c} \begin{array}{ccc} A & B & C \end{array} \\ \left(\begin{array}{ccc} 0 & 1 & 0 \\ 1 & 0 & 1 \\ 1 & 0 & 0 \end{array} \right) \\ \begin{array}{ccc} 2 & 1 & 1 \end{array} \end{array} \begin{array}{|c} 1 \\ 2 \\ 1 \end{array}$$

Sum of the elements in the factor's row = "Driver power"

Sum of the elements in the factor's column = "Degree of dependency"

Figure 9 – The structural analysis matrix for $n = 1$ corresponding to the system in figure 8. As an example, the value 1 in the first row, second column, means that factor A is a driver for factor B (row-wise), or, differently put, that factor B is dependent on factor A (column-wise).[112]

The analysis is simple and straightforward when only taking into account direct relationships. However, to find the "true" influence of the factors, the more elusive indirect and feedback mechanisms must also be taken into account. This is achieved by performing the MICMAC analysis. In the process, the structural analysis matrix is raised to ever higher powers until the rankings of driver power and degree of dependency among factors, i.e. the relations between the sums of their respective rows and columns, do not change any longer.[113] This usually occurs at the power of 4 or 5. For each successive power 1, 2…n, the influence paths of length n are revealed.[114] The underlying principle is based on the properties of Boolean matrices[115].

In the example from above, second-order relationships (figure 10) are revealed when M is squared, i.e. $n = 2$.

Figure 10 – Two of the second-order relationships in the example.[116]

[110] Godet (1986), p. 148
[111] Ibid., p. 148
[112] Ibid., p. 148
[113] Ibid., p. 147-148
[114] Arcade et al. (1999), p. 16
[115] Godet (1986), p. 147
[116] Ibid., p. 149

The relationship to the left (*A* to *A*) is visible in the matrix M^2 (figure 11) through the number 1 in the first row, first column, whereas the right (*B* to *A*) is seen in the second row, first column[117].

$$M^2 = \begin{array}{c} \\ A \\ B \\ C \\ \\ \end{array} \begin{array}{ccc|c} A & B & C & \\ 1 & 0 & 1 & 2 \\ 1 & 1 & 0 & 2 \\ 0 & 1 & 0 & 1 \\ \hline 2 & 2 & 1 & \end{array}$$

Figure 11 – The second-order (n = 2) structural analysis matrix.[118]

When continuing to higher powers, stabilisation in this case occurs from n = 4, see figure 12. The MICMAC analysis shows that factor *B* is the most powerful driver (largest row sum) followed by *A* (second largest) and then *C* (smallest row sum). *A* is the factor which is most dependent on the others (largest column sum), while *C* is least dependent (smallest column sum). Note that this ranking differs from the direct ranking obtained when n = 1. *B* is still most influential and *A* most dependent, but it is now possible to distinguish between *A* and *C* in terms of driver power and *B* and *C* in terms of dependency.[119]

$$M^3 = \begin{array}{c} \\ A \\ B \\ C \\ \\ \end{array} \begin{array}{ccc|c} A & B & C & \\ 1 & 1 & 0 & 2 \\ 1 & 1 & 1 & 3 \\ 1 & 0 & 1 & 2 \\ \hline 3 & 2 & 2 & \end{array} \quad M^4 = \begin{array}{c} \\ A \\ B \\ C \\ \\ \end{array} \begin{array}{ccc|c} A & B & C & \\ 1 & 1 & 1 & 3 \\ 2 & 1 & 1 & 4 \\ 1 & 1 & 0 & 2 \\ \hline 4 & 3 & 2 & \end{array} \quad M^5 = \begin{array}{c} \\ A \\ B \\ C \\ \\ \end{array} \begin{array}{ccc|c} A & B & C & \\ 2 & 1 & 1 & 4 \\ 2 & 2 & 1 & 5 \\ 1 & 1 & 1 & 3 \\ \hline 5 & 4 & 3 & \end{array} \quad M^6 = \begin{array}{c} \\ A \\ B \\ C \\ \\ \end{array} \begin{array}{ccc|c} A & B & C & \\ 2 & 2 & 1 & 5 \\ 3 & 2 & 2 & 7 \\ 2 & 1 & 1 & 4 \\ \hline 7 & 5 & 4 & \end{array}$$

Figure 12 – The structural analysis matrices for n = 3…6.[120]

3.10.1 The drivers vs. dependents matrix

When the MICMAC analysis is completed, the factors in the system are plotted in a *drivers vs. dependents* matrix. In it, each factor is classified as a function of its driver power and degree of dependency. The matrix is then divided into four sectors, in each of which the factors display certain characteristics (figure 13).[121]

[117] Godet (1986), p. 149
[118] Ibid., p. 149
[119] Ibid., p. 149
[120] Ibid., p. 149
[121] Ibid., p. 153

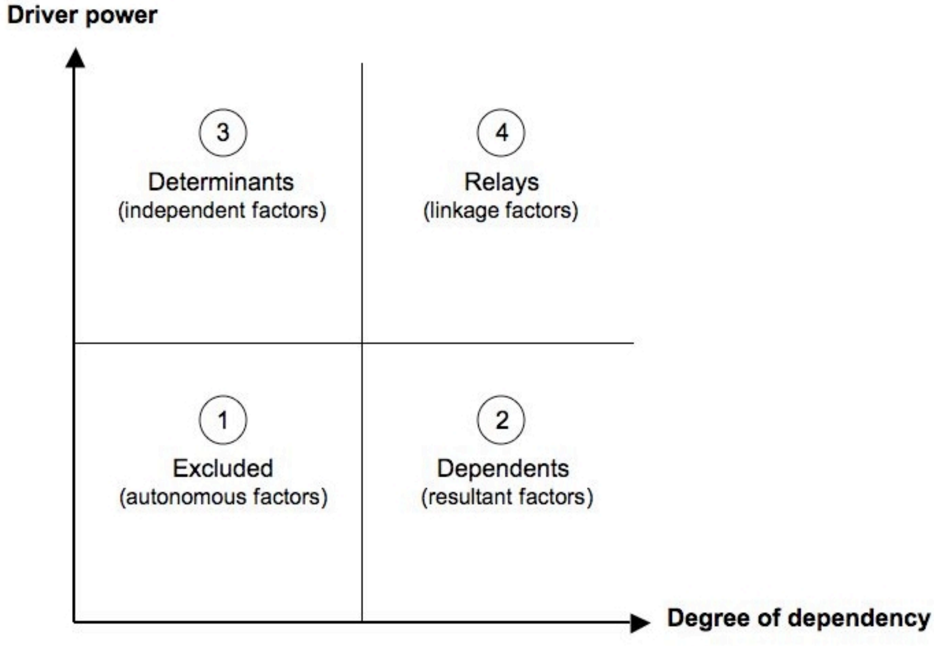

Figure 13 – The drivers vs. dependents matrix.[122]

The characteristics of the factors in each sector are specified in table 2 below.

Table 2 – Factor characteristics and descriptions.[123]

Sector	*Main factor characteristics*	*Description*
1	Weak drivers and weak dependents	Factors that are largely disconnected from the system through few links. However, these links may be very strong. They are not control factors for the system and can generally be excluded.
2	Weak drivers and strong dependents	Resultant or output factors, the state of which is determined by the control factors in sectors 3 and 4.
3	Strong drivers and weak dependents	Strong drivers that condition the rest of the system. Can be seen as entry factors, or determinants, of the system.
4	Strong drivers and strong dependents	Naturally unstable factors that should be studied with special care. Any action on these factors is either amplified or suppressed through their impact on other factors and feedback effects.

[122] Modified from Godet (1986), p. 153 and Arcade et al. (1999), pp. 17-18
[123] Created from Godet (1986), p. 153 and Arcade et al. (1999), pp. 17-18

From the descriptions in table 2 follows that the factors in sectors 3 and 4 are the most important for the state of the system, while sector 2 factors also are important in efforts to fully describe the resulting state. Factors in sector 1 can generally be excluded if they do not display extremely strong relationships.[124]

Another interesting output from the drivers vs. dependents matrix is the shape of the system, illustrated in figure 14. By looking at the way the factors are distributed in the matrix, a judgement can be made on whether the system is stable or unstable. An absence of *relay* factors and a clear distinction between *determinants* and *dependents* makes the connection between the system's input and output clearer, which creates stability.[125]

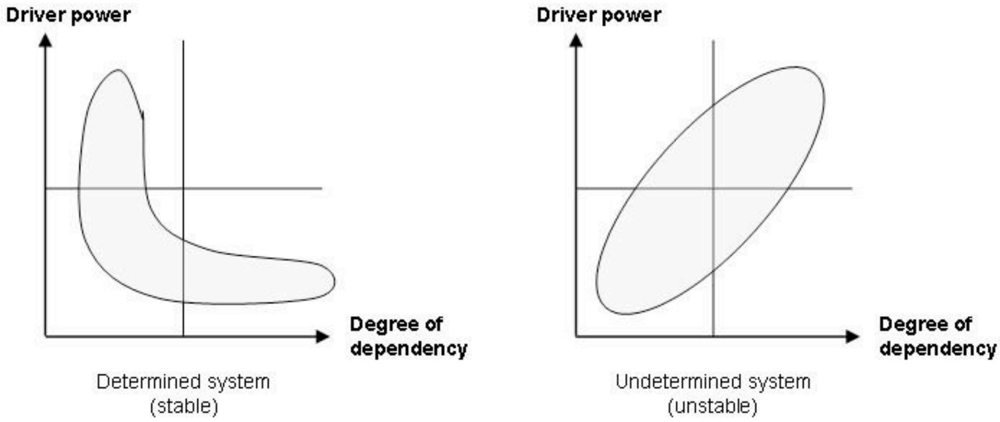

Figure 14 – The shape of the factor distribution in the drivers vs. dependents matrix in stable and unstable systems, respectively.[126]

With the help of MICMAC analysis, it is possible to extract the most important factors from the complex windings of a socio-technical system such as the one depicted in the case study. The structured approach will help in receiving a credible result from the analysis. Finally, through looking at the distribution of factors, we will also get a notion of whether the existing system is stable or not, i.e. whether it is prone or not to change.

[124] Arcade et al. (1999), pp. 17-19
[125] Ibid., p. 22
[126] Ibid., p. 22

4 The FUTSTEPS method

In this section, a unique method for analysis and presentation of empirical data is derived from the theory presented in the preceding chapter. The method enables systematic treatment of data regarding complex issues involving technology and society, as well as helps in visualising what the future of the issues may look like.

4.1 Relation to other scenario-based techniques

The theoretical framework chapter showed that a suiting way to address issues involving technology and society was to describe them by using a socio-technical systems framework. Also, we showed that a good way to present the findings was to use scenario-based techniques. The question then remains on how to combine these two elements of the analysis in practice. We chose to develop a method where the scenario creation process provides the step-by-step logic, while the socio-technical system framework fills the process with content. For each step, the method provides more information, which builds a solid ground for the scenarios and thus enables a vivid and detailed presentation of the possible.

Our method, which is called the FUTSTEPS method, was developed through combining parts from three different scenario methods with socio-technical systems aspects. In table 3 below, a clear overview of the relationship between the FUTSTEPS method and Godet's, Schoemaker's, and O'Brien's respective methods, from which we took inspiration, is presented.

Table 3 – An overview of the similarities and differences between the FUTSTEPS method and the three methods that served as inspiration.

Godet (1986)	*Schoemaker (1995)*	*O'Brien (2004)*	*FUTSTEPS method*
	1. Define the scope *Set the time frame and scope of the analysis. Look at earlier changes and sources of uncertainty to increase understanding*	**1. Set the scene** *Present the characteristics of the organization affected, the scenario planning horizon, and past and current issues in the industry*	**1. Set the scene** *Present the character-istics of the issue at hand, the scenario time horizon, and relevant past and current developments in the investigated system. Use the socio-technical system aspects as headlines and to sort data*
1. Identify internal and external variables *List relevant internal or external (environmental) variables through any brainstorming or intuitive method through considering different political, economical, political and sociological viewpoints. The total number of variables should be a few dozen*	**2. Identify the major stakeholders** *Identify who will be affected by, have interest in and influence on the issues investigated* **3. Identify basic trends** *List the political, economical, societal, technological, legal and industry trends that are likely to continue and surely will affect the issue*	**2. Generate uncertain and predetermined factors** *List all conceivable factors affecting the organization's future through free thinking exercises*	**2. Identify relevant system factors** *Analyze the current and possible future situation and list relevant factors in the following areas:* *a) Technology and infrastructure* *b) Stakeholders* *c) Societal rules* *d) Innovation phenomena* *e) Macro landscape*

Godet (1986)	*Schoemaker (1995)*	*O'Brien (2004)*	*FUTSTEPS method*
2. Define system outlines and search for key variables *Identify external driver variables and internal dependent variables through the MICMAC method*	**4. Identify key uncertainties** *List the political, economical, societal, technological, legal and industry factors, whose outcomes are uncertain and which will significantly affect the issues. Specify relationships among them*		**3. Determine interrelationships between factors** *Create the structural analysis matrix through marking direct relationships with 1 and no relationship with 0. Specify them as either weak or strong.*
			4. Identify key factors through MICMAC analysis *Identify driver and dependent factors, respectively, through the MICMAC method*
3. Analyze actors' roles *Identify important actors through analyzing in retrospective (mechanisms, tendencies, key actors) and the present situation (seeds of change, actors' projects)*			
4. Construct an actors' strategy table *Create a matrix where each actor's presumed actions and objectives vis-à-vis other actors are specified and described in details*			
		3. Reduce factors and specify factor ranges *Rank the generated factors according to degree of uncertainty and importance to the organization. Identify key factors and specify their ranges*	**5. Specify factor ranges** *Specify the range of possible values for each key factor based on empirical data*
5. Create sets of probable assumptions based on key variables for the future *An expert group sets values and assumptions that are used in constructing scenarios*	**5. Construct initial scenario themes** *Use the identified trends and uncertainties to construct scenario themes*	**4. Choose themes and develop scenario details** *Choose overall themes for the scenarios and project suiting values to the key factors*	**6. Develop scenario themes and set factor values** *Choose overall themes for the scenarios and project suiting values to the key factors*
	6. Check for consistency and plausibility *Analyze the scenarios for internal inconsistencies and adjust them to increase plausibility*	**5. Check consistency of scenarios** *Check the factor values for consistency vis-à-vis each other through a cross-impact analysis*	**7. Check consistency of scenarios** *Analyze the scenarios for internal inconsistencies and adjust them to increase plausibility*
6. Create scenarios *Construct scenarios through using the hypothetical assumptions set in step 5*	**7. Develop learning scenarios** *Construct fully-fledged and descriptive scenarios, which tell a capturing story*	**6. Present scenarios** *Present the scenarios as vivid and credible narratives to spur people's imagination*	**8. Present scenarios** *Present the scenarios as vivid and credible narratives to spur people's imagination*

Godet (1986)	*Schoemaker (1995)*	*O'Brien (2004)*	*FUTSTEPS method*
7. Assess probability of scenarios and choose the most likely ones *Determine the global probability of each scenario by letting experts set probabilities for each of the underlying assumptions, then discard the most improbable scenarios*			
	8. Develop research needs *Identify areas where there is a lack of knowledge or a high degree of uncertainty and therefore require increased understanding*		
	9. Develop quantitative models *Formalize interactions in a quantitative model, which helps avoiding implausible scenarios and quantifies consequences of various scenarios*		
	10. Evolve toward decision scenarios *Converge, through iteration, toward final, credible, totally consistent and archetypal scenarios, which can be used to test strategies and generate new ideas*		
		7. Assess impact of scenarios *Specify the effects of scenario issues on the organization*	**9. Assess impact of scenarios** *Specify the effects of scenario issues on the organization*
8. Develop alternative strategies *Identify the priority strategic actions that need to be initiated to take advantage of expected changes*		**8. Develop and test strategies** *Develop strategic options suiting the scenarios and test them for robustness*	
9. Develop plan of actions *Make a plan for how the strategic actions should be implemented*			
			10. Identify needs for monitoring and further research *Identify the most important factors to monitor in order to anticipate future developments, and pinpoint areas of insufficient knowledge*

4.2 Step details

Our FUTSTEPS method includes ten distinct steps, each of which constitutes one more move on the way to a deeper understanding of the future of the socio-technical system in question. The output from each step is used as input in the next. Below, these steps are described in detail and, in relevant cases, related to the theoretical framework described in chapter 3.

4.2.1 Step 1: Set the scene

In the first step of the scenario-building, the investigated issue is described in terms of scope and characteristics. Also, the system limits are specified and the scenario time horizon is set. A general presentation of the past, covering about as far backwards in time as the investigation looks forward, serves to put the issue and future developments in perspective. The thorough description of the present situation is roughly divided into five sections taken from the theoretical framework: technology and infrastructure; stakeholders; societal rules; macro landscape; and innovation phenomena.

4.2.2 Step 2: Identify relevant system factors

In the second step, the goal is to identify and list relevant factors affecting the future state of the investigated system. The factors are found through analysis of and reasoning about the empirical data from the present situation described in step 1. The factors are found by asking questions such as "Are there any important complementary products? Which stakeholders are the most powerful? Are there any laws regulating the issue? Are there any new innovations in the pipeline?" etc etc. The answers, i.e. the factors, are found by pointing to concrete examples in the empirical information and grouped according to investigated area. Once identified, the factors are not ranked or assessed in any other way than that they are deemed to be relevant to the issue at hand. The total number should be not more than a few dozen to reduce complexity in the following steps. The investigated areas, described in table 4, are the same as the different dimensions in the theoretical framework developed in chapter 3.

Table 4 – Areas in which system factors are identified and classified through analysis.

Investigated area	***Description***	***Examples of factors***
Technology and infrastructure	"Hard-ware" factors that affect the system's state and create technological momentum and stability	Artefacts; Infrastructure; Complementary products
Stakeholders	Powerful persons and organizations, which affect the system	Policy makers; Firms; Media
Societal rules	Rules that guide the perceptions and actions of stakeholders	Laws; Regulations; Morale values; Problem agendas
Macro landscape	Macro-level factors in the exogenous environment creating preconditions for the system	Oil price; Economic growth; National security policy; Environmental consciousness
Innovation phenomena	Micro-level innovations and processes that may change the state of the system	Dominant designs; "Incubatory" environments; Interest groups; Strategic programmes

4.2.3 Step 3: Determine interrelationships between factors

In the third step, each identified factor's direct effect on all other individual factors is specified as either 1, there is effect, or 0, no effect (figure 15). The relationship can be currently existing or potential. Additionally, an intuitive judgement of the strength of the relationship, weak or strong, is made. The result is the structural analysis matrix with n = 1, i.e. the basic matrix showing the direct relationships which is used as input to the MICMAC analysis.

$$
\begin{array}{c}
\\ A \\ B \\ C \\ D \\ E
\end{array}
\begin{array}{c}
\begin{array}{ccccc} A & B & C & D & E \end{array} \\
\begin{pmatrix}
0 & 1 & 1 & 0 & 1 \\
1 & 0 & 1 & 0 & 0 \\
1 & 1 & 0 & 1 & 0 \\
0 & 1 & 1 & 0 & 1 \\
0 & 0 & 1 & 1 & 0
\end{pmatrix}
\end{array}
$$

Figure 15 – Example of a structural analysis matrix (see also section 3.10). The identified factors' effects on each other, i.e. their interrelationships, are marked as 1 or 0. For example, in this case factor A affects factor E, but factor E does not have a direct effect on A.

How to determine interrelationships

To determine relationships between factors is no easy task. It must be made in an intuitive way, but at the same time the relationships need to be as objective as possible. Also, the relationships that go into the structural analysis matrix should be direct, not indirect, which often is hard to tell the difference between.

We propose the following method to find relationships:

1. Ensure that you understand the definition of the influencing factor (X)
2. Ensure that you understand the definition of the influenced factor (Y)
3. Give examples from empirical data of how factor X may influence factor Y
4. Logically analyze whether the impact from X on Y is direct or indirect
5. If it is direct, determine the strength of the impact (weak or strong), preferably from empirical evidence
6. Enter 1 (or 0 if no or an indirect effect was found) into the matrix and make a notation on whether the relationship is weak or strong

4.2.4 Step 4: Identify key factors through MICMAC analysis

In the fourth step, each individual factor's importance for the state of the system is determined through a MICMAC analysis. After the analysis is completed, all the factors are plotted in a drivers vs. dependents matrix, see example in section 6.4. The system can thereafter be characterized as stable or unstable, depending on the distribution of factors in the matrix. Finally, removing those that do not qualify as "determinants" or "relays" singles out the key factors.

The key factors should not number more than approximately a dozen, in order to keep the scenario-building complexity at manageable levels. This is achieved by drawing the matrix area borders in the following way; The X-axis border is placed so that 50 percent of factors are on either side. The Y-axis border is thereafter drawn so that the wanted number of factors is above it. Thereby, the determinant and relay factors with the most driver power are always included in the selection.

The system's stability is determined by making a linear regression of the plotted factors. Around the regression line, an ellipse is thereafter drawn. The ellipse should preferably cover 90 percent of all factors, and its perimeter should touch the outer data points. This will determine its form. By looking at the regression's gradient and the wideness of the ellipse, a judgement can then be made of the system's stability according to what was explained in the theoretical framework (section 3.10.1).

4.2.5 Step 5: Specify factor ranges

In the fifth step, each key factor is assigned a relevant dimension based on the empirical data. In the dimension, the factor can assume a range of values. The ranges may be quantitative or qualitative and should be based on knowledge from the empirical data. In some cases, when the factor is relevant but empirical data about ranges is missing, logical reasoning must be used. Three examples are given in table 5.

Table 5 – Examples of factors, dimensions, and factor ranges.

