Tackling Wicked Problems: The Development of a New Decision-Making Tool, Applied to the Estonian Oil Shale Conundrum

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<th>Abbreviation</th>
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<tr>
<td>AHP</td>
<td>Analytic Hierarchy Process</td>
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<td>EPA</td>
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<td>GDP</td>
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<td>MCA</td>
<td>Multi-Criteria Analysis</td>
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<td>STORM</td>
<td>Stakeholder analysis Through Outcome Rating Matrices</td>
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<td>UN</td>
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<td>USSR</td>
<td>Union of Soviet Socialist Republics</td>
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Wicked problems are a special subset of particularly complex issues that current problem-solving tools fail to fully address. Because of this deficiency, a new tool for evaluating and resolving wicked problems must be developed. Theories such as anti-positivism and systems thinking are explored in order to understand the nature of wicked problems, which are often defined by the involvement of multiple stakeholders as well as non-linear interrelations between various elements of the problem. Although traditional problem-solving methods are inadequate for wicked problems, there are certain tools that are more appropriate for handling such problems. These tools include the analytic hierarchy process, positional analysis, mess maps and heat maps. With their organized structures, visual languages and collaborative processes, these methods provide features that are well suited for tackling wicked problems. However, no single tool incorporates all of the necessary features. Therefore, a combination of the tools explored can yield a new and even more effective tool for wicked problems. This new tool, called STORM, is demonstrated through an evaluation of oil shale exploitation in Estonia. With Estonia currently dependent on energy from oil shale despite the environmental drawbacks, the situation is an ideal example of a wicked problem. The Estonian example shows how STORM can provide a greater understanding of wicked problems and allow resolutions to be negotiated. As sustainable development issues are usually considered to be wicked problems, the new STORM method represents a concrete contribution to sustainable development research.

Keywords: Estonian Oil Shale, Multi-Stakeholder Process, Problem-Solving Tool, Sustainable Development, Systems Science, Wicked Problem

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Summary:

Certain problems, especially those within sustainable development, are very complex and therefore require special approaches for handling them. The complexity of these problems — called wicked problems — can in part be attributed to the variety of people who have different opinions about how the problem should be resolved. Moreover, choosing to resolve a wicked problem in one way may lead to unintended consequences because the problem is made up of various elements that all interact with each other. These difficulties make it undesirable to apply traditional problem-solving methods to wicked problems. Traditional methods are too restricted and shortsighted to handle the breadth and unpredictability of wicked problems.

As a result, there is room for a new and more effective tool specifically created for wicked problems. To create such a tool, various features from other decision-making tools are combined into one method. These features include a structured matrix format, color coding and a flexible, cooperative process that can be altered as progress is made. To test out the new tool, a situation involving oil shale in Estonia is explored. Oil shale is a dirty fossil fuel that is abundant in Estonia and used to produce most of the country's energy. Oil shale positively impacts the Estonian economy while negatively impacting its environment, and decision-makers within the country have different ideas about what should be prioritized. This complex situation provides a good opportunity to demonstrate how the new tool works. With specific approaches for dealing with complexity and collaboration, the tool gives decision-makers a more effective way to resolve complex issues.

Keywords: Estonian Oil Shale, Multi-Stakeholder Process, Problem-Solving Tool, Sustainable Development, Systems Science, Wicked Problem

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1. Introduction

Estonia is a major producer of oil shale, responsible for about 70 percent of the world's production (Adamson et al. 2006). As a result, inexpensive oil shale has become the primary source of energy in the country, helping to offset the economic difficulties that Estonia and its inhabitants are currently facing. However, the oil shale exploitation that enables Estonia to maintain energy independence is also a source of quantifiable environmental damage that affects both nature and human health (Soares 2013). Any increase or decrease in the production of oil shale energy will therefore have environmental, economic and social implications. For this reason, Estonia's oil shale conundrum provides an excellent example of a sustainable development issue. This is because the common definition of sustainable development is development that takes into consideration environmental, economic and social impacts. Sustainable development is a relatively new field of study, with foundational texts — such as Our Common Future (World Commission on Environment and Development, 1987) — dating back to the 1970s and 1980s. As such, sustainability researchers are still in the process of developing tools that can effectively handle these especially complex situations. Problem resolution is particularly difficult due to the interconnections between economic, social and environmental issues.

It soon becomes clear that sustainability's core issues are interdependent, and it is also hard to predict how the outcomes will impact each other. In this way, sustainable development problems reveal themselves to be, by nature, wicked problems. The Australia Public Service Commission (2007, p. 1) describes wicked problems as problems with “multiple causal factors and high levels of disagreement about the nature of the problem and the best way to tackle it.” Wicked problems can therefore be defined by the interconnectedness of potential outcomes (as demonstrated in the manufacturing activity example) as well as by the involvement of multiple stakeholders from different disciplines (another common characteristic of sustainability issues). The interdependence displayed by wicked problems can be explained through systems thinking theory, in which the problem is imagined to be a complex system of interconnected elements. The involvement of multiple stakeholders is supported by theories of multisciplinarity and anti-positivism, which encourage a multiplicity of perspectives in the face of complex issues. With these theories, research that accounts for a diverse set of viewpoints is contrasted with, and preferred over, research conducted from a single, ostensibly unbiased perspective (Olsson and Sjöstedt 2004). This theoretical approach is essential for wicked issues, which involve a myriad of stakeholders and decision makers who may all perceive the problems and the answers differently.

Due to their complex nature, the methods for addressing wicked problems are just as underdeveloped as the methods used in sustainability. Traditional problem solving tools have proven to be completely ineffective, as their step-wise, exclusionary tactics are too narrow for the broad scope of wicked problems (Conklin and Weil 2007). Indeed, traditional problem solving attempts to narrow-down the focus of the research so that a complete answer may be provided to the single problem that has been identified. The key to resolving wicked problems, however, is to keep the focus wide, always leaving room to learn about new strategies, new perspectives and new consequences (Checkland 2000). There are innovative tools that are being used to tackle wicked problems, such as the analytical hierarchy process, positional analysis, mess maps and heat maps. Each of these tools offers advantages beyond those which traditional problem solving tools provide. However, none of the methods offer all of those advantages in one tool. Addressing the deficiency in wicked problem methods is therefore the research objective of this thesis. The research objective will be achieved through the creation of an entirely new tool called the Stakeholder analysis Through Outcome Rating Matrices — STORM, for short. STORM rectifies many of the inadequacies of traditional problem solving tools and gathers the most effective techniques from existing wicked problem methods into one tool. The result is a method that offers a range of advantages previously unavailable in a single tool. When used in real-life situations, STORM can therefore increase both the efficiency and efficacy of wicked problem resolution processes.

Because all sustainable development problems possess characteristics of wicked problems, the development of a tool specially formed to handle wicked problems would also add to the range of tools that can be used in sustainable development. To demonstrate the STORM tool, the example of Estonian oil shale will be used. With multiple stakeholder perspectives and interconnected consequences, the Estonian situation represents an ideal opportunity to demonstrate this new method.

The thesis begins with a description of the situation
in Estonia in Section 2.1., so that the real-life example can be kept in mind throughout the reading. Because the primary goal of the STORM tool is to be applied to actual problems, it is essential to provide a real situation as context. Then, the principles of sustainable development are outlined in Section 2.2. so that the sustainable aspects of the Estonian situation can be highlighted in Section 2.3. Illustrating the sustainable development aspects of the oil shale predicament in Estonia demonstrates how the problem can be seen as wicked. After this background information is given, the thesis provides a theoretical framework for understanding wicked problems in Section 3. Next, the methods currently used to tackle wicked problems are explored in Section 4. Once wicked problems and their tools are fully investigated, the new STORM tool is introduced in Section 5. Section 5 also includes a description of the application of the tool to the Estonian example. Section 6 wraps up the thesis by analyzing the STORM tool and its ability to meet the demands of wicked problems. The section also analyzes the Estonian example, addresses the limitations of the study and makes suggestions regarding future research. In this way, wicked problems are addressed in a new and innovative way that can offer a variety of practical applications.

2. Background

It is important to begin with a general description of the oil shale industry in Estonia, as the new STORM tool will ultimately be tested by applying it to this situation. Therefore, having preliminary knowledge of Estonia and its oil shale exploitation provides a context that is grounded in reality, which is essential when developing a practical tool. The issue represents a classic problem for sustainable development and, by extension, wicked problems. Therefore, the description of the Estonian oil shale industry in Section 2.1 is followed by an explanation of the basic principles of sustainable development in Section 2.2. Finally, the Section 2.3 addresses how these sustainable development principles are embodied by the Estonian oil shale situation.

2.1. The Oil Shale Industry in Estonia

Oil shale is a raw material found all over the world. It is a sedimentary rock with enough organic matter to make it a viable energy source. In fact, oil shale can contain up to 50% organic kerogen, a compound that is rich in hydrogen. Thanks to kerogen, oil shale is fairly calorific, although the production of energy through oil shale combustion is much less efficient than coal. In addition to being directly combusted in order to fuel power plants, oil shale can also be processed into shale oil with a wider variety of applications, including use as a transportation fuel (Khitarishvili 2014). Moreover, because refined oils and fuels can be more easily exported, modern oil shale production is turning towards greater production of oil-shale oil.

Estonia benefits from vast oil shale resources, the majority of which are located in the northeastern county of Ida-Viru. In 2010, Estonia reported oil shale reserves of 4.8 billion tons, with 3.5 billion located in Ida-Viru county. Of the 15.1 million tons of Estonian oil shale mined in 2010, 99.6 percent was produced in Ida-Viru (Statistics Estonia 2011). Such concentration of resources and production has particular implications for the local environment and inhabitants of Ida-Viru. These resources have enabled oil shale combustion to serve as the primary source of energy in Estonia for many decades. Roughly 70 percent of total primary energy in the country comes from this source, making all aspects of Estonian life heavily dependent on this important raw material (Khitarishvili 2014). In addition, electricity-generating power plants are the prime consumer of oil shale resources, taking up roughly 90% of the mined supply. Oil-shale oil production takes up the remaining 10% of the oil shale supply. Estonia's natural resources are not just important domestically, they are also an important part of the country's exports since Estonia produces roughly 70 percent of the world's oil shale (Adamson et al. 2006).

Oil shale production began in Estonia in 1916, but it did not truly take off until the 1930s when the activity began to receive financial backing from the Estonian government. Then, when Estonia was under Soviet power starting in the 1940s, the USSR-controlled government invested heavily in developing infrastructure to support the burgeoning industry, understanding what an important energy source oil shale could be. Production increased even more during the 1960s, with the construction of large oil-shale power plants. In the 1970s, problems posed by environmental damage and quickly depreciating equipment began to become evident, but this did not trigger any major concern from the government (Terk 1998). Oil shale mining reached its peak in 1980, and roughly 31 million tons of oil shale was excavated that year (Kahru and
Põllumaa 2006). Although present-day mining numbers have decreased to about half that amount, the oil shale industry is still very important to Estonia's energy and export activities.

Because of its extensive history in oil shale mining and production, Estonia is at the forefront of research on oil shale exploitation. As a result, the country has specialized knowledge that enables it to run shale operations outside of its borders. The state-owned oil shale company Eesti Energia has even established oil shale operations in countries with considerable resources — like the United States, which possesses over 60 percent of the world's oil shale reserves (Khitarishvili 2014). Despite currently producing 70 percent of the world's mined oil shale, Estonia possesses only 1 percent of the world's reserves. Therefore, establishing a presence in countries with larger reserves ensures that Estonia's expertise can be applied on a much larger scale. By branching out beyond its borders, Estonia has demonstrated that it intends to be a worldwide actor in the exploitation of the abundant oil shale resources.

2.2. The Principles of Sustainable Development

Many definitions of sustainable development have been proposed throughout the decades. The 1987 Brundtland Report, widely considered to be one of the pioneering works in the field of sustainable development, provides a simplistic definition that nonetheless illustrates the basic philosophy and value system behind the sustainability movement: “Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (World Commission on Environment and Development 1987, p. 43). As prescribed by the World Commission on Environment and Development (1987), the goal of sustainable development is to ensure that future generations have the ability to survive and thrive on the planet just as current and past generations have been given the chance to do.

Such a goal seems both obvious and lofty at the same time. As human beings who continue to reproduce, it seems to be common sense that a livable society and environment should be maintained for the resulting offspring. At the same time, the nebulous and vague nature of these aspirations makes it difficult to determine the best way to achieve such a goal. The United Nations provided a measuring stick for sustainability during its Rio+20 conference in 2012. The conference, which gathered world leaders for sustainable development discussions, established a sustainability framework that participating members agreed to follow. During the conference, a commitment document entitled “The Future We Want” was established. In the document, participating governments pledged to promote economic growth, social development and environmental protection (United Nations Conference on Sustainable Development Rio+20 2012). The document therefore summarized a common belief in the field of sustainability that sustainable development could be described as development in which the economic, social and environmental impacts were allotted equal importance. Such a sentiment runs counter to historic viewpoints that have prioritized economic growth. This viewpoint is still commonly held by organizations and individuals at all levels and in all regions of the world. Such thinking leads to the prioritization of exclusively economic statistics, like a country's gross domestic product (GDP), which measures the economic value of goods and services it has produced. The GDP is often cited as one of the primary indicators of a country's well-being, regardless of social and environmental conditions. The goal of sustainable development is to bring equal consideration to social and environmental values.