Factor	***Dimension***	***Factor range***
Heat	Temperature	0°C-100°C
Mood	Happiness	Very sad-Very happy
Price competitiveness	Price	Very cheap-Very expensive

4.2.6 Step 6: Develop scenario themes and set factor values

In the sixth step, the general themes for the scenarios are chosen. This is done by either using a bottom-up approach, where the individual factor values together build the overall scenario theme; or by using a top-down approach, where the theme is set first and the factors are then assigned the values needed to achieve accordance with the theme. Further descriptions of the two ways are specified below:

Bottom-up
Begin with creating different sets of values by varying the factor values of the two-three most powerful determinants of the system. Since the determinants' values greatly affect the other key factors' respective state, a whole list of factor values is thereby logically derived through the initially listed direct relationships from step 3. Interpret the sets as different themes and find out what differentiates them from each other. Assign general and descriptive scenario names to the different sets.

Top-down
First decide on overall themes for the scenarios and assign general and descriptive names to them. For example, there may be a choice between a few technological or societal alternatives. For each alternative future "world", the appropriate factor values are then assigned. Check for similarities and differences between the sets.

4.2.7 Step 7: Check consistency of scenarios

In the seventh step, the sets of factor values for the proposed scenario themes are checked for internal consistency. This is made in a structured manner with basis in the structural analysis matrix. If the set of factor values for a scenario turns out to be inconsistent, step 6 is repeated and the set of values is adjusted.

The check is performed through initially making a correlation matrix from the structural analysis matrix consisting only of the strong internal relationships between the key factors. Weak relationships are not included in order to make the consistency check manageable. A judgement is made on whether the correlations between the factors are positive (+), negative (-), or undetermined (?), see table 6. A S+ between factors A and B thereby depicts a strong relationship where the effect of a change in A's value gives a clear change also in B's value in the same direction, whether it is an increase or a decrease of value. A S- depicts a relationship where the change of value of one factor results in a change of value in the opposite direction of the other factor. Undetermined relationships depict cases when it is by intuitive reasoning impossible to say whether the correlation is positive or negative. By concentrating on the strong relationships, it is implicitly assumed that the scenarios will be sufficiently consistent as long as the factors influenced by strong relationships have correctly correlated values.

Table 6 – Example of a correlation matrix used for the consistency check. It shows the key factors' (A-E) strong internal relationships and the nature of their correlation.

		Influence on				
	Factors	A	B	C	D	E
Influence from	A		S+		S?	
	B			S-	S-	S+
	C	S-	S?			S-
	D	S?	S+	S+		
	E	S-		S?		

After the correlation matrix is complete, each scenario's set of factor values is transformed. The transformation consists of an interpretation, where each value is depicted as being in the lower, medium, or higher part of the factor's interval. A factor assuming the value "cold" in an interval ranging from very cold to very hot, would thereby be given the new value "low". A factor assuming the value "middle-class" in an interval from poor to rich would instead be depicted medium. When this is done for all factors, the inconsistency check can be made on basis of the correlation matrix. Consistent value pairs are depicted with a simple "ok", whereas inconsistent pairs are marked with a "√". The different combinations of the factor values are illustrated in table 7. If not obviously incorrect, pairs where both factors should assume the same end of their ranges, but where the consistency check shows for example "high" and "medium", i.e. the difference against the ideal is small, are deemed as ok.

Table 7 – There are nine possible factor value pairs and three kinds of direct strong relationships. Of these, four combinations of pair-wise values and relationships are deemed as inconsistent.

Factor value in range		***Relationship***		
Factor A	*Factor B*	S-	S+	S?
low	low	*√*	*ok*	*ok*
low	medium	*ok*	*ok*	*ok*
low	high	*ok*	*√*	*ok*
medium	low	*ok*	*ok*	*ok*
medium	medium	*ok*	*ok*	*ok*
medium	high	*ok*	*ok*	*ok*
high	low	*ok*	*√*	*ok*
high	medium	*ok*	*ok*	*ok*
high	high	*√*	*ok*	*ok*

4.2.8 Step 8: Present scenarios

In the eighth step, the scenarios are presented as a vivid narrative text. The text may have the form of a news message, a chronicle, or a short story. However, it is up to the author to find the most suiting way to capture the reader's attention. In any case, the development line from the present to the future should be described and the key factor values spun into the story. Key events and turning points should receive extra attention. The overall purpose is to stimulate the reader's imagination and belief in the scenario's plausibility.

4.2.9 Step 9: Assess impact of scenarios

In the ninth step, the scenarios are related to the investigating organization's own situation. What will be the consequences of the scenario? Which challenges and opportunities arise? It is important to view the scenarios as equally likely to occur in order not to take light on some of the eventualities and their consequences.

4.2.10 Step 10: Identify monitoring and further research needs

In the last step, the most important output of the whole FUTSTEPS method is identified. Here the main indicators of respective development path are pinpointed, which enables effective monitoring of the system. The monitoring helps the organization in perceiving which of the alternative futures is actually unfolding. At this stage, however, it may be evident that there are areas where there is a profound lack of knowledge. This is in itself a useful finding and may result in recommendations for further research.

5 Case study: The Russian fuel market

In this section, the case background and problem are presented. Additionally, an overview of technical fuel data and a short description of the reasons for choosing four fuels for further investigation are given.

5.1 Case background

Scania is a truck and bus manufacturer with a focus on heavy commercial vehicles for transportation. The company acts on a global market with customers in more than 100 countries[127]. To secure a leading position in the global market, as well as keep and expand its market shares in the future, Scania increasingly needs to cover growing markets outside Western Europe. For example, the Russian market has gone from being Scania's eighth largest in 2006, in terms of number of sold heavy trucks, to being the third largest in 2007. The rapid growth is projected to continue, with Russia becoming Scania's single largest market within the coming one or two years.[128]

The engines in the vehicles sold in Russia were originally developed to adhere to Western European emission and fuel standards. Because of Russia's generally less strict emission regulation and lower fuel quality, Scania has on the Russian market traditionally sold engines that are one or two development generations older than those sold in Western Europe. Thus, Scania has been able to use already existing "old" technology to serve demands on the ever more important Russian market.[129]

In Western Europe and the EU, the trend is towards cleaner fuel and emission standards. The main driving force has been to improve local air standards. The current climate change discussion and debate about alternative fuels also have major influence. The EU has said that 10 percent of all transport fuel consumed should be from biofuel sources in 2020[130]. When taken together, these trends mean that alternative, e.g. natural gas, and renewable, e.g. ethanol, vehicle fuels will become more important. This will in turn be reflected in Scania's engine development. The company has already presented powertrains running on a number of alternative fuels[131].

In Russia, however, the development may take another turn. The country has the world's largest natural gas reserves, the second largest coal reserves and the eighth largest oil reserves[132]. Fossil fuels are abundant and one of Russia's main sources of political and economical power.

> ***I cannot forecast to you the action of Russia. It is a riddle wrapped in a mystery inside an enigma: but perhaps there is a key. That key is Russian national interests.***
>
> *Winston Churchill*

[127] Scania webpage (2008)
[128] Jyde (12/11/2007)
[129] Holmborn (12/11/2007)
[130] Spiegel Online (23/01/2008)
[131] Scania webpage (2008)
[132] EIA (2007), p. 1

5.1.1 Scania's issue

If the fuel market development in Russia takes a very different path from that in Western Europe, Scania will in the future not be able to sell even vehicles equipped with its older engine generations on the Russian market. The reason will be that the engines have originally been designed for a significantly different type, or quality, of fuel. Scania may in that case face demands for regionally adapted, separate engine development lines, which will have to be considered when planning the future R&D setup.[133]

To increase Scania's knowledge about, and preparedness for, the possible above-described problem, we conducted an extensive case study in Sweden and Russia. The goal of the study was to:

Identify the determining factors for which heavy-vehicle fuels, and of which qualities, that will be dominant on the Russian market within 20 years.

In the study, the FUTSTEPS method was applied to conduct a thorough analysis of the future fuel market in Russia, which is presented in chapter 6.

5.2 Overview of conventional and alternative fuels

Through information from Scania and the literature survey, 19 potential future fuels were initially identified in the study. These were either conventional (diesel, petrol etc.), quite well established alternatives (ethanol, liquid propane gas etc.) or future prospects (dimethyl ether, butanol etc.). The complete list can be seen in table 8 below.

[133] Holmborn (12/11/2007)

Table 8 – Overview of the nomenclature for the investigated fuels.

Name used in thesis	*Main ingredients*[134]	*Alternative names*[135]
B-fuels	Liquid diesel with FAME (Fatty Acid Methyl Esters) addition in proportions from 0-100 %	Biodiesel, FAME (if 100 %), RME (if made from rape), B10 etc (special blends)
Batteries	NiMH or Li-Ion batteries	
Biogas	Gaseous methane	CBG (Compressed Biogas) or LBG (Liquid Biogas) depending on state
Butanol	Liquid butanol	Biobutanol
CNG (Compressed Natural Gas)	Gaseous methane	Natural gas
Diesel	Liquid saturated hydrocarbons	
DME (Dimethyl ether)	Gaseous dimethylether	
E-fuels	Petrol with ethanol addition in proportions from 0-100 %. Alternatively ethanol with appr. 5 % ignition additive for use in diesel engines	Gasohol (blends), Ethanol (if 100 %), E10/E85 etc (special blends)
FT-HC (Fischer-Tropsch Hydrocarbons)	Liquid hydrocarbons	Synthetic diesel, Syndiesel
GH2 (Gaseous hydrogen)	Gaseous hydrogen	Hydrogen
Hythane	Gaseous hydrogen and methane	HCNG
LH2	Liquid hydrogen	Hydrogen
LNG (Liquid Natural Gas)	Liquid methane	Natural gas
LPG (Liquid Petroleum Gas)	Liquid propane and/or butane	LP Gas, Autogas, Cooking gas
Methanol	Liquid methanol	Wood alcohol
Petrol	Liquid aliphatic hydrocarbons	Gasoline (Am.)
PPO	Plant oil extract	Plant oil
Propanol	Liquid propanol	
Syn-diesel	Liquid hydrocarbons	Synthetic diesel, 2nd gen. biodiesel, NexBTL (brand)

Some of the fuels identified can be produced from more than one feedstock and can therefore either be a fossil or a renewable fuel. To illustrate this, a basic classification of the fuels is displayed in figure 16 below. The production potential for a fuel is dependent of the processes required to produce it. Various feedstocks – fossil and

[134] Information from Erlandsson (11/02/2008), Holmborn (12/02/2008) and Holmgren (07/02/2008).
[135] Alternative names collected from anecdotal evidence at Scania and from searches on the Internet.

renewable – can be converted into suitable form through scores of chemical processes. An overview of the most important production processes of fuels included in the initial screening can be seen in Appendix II.

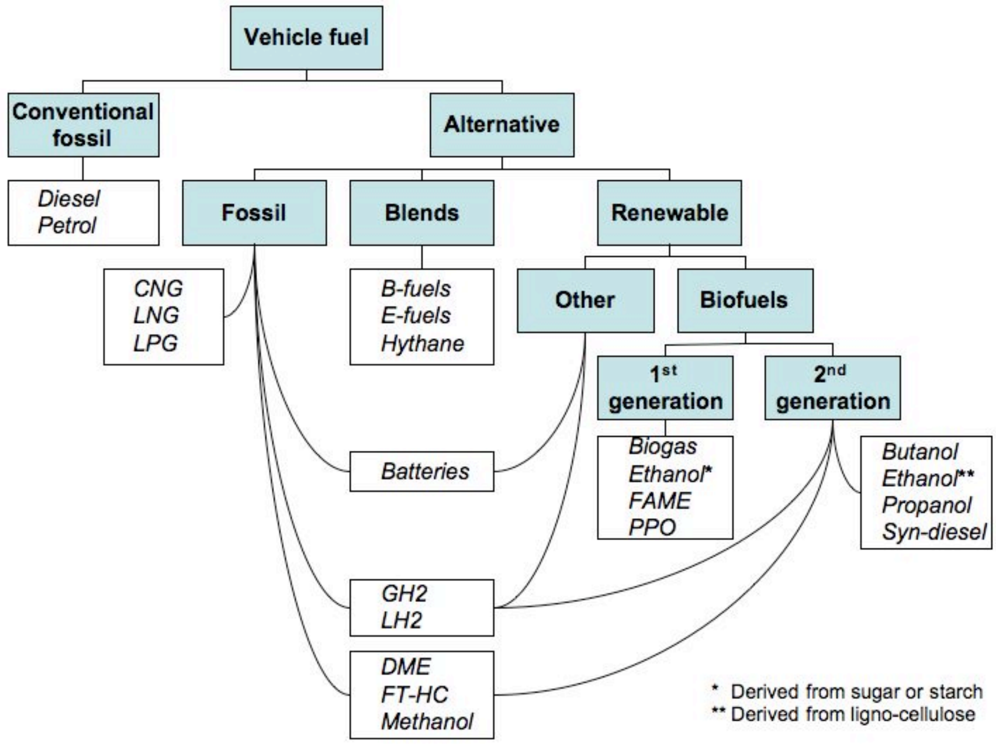

Figure 16 – The relationship between the fuels investigated in the initial screening. Some, e.g. methanol, can be produced from more than one feedstock and can therefore either be a fossil or renewable fuel. Observe that batteries are not a fuel in the sense of the word. The electricity they are charged with is, however, either produced from fossil or renewable sources.[136]

5.2.1 Technical data

As for technical data, a few key numbers (table 9) were collected and converted in order to create comparable information. The characteristics all affect how well the individual fuels work in bus and truck engines.

The RON (Research Octane Number) and cetane numbers are measures of how well individual fuels fit otto or diesel engines, respectively. The higher the number, the better suited is the fuel for the respective engine type.[137] Energy density is another important indicator of a fuel's feasibility for transport applications[138]. To achieve an acceptable range it must be possible to carry enough energy, in the form of fuel, in the vehicle's limited space. Therefore, the higher the energy density the better, since high

[136] Inspired by Landbring (2007), p. 5
[137] Erlandsson (11/02/2008)
[138] Holmborn & Kleinschek (2008), p. 19

density means that less space needs to be used for the same amount of energy. In the table below, the investigated fuels are compared in these dimensions.

Table 9 – An overview of some of the most important technical characteristics for the fuels included in the screening.

Fuel	***RON***[139]	***Cetane number***[140]	***Energy density (MJ/l)***[141]
B-fuels/FAME	-	56-58	31.4-35.0
Batteries	-	-	~0,31
Biogas	>120	-	~5.4
Butanol	94	25	~27
CNG	>120	-	7.9
Diesel	-	40-55	~35.7
DME	-	55-60	18.9
E-fuels	109	10	26.9
FT-HC	-	>74	34.5
GH2/Hythane	130	-	7.6
LH2	130	-	8.5
LNG	>120	-	20.8
LPG	~105	-	23.7
Methanol	109	3	15.8
Petrol	87-98	-	~32.1
PPO	-	(No test method)	~32
Propanol	N/A	-	N/A
Syn-diesel	-	84-99	~34

[139] *Biogas:* Erlandsson (2008), p. 14; *Butanol:* BP (2007), p. 4; *CNG:* Erlandsson (2008), p. 14; *E-fuels:* Erlandsson (2008), p. 14. Number valid for pure ethanol.; *Petrol:* Erlandsson (2008), p. 14; *GH2/Hythane:* Roads2HyCom (26/03/2008). Number valid for pure GH2.; *LH2:* Roads2HyCom (26/03/2008); *LNG:* Erlandsson (2008), p. 14; *LPG:* Stargas (2007); *Methanol:* Owen & Coley (1995), p. 591;

[140] *B-fuels/FAME:* Biodiesel.de (15/02/2008). The number is valid for pure FAME.; *Butanol:* Green Car Congress (08/07/2007); *Diesel:* Olah et al. (2007), p. 213; *DME:* Olah et al. (2007), p. 213; *E-fuels:* Erlandsson (2008), p. 14. Number valid for ethanol with 5 % ignition additive.; *FT-HC:* DieselNet (2008c); *Methanol:* Olah et al. (2007), p. 211; *Syn-diesel:* Hodge (2006), p. 6. Number valid for NexBTL.

[141] *B-fuels/FAME:* U.S. Department of Energy (2007). The number is valid for B100 biodiesel.; *Batteries:* Holmborn & Kleinschek (2008), p. 23; *Biogas:* Automotive Handbook (1996), p. 239. Value at 200 bar. Calculated from value at 0ºC and 1013 mbar. Energy content for 95 % methane gas.; *Butanol:* BP (2007), p. 4; *CNG:* Automotive Handbook (1996), p. 239. Value at 200 bar. Calculated from value at 0ºC and 1013 mbar.; *Diesel:* Semelsberger et al. (2006), p. 498; *DME:* Semelsberger et al (2006), p. 498; *E-fuels:* Erlandsson (2008), p. 16. Number valid for pure ethanol.; *FT-HC:* Hydrogen Analysis Resource Center (2007); *Petrol:* Semelsberger et al. (2006), p. 498; *GH2/Hythane:* Automotive Handbook (1996), p. 239. Value at 700 bar. Calculated from value at 0ºC and 1013 mbar. Number valid for pure GH2.; *LH2:* Hydrogen Analysis Resource Center (2007); *LNG:* Hydrogen Analysis Resource Center (2007); *LPG:* Hydrogen Analysis Resource Center (2007); *Methanol:* Semelsberger et al. (2006), p. 498; *PPO:* Crude Country Biofuels Inc. (2005); *Syn-diesel:* Hodge (2006), p. 6. Number valid for NexBTL.

5.3 Fuel selection

The extensive list of fuels needed to be reduced to the most important ones in a Russian context. This meant we had to make a pre-study of the 19 original fuels' potential, as a result of which four fuels were included in the remaining study. In the selection, we took into consideration the existing technologies potential in truck and bus applications, infrastructure and production potential in Russia, and the political and scientific interest for the fuel in the country.

5.3.1 Selected fuels

On the basis of the information obtained in the screening process four fuels could be selected. We considered them more likely to be the major alternatives on the future Russian fuel market. A thorough description of the selected fuels is presented in chapter 6. Below, the main reasons for selecting the four fuels are specified:

CNG

- CNG is well suited for local city bus and distribution applications
- Russia has the world's largest natural gas reserves
- Gazprom is a very powerful stakeholder

Diesel

- Well suited for long-distance applications
- Dominates the market today
- The big oil companies are powerful stakeholders

DME

- Is a good truck fuel
- Solves the problem of distributing "stranded" Siberian natural gas
- Large-scale production and consumption is developing in China and Japan

E-fuels

- Examples of already running buses and a few commercial truck applications
- Russia has enormous areas of farmland and forests
- There seems to be a sincere political interest in developing an industry

6 Case study: Analysis with the FUTSTEPS method

In this chapter, the future Russian fuel market is analyzed with the help of the FUTSTEPS method. The ten steps in the method are used to give the reader a comprehensive understanding of what the future may bring.

6.1 Step 1: Set the scene

In this chapter we first specify the delimitations. Secondly, a very basic historic background and presentation of today's Russia follow. Thereafter, we thoroughly describe the fuel market by first looking at aspects relating to the four investigated fuels and then at non-fuel specific aspects. Each fuel is analyzed in the technology and infrastructure, stakeholders, and – where applicable – societal rules dimensions (table 10).

Table 10 – Illustration of the socio-technical system dimensions described in each of the text sections found below.

	Section					
Aspect	*Russia: A basic background*	*CNG*	*Diesel*	*DME*	*E-fuels*	*Non-fuel specific information*
Technology and infrastructure		x	x	x	x	x
Stakeholders		x	x	x	x	x
Societal rules	x	x	x		x	x
Macro landscape	x					x
Innovation phenomena						x

6.1.1 Issue of interest, time horizon, and system limits

The analysis covers a timeframe of 20 years into the future, which coincidentally corresponds to five presidential mandate periods from now. The focus is solely on Russia and the Russian fuel market, although global aspects are taken into consideration. Furthermore, the analysis is limited to the aspects specified in the description of the FUTSTEPS method in chapter 4.

6.1.2 Russia: A basic background

Below, a few basic facts about today's Russia and the situation 20 years ago are presented. The short history serves to remind the reader of how much that may happen in the course of 20 years, while the section about the present is supposed to serve as background for the more detailed information following.

1987-1992: Times of massive change

In 1987, the General Secretary of the Communist Party of the Soviet Union, Mikhail Gorbachev, already was well on his way with his famous *perestroika* ('reconstruction and reform') and *glasnost*' ('publicity and openness') reforms. The latter had taken a serious beating in the spring of 1986 when Gorbachev and the Soviet leadership tried to deny that the worst nuclear disaster in history had taken place in Chernobyl in present Ukraine. The event stimulated the formation of an environmentalist movement and forced the government to a more open attitude. A change process that accelerated in the coming years had started.[142]

During the battle between the new and the old that took place in the last years of the Soviet Union, the economy stagnated. GDP did not grow, inflation was low, and unemployment hovered around 4 percent. In 1990, the usual shortages of basic consumer products had become acute. Queuing, i.e. simply waiting in line to buy products, amounted to a mind-boggling 30 to 40 billion man-hours per year. From 1987, there was a serious state budget deficit, which was covered by printing new money. In light of increased state investment and defence spending, the deficit reached 10 percent in 1988. By 1991, the economy was close to collapse. Reform plans towards creating a more market-oriented economy were presented and consequently dismissed.[143]

In the spring of 1991, the whole Soviet Union was falling apart. The Baltic republics, Georgia, and other republics held referendums on independence. The overwhelming majority voted for increased sovereignty from the Soviet Union. In many of the republics, violence occurred; either because of clashes between Soviet troops and nationalist movements, or as a result of ethnic conflicts. On 18 August 1991, the developments reached their extreme when the eight-man 'Emergency Committee' attempted a state coup against Gorbachev. The plan to re-establish order in the Soviet Union was foiled by Gorbachev's denial to resign, parts of the military's refusal to obey the coup leaders, and above all, the would-be first President of the Russian Federation Boris Yeltsin's courageous resistance. In the dramatic days that followed, many of the Soviet republics declared their independence, which practically put and end to the whole union. The most powerful communist country in the world was formally dissolved on 31 December 1991.[144]

Russia was left with 76 percent of the territory and 51 percent (148 million) of the Soviet Union's population. Despite initial 'shock therapy' with the goal of rapidly creating a liberal market economy, the economy went into a free fall and inflation was rampant; in the coming years it was to be counted in thousands or hundreds of percent. During the first five years, Russia's GDP fell 40 percent. Social indicators also plummeted; life expectancy with around five years; people living under the poverty line soon amounted to 20 percent; and crime skyrocketed.[145] The newborn Russian Federation was off to a tough start to its existence.