Economic values, social values and environmental values are measured in dramatically different ways by completely different actors: economists, social scientists, natural scientists, politicians, corporations, community leaders, etc. As a result, sustainable development problems are complex by nature because all of these perspectives must somehow be brought together in a single analysis. The complexity becomes even greater when potential outcomes must also be taken into consideration. Because economic, social and environmental consequences are all interrelated, it becomes very difficult to predict the final result, in terms of sustainability, of a given action. For example, if a country increases its manufacturing activity, that action will probably have a positive economic effect but a negative environmental effect, as increased emissions pollute the air. The air pollution can also have a negative social effect, as it can cause a decline in health for the inhabitants. At the same time, an increase in economic activity could create employment, which has a positive social effect that could possibly offset the earlier negative social effect. Having a richer populace will lead to higher rates of education, and advances in engineering can pave the way for pollution-
production was taking place. Two more waves of oil shale exploitation by increasing employment opportunities for non-Estonians had a large impact on the social makeup of the country. Soviet labor was brought into the country and settled primarily in the Ida-Viru county, where the oil shale production was taking place. Two more waves of immigration waves followed the first one, and by the end of the 1980s, the demography of the country had shifted dramatically. From the mid-1940s to the late 1980s, the number of non-Estonians in the country increased by 26 times, going from 23,000 to 602,000. This increase in non-Estonians was accompanied by a decrease in ethnic Estonian populations, which went from about 1,000,000 to 965,000 over approximate the same time period. The quick and extreme demographic shift forever changed how Estonians perceived themselves and the world around them. Vetik (1993, p. 274) confirmed that “as a result of demographic changes during the Soviet period (as well as many other factors) strong existential fears arose among Estonians about their future in the land of their ancestors.” An interview with Estonian geologist Heikki Bauert (Appendix I) revealed that Estonia is still a country where the citizens' sense of identity is very much tied to the land. As a result, it is likely that the perceived threat posed by the USSR was psychologically traumatizing, or at the very least destabilizing, for the ethnic Estonians.

Wicked problems are discussed more extensively in Section 3, but it should be noted that, although all sustainable development problems are wicked problems, not all wicked problems are sustainable development problems. Since the new STORM method has been developed as an approach for wicked problems, it can be applied to all sustainable development issues and even address other wicked problems outside of sustainability.

2.3. Sustainable Development Issues in Estonia

Now that the Estonian oil shale industry and the basic principles behind sustainability have both been described, the ways in which sustainable development principles apply to the Estonian situation can be explored. Such an exploration will reveal the aspects of the Estonian oil shale issue that can be analyzed using the STORM method. As customary in sustainable development, the situation is broken down into a social considerations, economic considerations and environmental considerations.

2.3.1. Social Considerations

The current social context of Estonia has been greatly impacted by Soviet support of the oil shale industry. During the 1940s, when Estonia became part of the USSR, waves of Soviet immigrants were brought in to support the new government's large-scale industrialization projects. In this way, social implications and economic implications were tightly yet unpredictably linked, and the situation proved early on to be a wicked problem. The desire of the USSR-controlled government to increase oil shale exploitation by increasing employment opportunities for non-Estonians had a large impact on the social makeup of the country. Soviet labor was brought into the country and settled primarily in the Ida-Viru county, where the oil shale production was taking place. Two more waves of reducing technologies. That could eventually offset the negative environmental impact caused by increased emissions. It is usually difficult to predict the extent to which all of these possible interdependencies will manifest themselves, thus creating a large degree of uncertainty. The multidimensional, interdependent and uncertain nature of sustainable development issues places them squarely within the scope of wicked problems.

Although Estonia regained its independence in the early 1990s, the ethnic tension brought about by Soviet-enforced immigration remains. The post-Soviet transition began less than 25 years ago. The post-Soviet social tension is still very much a part of life in Estonia. It is not uncommon to hear, in the course of casual conversation, mentions of USSR totalitarianism or jokes about the quality of Soviet goods. The ghost of the turbulent political period still lingers on in Estonia's collective memory. Further stoking ethnic tension is the distribution of populations across the Estonian territory. As noted earlier, most oil shale activity occurs in Ida-Viru county. Currently, Ida-Viru county has a population made up of 88% ethnic Russians (Statistics Estonia 2013a). This is logical since Soviets brought immigrants to Estonia in order to supply a larger work force for the oil shale industry. Narva and Kohtla-Järve, both located within Ida-Viru, are two of the most valuable Estonian cities in terms of oil-shale reserves. The populations of these two towns also feature the greatest concentrations of ethnically Russian residents in Estonia. It is therefore not surprising that these two towns were the source of the greatest number of votes against Estonian independence and when a referendum was held in 1991. The residents in these regions were also more likely to feel alienated and inferior after the referendum's positive results, which confirmed the country's independence (Vetik 1993). As such, the heart of Estonia's oil shale industry is also the place where ethnic tensions are more likely to destabilize the populace.
While ethnic Estonians felt a loss related to their land, ethnic Russians who had settled there when the USSR had control felt insecure about their status in the country post-independence. In 1992, a law was passed that denied non-Estonians the right to citizenship, making them ineligible to vote in elections and condemning them to protracted uncertainty regarding their legal status (Vetik 1993). Furthermore, non-citizens did not have the right to own property, leaving ethnic Russians with an even greater sense of transience and uncertainty (Reardon and Lazda 1993). This transition period was difficult for both ethnic Estonians and ethnic Russians, as both groups were forced to adjust to the a “new normal.” Since different cultures perceive and experience such transitions differently, the post-independence transition marked a time of increased ethnic tension in Estonia, particularly in Ida-Viru county (Vetik 1993). As demonstrated above, increased employment of non-Estonians in the Estonian oil shale industry has had a significant impact on the country’s social conditions over the past 70 years. Therefore, the social effects of changes in oil shale industry employment should be analyzed in the STORM study.

On a more positive note, the oil shale industry has also been the source of advances in Estonia's knowledge capital, another important aspect of a country's social conditions. As a leader in the industry, Estonia has amassed a large amount of research on the topics of oil shale exploitation and processing. Estonia has also developed the most sophisticated oil shale processing techniques in the world, and the country boasts extensive expertise in this sector (Soone and Doilov 2003). Sonne and Doilov (2003, p. 313) outlined the magnitude of Estonian oil shale research: “Currently, in Estonia there are more than ten acting research groups and laboratories in Tallinn, Tartu and Ida-Viru County, each of them dealing with certain aspects of the oil shale complex. One of them – founded in 1958 – is for the present time the only specialized oil shale research institute in the world.” In consequence, the industry's considerable positive contribution to human knowledge must also be taken into account when conducting the sustainability study.

2.3.2. Economic Considerations

Just like the country's social identity, Estonia's economy also has strong ties to the land. This link dates back to the end of World War I, when the government sought political and economic stability by carrying out agricultural reforms. Consequently, Estonia established itself as an agriculture-driven economy. With the establishment of oil shale mining in the 1910s, the new resources added even more strength to the economy. Thanks to these resources, Estonia's living standards were close to those of Finland by 1938 (Reardon and Lazda 1993). Economic stability lasted until the country was forced into the Soviet Union in 1940. In accordance with Soviet desires, the oil shale industry was rapidly scaled up and industrialized when control was ceded to the USSR. The goal was to centralize and intimidate the Soviet economies in a way that reduced the self-sufficiency of the once independent states. Estonia, with its rich oil shale resources, was one of the Baltic states that received the most focus from Soviet powers. Estonian resources were of such interest to the USSR that deportations were organized to keep Estonians in check (Reardon and Lazda 1993).

The USSR's efforts to reduce economic self-sufficiency in Estonia had a significant and detrimental effect on the country's economy. Estonia's independence in the 1990s was followed by a 37 percent decrease in GDP from 1989 to 1994 as the country shifted to a market economy. The GDP decline has been attributed to decreasing industrialization and reduced use of raw materials (Terk 1998). Once on par with Finland, Estonia now occupies a position that is 12 places below Finland on the UN's 2013 Human Development Index. The index ranks countries in terms of life expectancy, education, income and standard of living, with Finland ranking 21st worldwide and Estonia ranking 33rd. The drop in living standards that has accompanied the decrease in natural resource exploitation reveals an inverse relationship between economic prosperity and environmental prosperity, an important point that will be further illuminated by the STORM analysis.

As sustainable development gains political traction, a rebalancing is bound to occur. On a global level economic dominance will give way to social and environmental concerns. However, because of the generally inverse relationship between the economy and the environment, the effects of such a rebalancing must be carefully weighed out. In Estonia, a country with abundant natural resources and a very fragile economy, it will be important to keep in mind the key role of oil shale production in Estonian society. As of 2007, the oil shale industry, including mining, power production and shale oil production, accounted for around 4 percent of Estonia's GDP (Laherrère 2005). Accordingly,
changes in oil shale activity can have considerable effects on the country's GDP growth, which usually varies between -10 percent and 10 percent from one year to another. Not only would a decrease in oil shale production reduce income generated for the Estonian economy, it would also force the country to find a new source to energy. Since other possible sources of energy, such as Russian gas or wind power, are more expensive than cheap domestic oil shale, Estonia would incur greater energy costs just to maintain the same amount of electricity (Soares 2013). As it currently stands, the oil shale industry contributes revenue and lowers energy costs, supporting the Estonian economy, the living standards and ultimately the society in an essential way.

2.3.3. Environmental Considerations

The last piece of the sustainability puzzle is the consideration of environmental impacts related to oil shale mining, processing and combustion. One of the most significant impacts is the increase of harmful emissions into the air. Unfortunately, both direct combustion oil shale and transformation of the rock into shale oil create greater carbon dioxide emissions than any other primary fuel (Khitarishvili 2014, p. 42). Throughout the entire country, 72.7 thousand tons of sulphur dioxide and 35.7 thousand tons of nitrogen oxide were released into the air in 2011 (Statistics Estonia 2013b). Approximately 64 percent of nitrogen oxide emissions and 100 percent of sulphur dioxide emissions came from energy use and supply (European Environment Agency 2013). As could be anticipated, Ida-Viru county is the most polluted region in Estonia, especially the area between Kiviõli and Narva, where many power plants and oil shale processing centers are located (Terk 1998). Water consumption is also a major concern in the oil shale industry. Oil shale production is a very water-intensive process, taking up an inordinate proportion of Estonia's water resources. About 70 to 80 percent of Estonia's water consumption comes from the oil shale industry (Soares 2013).

Oil shale exploitation also has a negative impact on the landscape of Estonia. One consequence comes from the accumulation of waste products in the form of semi-coke. Semi-coke is a solid residue that forms when oil shale is combusted at low temperatures in order to produce energy. Historically, semi-coke waste has simply been dumped in piles on top of the land. The piles of semi-coke have grown so large that some are now major features of the landscape. For example, the highest manmade hill in the Baltic states is found in Ida-Viru county and measures 173 meters above sea level (Narva City Department of Development and Economy 2014). The hill is made up entirely of residue from oil shale processing (Estonian Tourist Board 2014). There are many such hills throughout Ida-Viru county, where the majority of oil shale processing takes place. Two others, known as “old mountain” and “new mountain” are comprised of about 10 million and 9 million cubic meters of semi-coke, respectively (Pae et al. 2005, 337). Although the hills are often touted as attraction sites by both local and national tourist departments, they also reveal the enormous visual impact that oil shale waste has had on natural landscapes. However, the hills of waste are not merely an eyesore. According to Pae et al. (2005, 336), “semi-coke is a residue classified as environmentally harmful due to its components like sulphides, volatile phenols, benzo(a)pyrene, etc”. For this reason, the semi-coke hills are also potentially toxic and susceptible to spontaneous combustion. In addition to immense residue hills, open-cast mines also represent another blight on the landscape caused by oil shale exploitation. Open-cast mines are large pits that are created in the earth in order to extract the rock from the surface instead of mining for it underground. A large part of northeast Estonia has been covered with these unsightly open-cast mines, and at the same time, areas with underground mines have had cases of ground sinking (Terk 1998). From waste hills to open-cast and underground mines, oil shale exploitation has caused significant damage to the Estonian landscape.