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[142] McCauley (1997), pp. 386-392
[143] Ibid., pp. 401-403
[144] Ibid., pp. 407-413
[145] McCauley (1997), pp. 413-416

The present: Fast economic development

With its current 140.7 million inhabitants, Russia is at present fast becoming an economic power in Europe. 2007 was the ninth consecutive growth year.[146] The economic development has been astonishing; since 2000, GNP has increased 72 percent, foreign debt has been slashed from 90 to 4 percent of GNP, and medium wages have doubled. At the same time, the stock market's worth has increased to 22 times the year 2000 level.[147]

During Vladimir Putin's administration 2000-2008, important reforms have been implemented in the areas of tax, banking, labour, and land codes. This has raised investor confidence, which in turn has increased foreign investments in the country.[148] In 2007, direct foreign investment amounted to $45 billion[149], which was an increase of 58 percent since the previous year.[150] Problems exist however, with the economy being much too dependent of commodity prices. 80 percent of exports, and 30 percent of government revenues, come from Russia's oil, natural gas, metals, and timber. The banking system is too small and the manufacturing industry needs modernization.[151]

Parallel with the economic success, political power has been concentrated to the Kremlin, which has undermined democratic institutions. Also, forces within the government strive to increase their power over the economy. Together with corruption and other negative factors, this makes the political uncertainty in the country considerable, which in turn negatively affects domestic and foreign investors alike. Russia still has a long way to go before having a stable rule of law.[152]

6.1.3 CNG

Technology and infrastructure

Natural gas consists mostly of methane of fossil origin. Russian natural gas for consumption usually contains about 98 % methane[153] and has a gross calorific value of 38,231 kJ per cubic metre[154]. In compressed form (CNG), it can be used as a combustion fuel in an otto engine. The compression level is typically 250 bars.[155] The main drawback with the fuel is that the tanks need to be very large in order to achieve an acceptable vehicle range. Additionally, gas vehicles work better in warmer climate since cold air (less than -10°C) causes too low injection pressure[156].

[146] CIA (2008)
[147] Forss & Ivanov (2008), p. 1
[148] CIA (2008)
[149] Ibid.
[150] Forss & Ivanov (2008), p. 1
[151] CIA (2008)
[152] Ibid.
[153] IEA (2006b), p. 167
[154] IEA (2006a), p. 59
[155] Daniels (2008), p. 27
[156] Holmgren (07/02/2008)

Buses together with smaller trucks for local distribution, such as waste collection, are the most suitable applications due to their local area of operation and subsequent possibility to refuel often.[157] At present, only one Russian bus manufacturer has CNG buses ready for production[158]. There are currently approximately 70,000 vehicles in Russia that can run on methane gas fuel[159]. In 2002, about 85 percent of these were trucks[160].

There is a firmly established system of pipelines from gas fields to urban areas in Russia[161]. The total number of CNG filling stations for vehicles is 218, of which the major gas company Gazprom owns 191[162]. The stations are mainly located along the federal highways[163]. Gazprom has signalled that they are ready to build an extensive infrastructure for CNG consisting of 2,000 – 3,000 refilling stations.[164,165] They are also said to even have pinpointed exact locations for these stations[166]. However, there are indications that only persons at middle management-level at Gazprom are in favour of this project. There has been no visible support at top level.[167] Another parallel in this aspect is the Blue Corridor Project, which was initiated in 2000 by the Vernadsky Environmental Foundation in cooperation with Gazprom. The aim was to create CNG filling stations for heavy vehicles along major transport routes between Western Europe and Russia. Despite support from, among others, United Nations' Economic Commission for Europe[168] the project has generated no visible activity since 2003.

According to one source, Gazprom has approved the "Targeted Comprehensive Program" for the build-out of CNG filling stations and development of a natural gas vehicle fleet between 2007 and 2015. The program stipulates that Gazprom shall construct 200 filling stations across Russia, which would enable CNG use in more than 400 thousand vehicles. Also, there is a separate Gazprom strategy for the development of natural gas as a motor fuel in Russia's Siberian and Far East federal districts.[169]

The consumption of natural gas for vehicles tripled between 1998 and 2005 to about 174 million cubic metres[170]. However, these numbers are insignificant when compared to Russia's reserves, which constitute the world's largest natural gas

[157] Mårtensson (18/02/2008)
[158] Fedartsov (13/03/2008)
[159] Donchenko (13/03/2008)
[160] Pronin & Stativko (2002)
[161] EIA (2007), p. 11
[162] IANGV (2007)
[163] Pronin & Stativko (2005)
[164] Eriksson (13/03/2008)
[165] Fedartsov (13/03/2008)
[166] Ibid.
[167] Wöllert (19/03/2008)
[168] Pronin & Stativko (2002), p. 2-3
[169] IANGV (2007)
[170] Pronin (2005)

reserves (~1/3 of total) at 48 trillion cubic metres.[171] The export of gas, mainly to Europe, is very profitable[172]. In combination with a projected massive shortage of gas available for export in 2020[173] this makes it less likely that the gas will be used as a vehicle fuel domestically. As one source puts it: "the time when Gazprom did not know what to do with all its gas has passed"[174].

Stakeholders

Gazprom has strong political ties, with the new President of the Russian Federation, Medvedev, being its former chairman. Current large publicly funded projects for gas-powered vehicles include local buses in Sochi, which will host the 2014 Winter Olympics. In this case the authorities want to build new natural gas filling stations, buy new gas-powered buses, as well as convert old buses to run on gas.[175] Earlier interest in CNG has come from, for example, St. Petersburg city, which discussed purchasing gas buses on a large scale a few years ago[176]. Moscow city in 2003 started a project to convert a large number of city buses to CNG in order to increase the city's air quality[177]. In a continuation of this project, plans were recently launched to build 16 CNG filling stations across the city[178].

Societal rules

One significant problem for the large-scale development of CNG refilling stations is that by law they are required to have a safety distance of 150 metres to other buildings. This limits the number of available locations, especially in cities.[179] Due to these kinds of security concerns, investment costs are in general high for gaseous fuels[180].

The government currently limits the price of one cubic metre of CNG to 50 percent of the price of one litre of low-grade petrol, which is seen as a major market driver[181]. Despite this fuel cost advantage, private bus operators are generally not interested in investing in expensive gas buses. The main reason is that they feel that local city governments are not really interested in public transport, which they often operate. Therefore, they look for as short a payback time as possible, which causes them to invest in the cheapest possible alternatives.[182]

[171] EIA (2007), p. 8
[172] Wöllert (19/03/2008)
[173] Murray (2006), p. 12
[174] Wöllert (19/03/2008)
[175] Lebedev (18/02/2008)
[176] Eriksson (13/03/2008)
[177] Government of the city of Moscow (07/09/2005)
[178] Gudok (12/04/2007)
[179] Turovsky (13/03/2008)
[180] Mårtensson (18/02/2008)
[181] Pronin (2005)
[182] Fedartsov (13/03/2008)

6.1.4 Diesel

Technology and infrastructure

Diesel is the dominating heavy-vehicle fuel today and is predicted to be significant on the market for at least another 15-20 years, although to a large extent in blends with alternative fuels[183]. Newer engines, with lower particle and NO_x emissions, require high-quality fuel with very low sulphur content. The general worldwide trend is therefore towards diesel with higher cetane number and lower sulphur levels.[184]

Low-sulphur diesel (Euro IV and V) is available to international freight carriers in so called international corridors along the major transportation routes from European Russia to Western Europe. Lukoil is the company mostly involved in serving this network of gas stations.[185] According to one source, citing a Gazpromneft representative, there will "easily" be 10 ppm diesel widely available on the Russian market in two years[186]. See table 11 below for percentages of the sulphur content in diesel as of 2006.

Table 11 - The diesel production profile in Russia in 2006.[187]

Sulphur content (ppm)	***Percentage***
10 (Euro V)	1.7
50 (Euro IV)	9.1
350 (Euro III)	5.7
500	4.4
1000	2.6
2000	70.9
5000	5.6
Total	100

The net of conventional gas stations in Russia is at par with Western countries. They are usually owned by any of the major oil companies, e.g. Rosneft, Lukoil, TNK-BP. The oil companies also control oil fields and refineries. The refineries, which generally were built close to the end customers, are old. Most of the 28 major facilities[188] were erected already during the 1940's to 1960's[189] and therefore require large investments to meet demands for cleaner fuel[190].

Russia has proven oil reserves of approximately 60 billion barrels[191]. The current total refining capacity is approximately 5.3 million bbl per day[192]. At present, there are a

[183] Mårtensson (18/02/2008)
[184] Erlandsson (11/02/2008)
[185] IFQC (2008a)
[186] Chursin (12/03/2008)
[187] Donchenko (2007), p. 14
[188] IFQC (2008c), p. 6
[189] Filkine (17/03/2008)
[190] IFQC (2008a)
[191] EIA (2007), p. 2
[192] IFQC (2008c), p. 6

number of refinery modernization projects going on, mainly among the big industry players[193]. Additionally, there exist plans to build new refineries, e.g. in Tatarstan[194]. Taken together, these projects will increase the availability of high-quality diesel, most of which is currently exported. In 2005 Russia produced about 4.4 million tonnes of low-sulphur diesel (less than 50 ppm)[195].

At present, there is a worldwide low-sulphur diesel deficit[196] and steadily increasing demand, which is visible through rising prices on diesel[197]. The price of one litre of diesel in Moscow at a typical Rosneft gas station is according to our own observations currently (20 March 2008) about 20 rubles (€0.54). From 2004 to 2007, the price of diesel rose 75 percent in the city [198].

Stakeholders

Diesel is the incumbent heavy-vehicle fuel. The large oil companies are very important to the economy since they position Russia as one of the major oil producers in the world[199]. This indirectly makes the output of their refineries, among it the diesel, the concern of the government. The government has tried to push the industry towards more value-added products through tax incentives.[200] However, the main driver behind the development towards cleaner fuels has been the industry itself, which mainly upgrades its production to meet demand on export markets[201].

Societal rules

The above-described trends are closely connected to the implementation of Euro standards on vehicle emissions and fuel sulphur content. In Russia, the regulatory framework consists of GOST[202] standards, each of which usually corresponds to a Euro standard. There are also older GOST standards specifying lower-quality fuel. Recently, the timetable was set for implementation all the way to Euro V for both vehicle emissions and fuels[203]. According to information, there will probably be a delay in the implementation of the fuel standards due to refineries not being able to modernize quickly enough, which will cause a gradual transfer stretched out over time from one fuel quality to another. However, the government has set definite phase-out dates, which are seen in table 12 below. In addition to the GOST standards, there are also so called TU[204] standards, which are stricter and set by regions and cities to reduce emissions in urban centres. For example, Moscow city has TU

[193] Filkine (17/03/2008)
[194] Wöllert (19/03/2008)
[195] IFQC (2008a),
[196] Mårtensson (18/02/2008)
[197] di.se (12/03/2008)
[198] Government of the city of Moscow (24/04/2007)
[199] EIA (2007), pp. 1-2
[200] Filkine (17/03/2008)
[201] IFQC (2008c), p. 11
[202] GOST = Gosudarstvenniy Standart (Government Standard)
[203] Donchenko (13/03/2008)
[204] TU = Tekhnicheskye Usloviya (Technical Regulations)

standards for petrol, which call for lower levels of sulphur, benzene, aromatics and olefins than the federal standards.[205]

Table 12 – The timetable for introduction of vehicle emission and diesel fuel quality standards in the EU and Russia. The implementation years for fuel in Russia mark the point in time when the preceding quality is banned from sale on the market. [206,207,208,]

Standard	***Implementation year per region***			
	EU vehicle emissions	*Russia vehicle emissions*	*EU fuel quality*	*Russia fuel quality*
Euro II	1996	2006	1996	-
Euro III	2000	2008	2000	2009
Euro IV	2005	2010	2005	2010
Euro V	2008	2014	2009	2014

6.1.5 DME

Technology and infrastructure

Dimethyl ether is a gaseous fuel, which is well suited for diesel-type engines[209]. Any carbon-rich subject, from coal to biomass, can be used as production feedstock. The feedstock is gasified and then synthesized to DME either directly from the resulting syngas or by way of methanol.[210] The fuel emits very few particles, but a lot of NO_x, when combusted[211]. DME is poisonous and therefore requires safe handling[212]. Also, it needs to be pressurized (5-7 bar) to liquid state for easier transport and sufficient energy density[213]. The combustion is difficult to regulate. Therefore, a specially adapted injection system is needed.[214] Among heavy-vehicle manufacturers, Volvo has been the main promoter of DME[215].

In the coming decades, an increasing portion of Russian gas reserves will be "stranded", i.e. located in remote and harsh climatic regions. Gas pipeline costs for connection of these fields will be very high, which makes it more attractive to convert the gas into, for example, liquid DME and then transport it by railway to the consumers.[216] As a result of this, there have been discussions on building large production facilities for DME at some Siberian fields, e.g. Chayanda[217].

205 IFQC (2008c), p. 8
206 DieselNet (2008a)
207 DieselNet (2007)
208 DieselNet (2008b)
209 Mårtensson (18/02/2008)
210 Semelsberger et al. (2006), p. 499
211 Erlandsson (11/02/2008)
212 Holmgren (07/02/2008)
213 Holmborn (08/05/2008)
214 Erlandsson (11/02/2008)
215 Mårtensson (18/02/2008)
216 Miroshnichenko et al. (2003), pp. 2,5
217 Green Car Congress (28/08/2004)

Today, large-scale production and consumption of DME is found mainly in China and Japan, where natural gas and, especially in China, coal are the feedstocks[218]. China is also a likely driver for DME production for export from eastern Russia, since the market for the fuel in the country is growing exponentially[219].

There are currently only small DME production facilities operating in Russia. The only industrial-scale complex is located in the Tula region[220]. Production technology is being developed by at least two Russian research facilities[221]. Both Gazprom and TNK-BP have also signed cooperation deals with Japanese authorities and companies in order to acquire production technology and, eventually, build large production facilities in eastern Russia[222].

Local infrastructure is mainly found in Moscow, where the city authorities' program for increased use of renewable fuels has resulted in the development of a small number of filling stations selling DME[223]. However, there is an important principal rule that all new gas stations, beginning in 2007, must offer alternative fuels at the pump[224].

Stakeholders

One of the main drivers towards DME in the long run is that oil companies, which possess remote gas fields, have at occasions gotten in conflict with Gazprom. The reason is that Gazprom has at times arbitrarily denied access to its monopolized national network of gas transport pipelines. This effectively leaves the companies with fields that cannot be developed properly, which in turn creates an incentive to convert the gas into liquid end products, e.g. DME, which are suitable for rail transport.[225]

On the consumer side, Moscow city have during the last few years conducted concrete trials of DME as a motor fuel. In the project, 30 light ZIL Bychok lorries were converted to run on the fuel. There were also plans to test heavy KamAZ trucks in the same way.[226] According to the sceptical NIIAT transport institute, these trials are in reality a technical fraud, which has spent huge money[227]. In any case, the project seems to continue with the addition of more DME filling stations in Moscow[228].

[218] Garimella (2007)
[219] Fleisch & Sills (2007)
[220] Gudok (21/06/2006)
[221] Lapidus et al. (2005), p. 111
[222] Pasternak (2006)
[223] Gudok (12/04/2007)
[224] Government of the city of Moscow (24/04/2007)
[225] Wöllert (19/03/2008)
[226] Luzhkov (2006), pp. 5-6
[227] Donchenko (13/03/2008)
[228] Gudok (04/12/2007)

6.1.6 E-fuels

Technology and infrastructure

E-fuels are either blends of ethanol and petrol for use in otto engines, or ethanol and ignition-additive for use in diesel engines. The most common ethanol-petrol blends are E10 and E85.[229] In Russia, petrol may according to standards contain up to 10 percent ethanol[230]. The energy density is lower than in diesel or petrol, which calls for more frequent refilling or larger tanks[231]. There are many examples of already running buses and a few commercial truck applications, even though there is a profound scepticism towards the fuel's long-term outlooks among some heavy vehicle manufacturers. 2[nd]-generation ethanol, with ligno-cellulosic origin, is however seen as a very promising alternative.[232]

In Russia after the Bolshevik revolution, Lenin proposed to use agricultural alcohol for industrial purposes. This diversion was aimed at the use of the Russian people's beloved vodka, but the plans were soon abandoned.
Olah et al. (2007), p. 126

At present, there is no infrastructure especially adapted to ethanol in Russia[233]. Since ethanol is usually introduced as a blend in petrol it would, according to our knowledge, most likely be possible to use existing gas stations and transport system also for E-fuels.

The current production of bioethanol in Russia is negligible, but is projected to reach 200,000 tonnes in 2009[234]. The total potential for ethanol from sugar and starch biomass feedstock has been estimated at about 4.2 million m^3 yearly[235], but other sources claim that 10 million tonnes could easily be reached through the cultivation of unused land and an increase in agricultural efficiency[236].

A government program to support the construction of 30 new ethanol plants, producing 2 million tons of ethanol per year, was recently presented by the Prime Minister[237]. The target can probably be reached in about five years[238]. However, there are serious doubts about the underlying political will and realism behind the statement[239,240]. At present, there are at least six already started large-scale ethanol plant projects[241].

229 Erlandsson (11/02/2008)
230 Turovsky (13/03/2008)
231 Holmgren (07/02/2008)
232 Mårtensson (18/02/2008)
233 Fedartsov (13/03/2008)
234 Vasilov & Ablaev (2007), p. 34
235 Pantskhava & Pozharnov (2006), p. 235
236 Vasilov (18/03/2008)
237 Moscow Times (13/03/2008), p. 5
238 Vasilov (18/03/2008)
239 Ibid.
240 Wöllert (19/03/2008)
241 Russian Biofuels Association (2007b)

Stakeholders

There is a clear political interest in developing a large-scale fuel ethanol industry. This was expressed at highest level when President Putin said "It is necessary to create conditions for the building of bioethanol production facilities"[242]. He has later also expressed that Russia should be the leading country in terms of biofuel production[243]. The main reason seems to be that the government has realized that there is money to be made from Russia's vast farmland, of which 20-40 million hectares is currently not in use. Interest from the business community also has risen recently. For example, a former Gazprom deputy chief executive is planning to build a 250,000-ton plant in the Tambov region. New production will likely initially be aimed at export markets.[244]

St. Petersburg city has earlier shown interest in ethanol buses. The main reason was, according to our source, that the city had taken impression from other big European cities and did not want to be any less progressive in comparison.[245]

Societal rules

An important obstacle for a functioning bioethanol industry in Russia is the legal situation. Fuel ethanol is currently not regulated separately. Instead, laws regulating the production of alcohol for human consumption apply.[246] This means that the government charges an excise duty of 26 rubles (€0.70) per litre ethanol[247], which can be compared to the current petrol retail price of about 21 rubles (€0.57) per litre. However, this tax on fuel ethanol is expected to be removed during the current or next year[248].

6.1.7 Non fuel-specific information

Technology and infrastructure

Vehicles

Of all vehicles running in Russia, more than 80 percent are of Euro II class or less and about 50 percent of the vehicle park is older than ten years (table 13).[249,250] The share of Russian-brand cars currently decreases since the domestic car industry is unable to compete effectively.[251]

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242 Russian Biofuels Association (2007a). Quote translated from Russian by the authors.
243 Rosbalt (11/03/2008)
244 Moscow Times (13/03/2008), p. 5
245 Eriksson (13/03/2008)
246 Russian Biofuels Association (2007b).
247 Moscow Times (13/03/2008), p. 5
248 Vasilov (18/03/2008)
249 Turovsky (13/03/2008)
250 IFQC (2008b), p. 11
251 Swedish Trade Council (2006)

Table 13 – The Russian vehicle fleet as of January 2007.[252,253]

Vehicle type	***Number (million)***	***Foreign brands***	***More than 10 years old***	***Less than Euro II standard***
Cars	26.8	25 %	52 %	84 %
Trucks	4.9	11.8 %	65 %	87 %
Buses	0.8	-	48 %	85 %
Total	32.5	-	-	-

The domestic vehicle production in Russia, especially of foreign brands, is increasing[254]. A ban was in 2006 imposed on imported second-hand cars that do not fulfil Euro II demands in order to stop the import of old and polluting vehicles[255]. Generally, the demand for foreign cars in Russia has increased, and will continue to increase, with higher purchasing power[256].

Stakeholders

Other countries

In 2006, the Asian region was the world number one in terms of total consumption of refined oil products. Additionally, China is predicted to experience a greater increase in energy consumption than any other country in the world.[257] In 2006, the Asian Pacific Region also became Russia's second most important trading partner after the European Union. Two-thirds of Russia is situated in Asia. Also, this is where a significant part of the country's natural resources are found. The immense resources in Siberia and the Far East are important for the development of a comprehensive cooperation with Asian countries. Large-scale integration projects in the energy sector would open up for a new phase of development in the region. This would in turn strengthen the business ties not only between Russia and Asia, but also between the European Union and the Asian Pacific Region.[258] The status of relations and cooperation with countries such as China and Japan would also impact Russian politics since there is a sincere geopolitical fear of their increasing influence in the region[259].