The negative effects of oil shale mining and production are widely acknowledged in Estonia. The disproportionate environmental harm caused by oil shale relative to its economic value makes the issue hard to ignore. Although the industry contributes 4 percent to GDP, it also contributes a staggering 80 percent of the country's emissions, 90 percent of the hazardous waste and consumes at least 70 percent of the water (Soares 2013). Despite their extensive use of an extremely dirty fossil fuel, Estonians have historically demonstrated great awareness of environmental issues, with forestry laws being established as far back as the 18th century. The country's long tradition of nature conservation continued into the 20th century, as Estonians proved themselves to be exceptionally well informed about ecological issues in the late 1980s, making them hostile to further large-scale industrialization projects proposed by the Soviets (Terk 1998). In light of their environmentally friendly history, Estonians' current acceptance of oil shale exploitation may seem strange. One
explanation could be their belief that Estonia's vast resources enable nature to easily absorb the damage, an assertion confirmed by interviews with geologist and geoheritage consultant Heikki Bauert (Appendix I). Estonia's population density is incredibly low, with only 30.5 inhabitants per square kilometer compared with the European Union average of 116.3 (Statistics Estonia 2014). Forty-four percent of Estonian land is covered with forest and twenty-two percent is covered with peat (Terk 1998). The country is also located in what is called a humid zone, “where precipitation usually exceeds evaporation,” leading to net positive precipitation (Vaht 2004, p. 8). This abundance of space, emissions-absorbing greenery and water may therefore decrease the amount of concern that the average Estonian has regarding landscape damage, emissions and water consumption. Understanding the environmental impacts of oil shale, as well as how these impacts are experienced by Estonians, is a crucial part of using the situation as an example for the STORM tool.

3. The Theory of Wicked Problems

Now that an understanding of sustainable development and its relevance to the Estonian oil shale industry has been established, the theory of wicked problems can be explored. As asserted earlier, all sustainable development issues have the qualities of wicked problems. An overview of the theoretical framework behind wicked problems therefore contributes to a better comprehension of sustainability. Moreover, the establishment of a theoretical framework makes it possible to identify the features that should be included in the new wicked problem tool. By comprehending the structure of wicked problems, the particular difficulties that they present during the decision-making process can be more effectively addressed in the development of the STORM method. The following subsections cover the development of wicked problem theory as well as the specific theoretical elements that make the problems wicked — namely, the multiplicity of perspectives as well as systems thinking. This theoretical framework establishes the main difficulties of wicked problems, which are linked to the involvement of a diverse set of stakeholders and the interdependencies between various elements of the problem, all of which leads to a high degree of complexity.

3.1. Development of the Wicked Problem Concept

The development of the wicked problem concept dates back to the 1970s, when Horst W.J. Rittel and Melvin M. Webber published a groundbreaking paper entitled “Dilemmas in a General Theory of Planning” (1973). This laid out several rules for determining the wicked nature of a problem. They generally characterize wicked problems as those that cannot be easily solved due to:

- a difficulty in defining the problem;
- a reliance on judgement in order to resolve the problem;
- an uncertainty about what a successful result would look like;
- an uncertainty about when the result is considered to be achieved;
- a set of circumstances that makes the problem completely unique;
- interdependencies that cause the resolving of one aspect of the problem to impact other aspects of the problem;
- the existence of multiple perspectives on how to resolve the problem.

In order to be declared “wicked,” a problem does not necessarily need to possess all of these qualities. Instead, Rittel and Webber (1973) found that most wicked problems possess at least a few of these qualities. It also seems that certain wicked problem characteristics can be attributed to other identifiable factors. For example, the lack of certainty about the desired outcome can often be attributed to the existence of multiple perspectives as well as interdependencies.

3.2. Multiplicity of Perspectives

Wicked problems are identified by their nebulous nature and reliance on judgement for resolution. They often spread out across various domains and stakeholders. It is impossible to arrive at the right answer when dealing with a wicked problem because wicked problems do not have answers that are objectively correct. Instead of aiming to solve a wicked problem, decision-makers must attempt to resolve the problem (Rittel and Weber 1973). Rittel and Weber (1973) were careful to note that a resolution differentiates itself from a solution through its social nature. Whereas a solution can be considered the “correct” answer (which cannot be found for a wicked problem), a resolution is the outcome that decision-makers mutually choose.
from among the range of possibilities. Therefore, the optimal resolution of a wicked problem will always depend on the individual decision-makers who are able to participate in the process. The decision-makers play an important role because they represent the interests of the stakeholders. Stakeholders are all those who will be potentially involved with or affected by the outcome. They have the power to make the implementation of the resolution succeed or fail. As such, the decision-making process should include representatives from diverse stakeholder interests; otherwise, the project risks failure at the hands of unhappy stakeholders. When decision-makers represent multiple stakeholder interests and can agree on an optimal outcome, the risk of failure is minimized (Conklin and Weil 2009).

This multiple stakeholder approach can be contrasted with the typical scientific approach of identifying a specific problem and then searching for a definitive solution, which is objectively considered to be the correct answer. That scientific approach falls under a branch of epistemology known as positivism. Its opposite, anti-positivism, is an important aspect of wicked problem theory. With an anti-positivist approach, researchers assert that there is no such thing as an objective position because the researcher’s perspective will always impose itself on the research being conducted. Proponents of the wicked problem concept are necessarily anti-positivist as wicked problems are characterized by the multitude of perspectives that must be taken into account during the holistic analysis process. As such, the ideal of objectivity does not exist because the observer’s perspective cannot be separated from that which he or she is observing (Olsson and Sjöstedt 2004). Instead of relying on a supposedly objective perspective, wicked problems must be considered in terms of the various values held by the stakeholders. It is acknowledgement of these values that provides context and facilitates discussion during the resolution process. In fact, because resolution of wicked problems depends entirely on stakeholder agreement, stakeholder values and perspectives should be one of key areas of focus during the process.

3.3. Systems Thinking

Systems thinking is a field of knowledge that helps to shed light on the complex interdependencies that plague most wicked problems. The danger of interdependences manifests itself within the very definition of a complex system. Liljenström and Svedin (2005, p. 1) provided the following definition: “Characteristic features of complex systems have to do with the web of frequently non-linear interrelations between variables. This setting introduces thresholds, lags and discontinuities.” Because the units within such a system are related to each other in complex, non-linear ways, it is difficult to know how changing one unit might affect the other units of the system. As a consequence, the short-term and long-term effects of specific actions remain uncertain. However, viewing a wicked problem as a system can help to alleviate some of that uncertainty. Researchers dealing with wicked problems are beginning to see the usefulness of using systems thinking in policy-making that is becoming increasing complex (Bentley and Wilsdon 2003). To combat complexity and uncertainty, systems approaches encourage discussing the problem in a way that is structured and efficient. Furthermore, because complex systems — like wicked problems — often require input from various sources, a structured communication system provides a common language (Olsson and Sjöstedt 2004). Modeling a wicked problem as a interconnected system enables stakeholders from diverse disciplines — each with their own specialized jargon — to nonetheless visualize their position within the system. The system itself has its own language that is common to all the stakeholders, no matter what the discipline, and in this way, enables them to speak to each other in mutually understandable terms. This self-contained visualization technique is revisited later during the development of the STORM tool.