The EU and Russia are important trading partners with European countries being Russia's most important export and import markets[260]. The European Union gets about 25 percent of both its oil and gas from Russia, whereas the EU's import of raw materials account for 40 percent of Russia's federal budget[261]. Our impression from

[252] Donchenko (2007), p. 2-6
[253] IFQC (2008c), p. 11
[254] Steiner (19/03/2008)
[255] IFQC (2008c), p. 12
[256] Swedish Trade Council (2006), p. 13
[257] IFQC (2008b), p. 7
[258] Mironov (2007)
[259] Beldyushkin (12/03/2008)
[260] CIA (2008)
[261] EurActiv.com (2007)

interviews is that EU actions and legislation seem to affect both the thoughts of the Russian public and the policies of the government. This is especially evident in the environmental sector, where EU's policies affect Russian vehicle-emission regulation through requirements on trucks entering the union.[262]

Gazprom

As mentioned, the EU gets about 25 percent of its gas supply from Russia, i.e. Gazprom[263]. The company is a state-run natural gas monopoly[264], which is seen as an empire in its own in power of its massive export incomes and tax payments[265]. Gazprom is the biggest company in Russia in terms of revenues[266]. In spite of being the number one gas extractor in the world in terms of volume[267], Gazprom is widely seen as ineffective[268]. It produces 90 percent of Russia's natural gas and operates the country's natural gas pipeline network. Gazprom accounts for around 25 percent of all federal tax revenues and is Russia's largest earner of hard currency.[269] The gas exports are currently so profitable that the amount of gas available is the main limitation of the company's operations[270]. By law, Gazprom must supply natural gas used for heating and power generation on Russia's enormous domestic market at government-regulated prices (currently $28 per thousand cubic metres), from which follows that the company is not able to maximize its profits.[271]

Cities and regions

The largest cities play a vital role in Russia as they usually are at the forefront of development. Moscow and St. Petersburg together represent 85 percent of the economical activity in Russia. Other regions are also growing rapidly but are still far behind.[272] One specific national problem is that there is a massive "braindrain" of people from the regions to especially Moscow. Moscow is seen as a heaven of possibilities in comparison to other parts of the country. According to one source, 80 to 90 percent of all Russians would like to live in Moscow.[273] However, the economical activity and belief in the future in the regions should not be underestimated[274].

The automotive industry

The Russian automotive industry is the country's 6th largest industry with a turnover of around €14 billion and 1.35 million produced vehicles in 2005[275]. The booming

[262] Lindberg (07/03/2008)
[263] International Herald Tribune (24/01/2007)
[264] EIA (2007), p. 8
[265] Filkine (17/03/2008)
[266] cnnmoney.com (2007)
[267] EIA (2007), p. 8
[268] Filkine (17/03/2008)
[269] EIA (2007), p. 8
[270] Wöllert (19/03/2008)
[271] EIA (2007), p. 8
[272] Hansson (13/03/2008)
[273] Beldyushkin (12/03/2008)
[274] Forss & Ivanov (2008), p. 6
[275] Swedish Trade Council (2006), pp. 3, 5

transport market has increased the demand for heavy trucks[276]. The domestic industry was earlier subsidized, which has left it behind its new foreign competitors in terms of competitiveness. One of the problems is that the domestic manufacturers cannot match the quality of engines produced in other countries.[277] However, this may change very fast if Russian vehicle manufacturers were bought by foreign companies, or the other way around[278]. On the other hand, the government seems to consider consolidation of the largest Russian automotive manufacturers AutoVaz, GAZ and KamAZ into one holding company[279].

Companies in the Russian automotive industry try to cooperate with international car companies with the intention to upgrade their vehicle models. The international producers either set up their own operation in Russia or form joint ventures with Russian companies. By forming joint ventures, market introduction of new technology becomes faster and more economical. However, the Russian vehicle manufacturers would ideally like to offer their own domestically designed and manufactured engines on the market.[280,281] The number of joint ventures with international car producers is growing; Volkswagen, Volvo, Toyota, Renault, and others have already started cooperation projects.[282] As a result of this development, the foreign share of production went from 0.3 percent in 2000 to 14 percent in 2005. In 2010, it is expected to reach 50 percent. The St. Petersburg region is emerging as a centre of production for international manufacturers.[283]

The oil industry
In 2006, Russian total petroleum products production averaged almost 9.7 million bbl per day, including 9.2 million bbl per day of crude oil. Total Russian oil production is expected to grow with an annual rate of 1.5-2.5 percent in the coming years. Almost all of Russia's annual oil growth in the next five years will come from the development of new fields.[284] The largest Russian oil companies are Rosneft, Lukoil, and TNK-BP. Together these companies control 19 of the 28 major refineries, which make their investment decisions crucial for the fuel being offered on the market. Currently, about 65 percent of the refinery output is consumed domestically, while the remaining export part consists mostly of diesel and fuel oil.[285]

[276] Swedish Trade Council (2006), pp. 14, 18
[277] Barmoro (11/03/2008)
[278] Häggström (14/03/2008)
[279] Swedish Trade Council (2006), p. 11
[280] Steiner (2008)
[281] Swedish Trade Council (2006), p. 8
[282] Filkine (17/03/2008)
[283] Swedish Trade Council (2006), p. 9
[284] EIA (2007), pp. 2-3
[285] IFQC (2008c), p. 6

One oil company that seems to differ from the rest is Lukoil. The company has profiled itself as a leader and progressive trendsetter in the industry[286]. Lukoil has consequently been first with launching fuel of superior quality on the market, often before being obliged to do so. An example is the gas stations along the international corridors offering Lukoil's Euro IV diesel.[287]

Policymakers and media

The Russian president is the head of the state and defines domestic and foreign policies, controls the military, and oversees all other bodies of state power[288]. Both the former President Putin, and the new Medvedev, received massive popular support in presidential elections; the latter had approval of more than 70 percent of voters in March's elections.[289] The combination of the President's constitutional power and public support makes him a pivotal figure in the Russian Federation.

Policy makers in the Kremlin have during Putin's time aimed to increase the state's control of the energy sector. Russia's state-influenced oil and gas companies have come into possession of controlling stakes in previously foreign-led projects. Private projects have been met with roadblocks, whereas state-owned export facilities have grown rapidly.[290] The most noticeable case of state takeover was Yukos, where the owner Khodorkovsky was sentenced to jail for alleged tax crimes and Yukos assets were taken over by the state-controlled company Rosneft.[291]

Other politicians than the ones in the Kremlin are also important. In the fuel sector, both the Prime and Agricultural Ministers have launched initiatives about ethanol[292]. Also, regional politicians exert considerable influence through encouraging or obstructing local investments and business[293].

Most Russians use television as their main source of domestic and international news. All national television channels in Russia are either directly controlled by the state or through companies with close relations to the government, e.g. Gazprom. There are over 400 newspapers, of which companies with close links to the government have bought several influential. The Internet is unregulated and has about 30 million users. Journalists have been harassed and physically abused in Moscow and in the regions. It is especially risky to investigate the affairs of the political and corporate elite.[294] In some cases, journalists have even been murdered[295].

[286] Kolesnikova (14/03/2008)
[287] IFQC (2008c), pp. 7, 11
[288] President of Russia website (2008)
[289] CIA (2008)
[290] EIA (2007), p. 1
[291] BBC News (2008)
[292] Moscow Times (13/03/2008), p. 5
[293] Hansson (13/03/2008)
[294] BBC News (2008)
[295] BBC News (07/10/2006)

Societal rules

Fuel regulations and enforcement

Laws, regulations and fuel standards change partly due to requirements on vehicles transporting goods to the European Union[296]. The pressure for introducing better fuels thus does not come from society or motorists. Instead, government agencies are the driving force.[297] Also, car manufacturers want the government to put more pressure on fuel producers in order to get better fuel for high-quality cars.[298]

The control systems for ensuring proper fuel quality in Russia are very poor, mainly due to limited interest from authorities and inadequate financing[299]. In gas stations there is always a risk of not getting the quality of fuel, which has been paid for. One investigation of fuel quality sampled 15 different gas stations. Although the diesel was supposed to be of the same quality, the study showed that the quality of the fuel differed between all samples.[300]

Local gas stations, especially in the regions, often simply do not follow what the law requires but offer low-quality fuel and their own homemade mixtures. Black market-fuel is another common problem.[301] This problem is accentuated by the fact that some truck drivers tend to not care much about what they put in their tanks as long as they can save some money on buying cheaper fuel.[302] As long as the majority of Russians do not have more money to spend than today, they cannot afford a newer car requiring better-quality fuel. Therefore low-quality fuel will likely continue to be offered on the market until the general population increases its purchasing power.[303]

Formally, the producer of a fuel is responsible to control its quality. A new system for fuel certification is under development, which will oblige retailers to clearly mark the quality of the fuel on the pump. A control authority, Rostekhregulirovanie, will enforce the system although it is not clear who will take actual fuel samples in the field.[304] Historically, enforcement of new regulations has been very slow[305].

Corruption

Corruption is a serious problem in Russia. Research shows that corruption since 2001 has increased from $40 billion to $300 billion per year. In Transparency International's corruption index, Russia dropped from 121st place in 2006 to 143rd in 2007.[306]

[296] Wöllert (19/03/2008)
[297] Donchenko (13/03/2008)
[298] Zhdanov (17/03/2008)
[299] IFQC (2008b)
[300] Lebedev (13/02/2008)
[301] Lindberg (07/03/2008)
[302] Steiner (2008)
[303] Ibid.
[304] Turovsky (13/03/2008)
[305] Steiner (2008)
[306] Forss & Ivanov (10/03/2007)

Status and values among vehicle owners

Among Russian car owners, a big and expensive car is a symbol of wealth and power. The consumer generally does not care about the vehicle's environmental impact or fuel consumption, but values material things such as speed and design.[307,308] Among truck buyers on the other hand, there is a growing awareness about the total costs of operating a vehicle. As competition on the market and haulage contractors' professionalism increase, their preferences shift toward reliable Western trucks that give a lower total cost and better performance. Currently, it is becoming a status symbol to operate Western trucks instead of the much cheaper Russian or Chinese alternatives.[309,310]

Macro landscape

Freedom and democracy

Russia's evolution from the former Soviet past and from the chaotic early days of democracy has been swift. Nowadays, Russia is a different country where basic political, civic and economic freedoms are in a greater balance in comparison to the situation in Soviet times. However, Russia would benefit from further strengthening of democratic and market-supporting institutions, enhanced accountability, more objective treatment of the law, and firmer protections of human and civic rights.[311] During the Putin era, there has been a worrying development towards less political freedom. The authorities have through court decisions and other methods repressed opposition parties. The trend towards a tighter political climate has been clearly evident when riot police has clamped down on opposition rallies, while organizations loyal to the president have been allowed to demonstrate, and opposition candidates have been stopped from running in elections.[312]

Economic growth and trade

Russia had a GNP growth of 8.1 percent in 2007. Strong domestic consumption, increased investment flows, high world market commodity prices, and industry production were the main drivers. Given these factors, continued growth with 6 percent per year is expected in the coming years. The economic development of Russia is geographically unevenly distributed, with the Moscow and St. Petersburg regions contributing disproportionately high amounts of the country's economical development.[313] Overall, Russian companies are doing very well for the moment, but in some regions there is negative growth[314]. People in general expect continued growth under the lead of the new president Medvedev. There are four general reasons that help to explain the continuous growth in recent years: Firstly, Russia had a low starting point; Secondly, new institutions and markets have formed, although there are

[307] Beldyushkin (12/03/2008)
[308] Wöllert (19/03/2008)
[309] Lindberg (17/03/2008)
[310] Barmoro (11/03/2008)
[311] EBRD (2008), p. 1
[312] BBC News (26/03/2007)
[313] Forss & Ivanov (2008), p. 3
[314] Sonin (11/03/2008)

too few entrepreneurs in the country. Thirdly, Russia has had a conservative fiscal policy, which, however, is under constant threat. Fourthly, the high oil price has created favourable conditions for the country.[315]

Compared to other large economies, external trade plays a relatively more important role in the Russian economy. An entry into the World Trade Organization (WTO) would allow for adoption of new technology and innovations in Russia. Reducing protectionism would also lead to possibilities for increased scale economies, and would also enlarge markets and induce more competition, thus forcing inefficient producers out of business.[316] In Russia, there are two camps in relations to WTO: those who want a membership and are open for internationalisation, and those who do not want to change anything with reference to Russian strategic interests. Entry negotiations with the WTO are currently being conducted. There have been delays in the process due to some unresolved issues.[317] Russia is expected to gain entry acceptance in the latter half of 2008[318]. If or when Russia enters the WTO, the government has to abandon a number of subsidy programs, due to which, for example, the car industry in Russia has been able to compete internationally[319]. In a long-term perspective, an entry into the WTO would force Russia to open up for free trade[320].

There is nowadays a prosperous, and growing, middle-class in Russia. Real wages have risen for large groups in society. Since year 2000 the medium income has doubled. The real wage rises have been concentrated to the largest cities, but is starting to be noticed also in the regions.[321] As the need for educated labour has increased, new problems have arisen. For example, it is hard to get highly educated people to move to the regions due to the large geographical distances and the generally lower standard of life.[322]

Commodities and the economy

There is no common agreement in Russia on which economical program the country should follow. There are two general options; preserve status quo by continuing to be a supplier of oil, gas, metals, and other commodities; or create a more balanced economy with less focus on oil and gas. This would require development of the service sector and high-technology businesses, as well as encouragement of innovation and change. It also requires large investments and would probably take around 40-50 years to fully implement. Industries like retail are now dependent on inflow of money from oil exports. Therefore, Russia will in the foreseeable future still be very dependent of its oil and gas.[323] To understand the state budget's dependence

[315] Sonin (11/03/2008)
[316] Akhtar (2002), p. 4, 6
[317] Talvitie (11/03/2008)
[318] Forss (19/03/2008)
[319] Filkine (17/03/2008)
[320] Forss & Ivanov (2008), p. 6
[321] Hansson (13/03/2008)
[322] Sonin (11/03/2008)
[323] Beldyushkin (12/03/2008)

of oil prices it is illustrative to know that a $1 per bbl change in the oil price for a year creates a 0.35 percent ($3.4 billion) rise in state revenues[324]. The current budget will formally be in balance as long as the price keeps above $44 per bbl. However, if it would drop below about $60 per bbl this would lead to very serious social and political problems.[325] Since 1998, the oil price has risen from $9 per bbl[326] to over $110 per bbl today (May 2008).

Through different measures, the Russian government tries to increase the proportion of value-added goods in the economy. One example is through imposing export duties on timber, thus forcing the refining of the product to take place in Russia.[327] In line with this policy, it is at present more profitable to export refined products than crude oil because of the higher export duties on the latter. However, the refining industry has not had enough money for investments to update their infrastructure; more or less it has been neglected since Soviet times.[328] In combination with the current high crude oil price and consequent lucrative export opportunities; the majority of investments are thus allocated to oil exploration and production rather than the refining sector.[329]

Other commodities such as gas, metals, and agricultural and forest products also play an important role in the Russian economy[330]. Rising wheat and other grain prices spell trouble for the government since they hit the consumers through higher food prices. The government has imposed "voluntary price stops" to freeze the cost of foodstuffs, which have been prolonged to the 1st of May 2008. New price stops are to be expected during the year, among others also on motor fuel. The longer the government waits with releasing the price freezes, the worse the effects will be when they let them go. Food prices are a very sensitive issue for Russian politicians having the pensioners' uprising in 2005 in mind.[331] Therefore, the food vs. fuel debate is potentially a very controversial subject in the country and is, according to our observations, often mentioned in media in articles about biofuels. Specifically, the discussion has caused scepticism about the benefit of ethanol[332].

Foreign investments

Increased foreign investments are not only seen as something positive in Russia. Instead, they are also regarded as a serious concern for Russia's independence, especially in the energy sector. As part of this, several agreements signed with foreign companies in the 1990's have been revised during the last few years and the control of resources transferred to Russian hands. The aim is national control of Russian natural resources, often through loyal companies taking over.[333] Some sectors, e.g. the

[324] EIA (2007), p. 1
[325] Sonin (11/03/2008)
[326] Larsson (2008), p. 12
[327] Häggström (14/03/2008)
[328] Wöllert (19/03/2008)
[329] Beldyushkin (12/03/2008)
[330] CIA (2008)
[331] Forss & Ivanov (2008), p. 3-4
[332] Donchenko (13/03/2008)
[333] Larsson (2008), pp. 17-19, 53

defence, space, oil, and possibly, automotive industries, are in the process of being declared as strategic industries, which would protect companies from being majority owned by foreign companies. This policy may lead to future nationalization in some cases. Among experts, it is widely acknowledged that if and when too many industries are considered strategic it will be a clear sign of trouble rising in Russia's economy and in the country's relationships to other countries.[334]

Inflation and interest rates

In 2007, Russia's inflation rate rose to 11.9 percent, which was the highest level in four years. Inflation is estimated to rise further if the government is unsuccessful with putting a break on food prices. Other reasons to the rising inflation rate is, for example, the high world market prices on grains, a rising price on gas, and high oil prices, which have created a large capital injection in the country. At the same time the government has turned towards a more expansive budgeting policy.[335] Inflation in the coming years will mainly depend upon the monetary policy, productivity development, and promises of raised salaries. The banks predict an inflation rate of 8 percent, which is a decrease with approximately 5 percentage points from now.[336]

Since 2006, loan rates have hovered around 10 percent[337]. This high level of interest together with other factors creates a shortsighted investment climate, where companies prioritize short payback time. Long-term investments are not rational.[338]

Foreign policy and national security

Russia has thanks to its strong economic development through oil and gas exports in recent years re-emerged as a major international power. It has displayed its new muscles in conflicts with Ukraine, Georgia, and Belarus, where cuts in gas supplies was the weapon.[339] The world suspects that Gazprom and other oil companies are in reality government tools. Therefore, Russia's future actions on the international scene will be important in order to create trust and increased cooperation with among others the EU.[340]

National security is a very serious issue in Russia. There are, as earlier mentioned, a fear that foreign companies may come in possession of industries that may be more or less important to the defence of the country, e.g. KamAZ.[341] Also, there are constant fears of China and Japan making territorial claims in Eastern Siberia. Due to the shrinking population, and the unwillingness of ethnic Russians to move to distant regions, some politicians see an increased Chinese influence through the inflow of people and money and increased cross-border trade.[342]

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[334] Talvitie (11/03/2008)
[335] Forss & Ivanov (2008), p. 3
[336] Talvitie (11/03/2008)
[337] The Central Bank of the Russian Federation (2008)
[338] Swedish Trade Council (2007)
[339] Larsson (2008), pp. 16, 47-50
[340] Swedish Trade Council (2007)
[341] Barmoro (11/03/2008)
[342] Beldyushkin (12/03/2008)

The educational system

Russians in general believe that the country's educational system is the best in the world and that the only problem is that it lacks money. The talented mathematicians and physicists coming out of the Soviet system were, however, more the products of the lack of chances in areas such as entrepreneurship and social sciences than genuine output of the educational system. There was simply nothing else to do for talented people than to go into natural sciences. To fix the problems in higher education, there is a need for an exchange of students in and out of Russia, i.e. the system must open up for internationalisation.[343] This is even more important for the Russian economy since what is taught in schools and at universities is crucial for tomorrow's leaders. Well-educated people are important in order to implement broader domestic reforms to achieve macroeconomic stability, efficient governance, and better infrastructure, which are all prerequisites of sustainable trade growth.[344]

Climate change and environmental awareness

There is a beginning of understanding of climate change and its effects. However, the general view is that it is not a problem.[345] Many people in Russia even emphasize the positive effects a warmer climate may have on regions such as Siberia[346]. Also, the country sees a possibility in the opening of new shipping routes and oil and gas fields in the Arctic region[347]. These positive views should be put in contrast to the possible negative effects global warming may have in other parts of Russia. Serious impact is likely to affect the public's awareness of the problem.

In the major cities, local pollution is a serious problem, especially from traffic. Therefore, increased environmental and health consciousness among the population is likely to start to occur among city dwellers.[348] At present, awareness about safety issues in traffic is more widespread than knowledge about the environmental consequences of driving.[349]

Innovation phenomena

During Soviet times, there were approximately 30 ethanol plants making ethanol from ligno-cellulosic feedstock. They were eventually shut down since they could not compete in the new market economy. Present research in production processes is also according to information fairly well developed. According to one source, Russia is performing some research on 2nd-generation fuel production. It is not impossible that Russia will be on the same technical level as Europe in a not so distant future.[350]

[343] Sonin (11/03/2008)
[344] Akhtar (2002), 5
[345] Donchenko (13/03/2008)
[346] BBC News (24/09/2007)
[347] Larsson (2008), pp. 63-69
[348] Wöllert (19/03/2008)
[349] Donchenko (13/03/2008)
[350] Vasilov (18/03/2008)

6.2 Step 2: Identify relevant system factors

From the empirical data described in step 1, 60 different system factors were identified. The factors were grouped according to the theoretical framework. An overview is presented in table 14. A more detailed description of the individual factors can be found in Appendix III.

Table 14 – Overview of the identified system factors.

Area	*No.*	*Factor*
Technology and infrastructure	1	Production capacity
	2	Transport and handling infrastructure
	3	Vehicle fleet
Stakeholders	4	Asian countries
	5	The automotive industry
	6	Control authorities
	7	The European Union
	8	Gazprom
	9	Interest groups
	10	Media
	11	Moscow and St. Petersburg
	12	The President
	13	The oil industry
	14	Other politicians
	15	Universities and research institutions
	16	Strategic alliances among vehicle manufacturers
Societal rules		
Regulative rules		
- Policy	17	Fuel taxes
- Technology	18	Federal emission and fuel quality regulation
	19	Local emission and fuel quality regulation
Normative rules		
- Industry	20	Companies' desired image
	21	Investment willingness
- Policy	22	Relations between government and companies
- Culture	23	Corruption
	24	Law-abidingness
	25	Material vs. immaterial values
Cognitive rules		
- User and market preferences	26	Food vs. fuel debate
	27	Vehicle performance preferences
- Industry	28	Life-cycle cost consciousness
- Culture	29	Status symbols
Macro landscape	30	Concern about the global environment
	31	Concern about the local environment
	32	Economic difference between cities and regions
	33	Education
	34	Export opportunities
	35	Focus on commodities or value-added goods
	36	Food prices
	37	Fuel prices
	38	General economic policy
	39	Global warming
	40	GNP growth
	41	Health consciousness
	42	Industry investments
	43	Inflation
	44	Interest rates
	45	International cooperation
	46	National security policy
	47	Oil price
	48	Other commodity prices
	49	Political freedom
	50	Protectionism
	51	Standard of living
	52	Strategic industries
	53	Technology transfer from large cities to regions
	54	Technology transfer from Western countries
	55	Trade with the EU
	56	Transport volume
	57	WTO entrance
Innovation phenomena	58	2nd generation production processes
	59	Experimental fuel and vehicle projects
	60	Strategic investment programmes

6.3 Step 3: Determine interrelationships between factors

Each factor's effect on the others was specified in the structural analysis matrix (Appendix IV). In this case, there were slightly more weak (953) than strong (727) relationships. Also, the total number of direct relationships was quite large at 1,680 identified interconnections out of 3,600 possible, which was interpreted as a sign of the system being heavily intertwined and complex. This in turn made a solid case for using MICMAC analysis.

6.4 Step 4: Identify key factors through MICMAC analysis

The MICMAC analysis was performed in Microsoft Excel. In this case, stabilization occurred at $n = 7$. The analysis changed a number of our original assumptions about the relative power and dependence of the factors. For example, among the ten factors we had intuitively determined to be the most powerful, the original ranking order was only correct in five cases out of ten. Below in figure 17 is the result of the MICMAC analysis in the form of the system's drivers vs. dependents matrix.

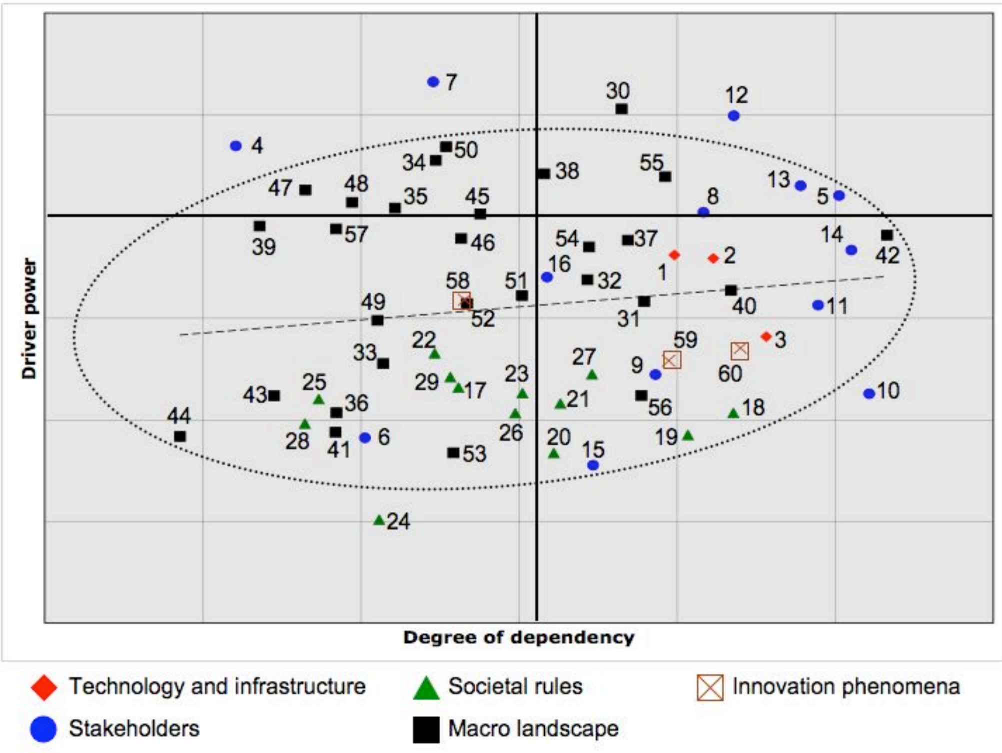

Figure 17 – The drivers vs. dependents matrix for the Russian heavy-vehicle fuel market. The numbers are the factor numbers from step 2.

The X-axis border between matrix areas was drawn so that 50 percent of the factors are on either side. On the Y-axis, the border was placed so that approximately a dozen key factors, i.e. those that have the greatest driver power, are above it. The system's form was created on basis of the data points' linear regression (dotted line). The ellipse around the regression covers 90 percent of all factors and indicates an unstable system.

From the matrix, we identified the 15 most influential system factors through dividing the matrix into four fields and selecting the factors in the determinants and relays areas. In table 15 the chosen factors are sorted by category and driving power:

Table 15 – The 15 identified key factors, sorted by driver power.

Category	***Depiction***	***Name***	***(No.)***
Determinants	A	The European Union	(7)
	B	Asian countries	(4)
	C	Protectionism	(50)
	D	Export opportunities	(34)
	E	Oil price	(47)
	F	Other commodity prices	(48)
	G	Focus on commodities or value-added goods	(35)
	H	International cooperation	(45)
Relays	I	Concern about the global environment	(30)
	J	The President	(12)
	K	General economic policy	(38)
	L	Trade with the EU	(55)
	M	The oil industry	(13)
	N	The automotive industry	(5)
	O	Gazprom	(8)

It is interesting to note that among the determinants two are from the stakeholders category, whereas the other six are macro landscape factors. Among the relays, the relation is more even; four are stakeholders and three macro landscape factors. What first surprised us was the large influence of the EU and Asian countries. Having in mind their large importance for Russia's trade and economy, it however makes sense to assume that their policies and decisions are very influential.

The relay characteristics of the President and the oil and auto industries are also extremely interesting. This means that these factors may very rapidly change their views on which fuels should be promoted (due to their large dependency), which in turn would profoundly change the state of the system (due to their large power). Also, a change in concern about the global environment would be a decisive influence on the future of fuels in Russia.

The system's form indicates that it is unstable. This means that there is a relatively high amount of relay factors and no clear input-output relationship within the system. As a consequence, it is reasonable to assume that there are tipping points where the system may change its configuration very rapidly. In other words: trigger events may cause a sudden change in the direction of relay factors' influence on the fuel market, causing an upheaval.

Lastly, we can conclude that macro landscape factors (30-57) are evenly spread across all sectors with a slight inclination to relatively high power. This implies that the environment is both influential and, in many cases, dependent of what happens in the system. The stakeholders (4-16) are with two important determinant exceptions mainly found in the relays and dependents sectors, which mean that they are likely to take impression from surrounding events. The societal rules (17-29) are all found in the bottom half of the matrix. This is probably due to them being the people's expressions of input received, which is largely determined by macro factors and the actions of stakeholders. Innovation phenomena (58-60), are in this case dependent of what happens on a macro level and are therefore found in the dependents or excluded sectors. If there is not an inclination towards changing the system, there is no interest in, or funding of, special projects or research. Finally, technology and infrastructure factors (1-3) are all dependents, which is logical in the sense that their development is determined by what investment decisions are made by stakeholders.

6.4.1 Descriptions of the key factors

Below, the key factors are described and explained more in detail:

A. The European Union
The European Union is Russia's largest trading partner. It is also progressive in terms of fuel standards and the implementation of biofuels, which affects Russia both directly by demands on Russian vehicles that traffic Europe and indirectly by driving a general development towards cleaner and more advanced vehicles.

B. Asian countries
Asia is an important trading partner for both export and import. If a fuel is in growing demand on the Asian market, e.g. in China, there are incentives for Russia to start producing it at a large scale. Domestic production for export may eventually also lead to domestic use.

C. Protectionism
A protectionist market policy means that foreign direct investment and development of new technologies likely decreases. Also, for example domestic vehicle manufacturers with inferior engine technology are protected. This affects the choice of fuel on the market.

D. Export opportunities
Other countries may experience changes on the fuel market earlier than Russia. This may open up export opportunities, which affect production investments and consequently the domestic fuel market.

E. Oil price
Oil exports drive the Russian economy. Higher oil prices mean that the country gets richer and that the economy expands. Lower prices create numerous negative effects.

F. Other commodity prices
The prices of other commodities affect the Russian economy significantly since the country has large commodity exports. Also, if the commodities, such as wood or crops, are feedstock for fuel, fuel prices are affected.

G. Focus on commodities or value-added goods
Russia mainly exports unprocessed commodities. A focus on value-added goods would have great consequences for investments and the structure of the economy.

H. International cooperation
Russia is one of the great powers in the world. Its perception of its role in the international community affects trade, foreign investments, as well as its alignment with other economies in terms of technical standards.

I. Concern about the global environment
Increased global environmental consciousness enables a wider view of large-scale policy or micro purchasing decisions. The connections to other people on Earth stand clearer and require consideration.

J. The President
The President holds considerable power in all aspects of Russian politics. His policies and views have considerable impact on other politicians, the public, the business community, as well as on other countries and international organizations.

K. General economic policy
The general economic policy may be inspired by liberal ideas or by a wish for more state control. This affects all sectors of the economy and ultimately also which fuels are on the market.

L. Trade with the EU
EU is Russia's most important trading partner. The more trade, the more there is a need to align technical standards between the two entities. A concrete example is that Russian trucks that transport goods to Europe must adhere to European emission standards. Therefore, they also need European-quality fuel.

M. The oil industry
The oil industry is a cornerstone of the Russian economy and is an integral part of the current fuel system. Its actions will heavily affect the developments on the fuel market.

N. The automotive industry
The automotive industry is an important part of the Russian economy and labour market. Fuel regulations and associated technological questions directly affect the competitiveness of the domestic automotive industry, which may create political pressure to change regulations.

O. Gazprom
Gazprom is a very powerful entity in the Russian society. It has close ties to the political establishment and has the power to influence the developments on the fuel market.

6.5 Step 5: Specify factor ranges

Through analysis of the empirical data and logical reasoning, we found that the key factors with a 20-year horizon may assume values within the extreme limits specified below. Each factor range is also motivated by a short description (table 16).

Table 16 – Factor ranges identified during the empirical investigation. The factors may assume any value between the lower (L) and higher (H) ends of the intervals.

No.	*Factor*	*Dimension*	*Range*	*Rationale*
A.	The European Union	Importance for Russia	L: Very low H: Very high	The EU may become more or less economically important for Russia. It may also put other issues, such as the environment, at the top of its agenda
B.	Asian countries	Importance for Russia	L: Very low H: Very high	Asian countries may become more or less economically important for Russia. They may also put other issues, such as the environment, at the top of its agenda
C.	Protectionism	Degree of Russian protectionism	L: Free trade H: Highly protected	Russia may choose to promote free trade or protect its markets
D.	Export opportunities	Number of fuel export opportunities for Russia	L: Few H: Many	Export opportunities for a fuel may arise due to economic development in other countries
E.	Oil price	World market price	L: $30 per bbl H: $500 per bbl	The oil price may rise or fall due to a number of factors
F.	Other commodity prices	World market prices on e.g. wheat, timber, soy beans	L: Low H: Very high	Prices of commodities are affected mainly by supply and demand, which in turn depends on their usage
G.	Focus on commodities or value-added goods	The goals of the Russian economic policy	L: Commodity-based economy H: Advanced goods economy	Russia may create an advanced industry producing value-added goods or settle with exporting commodities
H.	International cooperation	Russia's goals and behaviour on the international scene	L: Confrontational and aimed at unilateral power H: Cooperative and aimed at integration	The Russian foreign policy may aim at becoming a part of the world community or a unilateral power in its own
I.	Concern about the global environment	Level of consciousness and concern among ordinary citizens	L: No concern H: Very concerned	Global environmental issues may become a very influential part of people's everyday thinking
J.	The President	Interest and involvement in fuel-related issues	L: No specific views H: Very interested and involved	The President may put the fuel industry at the top of his agenda based on environmental, economical, or security concerns
K.	General economic policy	The general philosophy behind Russian economic policy	L: State-controlled H: Very liberal	The economic policy may develop towards more control by the state or more liberalism
L.	Trade with the EU	Trade volume	L: Very limited H: Extensive	Depending on Russia-EU relationships, trade may flourish or decline
M.	The oil industry	Progressiveness towards new fuels and willingness to participate in change	L: Orthodox H: Very progressive	The oil industry may be more or less progressive towards change in the fuel market
N.	The automotive industry	Level of technological knowledge	L: Low tech H: Modern high-tech	The Russian automotive industry may or may not go through technological modernization
O.	Gazprom	Action rationales	L: Purely economical H: Purely political	Gazprom's relations to the government may influence its actions. This will have ultimate repercussions also in the use of Russia's gas resources

6.6 Step 6: Develop scenario themes and set factor values

Since the goal of our case investigation was to determine which factors are the most important for the future of fuels in Russia, we chose to start our development of scenarios in worlds where each of the four fuels would dominate. Hence, the four scenarios were created using the top-down approach, and the factors assigned the values needed to achieve these worlds. An important reason for assigning one fuel to each scenario was that we wanted to avoid depicting a certain fuel as more probable to dominate in the future. We also wanted to put light on the significant chains of events required to create these in many ways extreme scenarios. The thematic worlds we in this step created from empirical knowledge served as the end points of the roads leading to the possible future system states. The factors' assigned values in each scenario are seen in table 17.

Table 17 – Factor values in each of the four scenarios.

No.	*Factor*	*Centralised CNG society*	*Dirty diesel depression*	*DME dragon days*	*European E-fuels era*
A.	The European Union	Low importance	Very low importance	Medium importance	Very high importance
B.	Asian countries	Medium importance	Low importance	Very high importance	Medium importance
C.	Protectionism	Protective	Highly protective	More free trade than protective	Free trade
D.	Export opportunities	Few	Few	Many	Many
E.	Oil price	High	Low	High	Very high
F.	Other commodity prices	High	Medium	Medium	Medium
G.	Focus on commodities or value-added goods	Commodity-based	Commodity-based	Advanced goods	Advanced goods
H.	International cooperation	Neutral	Confrontational and unilateral	Cooperative and integrative	Very cooperative and integrative
I.	Concern about the global environment	Limited concern	No concern	Concerned	Concerned
J.	The President	Interested for economic and security reasons	Not interested	Interested and involved	Interested and involved
K.	General economic policy	State-controlled	Neutral	Liberal	Liberal
L.	Trade with the EU	Limited	Very limited	Extensive	Very extensive
M.	The oil industry	Neutral	Orthodox	Progressive	Progressive
N.	The automotive industry	Neutral	Low-tech	Modern high-technology	Modern high-technology
O.	Gazprom	Political	Political	Economical	Economical

6.6.1 Scenario 1: Centralized CNG society

In the centralized CNG society, the ruling philosophy in Russia is trade profit maximization. The EU has detached itself from dependence on Russian gas. The consequent low demand for natural gas on the largest export market has led to a relatively cheap gas price, which has created room for other uses. Close connections between the government, Gazprom, and the domestic automotive industry has created a vehicle fleet and infrastructure largely based on CNG. The Russian economy is very dependent of oil exports, which mainly go to the growing and economically important Asian region.

6.6.2 Scenario 2: Dirty diesel depression

In the dirty diesel depression, the Russian economy is suffering from the aftermaths of a global economic downturn. Protectionist and nationalist politicians have taken over the country, leading to international confrontation and isolation. As a result, economic activity, trade, and investments are at a very low level. Russia has turned to itself in most aspects of the economy and has abandoned the development towards cleaner fuels. Instead, the diesel quality has, like the rest of the country, stagnated.

6.6.3 Scenario 3: DME dragon days

In the DME dragon days, China is an economic giant with considerable economic power. Aiming to improve local air quality, it has turned to large-scale use of DME. The EU has with some delay followed China's example, making DME a competitive fuel also in the Western market. Through liberal economic policies and a relatively free trade, Russian politicians have created opportunities for Gazprom and private companies producing DME from gas fields and biomass. A comprehensive domestic DME infrastructure, created through market mechanisms, is in place.

6.6.4 Scenario 4: European E-fuels era

EU is the world's environmental policy leader, having led the way to the European E-fuels era. The union has in 20 years managed to create a transport sector running mostly on ethanol produced from ligno-cellulosic biomass, much of which is imported from Russia. Russia, still trying to catch up with Western countries, has through its intense trade relationship with Europe been forced to adapt environmental policies almost at par with the EU. Russia's advanced automotive and bio-refining industries, in combination with continued high oil incomes, have created a flourishing and modern economy. The population enjoys a high standard of living and is concerned with the global environmental situation.

6.6.5 Types of change in the different scenarios

In the theoretical framework, different types of change processes are discussed. These may be applied to each of the four scenarios created:

The *Centralized CNG society*, is a case of transformation. The technology used largely already exists and the change is mostly caused by macro landscape events. The incumbent actors' existence is not under threat, but they are forced to transform themselves into something new, which creates the new system order.

In the *Dirty diesel depression*, change is virtually non-existent and can at best be described as reproduction. What happens is that there are no drivers for change neither in the macro landscape nor from innovation phenomena. Instead, the incumbent actors create new societal rules, which essentially stop development.

In the last two scenarios, *DME dragon days* and *European E-fuels era*, we have two clear cases of transition. Events at both the macro landscape and innovation phenomena levels together create conditions that allow for a radical shift in technology and infrastructure and among stakeholders. The fuel market thus created differs in fundamental ways from today's situation.

6.7 Step 7: Check consistency of scenarios

The scenario themes were checked for consistency through logical reasoning. As a help, a matrix showing only the key factors' direct impact on each other was created (table 18). The relationships are the same as those specified in step 3. The strong pair-wise relationships were further analysed by intuitively determining whether they were positively or negatively correlated. A positive correlation means that a change in value of one factor will affect the other factor in the same direction. Negative correlation means that a change in value of one factor affects the other factor in the opposite direction. Question marks were used when we found it impossible to determine the nature of the pair's correlation. Thereafter, the factor values in each scenario set in table 17 were given a value; low, medium, or high, corresponding to their place in the range. These were checked against the correlation in table 18 below, to make sure no conflicts occurred between the defined correlation and the factor values set. The complete results of the consistency checks for each scenario can be seen in Appendix V.

Table 18 – The key factors' direct strong correlations. The correlations are positive (+), negative (-), or undetermined (?).

	Influence on														
Influence from	The European Union	Asian countries	Protectionism	Export opportunities	Oil price	Other commodity prices	Focus on commodities or value-added goods	International cooperation	Concern about the global environment	The President	Trade with the EU	General economic policy	The oil industry	The automotive industry	Gazprom
The European Union			S-	S+				S+			S+			S+	
Asian countries			S-	S+	S?	S?	S+	S+						S+	
Protectionism				S-		S?		S-			S-	S-		S-	S+
Export opportunities							S?	S+		S+	S+	S+	S+	S+	S-
Oil price				S?			S?	S+		S?	S?	S?	S+		S?
Other commodity prices				S-			S?	S-			S-				
Focus on commodities or value-added goods				S+							S+	S+	S+		S?
International cooperation			S-	S+	S+				S+		S+		S+		S?
Concern about the global environment								S+					S+		
The President			S?				S?	S+	S+		S+	S+	S+		S?
Trade with the EU			S-	S+			S+						S+		S-
General economic policy			S-				S+				S+		S+		S-
The oil industry					S+		S+			S+	S+				
The automotive industry									S+		S+				
Gazprom								S?		S-			S-		

6.8 Step 8: Present scenarios

The following scenarios were designed from the factor values set in step 6. To create a lively narrative, they are presented as short chronicles complete with dates and places for important events. The events are the products of our fact-based notion of what is required to happen on the way from today's situation to the futures described. The reader should be very aware of that the chains of events described are *one* way of getting to the societies described. However extreme the scenarios may seem, the underlying reasons for important events depicted are to a large extent based on empirical evidence gathered during the study.

6.8.1 Centralized CNG society

(Moscow, 5 June 2028)
Speaking after Gazprom's board meeting today, the chairman of the board, and also President of the Russian Federation, Gennadiy Ivanov expressed his sincere satisfaction with another year of success for the company. "Through the excellent performance of Gazprom we have created an economically very favourable situation for the citizens of our dear Russia", the President remarked before adding: "But we should also not forget to mention that the close cooperation with our proud auto industry was essential in getting the much needed natural gas fuel vehicles to the market in sufficient numbers". In other events, second-quarter national revenues from oil exports came in at new record numbers thanks to continuously high oil prices of around $430 in the last few months.

During the presidential election campaign of 2012, the then President Medvedev launched his massive "Use what's cheap, sell what's expensive"-campaign in a bid to secure his re-election. In a campaign secretly funded by his former employer Gazprom, and also supported by the oil industry, he presented the public with a vision of a Russia, which would be "economically smart towards foreign elements, and full of care for its own citizens". Using equal parts of patriotic, economic, and security arguments, he managed to convince the majority of the people that the only way for Russia to secure its rightful place in the world was through economic power and a strong national industry.

Having won a landslide victory, Medvedev immediately launched initiatives securing the state's control of key sectors including the automotive, oil, and gas industries. The take-over was completed in 2015, when the last remaining privately-owned oil company Lukoil was forced to bankruptcy and eventually sold to subsidiaries of the state-controlled giant Rosneft.

Experts on Russia generally agree that a number of factors were behind the Russians' decision to move away oil-based fuels and create a natural gas-based transport sector instead. Firstly, the EU's determined struggle to decrease its dependence of Russian gas supplies lowered the export volume. This in turn created an effective overcapacity in gas production, which in combination with efficiency improvements and new gas field discoveries in Siberia effectively made it clear that floods of cheap gas would be available in the coming years. Secondly, Asia's, and especially China's, emergence as the undisputed economic powerhouse of the world caused ever higher oil prices. However, this development did not bring any new export volumes for natural gas comparable to the amounts earlier transported by pipelines to Europe. Russia pumped massive amounts of oil from its slowly depleting wells, but world demand still heavily exceeded supplies, resulting in high prices.

Rising prices on other commodities such as grain, already from 2007 created constantly rising food prices. Therefore, it became a necessity for the Russian government to ease the economic pressure on the population in other areas. This was done through a protective trade policy, the first signs of which were seen in late 2009 after the breakdown of WTO talks. In the policy, exports and imports of foodstuff were controlled through tariffs. Economically liberal reforms were discarded in favour of state-controlled centralized solutions; for example, the government starting from 2010 kept down fuel prices, much to the discontent of the oil industry. The new course of economic policy eventually caused the once-promising trade with the EU to dwindle to levels not seen since the mid-1990's.

Additionally, the domestic, and in many cases technologically backwards, automotive industry was in 2013 ordered to develop cheap cars and trucks running on CNG to ease the populations' costs for transport. In exchange, the government imposed extensive import duties on foreign-made vehicles, effectively putting an end to their competitiveness. At the same time, Gazprom started building CNG filling stations across the country at what it called "an unprecedented pace". The build-out of stations connected to the existing pipeline network was completed in 2022, which was two years later than the initial central plan had described.