4. Methods and Approaches for Wicked Problems

When resolving wicked problems, multiple perspectives and interdependencies must be taken into consideration. Since wicked problems represent a relatively new concept, few tools have been developed that are suitable for tackling issues deemed to be wicked. It is not enough to try to apply traditional problem-solving tools because they are too simplistic and fundamentally incompatible with the broad complexity of wicked problems (Conklin and Weil 2007). When applying traditional problem-solving approaches to wicked problems, failure can disguise itself as success if the real issue is obscured by a faulty process. The Australian Public Service Commission (2007, p. 11) explained how a faulty decision-making process could obfuscate decision-makers: “By their nature, the wicked issues are imperfectly understood, and
so initial planning boundaries that are drawn too narrowly may lead to a neglect of what is important in handling the wicked issues.” For example, traditional problems are often approached using a waterfall method in which data is gathered and analyzed, subsequently leading to the formulation and implementation of solutions. In traditional decision-making, the process follows this exact order (see Fig. 1).

Waterfall decision-making represents a process that, step-by-step, progressively funnels out information. Only data deemed most important remains within the scope of the project. As a result, the potential solutions will be based on a specific perspective that has been pre-defined at the earlier stages of the project. This is illustrated by the “Implement Solution” step (Fig. 1), which shows the jagged line at its lowest point. At this point, all of the data has been whittled down; the only remaining data is that which will be used in the implementation of the solution. The disadvantage of this method is that the information that has been eliminated could still be valuable from some stakeholder perspective. The funneling process that leads decision-makers to the “correct” answer is a distinctly positivist method that does not suit the anti-positivist nature of wicked problems. A wicked problem does not have one correct solution but instead a potentially infinite number of possible resolutions, each of which benefits the stakeholders in a different way. In this multidisciplinary, anti-positivist context one cannot afford to be locked into an ever-narrowing vision of the problem.

Unfortunately, traditional approaches continue to be used because the confusing nature of wicked problems obscures the ineffectiveness of these tools. Since decision-makers are not sure what success looks like (a common feature of wicked problems), it is almost impossible to evaluate the quality of their work tools. The multiplicity and interdependency that characterizing wicked problems makes it difficult to understand the problem well, especially at the beginning of the process. If the boundaries are drawn at the beginning when the problem is poorly understood and then gradually made narrower and narrower throughout the process (as Figure 1 suggests), then the decision-makers may completely miss what is truly important about the wicked problem. On the other hand, if decision-makers are given room to further explore the problem and its interdependencies during the resolution process, this will lead to a clearer understanding and, ultimately, a more effective resolution (Australian Public Service Commission 2007). Now that it is clear why traditional tools are not suitable for wicked problem resolution, some of the tools that are more suitable can be investigated.

The following subsections discuss several of the specific methods that can be useful when analyzing wicked problems. This includes tools that accommodate complexity, multiple perspectives and interdependence. Although no single method meets all of the needs of wicked problems, as a collective, they demonstrate how wicked problems can be organized, understood and analyzed. By combining the best features of several of these methods, a more effective tool can be conceived.

4.1. The Analytic Hierarchy Process

The field of multi-criteria analysis (MCA) shares a common objective with the field of wicked problem theory. In MCA, it is taken for granted that multiple interests and preferences will be taken into account during the decision-making process. Since this implies that a variety of stakeholders will participate in the process, the process must allow for the possibility of stakeholders judging the situation according to different criteria (San Cristóbal Mateo 2012). To accommodate for differing judgements, tools such as the analytic hierarchy process (AHP) have been developed within the field of MCA, and these tools are also useful for wicked problems. AHP relies on a ranking method in which the problem is decomposed into a number of sub-problems with
specified outcomes or criteria. This subdivision is done in order to help decision-makers see through the complexity of a problem by tackling one sub-problem at a time. The decision-maker then compares pairs of sub-criteria, declaring a preference of one criteria over the other. The process is repeated until every sub-criteria has been compared with every other sub-criteria. Using statistical approaches and weighting, a preferred outcome can be deduced based on the series of pairwise comparisons (Saaty 2008). Table 1 below is an example of a matrix created to analyze these pairwise comparisons.

Tools such as AHP have been developed within the multi-criteria analysis field in order to resolve problems that rely on judgements and varying perspectives. To do this, AHP transforms subjective judgements into a concrete numbers by having decision-makers declare their preferences of one criteria over the other. Using pairwise comparisons is a statistically manageable way to establish a ranking of each criteria from least desirable to most desirable. In the end, a nebulous wicked problem is attacked by breaking it up into a series of smaller, more comprehensible issues and then ranking the possible outcomes for each one of those issues. That way, the judgement of the stakeholder can be taken in consideration in a systematic and orderly way despite the complexity of the problem.

4.2. Positional Analysis

Positional analysis is another method used to incorporate the judgements of multiple stakeholders into a problem study. Developed by Söderbaum (1982), positional analysis is used to illustrate the ideological orientations, potential actions, monetary and non-monetary impacts, as well as conflicts of interest surrounding an issue. Like AHP, positional analysis also structures the ill-defined or nebulous problem in a way that makes it easier to evaluate it from the perspective of diverse stakeholders. The anti-positive approach was strongly encouraged by Söderbaum (1982), who insisted on considering the ideological orientations of all affected stakeholders so that all the facets of the issue could be understood. Because such a multi-faceted evaluation can become unwieldy, Söderbaum (1982) used matrices and decision trees as a means of organization. Decision trees are typically employed to explore the consequences of each action taken over several stages of decision-making. In a decision tree each decision leads to a discrete set of additional decisions that must be made (Fig. 2).

Like the matrices of AHP, the decision trees in positional analysis offer structure for an initially unstructured problem. In addition, Söderbaum (1982, p. 397) provides a model for analyzing stakeholder preferences using matrices (Table 2 below). In Söderbaum’s example (Table 2) the stakeholders are represented in the column on the left while the potential outcomes are represented in the row at the top. The subsequent rows represent the rankings that each stakeholder would give to the potential outcome.