Oil companies were more than well compensated for their market loss by being allowed to export the absolute majority of their products at high world-market prices instead of selling them at state-controlled prices domestically. Despite this, the last petrol cars and diesel trucks will not be formally banned from Russian streets until the beginning of 2034, even though their share of the vehicle fleet was down to only 50 percent already in 2025. The bus fleet was in its entirety converted to CNG between 2014 and 2018, beginning in large cities such as Moscow and St. Petersburg. The most visual showcase, however, was the 2014 Sochi Winter Olympics, during which the entire transport infrastructure in the city was based on natural gas.

What started with Europe's desire for energy independency was through the complex intertwining of Russian politics and business transformed into an entirely new society based on natural gas being used for transport needs. Through shifting oil export focus from Europe to Asia, playing on patriotism and rising costs of living, and in some cases with populist references to the "environmental supremacy of natural gas over oil-based fuels", President Medvedev started a process that will affect Russia's relationship to the rest of the world for decades to come.

6.8.2 Dirty diesel depression

(Nizhniy Novgorod, 29 May 2028)
The giant Russian car and truck manufacturer AutoKamGAZ yesterday announced that it will lay off another 10,000 workers at its Toliatti main plant following continuing troubles in sales figures. Having relied almost entirely on the demand from a well-protected, but weakening, domestic market, the company had been left without options. In other developments, the city of Moscow today announced the plans for yet another oil-fired power station. Citing sources close to the mayor, one energy expert remarked that "oil is seen as the cheapest and easiest alternative for large-scale power generation in Russia".

The story of the demise of the automotive industry is typical for many industrial sectors in Russia during the last few years. Following the sharp global economic downturn in the second decade of the millennium, many companies found themselves losing their international customers. One contributing reason were the extremely protectionist measures the Russian government imposed between 2011-2014 in order to save its domestic industries in light of tougher markets. However, the measures were often counterproductive since they were soon followed by reciprocal policies from major Russian trading partners such as the European Union, China, and Japan. Russian companies were thereby effectively cut off from all significant export opportunities and trade levels reached new lows.

The economic crisis also resulted in a sharp drop in oil prices to levels around $50, which together with the dismissal of environmental issues from the political agenda presented no incentives for the oil industry to invest in production of cleaner fuels. When imports of vehicles produced outside the country were effectively limited, and the general economic climate had put off foreign vehicle manufacturers from investing in local assembly, the demand for higher-quality fuel slowly began to diminish. The development towards cleaner fuels, which culminated with the implementation of Euro IV regulations in 2010, effectively came to a standstill.

Most devastating for the Russian economy were the low oil and other commodity prices. Faced with serious fiscal problems, the presidential campaigns in 2012, and especially, 2016 spawned some ugly rhetoric about mysterious “foreign complots”. Political experts generally agree that these conspiracies were fabricated in order to avoid attention to the serious economic situation. In the fall of 2016, the aggressive foreign-policy stance led the new President Aksenov to outright confrontation over Gazprom’s supply of natural gas to the former Soviet republics Ukraine, Georgia and the Baltic countries. The difference against earlier occasions was that the Russians this time also caused collateral damage to Western EU countries, which rushed to help their fellow union members. In the end, costs were high for Russia since the EU started an ambitious program for becoming less dependent of Russian energy.

The oil industry struggled with adjusting to the steadily lower oil prices in the decade from 2010-2020. Investments were very low, with a focus on just maintaining the production and refining capacity in terms of volume. Without any encouragement from the government, the companies were reluctant to abandon their low-value, but relatively more profitable, crude oil export and low-quality fuel production. In comparison to other countries, Russia got stuck in a self-sufficient low-tech economy, which is still prevalent today.

Had it not been for the economic crisis, commentators agree, Russia may had become one of the great countries on earth. However, through relying too much on a continuously growing demand for its natural resources, the country made itself vulnerable to changed conditions in the world. When the global downturn came, politicians were not up to the challenge but turned to petty nationalism and protectionist reflexes. Russia thereby became a technological backwater where factories, cars, and trucks still today continue to spew out their dirty exhausts in a manner not seen in Europe and other countries since the end of the last century.

6.8.3 DME dragon days

(Wuhan 12 July 2028)
The Chinese and Russian Prime Ministers signed yet another cooperation agreement today. As part of the deal, Russian oil and gas companies, with Gazprom at the head, pledged to deliver fuel-quality DME in volumes amounting to 10 percent of the needs in the Chinese transport sector in the coming five years. Through the newly signed and earlier similar agreements, Russia will now in power of its natural gas and forest resources deliver about 45 percent of China's DME. Also, the country supplies about 15 percent of Japan's total transport sector needs and around 10 percent of Europe's. After the ceremony, the Prime Minister went straight to the high-level WTO trade talks being conducted in Beijing to propagate for less protective policies from the American and European sides.

Almost by a strike of sheer luck, Russia a decade and a half ago found itself optimally positioned to supply China and Japan with the then new and cleaner fuel DME. Basically, a combination of generally liberal economic policies put in place by President Medvedev (2008-2016), and the monopolistic behaviour of gas giant Gazprom together created both the opportunity and need for private companies to develop so called “stranded” gas fields in remote regions of Russia. It all started when Gazprom refused to let other companies use its monopoly pipeline network for transportation of their gas. This forced the companies to look for other options. Across the border to China, they saw a growing demand for DME fuel, which in liquid state was easy to transport from the fields by rail. The growing confidence in the government's business-friendly intentions served to support the decisions to build massive DME production plants. The success of these private companies opened the eyes of Gazprom, which in 2015 built its first major DME production complex. In 2016, this was followed by gradual investments in DME filling stations in Russia; first in Moscow and St. Petersburg and then in other major cities. In 2022, something resembling a national network of filling stations, owned by either Gazprom or other companies, was in place.

Reflecting their economic dominance, most of the DME exports now go to Asian countries. It was not until 2019 that the European Union started to import the fuel at a larger scale from Russia. By then, a significant proportion of DME production was based on biomass feedstock instead of fossil natural gas and therefore was more in tune with the EU's ambitious environmental and climate policy. Also, the oil price had risen to just below the very high levels around $400 per bbl that we see today. Europe's old biofuel alternative, ethanol, did not reach the predicted popularity projected among heavy vehicles. This was mainly due to the massive discredit it received because of the rising price levels on grains and food that the world experienced from around 2010.

The Russian vehicle fleet has seen a slow transition from diesel and petrol to DME. The turning point came in the late 2010's when Chinese, and later European, vehicle manufacturers started joint ventures together with Russian producers with the goal of supplying the market with DME vehicles. Today, the market share of trucks running on DME is more than 60 percent; while among cars somewhere around 50 percent use the fuel.

The switch to DME in first the Asian, and thereafter the global, transport sector turned out to be quite positive for Russia. Thanks to liberal economic policies and the initiatives of entrepreneurial companies, the country managed to make optimal use of its resources. The new 2nd-generation production processes also allowed Russia to make good use of its massive biomass resources and create export opportunities for years to come. At the same time, local air quality in the cities has improved and Russia's contribution to global warming has lessened to the joy of the international community.

6.8.4 European E-fuels era

(Brussels 2 July 2028)
At the end of the European Union's two-day Council of Ministers meeting, yet another program aimed at mitigating the effects of global warming was presented. This time around, a comprehensive deal involving all member countries of the European Economic Cooperation Organization (EECO), including Russia, was signed. The parties agreed to further investments in bio-ethanol production and production process research. At the summit, the EU's President Santos and his Russian colleague Malinov also signed a treaty further formalising the legal framework covering the extensive trade relationship between the EU and the Russian Federation. Said President Malinov, "Through the important deals signed here today, we have taken yet another step in the EU's and Russia's quest to save the climate. Additionally, we have further strengthened our mutual bonds and created crucial tools for the regulation of our other major mutual interest – trade."

The close cooperation between the EU and Russia started already back in 2013, when the union and the then Russian President Medvedev signed a framework deal on supplies of bio-ethanol to the EU. The initial deal was preceded by the start-up of more than 30 ethanol plants beginning in 2008. The production plants, which were based on agricultural feedstock, sold almost all their production on export to Europe. The rationale behind their development was agro-economic rather than based on environmental concern. In the following years, an additional 50 new production units were erected across Russia. The final breakthrough came in 2016 when the first ethanol plant using ligno-cellulosic biomass was built. Since then, Russia has in power of its vast forest resources become the world's number one producer of fuel ethanol.

One major prerequisite for the development of an economically competitive ethanol industry in Russia were the very high world oil prices seen ever since 2009. The oil price both made ethanol comparably more attractive to consumers, and allowed the Russian government to spend money on developing an economy focused on value-added goods instead of commodities. For example, through generous government policies and a liberal position towards foreign investors, the Russian automotive industry saw an unprecedented technological catch-up in the 2010's. Already in 2012, the market saw the first Russian-designed ethanol city buses aimed at the domestic market roll out of the factories. These were soon followed by other cheap car, bus, and truck models, which turned out to attract also wider circles of environmentally conscious European customers, thus adding to the growing mutual trade between the EU and Russia.

The further intertwining of Eastern and Western European economies created political room for spawning a fresh cooperation forum, the European Economical Cooperation Organization (EECO), which was founded in 2018. The organization eased cooperation in areas such as energy and trade. For example, Gazprom, which had been definitely detached from government influence after the re-election of Medvedev in 2012, was allowed to compete on the EU market on equal terms as European companies. The prosperity that followed the increased economic activity led to generally higher living standards in Russia. The public became more and more "Europeanized" in the coming decade, also in the form of ideas and commonly shared ideals. A new environmental movement evolved around the old ideas about "Mother Russia, the people, and the land". A nationwide poll in 2022 showed that the level of environmental consciousness and concern about global problems such as the climate, had reached Western-European levels.

The growing trade and cooperation between Russia and the EU was not mirrored in Russia's relationship to China and other Asian countries. Even though they clearly had become important economies in the mid-2010's, their uninterested stance towards environmental issues severely damaged their international competitiveness. Also, the technologically advanced Russian companies found more attractive customers in Western Europe. The exception was the oil industry, which for long followed a "dual-fuel" policy. It continued to supply oil and fossil fuels to both Asian countries and the domestic market, but also made heavy investments in ethanol production. Beginning in 2017, all petrol was blended with ethanol on the Russian market. From 2020, all gas stations offered ethanol with ignition additive for use in trucks and buses. Today, approximately 65 percent of all cars run on either E85 or pure ethanol, while the older 35 percent run on E10. Among trucks, around 60 percent are ethanol-powered, while the remaining 40 percent still run on diesel.

Russia's history in the last 20 years is largely a tale of success. Today, it is a prosperous country, which through its openness to the world in general, and Europe in particular, has created a modern liberal society. Through following the global trends towards a more environmentally sound society, Russia has been able to modernize old industries, such as the automotive industry, into internationally competitive high-tech companies. While still in many aspects continuing to fulfil its decades-old role as an energy supplier to the world, Russia is now doing it with a new sense of pride and clean conscience.

6.9 Step 9: Assess impact of scenarios

Below, each scenario is related to Scania's situation and organization. The company will in each of the prospective worlds face both challenges and opportunities for new business.

6.9.1 Centralized CNG society

Challenges

The Centralized CNG society for Scania represents a Russian market functioning very different from today. First of all, the higher degree of protectionism described, especially towards vehicle imports, creates difficulties for all foreign manufacturers to enter the market at equal terms with domestic firms. Secondly, the fuel used is technically different from that used in the EU and elsewhere, effectively making Russia a unique market. Additionally, the high cost of living in Russia has lowered overall purchasing power, making price the most important competitive advantage and opening the door for domestic low-cost brands even more. Since CNG is not an optimal fuel for heavy trucks, there may also be an increased competition from rail and other transport options. In any case, the economy and society are more politically controlled than today, which makes close relations with politicians and companies loyal to the state essential for success.

Opportunities

For Scania, the main opportunities in this scenario are in the bus market. This is where the massive conversion to CNG starts. Since it according to the scenario happens early in the development, Russian companies may be assumed not to have reached highest technological level in the field yet. In combination with local assembly and production in Russia, this would make Scania’s buses attractive for large state or city contracts. Through cooperation with Gazprom and authorities, Scania may win the tender to supply the Olympics with transportation, which in the end may turn out to be the key to become the leader on the entire market.

6.9.2 Dirty diesel depression

Challenges

The Dirty diesel depression is part of a gloomy future not very attractive to any company. The Russian market is essentially closed. The international political situation is shaky, and the investment climate is harsh. As a foreign company, Scania is likely to run into politically motivated trouble. This creates a need for having Russian partners, which can legitimate the company when facing the authorities. The standard of vehicles is best described as low-tech, which causes Scania to lose its traditional technology leadership advantage. This also opens up to more competition on the shrinking market from less technically advanced Russian companies. Due to the disastrous state of the economy, low price will be essential.

Opportunities

There are almost no attractive opportunities for Scania in the Dirty diesel depression scenario. The only noticeable thing is that road transports become cheaper due to the low oil price. This may create a somewhat larger market for trucks. However, this is likely balanced by the lower demand caused by the gloomy economy.

6.9.3 DME dragon days

Challenges
DME is not Scania's preferred fuel for the future. The technology therefore needs to be developed. In the DME dragon days, the economic power in the world has transferred to Asia and China. Scania thereby needs to increase its presence there in order to follow the development. New competitors to Scania, which will have to be met, are likely to arise from the DME cooperation between Russia, China, and Japan.

Opportunities
The main opportunity lies in the fact that Russia and Asia will comprise an enormous market for Scania. Thereby, the development of DME vehicles will be easy to motivate for scale reasons. It will likely be easier to reach large volumes by having local assembly in Russia and/or China to avoid possible trade obstacles. Also, the somewhat increased environmental consciousness associated with the large-scale introduction of DME fits the Scania profile. To have DME vehicles with clean emissions may become a competitive advantage.

6.9.4 European E-fuels era

Challenges
The main challenge for Scania in the European E-fuels era is to preserve its technological edge. The massive and attractive market for ethanol vehicles, in the EU and Russia will attract the attention of many competitors. Also, in light of the surge in Russian trade and economy, Scania will have to possess sufficient production capacity to serve the large demand.

Opportunities
This is the scenario of choice for Scania. The company can use its technological knowledge to serve an open and fast-growing Russian market. Doing business in the country is easier than today due to the development of a modern society. Since the fuel market in this case is largely determined by the Europeans Union's choices, Scania has the opportunity to first capture the European home market. By securing dominance at home in power of the best technology, a good basis may be created for dominance also in Russia.

6.10 Step 10: Identify monitoring and further research needs

Below, monitoring needs as well as further research needs are presented for Scania based on the study's findings about the key factors identified on the Russian fuel market.

6.10.1 Monitoring needs

From the scenarios described above, it is evident that there are a few of the key factors that Scania should keep an extra eye on. Some are obvious and will affect Scania's choices also on other markets, such as the oil price, while others, e.g. concern about the global environment or the oil industry's attitude towards change, are hard to quantify or measure. However, there are some that are actually possible to monitor in a meaningful way. By watching them, Scania can get a good notion of where the development is heading. These factors are described in detail below:

The European Union and trade with the EU

EU's choices will be very important for the development in Russia. EU and Russia will be more interdependent the more trade there is between the two entities. By watching the level of trade and fuel development in the EU, Russia's path becomes clearer.

Asian countries

Asian countries may one day become more important to Russia. Especially the development of the fuel market in China may be crucial for Russia's choices. Scania should therefore closely watch the Chinese fuel policy and consequent sourcing decisions closely. Also, the level of energy sector cooperation may be an indicator in this aspect.

The President

The Russian President will, if he is interested in the questions, heavily affect the fuel market. By monitoring his policy decisions and public statements, Scania will get a better understanding of the government's priorities in the sector.

The automotive industry

To achieve an advanced fuel market, the Russian automotive industry must also be advanced. In order for this to happen in the foreseeable future, foreign companies must become more involved. Scania should therefore monitor the further trends in this field. The more foreign involvement, the faster the development towards clean and advanced fuels will be.

Gazprom

Gazprom is so important in the energy sector that it deserves monitoring in its own. Especially this is the case regarding the fuels with origin in natural gas, i.e. CNG and DME. Gazprom's investment programs, public announcements, actions against other companies, and possible problems, will all give signals of where CNG and DME are heading. Also, the company's relations to the Kremlin are worth giving attention.

6.10.2 Further research needs

There are a few things in our case study that preferably should become objects for further research. There are some factor characteristics that may change in several aspects. The questions that arise are listed below:

Which information from stakeholders should be taken seriously?

The relationships between industry and policy makers are somewhat murky. If Scania could build deeper knowledge about the connections, it would likely help in determining which messages from the market are to be taken seriously and which can be disregarded.

What does the future hold for the automotive industry?
A special case in this aspect is the automotive industry. Scania should here try to stay as close to the developments as possible. The goal should be to find out whether the industry will be liberalized or the object of more involvement by the government.

Is there enough natural gas?
Gazprom is another subject for further investigation. The company is as mentioned very large and complex and sends out mixed signals. Scania would therefore benefit from knowing whether there will actually be a gas shortage, as the experts predict, or whether Gazprom's strive to find new uses for natural gas are realistic from a production point of view.

Will there be large-scale ethanol production?
A fourth question to explore is the recently announced plans for construction of ethanol plants. Scania should try to find out whether there is any sincere political support for them, or if their announcement was more of a testing balloon. At the same time, a judgement should be made on the prospects of private initiatives.

What are the cities' plans for the future?
Lastly, Scania should contact the administrations in Russia's largest cities to hear their thoughts on urban transport solutions and traffic pollution. The development towards cleaner fuels will likely start in these cities. By knowing their preferences and thoughts on the future, Scania will be off to a head start once things start to move.

7 Discussion

In the discussion section, different aspects of the study are reasoned about. The goal is to put new light on issues that have been treated in the thesis, as well as motivate why the selected way of conducting the study. Furthermore, suggestions for improvements and possible further studies are presented.

7.1 Theoretical framework

To claim possession of a method to predict the future is not recommendable. Therefore, this study does not make such a claim. Rather, it has presented a way to describe, analyze and present what the future *may* possibly look like. The study has been influenced by the notion that the world is rapidly changing as more countries reach higher standards of living and open up against the world. From this process follows both fast development and diffusion of new technology, and consequential changes in society, which makes radical shifts in "the ways we do things" and use technology in everyday life an unavoidable effect.

Within this context, political, economic, and environmental factors are just some of the many things that will affect what happens in the future. We found that the future of technology and society in interaction best could be described with the help of the socio-technical systems theory, in which was included the technology and infrastructure, stakeholders, societal rules, macro landscape, and innovation phenomena dimensions. The socio-technical systems theory thereby helped us understand the intertwined relationship between technology and society within the context of a certain system.

Were the study conducted in a more "traditional" manner, Porter's *Five forces model*[351] or a *PEST analysis*[352] would have been the easy and obvious choices for describing the macro environment and interactions of stakeholders. However, we believe that the socio-technical systems approach provided us with better tools to systematically investigate and describe a situation like the one in the case study, mainly because it allowed us to capture micro and macro factors, as well as stakeholders, within the same framework. The real strength of the theory, however, lies in the existence of the mesa societal rules level, which connects the micro and macro levels and also gives an explanation to how and why change occurs in a system. Taken together, these characteristics of the socio-technical systems theory allowed us to describe reality in a structured and easy way, while at the same time being able to catch details and nuances in the investigated system.

The socio-technical systems theory may be criticized for not being able to provide a complete and explanatory picture of all dimensions of technology and society. It may, due to its aim to cover "everything", sometimes be perceived as a bit shallow in

[351] See for example Grant (2005), p. 74
[352] See for example Grant (2005), p. 68

certain aspects. We dealt with this problem through adding other, more specific, theories where appropriate. These sub-theories gave an in-depth understanding when needed and complemented the overall socio-technical systems theory. Through this, we enhanced the quality of both the description of the present and the analysis of what the future may bring. Hence, we do not see any major issues with the theoretical framework used in the study. However, there is a need to apply it to more cases in order to confirm its universal validity in issues regarding technology and society in interaction.

7.2 Presentation of empirical data

We chose to present empirical data by creating scenarios, which is a well-established way of presenting possible futures. There are alternatives to using scenario methods for pointing to important aspects of the future. For example, we could have used *Key Success Factors* (KSF)[353] to describe which assets and competences the future situation would require from the organization. In our view, the KSF concept is useful when connecting an organization's own capabilities to general technological development and changing consumer demands. However, we see this as a natural continuation of analyses done with the FUTSTEPS method. Once the scenarios are known, the appropriate KSF:s for them may be found and then compared to the organization's capabilities. Thus, the construction of scenarios remains a better way for the presentation of the empirical findings.

Scenarios aim to visualize complex situations and spur people's imagination. This was also the aim of the case study, since it is impossible to really know what is going to happen in the future. However, having at least thought about and pictured to oneself what may happen can help individuals and organizations to increase awareness and preparedness. One dangerous aspect of this process is that humans tend to look for the most likely alternative, discarding the rest as improbable to ever occur. We tried to address this problem by not assigning any personal views on the scenarios. Additionally, we avoided attaching probabilities to them, which, apart from being very difficult, also implies that there are more likely "middle paths" to the future. On the contrary, we believe that the world is full of surprises that are impossible to predict or even intuitively think of.

7.3 The FUTSTEPS method

In this thesis we presented and then applied a comprehensive and logical method, based on scenario analysis, to structure our empirical findings and the following analysis. By developing the FUTSTEPS method we fulfilled our purpose to create a method for analysis of future developments in issues regarding technology and society in interaction. Since the study was limited to describing, analyzing, and presenting possible futures for technology and society, it did not treat the question about which strategies suit the future scenarios. Instead, the method is to be seen as a

[353] See for example Grant (2005), p. 92

guide and a checklist in creating a comprehensive background material for strategic decisions.

Since we used an iterative process in the study, there is a risk that the developed FUTSTEPS method was influenced by the system we investigated, i.e. the Russian fuel market. However, we believe this risk to be minimal, as our method has a very broad approach inspired by the quite universal socio-technical systems theory. Moreover, the MICMAC analysis enhances the credibility of the factors identified, regardless of which system is investigated.