Table 1. A table illustrating how weights are assigned to specific pairings within an AHP analysis in order to determine the user’s priorities. Reproduced from Saaty (2008, p. 88).

<table>
<thead>
<tr>
<th>Flexibility</th>
<th>Opportunities</th>
<th>Security</th>
<th>Reputation</th>
<th>Salary</th>
<th>Priorities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1/4</td>
<td>1/8</td>
<td>1/14</td>
<td>1/9</td>
<td>0.036</td>
</tr>
<tr>
<td>Opportunities</td>
<td>4</td>
<td>1</td>
<td>1/3</td>
<td>3</td>
<td>1/7</td>
</tr>
<tr>
<td>Security</td>
<td>6</td>
<td>3</td>
<td>1</td>
<td>4</td>
<td>1/2</td>
</tr>
<tr>
<td>Reputation</td>
<td>4</td>
<td>1/13</td>
<td>1/14</td>
<td>1</td>
<td>1/7</td>
</tr>
<tr>
<td>Salary</td>
<td>8</td>
<td>7</td>
<td>2</td>
<td>7</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 2. A matrix that models stakeholder preferences for specific outcomes by ranking the outcome alternatives (each column) for every row of stakeholder. Reproduced from Söderbaum (1982, p.397).
Söderbaum's model demonstrates yet another example, in addition to AHP, of analyzing subjective judgment through matrices and ranking. Unlike AHP, in which the stakeholder makes the preference judgements him- or herself, Söderbaum's matrices are to be completed by an independent analyst who predicts what the stakeholder's would prefer. Söderbaum (2008) stipulated that the study should be carried out by an analyst in order to ensure stability and accountability for the analysis. When there is one analyst who can be held accountable for the analysis as a whole, that increases the credibility of the study. However, Söderbaum (2008) made it clear that it is highly important to communicate with stakeholders throughout the process in order to understand their preferences. It is also essential to receive their feedback about how to improve and refine the analysis. In this way, his tool is not only method of analysis but also a method of communication.

4.3. Mess Maps

Positional analysis is not the only method that emphasizes the importance of communication. The Mess Map is another such tool, developed to facilitate discussion among stakeholders (Horn and Weber 2007). Horn and Weber (2007, p. 1) described the Mess Map as a diagram that “combines interactive group processes with Visual Analytics to produce (among other outputs) detailed graphical representations and analyses of Wicked Problems.” An example of a Mess Map can be found in Appendix III. The tool consists of a diagram that models the problem as it is perceived by the stakeholders. Each stakeholder contributes information in the form of “chunks” (Horn and Weber 2007, p. 9). These chunks of information are color coded and connected to other chunks in the diagram in a way that reflects their relationships in reality. Thanks to this visual language, users from across diverse disciplines can use a single diagram to effectively communicate with each other.

The Mess Map is structured in exactly the way it sounds: messily. There is no way to calculate the results or derive a clear solution from its output. In fact, the opposite is true. Horn and Weber (2007) themselves readily admitted that the results are usually incomprehensible to outsiders — those who have not participated in the mapping process. Such exclusivity can have a negative impact on the effectiveness of the tool as it is more difficult to add new participants once the mapping process has begun. That limits the diagram's potential to adapt to evolving definitions of wicked problems, which may include new stakeholders. Despite this lack of flexibility, the Mess Map still offers a valuable feature: the facilitation of communication among a specific group of stakeholders through diagrams and color coding. When stakeholders see the ways in which their contributions interact with others, they are able to more effectively discuss potential solutions.

4.4. Cluster Heat Maps

Cluster heat maps are a variation of heat map diagrams that are used in a variety of fields, including biology, computer science, psychology and business. A heat map is a matrix in which colors are used to represent values. Heat maps, like Mess Maps use color to aid in the visual representation of an issue; however, heat maps are much more organized and comprehensible to outsiders. An example of a heat map can be found in Appendix IV. A cluster heat map takes the idea of data organization even further. Wilkinson and Friendly (2009, p. 179) presented the benefits of the cluster heat map as follows: “Within a relatively compact display area, it facilitates inspection of row, column, and joint cluster structure.” In other words, along with a matrix of colors representing values, cluster heat maps include hierarchical information about the row and column structure of the matrix. The rows and columns that represent similar criteria are placed next to each other. Then a hierarchical tree of labels is added to the top row and outer column. In this way, the context of the issue is broken down into a decomposition that is almost reminiscent of a decision tree (Wilkinson and Friendly 2009). An example of a cluster heat map is found in Appendix V. The cluster heat map reveals the connections between the criteria and outcomes in a heat map, thereby providing information about the interdependencies present in the issue. The diagram's highly structured format breaks down the complexity of the problem while the color coding offers a common visual language, enabling diverse stakeholders to more easily use and discuss it. As a result, the cluster heat map proves to be a highly effective technique for dealing with several of the major difficulties of wicked problems.

All of the above-mentioned decision-making tools contribute specific features that enable wicked problems to be evaluated. AHP and positional analysis provide rating systems for analyzing judgements. Mess Maps and heat maps implement color coding and visual logic to organize data. Almost all of the tools use matrices or decision
5. Results: A New Tool for Resolving Wicked Problems

After reviewing the theory of wicked problems and the tools that can be used to handle them, it is now possible to envision a new tool that addresses the special nature of wicked problems more thoroughly than any single tool has been able to thus far. The tool achieves a higher degree of effectiveness by combining the best features of the existing tools discussed previously. The next sections introduce this new tool: “Stakeholder analysis Through Outcome Rating Matrices” (STORM). The STORM method uses a hierarchical matrix format to organize and color code stakeholder preferences. The right side of the STORM analysis comprises the Response Matrix. Each column in the response matrix represents a different stakeholder or group of stakeholders. The Response Matrix can be completed either by the stakeholders themselves or by an independent analyst who uses research and interviews to approximate the preferences of all the stakeholders. In order to complete a column in the Response Matrix, the stakeholder in question must choose a rating for each outcome proposed in Outcome column. The rating choices are as follows, ordered from the most positive response to the most negative response: Require, Expect, Like, Neutral, Tolerate, Dislike, Cannot Accept. As an example (Fig. 3), it is predicted that the Ministry of Environment stakeholder in the far right column would choose the Dislike rating for the first outcome listed (More Waste). Once the Response Matrix has been completed by all stakeholders, each cell of that matrix is color coded according to the rating (see color coding in Fig. 3). The result of color coding is a heat map, which can be used to quickly see the areas of intense conviction, contention, agreement and possible negotiation.