It is important to note that despite the fact that MICMAC analysis is a quantitative method, the other steps in the FUTSTEPS method build on intuitive reasoning. This is largely unavoidable since quantitative information requires some kind of informed evaluation. Also, a fully quantitative treatment of data would demand a complete quantitative model of the investigated system, which would inevitably contain simplifications. Through treating quantitative data in the FUTSTEPS method's structured logic, and using the quantitative MICMAC analysis to increase rigour in the crucial selection of key factors, we feel that overall credibility is increased in comparison to entirely intuitive methods.

In light of what is described above, we believe that the FUTSTEPS method is a more rigorous way of constructing scenarios and depicting the future of issues regarding technology and society than any of the existing alternatives. However, we are aware that no method can ever entirely capture reality. Hence, the purpose of using our FUTSTEPS method is to get as close as possible when investigating technology and society in interaction. Having gone through all the method's steps, the researcher will in any case be better prepared for what the future may bring. We would also like to stress that it is possible to apply only parts of the FUTSTEPS method. For persons or organizations only interested in finding the key factors in a system, it is possible to stop after step 4, i.e. after the MICMAC analysis.

7.4 Choice of case study

As the Russian society has in the last two decades developed towards a more modern society in the Western sense of the word, future developments have become even harder to analyze given the new and fast exchange of ideas, information, and innovations in the world. In order to apply and test the developed FUTSTEPS method in this complex environment, a case study was performed, in which the future of the Russian fuel market was analysed. The main practical contribution of the case study was that it highlighted the most important stakeholders and macro factors, which will be necessary for companies to keep an eye on in order to anticipate the developments on the Russian fuel market.

As part of the case study, we also selected four fuels that were deemed to be the most important contenders in Russia in a 20-year perspective. The choice was made mostly on basis of information obtained from Scania, but with important input from other sources. From this arises the question whether there would have been another set of fuels were the sponsor any other stakeholder. We believe that we would have selected exactly the same fuels in such a case. The reason is that the longer the study lasted, the more we through finding additional material realized that these are four major future alternatives. The only contending fuel not to be included in the study, was B-fuels, i.e. what is often referred to as biodiesel. There is some information about it available, but the amount of attention it receives in Russia, as well as the potential it is generally perceived to have, are considerably lower than ethanol and DME, respectively.

It is important to keep in mind that the underlying question was originally Scania's: What is to expect in terms of fuel on the Russian market in 20 years from now? However, we believe that regardless of the study's sponsor and initiator; whether it might have been Scania or any other stakeholder; the question would have received the same answer. Therefore, the case study should be of interest not only to Scania, but also to anyone interested in the future fuel market in Russia.

To further increase the reader's confidence in the FUTSTEPS method, additional case studies are needed. Therefore, we believe it is of interest to test the method on other issues than the future of fuel in Russia, preferably on behalf of other companies or organizations and in a different context in terms of technology and society.

7.5 Suggestions for improvement and further studies

Depending on the context, and the system to be analyzed, it might be of value to add other suiting sub-theories to the framework. These sub-theories would allow for increased understanding and, possibly, easier analysis of the particular subject at hand. In the future, it may also turn out that other elements affecting technology and society may become important, thus creating a need for complementing the FUTSTEPS method.

One major improvement to the FUTSTEPS method would be to add a sensitivity analysis. For example, key factors could be identified with account taken to all, only weak, and only strong interrelationships, respectively. This would allow for an assessment of the impact of only concentrating of the clearest cases of factors' direct interdependency in comparison with more elusive relationships. For us, this was unfortunately beyond the scope of the study.

Another improvement would be to compare the results of the key factor selection with the results obtained from a workshop with a focus group. If a group of experts on the subject would reach the same conclusions this would be a confirmation of the work done. However, this could also be a sign that their preconceived ideas may have been passed on to the investigating party during their study. Differing views on the other hand, would lead to very interesting discussions and allow for new thoughts on explanations. We therefore conclude that a parallel focus group would in any case increase the quality of a study conducted with the FUTSTEPS method.

Lastly, a follow-up system of some kind would be useful to further check the results received in the method. This would increase the value of the FUTSTEPS method, since results checked in retrospect create great opportunities for improvement. However, one of the most important parts of performing an analysis, such as the one specified in this thesis, is that the process itself provides “food for thought” and thus a greater understanding for the challenges for the future. Thereby, the work itself has a considerable value to the organization no matter the final accuracy of the results.

8 Conclusion

In this final chapter, the conclusions drawn from both the work on the theoretical framework and the case study are presented in a short and concise form. The chapter ends with a section where the authors in light of the findings from the case study put forward their recommendations for Scania.

8.1 Theoretical contribution

In this study, we have presented the FUTSTEPS method, which was especially created for structured analysis of issues regarding technology and society in interaction. The method allows for a step-by-step description, analysis, and presentation of what the future may bring. It helps in finding the most important factors determining the future course of a certain issue regarding technology and society and reduces the perceived complexity of the investigated system.

The theoretical framework behind the method connects theory about socio-technical systems with ideas taken from scenario-based futures techniques. Through this unique connection between content and presentation, a powerful way to find and structure empirical data, analyze complex and seemingly illusive indirect and feedback interrelationships, and present the findings in a vivid manner, has been created. When needed, other useful theories, models, and hypotheses were also added to certain aspects of the socio-technical theory framework. This was done to increase understanding of certain issues, as well as increase the depth of the analysis.

In comparison with existing scenario-based techniques, the FUTSTEPS method constitutes a more formalized and theoretically structured way of constructing scenarios involving technology and society. Through combining intuitive and qualitative thinking with the non-intuitive and quantitative MICMAC analysis, the human mind's difficulties with perceiving complex feedback relationships are overcome. From original empirical data input, the method in each step creates output, which is used as input in the next step (figure 18).

Earlier proposed methods[354] are mainly concerned with how the scenarios should be constructed, not with what they should contain, i.e. which specific areas they should cover. We found that in order to create meaningful descriptions of possible futures involving technology and society, we needed to determine what was important to investigate in such a case. Therefore, the search guidelines that were found in socio-technical systems theory were vital to our work. The FUTSTEPS method is hence a framework for dealing with this type of questions without wasting energy on aspects that are unimportant for the credibility of scenarios depicting the development of technology and society.

[354] See for example Godet (1986), O'Brien (2004), or Schoemaker (1995)

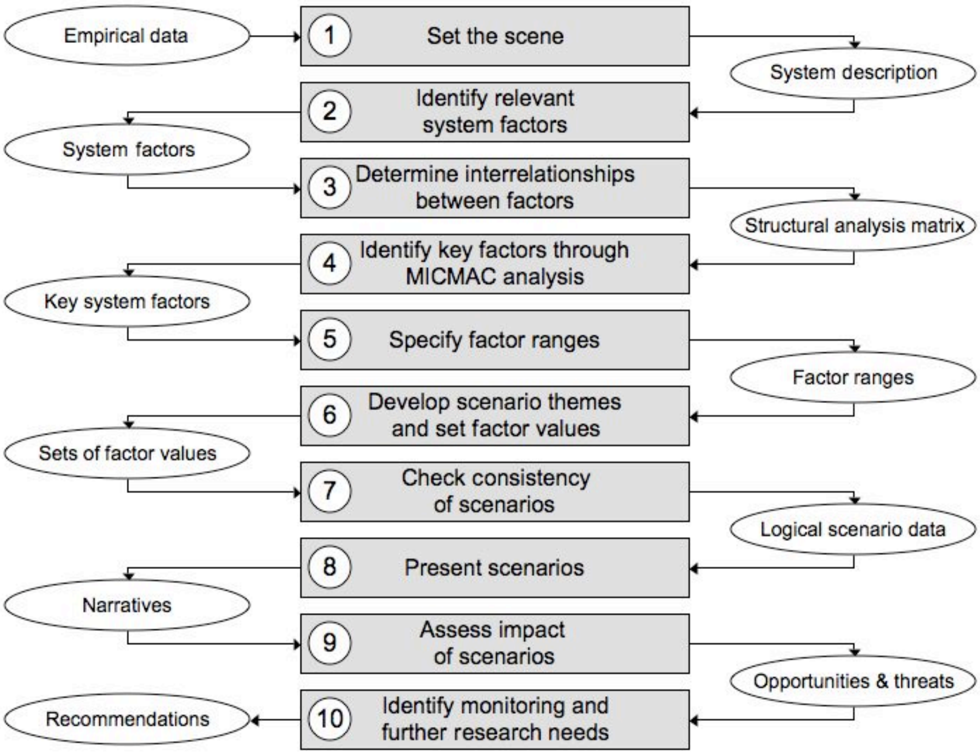

Figure 18 – The ten steps of the FUTSTEPS method. Output from one step serves as input to the next.

After having been developed, the FUTSTEPS method was applied to the case of the Russian fuel market. It may however be applied to any situation involving questions about technology, which develops in the context of society. For example, the method may be used to investigate issues as disparate as the future of wind power in Western countries, the electric car's chances of success in China, or the use of mobile Internet in Africa. Generally, questions that are perceived as complex, a bit "fuzzy", and involving many parties, are the best objects to examine with the help of the FUTSTEPS method.

8.2 The Russian fuel market

The case study of the Russian fuel market showed that the most important truck and bus fuels to consider for the future are CNG, diesel, DME, and E-fuels.

CNG is mainly put forward as a vehicle fuel by Gazprom, which continuously seeks new uses for Russia's vast natural gas reserves. There are currently around 70,000 gas-powered vehicles in the country, which are served by 218 filling stations. The main driver for increased use is that the price of one cubic metre of CNG is limited to 50 percent of the price of low-grade petrol. The Winter Olympics in Sochi in 2014 may become a showcase for a CNG-based transport system.

Diesel is the incumbent heavy-vehicle fuel in Russia. Quality is generally lower than in the EU, but low-sulphur diesel (Euro IV and V) is available in international corridors along major transport routes. The 28 major Russian refineries are generally 40-60 years old and in need of heavy investments. Euro III quality diesel will be standard on the market from 2009, Euro IV from 2010, and Euro V from 2014.

The main driver behind the use of DME in Russia is that there are "stranded" natural gas fields scattered across Siberia. To get the gas to markets, it needs to be liquefied into, for example, DME. China and Japan are the main export markets with the former growing exponentially. Russian companies are involved in cooperation with Chinese and Japanese authorities and companies in order to create large-scale production in Eastern Siberia. There is a small infrastructure in Moscow, which also has conducted trials with DME-powered trucks.

The development of E-fuels in Russia is mainly an economical and agricultural question. There is a sincere interest on the highest political level, which is mainly due to a perception of economic possibilities on export markets. Recently, the Prime Minister announced the building of 30 new production plants. In Russia, petrol may contain up to 10 percent ethanol according to regulation. The main obstacle against increased use is the tax of 26 rubles per litre ethanol, which is due to fuel ethanol being regulated by the same law as ethanol for human consumption.

8.2.1 Scenario learnings

Our analysis shows that the adoption of the respective fuels depends mainly on stakeholders and macro factors. Below, the top-line findings from the scenario creation process are presented. For more information about which developments are connected with what fuels, we refer to the full text in the case study.

Increased use of CNG is associated with strong connections between politicians, Gazprom, and the automotive industry, creating a politically motivated process towards large-scale use of gas as motor fuel. Another prerequisite is that there must be an abundance of cheap natural gas available on the market.

Use of low-quality diesel is generally associated with low levels of economic activity and international trade. Also, there is a strong connection to Russian protectionism. A low oil price also points to increased use of low-grade diesel.

Large-scale adoption of DME as a motor fuel is closely connected to an increased economic focus on Asia. It is also associated with a more liberal economy where companies' efforts to evade Gazprom's transport network monopoly and find markets for stranded gas are allowed.

An increase in the use of E-fuels in Russia is mainly the result of an increased focus on trade and cooperation with the European Union. Increased economic prosperity and higher standard of living create an increased concern for the environment, which changes consumers' fuel preferences.

8.2.2 Factors determining the future of the Russian fuel market

The case study showed that the most important factors determining the future of the Russian fuel market, ranked according to power to influence, are:

The European Union
The European Union is Russia's largest trading partner. Its policy decisions affect the Russian fuel market both directly through demands on trucks entering the union and indirectly through international agreements, research etc.

Asian countries
Asia is an important trading partner for both export and import. Demand from Asian markets affect the production of fuels in Russia.

Protectionism
Protectionism affects the fuel market both directly through restrictions on export and import, and indirectly through effects on investments.

Export opportunities
Export opportunities for a fuel affect Russian decisions to build production capacity.

Oil price
Oil exports drive the Russian economy. Higher oil prices mean that the country gets richer and that the economy expands. Lower prices create numerous negative effects.

Other commodity prices
The prices of other commodities affect the Russian economy significantly since the country has large commodity exports. Also, if the commodities, such as wood or crops, are feedstocks for fuel, fuel prices are affected.

Focus on commodities or value-added goods
Russia today mainly exports unprocessed commodities. A greater focus on value-added goods would have great consequences for investments and the structure of the economy.

International cooperation
Russia's perception of its role in the international community affects trade, foreign investments, as well as its alignment with other economies in terms of technical standards.

Concern about the global environment
Increased concern about the global environment enables a wider view of large-scale policy or micro purchasing decisions. The connections to other people on Earth stand clearer and require consideration.

The President
The President holds considerable power in all aspects of Russian politics. His policies and views have considerable impact on other politicians, the public, and markets, including the fuel market.

General economic policy
The general economic policy may be inspired by liberal ideas or by a wish for more state control. This affects all sectors of the economy and ultimately also which fuels are available on the market.

Trade with the EU
The EU is Russia's most important trading partner. The more trade, the more there is a need to increase cooperation and align technical standards.

The oil industry
The oil industry is a cornerstone of the Russian economy and is an integral part of the current fuel system. Its actions and investment decisions will heavily affect the developments on the fuel market.

The automotive industry
The automotive industry is an important part of the Russian economy and labour market. It is affected by all decisions concerning fuels and is therefore a clear stakeholder on the fuel market.

Gazprom
Gazprom is a very powerful entity in the Russian society. It has close ties to the political establishment and has the power to influence the developments on the fuel market.

8.3 Recommendations for Scania

On basis of the study's findings about the most important factors on the Russian fuel market, we recommend the following:

8.3.1 Scania should carefully monitor…

The European Union and trade with the EU
The more trade there is between the EU and Russia, the more interdependent they will be in terms of fuel. Scania should therefore watch the level of trade between the EU and Russia and the general fuel development in the EU.

Asian countries
The development of Asian fuel markets, especially in China, may be crucial for Russia's fuel choices. Scania should therefore closely watch the Chinese fuel policy and consequent fuel sourcing decisions.

The President
The Russian President's decisions will heavily affect the fuel market. Scania should therefore monitor his policy decisions and public statements in order to get a better understanding of the government's priorities in the sector.

The automotive industry
To achieve an advanced fuel market, the Russian automotive industry must also be advanced. In order for this to happen in the foreseeable future, foreign companies must become more involved. Scania should therefore monitor the level of foreign involvement in the automotive industry.

Gazprom
Gazprom's investment programs, public announcements, actions against other companies, and possible energy sector problems, will all give signals of where CNG and DME are heading. Scania should therefore monitor Gazprom's relations to the government and its publicly announced investment priorities.

8.3.2 Scania should conduct further research on…

The relationship between industry and policy makers
The relationships between industries that are significant for the fuel market and policy makers are not transparent. Scania should therefore build deeper knowledge about the existing connections between businesses and politicians. This will help Scania in determining which messages from the market are to be taken seriously and which can be disregarded.

The automotive industry's future structure
The automotive industry is closely connected to the developments on the fuel market. Scania should therefore try to find out whether the industry will be liberalized or the object of more involvement by the government. Besides giving a deeper knowledge about the expected technological level of the market, this research will also give valuable information on possible competitor moves.

Gazprom and natural gas reserves
Gazprom is a very large and complex company consisting of multiple departments and branches, which send out mixed signals regarding use of natural gas as a motor fuel. Scania should therefore make its own judgment on whether there will be a gas shortage, as the experts predict, or whether Gazprom's strive to find new uses for natural gas are realistic from a production point of view. Scania will thereby be prepared if CNG is launched as fuel on a large scale.

Plans for ethanol production
The recently announced plans for construction of ethanol plants marks a radical shift in the Russian fuel industry. Scania should therefore research whether there is any sincere political support for them, or if the public announcement was more of a testing balloon. At the same time, a judgement should be made on the prospects of private initiatives. Scania will thereby be better prepared for a large-scale introduction of ethanol as a motor fuel.

Large city transport plans

The largest cities in Russia play an important role as vanguards for new transport solutions. Scania should therefore contact their administrations to hear their thoughts on urban transport solutions and traffic pollution. By knowing the cities' preferences and thoughts on the future, Scania will be better prepared for an introduction of new fuels.

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APPENDICES

Appendix I: Screening questionnaire template

Fuel:

Aspect		Question
Technology	1.	Is it physically possible to use the fuel to power a heavy truck?
	2.	Is it physically possible to use the fuel to power a bus?
	3.	Is it possible to use already existing engine technology?
		i) If new technology is needed, will it likely be well known and widely available in 20 years?
	4.	Is the fuel generally seen as a viable alternative in terms of handling, environmental dangers and safety?
Production potential	5.	Is the estimated global production potential substantial[355] in a 20-year perspective?
	6.	Is the estimated production potential in Russia substantial in a 20-year perspective?
Infrastructure	7.	Is there existing infrastructure for distribution in Russia or is new infrastructure required?
Research and general interest	8.	Is there any research on the fuel in Russia?
	9.	Is there a visible domestic political interest for the fuel?
	10.	Are there any domestic interest groups lobbying for the fuel?

[355] Approximately 10 % of all fuel usage in transport sector.

Appendix II: Fuel production methods

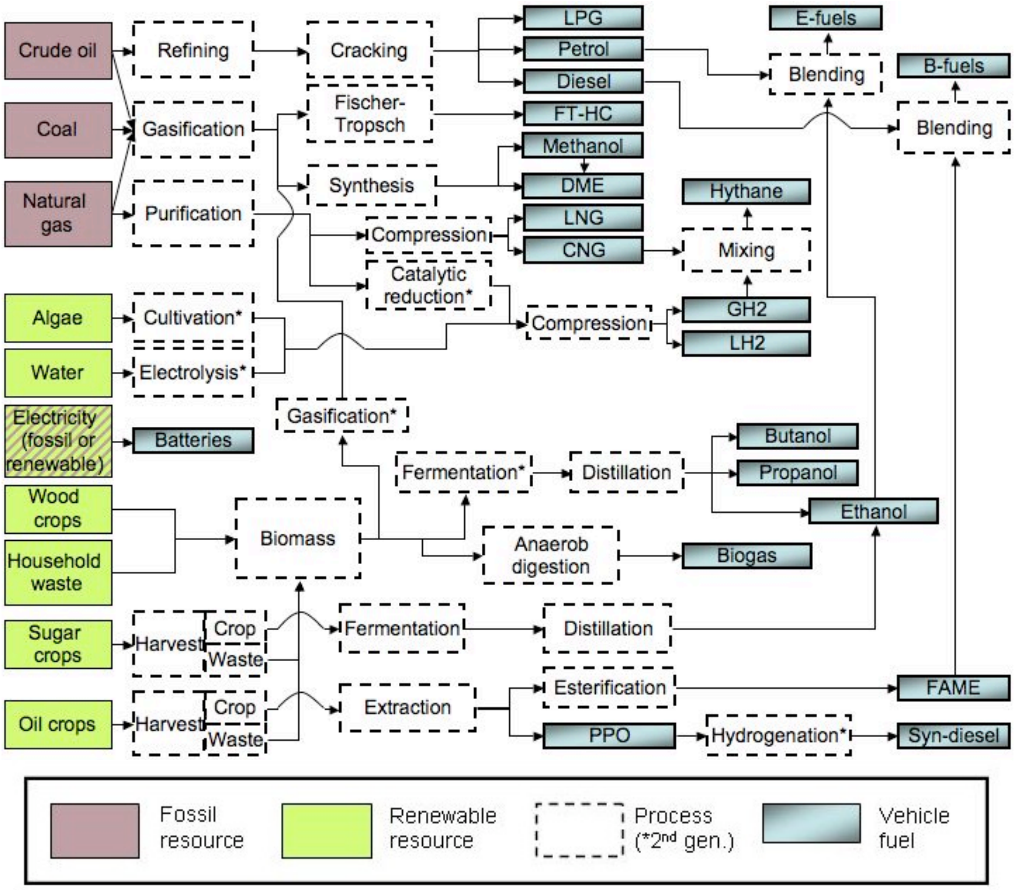

Figure II:1 – Overview over feedstocks, processes, and final products in the production of fuels included in the initial screening.[356]

[356] Modified from Daniels (2008), p. 16 and Holmborn & Kleinschek (2008), p. 10. Also, some process information was collected from Olah et al. (2007), pp. 213, 241-279 and Larson (2007), pp. 16, 23

Appendix III: Descriptions of system factors

Technology and infrastructure

1. Production capacity
In order to serve the Russian market, there must be enough fuel production capacity. The capacity is, among others, dependent of the availability of feedstock and investments in equipment such as refineries.

2. Transport and handling infrastructure
A proper transport infrastructure is a prerequisite for the use of any fuel. Lack of infrastructure means that heavy investments need to be made, whereas existing infrastructure consists of sunk investments that are not easily abandoned. If capital and technology is available for building a new infrastructure, or if it is possible to use existing infrastructure, it is easier to switch to alternative fuels.

3. Vehicle fleet
The status of the vehicle fleet affects the demand for fuel. Newer vehicles generally require better-quality fuel. Vehicles that run on other than conventional fuels increase the demand on alternative fuels. Thus, the more and the faster the car fleet is modernized, the faster is the development towards cleaner fuels.

Stakeholders

4. Asian countries
Asia is an important trading partner for both export and import. If a fuel is in growing demand on the Asian market, e.g. in China, there are incentives for Russia to start producing it at a large scale. Domestic production for export may eventually also lead to domestic use.

5. The automotive industry
The automotive industry is an important part of the Russian economy and labour market. Fuel regulations and associated technological questions directly affect the competitiveness of the domestic automotive industry, which may create political pressure to change regulations.

6. Control authorities
Without functioning control authorities it is hard to implement a homogeneous and trustworthy fuel standard. Thereby the development towards cleaner fuels may be affected by the control system configuration.

7. The European Union
The European Union is Russia’s largest trading partner. It is also progressive in terms of fuel standards and the implementation of biofuels, which affects Russia both directly by demands on Russian vehicles that traffic Europe and indirectly by driving a general development towards cleaner and more advanced vehicles.

8. Gazprom
Gazprom is a very powerful entity in the Russian society. It has close ties to the political establishment and has the power to influence the developments on the fuel market.

9. Interest groups
Interest groups try to market a specific fuel or group of fuels. They do this by addressing politicians and the public.

10. Media
The media have the power to influence problem agendas in society. Also, they may affect the public opinion by informing about the benefits of new fuels, the importance of environmental consciousness etc.

11. Moscow and St. Petersburg
Moscow and St. Petersburg are two megalopolises whose policies and examples set the agenda for other cities and regions in Russia and the world. They have the financial and intellectual capital to be important players in fuel market developments.

12. The President
The President holds considerable power in all aspects of Russian politics. His policies and views have considerable impact on other politicians, the public, the business community, as well as on other countries and international organizations.

13. The oil industry
The oil industry is a cornerstone of the Russian economy and is an integral part of the current fuel system. Its actions will heavily affect the developments on the fuel market.

14. Other politicians
Other politicians than the president may launch individual initiatives or drive certain questions, for example about fuels. They may be representatives at local, regional or federal level.

15. Universities and research institutions
Universities and research institutions set the academic agenda. Thereby they influence the knowledge base about fuels and also the problem agenda surrounding them, such as global warming.

16. Strategic alliances among vehicle manufacturers
Vehicle manufacturers may come together in alliances to propose a certain technical solution or technology. This may happen also in the fuel market, where a powerful coalition possibly could drive through an implementation of a particular fuel system.

Societal rules

Regulative rules

17. Fuel taxes
Fuel taxes regulate the price of fuels relative to each other. This creates economic driver effects since users are more likely to select the cheapest fuel.

18. Federal emission and fuel quality regulation
Federal emission and fuel quality regulation creates nationwide standards for vehicles and fuels. To decrease total emissions it is necessary to have better fuel. The regulations create minimum rules surrounding the usage and quality of fuels in all parts of the country.

19. Local emission and fuel quality regulation
Local emission and fuel quality regulation creates city standards for vehicles and fuels. To decrease local pollution better fuel and vehicles are needed. The regulation is always more ambitious than the federal minimum levels.

Normative rules

20. Companies' desired image
Fuel-producing companies may wish to be perceived as, for example, being technological market leaders, socially progressive, or environmentally friendly. This affects their choices of fuels to promote and the investments they make.

21. Investment willingness
Long-term solutions and business decisions require a stable economic and political climate. If the risk level is perceived as being too high, large investments are disfavoured. This also affects the will to pursue investments in new fuel solutions.

22. Relationship between government and companies
The government and companies may be entirely separate entities, or there may be close ties between them. Close ties mean that the will of the government are reflected in the policies of companies, while it may also lead to sub-optimized decision-making and ineffective operations. This is valid also for the fuel industry.

23. Corruption
Corruption makes the society ineffective. It means there are problems in the enforcement of laws and regulation. Additionally, corruption lowers people's confidence in authorities and institutions and negatively affects the investment climate.

24. Law-abidingness
If there is little trust in laws and regulations, or if there are no credible sanctions associated with them, law-abidingness is affected. Fuel regulation may be difficult to implement if no-one adhers to it.

25. Material vs. immaterial values
People may be oriented towards fulfilling their wishes in terms of material possessions, or they may prioritize immaterial aspects of life. Either the focus is on pure consumption or on other ways of achieving happiness.

Cognitive rules

26. Food vs. fuel debate
The food vs. fuel debate is present also in Russia. A public perception that an increase in use of certain fuels might mean higher food prices may affect fuel choice on a larger scale.

27. Vehicle performance preferences
Different vehicles exhibit different performance characteristics. The user may prefer big cars with strong engines or smaller cars with excellent environmental performance. The choice of car thereby directly affects the choice of fuel.

28. Life-cycle cost consciousness
A cheap vehicle may be more expensive in the long run than an expensive, depending on, for example, service and fuel costs. If there is consciousness about the real costs of investments among companies and consumers, this will affect which purchasing decisions are being made.

29. Status symbols
Status symbols are artefacts that display the owner's high social standing. This may be a large car, an environmentally friendly house, or expensive jewellery. The societal status symbols affect people's desires and purchasing decisions.

Macro landscape

30. Concern about the global environment
Increased global environmental consciousness enables a wider view of large-scale policy or micro purchasing decisions. The connections to other people on Earth stand clearer and require consideration.

31. Concern about the local environment
An increased focus on local environmental issues among the public and authorities may lead to stricter regulation of pollution from transport. Stricter regulation means higher demands on fuels.

32. Economic difference between cities and regions
Moscow, St. Petersburg and a few other regional capitals are in an economic class of their own. Per capita incomes differ widely. This creates a gap in terms of standard of living, investments, and implementation of new technology.

33. Education
The Russian educational system creates students with a certain problem agenda programmed. The nature of the agenda affects the behaviour of these students when they later work in the public or private sector.

34. Export opportunities
Other countries may experience changes on the fuel market earlier than Russia. This may open up export opportunities, which affect production investments and consequently the domestic fuel market.

35. Focus on commodities or value-added goods
Russia mainly exports unprocessed commodities. A greater focus on value-added goods would have great consequences for investments and the structure of the economy.

36. Food prices
Food prices are affected by a number of factors, such as oil prices. They are a sensitive issue in Russia, which affect among others the view on biofuels.

37. Fuel prices
Fuel prices are driven by available production capacity and feedstock price, as well as demand for the fuel in question. High prices for one fuel mean that other fuels get relatively more attractive.

38. General economic policy
The general economic policy may be inspired by liberal ideas or by a wish for more state control. This affects all sectors of the economy and ultimately also which fuels are on the market.

39. Global warming
If global warming leads to visible and clear effects this may have profound repercussions. On one hand, it may lead to increased environmental consciousness, on the other, it may affect feedstock availability in terms of agricultural potential.

40. GNP growth
GNP growth signals that the economy is expanding and that the country's wellbeing is increasing. This in turn means people get more money, which they can use to buy new goods such as cars. New cars mean new demands on fuel quality.

41. Health consciousness
Health questions are important for both people and government. An increased focus on the health aspects of fuels may lead to a development towards cleaner fuels and vehicles.

42. Industry investments
Industry investments are necessary to keep production and infrastructure running. The perceived risk level, wanted return on investments, and interest rates, affect the willingness to invest.

43. Inflation
High inflation damages the business climate. Therefore, an inflation under control is preferred in order to create favourable conditions for investments.

44. Interest rates
High interest rates make it more difficult to find attractive long-term investments, which may lead to shortsightedness in business decisions.

45. International cooperation
Russia is one of the great powers in the world. Its perception of its role in the international community affects trade, foreign investments, as well as its alignment with other economies in terms of technical standards.

46. National security policy
National security policy may affect the choice of fuels. An alternative may be seen as worse in terms of supply security than another.

47. Oil prices
Oil exports drive the Russian economy. Higher oil prices mean that the country gets richer and that the economy expands. Lower prices create numerous negative effects.

48. Other commodity prices
The prices of other commodities affect the Russian economy significantly since the country has large commodity exports. Also, if the commodities, such as wood or crops, are feedstock for fuel, fuel prices are affected.

49. Political freedom
Political freedom is important to create room for new ideas in the society. In a climate where the government's view is the only view, ideas that may profoundly change parts of the society may never reach the surface for debate.

50. Protectionism
A protectionist market policy means that foreign direct investment and development of new technologies likely decreases. Also, for example domestic vehicle manufacturers with inferior engine technology are protected. This affects the choice of fuel on the market.

51. Standard of living
The standard of living is a measure of how good or bad the situation is for people in a country. The standard of living generally increases when the economy expands and more jobs are created so people can earn an income. A good standard of living allows for appreciation of other aspects of life than the purely material.

52. Strategic industries
Strategic industries, as declared by the government, are protected from being owned by foreign companies. This puts limits on investments and may lead to sub-optimization of Russian companies' performance.

53. Technology transfer from large cities to regions
Within Russia, Moscow and St. Petersburg are in the forefront of adapting to advanced international city standards. This means that they are early adopters of new technology in Russia. It therefore is important with diffusion of technology from them to other, less developed parts of the country.

54. Technology transfer from Western countries
Much of the technology in the alternative fuels sector has its origin in Western countries. This means that it is important that the technology is transferred to Russia if the country is to catch up in this area.

55. Trade with the EU
The EU is Russia's most important trading partner. The more trade, the more there is a need to align technical standards between the two entities. A concrete example is that Russian trucks that transport goods to Europe must adhere to European emission standards. Therefore, they also need European-quality fuel.

56. Transport volume
Economic development generally means more transports. An increased transport volume creates a need for more trucks, which speeds up modernization of the fleet. This in turn creates an increased need for cleaner fuels.

57. WTO entrance
Russian entrance into the WTO creates new trading rules and limits the government's possibilities to protect its industry. It may also increase Russia's trade with other nations.

Innovation phenomena

58. 2nd generation production processes
The breakthrough of 2nd generation fuel production processes would mean that the alternatives to conventional fuels would become cheaper. For Russia, it would also mean that that there would be a big opportunity to increase the use of its vast natural resources, e.g. forests.

59. Experimental fuel and vehicle projects
Small-scale projects mean that there are learning opportunities for new fuel technologies. In a Russian context, this means that important knowledge is gathered, which later can be used in full-scale implementation.

60. Strategic investment programmes
Strategic investment programmes create opportunities for novel fuel technologies to develop without having to perform economically. Also, expressed support from companies or the government helps to gain acceptance for the new technology.

Appendix IV: The structural analysis matrix

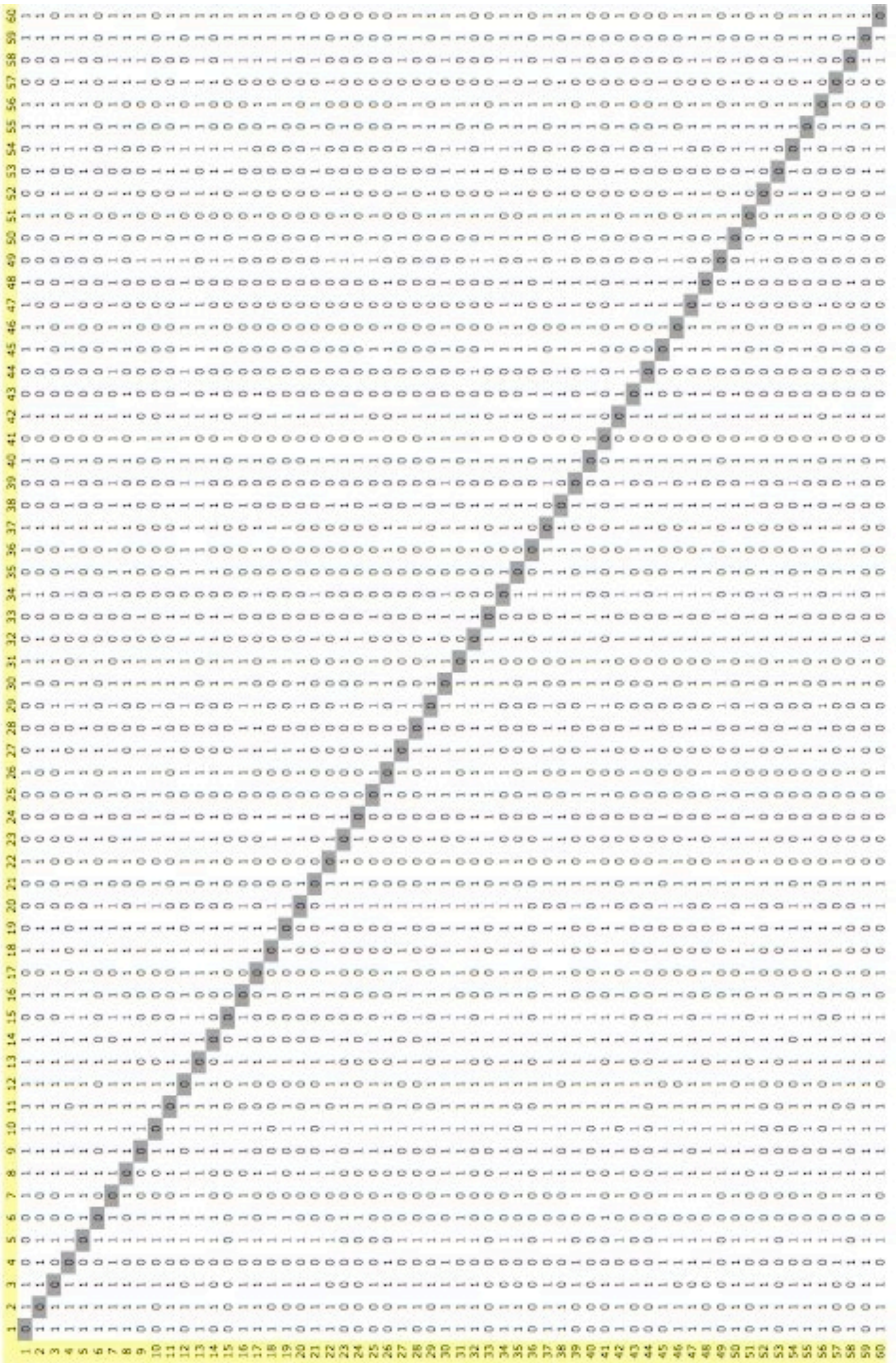

Figure IV:1 – The structural analysis matrix for the Russian fuel market. Relationships are marked with 1 (relation) or 0 (no relation). Read from a landscape view.

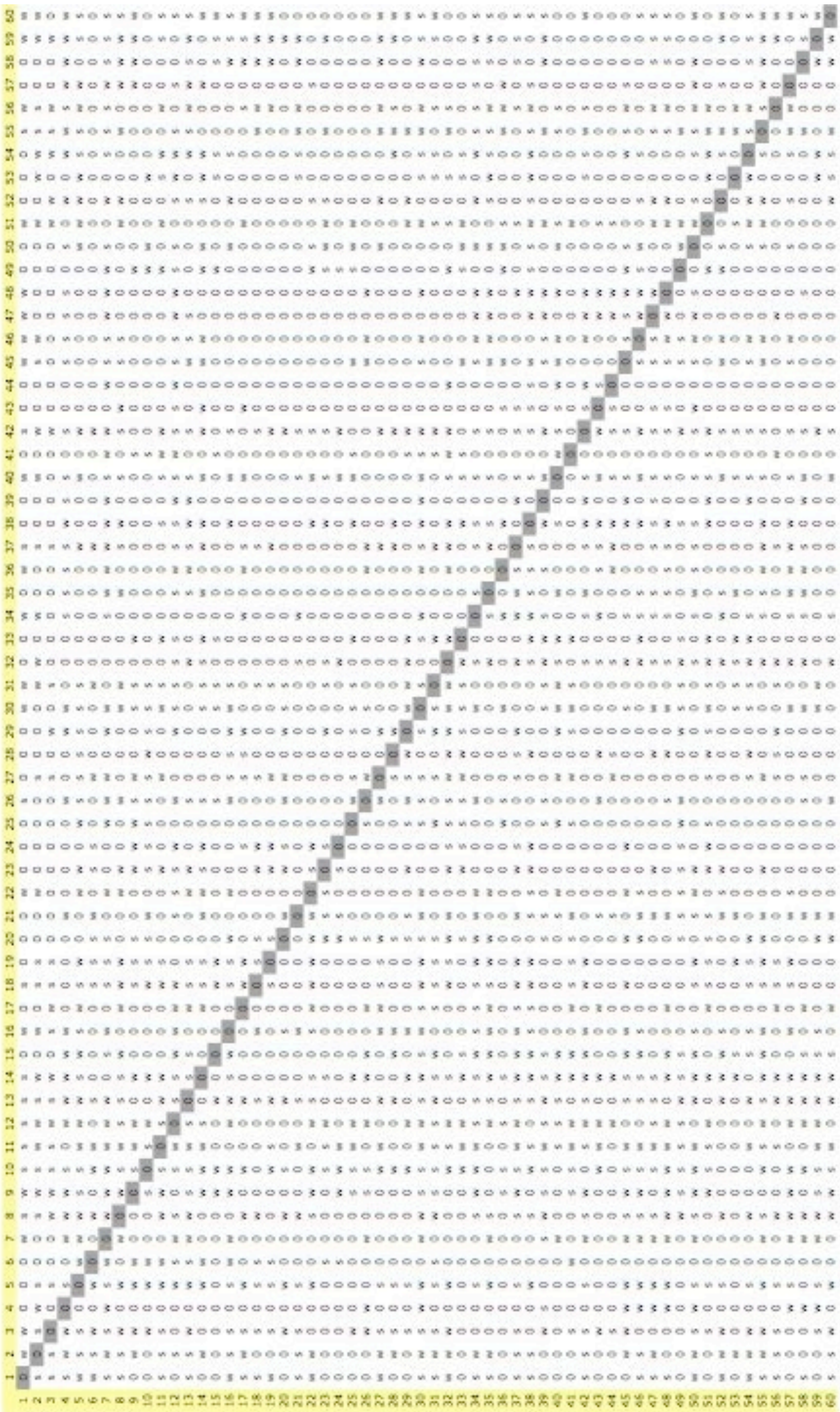

Figure IV:2 – The structural analysis matrix for the Russian fuel market. Relationships are marked as S (strong), W (weak), or 0 (no relation). Read from a landscape view.

Appendix V: Scenario consistency check

Table V:1 – The key factors included in the matrices below.

Depiction	*Factor*
A	The European Union
B	Asian countries
C	Protectionism
D	Export opportunities
E	Oil price
F	Other commodity prices
G	Focus on commodities or value-added goods
H	International cooperation
I	Concern about the global environment
J	The President
K	Trade with the EU
L	General economic policy
M	The oil industry
N	The automotive industry
O	Gazprom

Table V:2 – The consistency matrix for the Centralized CNG society scenario.

Centralized CNG society

No.	A low	B med.	C high	D low	E high	F high	G low	H med.	I med.	J med.	K med.	L low	M med.	N med.	O high
A low			ok	ok				ok			ok			ok	
B med.			ok	ok	ok	ok	ok	ok						ok	
C high				ok		ok		ok			ok	ok		ok	ok
D low							ok	ok		ok	ok	ok	ok	ok	ok
E high				ok			ok	ok		ok	ok	ok	ok		ok
F high				ok			ok	ok			ok				
G low				ok							ok	ok	ok		ok
H med.			ok	ok	ok				ok		ok		ok		ok
I med.								ok					ok		
J med.			ok				ok	ok	ok		ok	ok	ok		ok
K med.			ok	ok			ok						ok		ok
L low			ok				ok				ok		ok		ok
M med.					ok		ok			ok	ok				
N med.									ok		ok				
O high								ok		ok			ok		

Table V:3– The consistency matrix for the Dirty diesel depression scenario.

Dirty diesel depression

No.	A low	B low	C high	D low	E low	F med.	G low	H low	I low	J low	K low	L med.	M low	N low	O high
A low			ok	ok				ok			ok			ok	
B low			ok	ok	ok	ok	ok	ok						ok	
C high				ok		ok		ok			ok	ok		ok	ok
D low							ok	ok		ok	ok	ok	ok	ok	ok
E low				ok			ok	ok		ok	ok	ok	ok		ok
F med.				ok			ok	ok			ok				
G low				ok							ok	ok	ok		ok
H low			ok	ok	ok				ok		ok		ok		ok
I low								ok					ok		
J low			ok				ok	ok	ok		ok	ok	ok		ok
K low			ok	ok			ok						ok		ok
L med.			ok				ok				ok		ok		ok
M low					ok		ok			ok	ok				
N low									ok		ok				
O high								ok		ok			ok		

Table V:4 - The consistency matrix for the DME dragon days scenario.

DME dragon days

No.	A med.	B high	C low	D high	E high	F med.	G high	H high	I med.	J high	K high	L high	M high	N high	O low
A med.			ok	ok				ok			ok			ok	
B high			ok	ok	ok	ok	ok	ok						ok	
C low				ok		ok		ok			ok	ok		ok	ok
D high							ok	ok		ok	ok	ok	ok	ok	ok
E high				ok			ok	ok		ok	ok	ok	ok		ok
F med.				ok			ok	ok			ok				
G high				ok							ok	ok	ok		ok
H high			ok	ok	ok				ok		ok		ok		ok
I med.								ok					ok		
J high			ok				ok	ok	ok		ok	ok	ok		ok
K high			ok	ok			ok						ok		ok
L high			ok				ok				ok		ok		ok
M high					ok		ok			ok	ok				
N high									ok		ok				
O low								ok		ok			ok		

Table V:5 – The consistency matrix for the European E-fuels era scenario.

European E-fuels era

No.	A high	B med.	C low	D high	E high	F med.	G high	H high	I med.	J high	K high	L high	M high	N high	O low
A high			ok	ok				ok			ok			ok	
B med.			ok	ok	ok	ok	ok	ok						ok	
C low				ok		ok		ok			ok	ok		ok	ok
D high							ok	ok		ok	ok	ok	ok	ok	ok
E high				ok			ok	ok		ok	ok	ok	ok		ok
F med.				ok			ok	ok			ok				
G high				ok							ok	ok	ok		ok
H high			ok	ok	ok				ok		ok		ok		ok
I med.								ok					ok		
J high			ok				ok	ok	ok		ok	ok	ok		ok
K high			ok	ok			ok						ok		ok
L high			ok				ok				ok		ok		ok
M high					ok		ok			ok	ok				
N high									ok		ok				
O low								ok		ok			ok		