5.1. Describing the Newly Developed STORM Tool

The STORM evaluation of the Estonian oil shale situation is found in Figure 3 on the next page. The first step to establishing the matrix that is illustrated by Figure 3 is to determine the top and side labels. At the top of the matrix, each stakeholder or stakeholder category is defined. Along the left side of the matrix, there is a hierarchical structure that begins with three possible scenarios: Increased Production, Stable Production and Reduced Production. To the right, the Ideology column breaks the problem down into the three ideological orientations that are to be explored in the study. Because a sustainable development perspective has been taken, the ideological orientations are Environmental, Economic and Social. For each scenario, the impacts according to these three ideologies are explored. To the right of the ideology column is the Outcome column. Outcomes are defined according to the scenarios and ideologies that have been defined to the left. These three columns are labelled “Alternative Matrix” because they present the possible outcome alternatives. These are then organized under a hierarchical structure, which provides a rigorous and organized framework for the wicked problem. The hierarchical structure of the Alternative Matrix can just as easily be transformed into a self-standing hierarchical model, as in Figure 4 on page 14, which helps in the understanding of the problem.

At this point, the study enters its second phase. In this phase, the STORM evaluation is projected in front of the stakeholders, and they express their reactions, judgements and ideas in group discussion setting. A communication facilitator can be designated in order to guide the stakeholders through discussions. If an independent analyst has completed the Response Matrix, the stakeholders can give feedback about the accuracy of the analyst's predictions. Whether the STORM evaluation has been completed by stakeholders or an analyst, the discussion should revolve around the areas of conviction, contention, agreement and possible negotiation that have been made apparent by the color coding. The stakeholders should also talk about the structure of the matrix itself. They may wish to add or subtract outcomes, ideologies and scenarios. If the rest of the group agrees, these modifications should be made. As discussions progress, matrices and their inputs can be modified and revised in real-time. This can be done either by the facilitator or the discussion group as a whole.
Fig. 3 A STORM evaluation of the Estonian oil shale situation. The scenarios are outlined in the columns to the left (the Alternative Matrix) while the stakeholder preferences are estimated in the columns to the right (the Response Matrix).
Fig. 4 The Alternative Matrix section of the STORM evaluation in the form of a decision tree. This visualization highlights the causal relationship between the scenarios and the potential outcomes within each ideological orientation.
using technology like Google Sheets, a collaborative Internet spreadsheet application. Ideally, the stakeholders themselves will use these discussions to formulate solid propositions for how to go forward. Otherwise, the decision-makers can take the results of these discussions (decision makers should be either observing or participating) and determine where stakeholders can compromise and where their positions will never reconcile.

5.2. Using Perspectives from the Estonian Oil Shale Issue in a STORM Evaluation

In order to experience a practical application of the STORM tool, information drawn from the oil shale situation in Estonia has been used to establish the framework of the Alternative Matrix and complete the Response Matrix (Fig. 3). Because the wicked problem hinges on the amount of oil shale energy that is produced in Estonia, the three possible scenarios in the Alternative Matrix are based on production amounts. The ideologies to be explored are environmental, economic and social, as the problem is being explored in a sustainable development context. For each ideology, the alternatives presented are those considered to be amongst the most important environmental, economic and social goals that could be achieved by altering (or maintaining) oil shale production. In the Response Matrix, the stakeholders used for the example study are a Producer of oil shale energy, a Geologist and the Estonian Ministry of Environment. These three stakeholders are represented by the columns on the right half of the matrix. An independent analyst carried out research and interviews in order to predict the stakeholder preferences. For the Producer and Geologist response predictions, interviews were conducted. For the Ministry of Environment response, the estimated preferences were based on the National Development Plan for the Utilization of Oil Shale 2008-2015, a document published in 2008 that outlines the Ministry's position on oil shale mining and energy production. These responses are explained in further detail below.

5.2.1. The Producer Response Predictions

The Producer column represents the predicted responses of a representative of an oil shale producer in Estonia. The predictions are based on an interview conducted with Olavi Tammemäe (Appendix II), an environmental manager at Eesti Energia, Estonia's state-owned energy company. His position can be summarized by a desire to fully exploit as much oil shale as possible in order to create value for the Estonian government. He is considered to be an environmental manager insomuch as his department seeks out ways to fully exploit the rock in increasingly efficient ways. He describes his role as reactive rather than proactive. Tammemäe declares, “If somebody tells us that Estonian Energy has made some decisions following certain past ways, I would like to tell you that we are following very strictly the owner. […] My primary objective is to do this in a way that all environmental requirements are followed, all rules are followed, and that we have the capacity to do this in the long term.” His department receives instructions from the Estonian government as well as EU directives regarding environmental regulations, and he reacts to these instructions. His main concern is extracting the most value from the oil shale that Eesti Energia is allowed to exploit while still following environmental directives decided by other parties. He is therefore less proactive in his environmental ideology and more proactive in his economic ideology. For this reason he prefers economic outcomes to environmental ones. However, he is slightly more environmentally oriented and slightly less economically oriented than the Geologist. Moreover, the Producer's ability to produce energy more efficiently is dependent upon the discovery of new technologies. For example, a new, more efficient model of power plant called the Enefit 280 has recently been unveiled and is being installed in various locations.

As a result, the production of energy knowledge is important to him.

5.2.2. The Geologist Response Predictions

For the predictions of the Geologist response, an interview with Heikki Bauert was conducted (Appendix I). Bauert is a geologist by training and now acts as a consultant for projects related to geological resources and geoheritage in Estonia. His overall perspective is characterized by a strong preference for economic growth in Estonia. He sees the natural resources in Estonia as being abundant enough to absorb temporary negative effects, stating, “Actually, we don't see that much is harmed in nature because […] here, it's in such a climate that everything will be restored by nature. Trees will take over, grasses will take over by themselves very, very fast.” Before the interview, Bauert noted the very low population density of Estonia, which is...
also discussed in Section 2.3.3. According to him, such a density enables Estonians to further exploit nature in order to be able to improve their living conditions. Furthermore, Bauert believes that undue concern over the environment is blocking Estonia from the economic growth that it desperately needs. He states:

“We know everything should be in balance. Right now it is out of balance. We cannot just make the goal that Estonia is a big nature reserve because the people are barely managing here. The average pension received here is 300 euros per month. People can barely survive with this amount. At the same time the pension fund is already in red because taxes are not coming and taxes cannot be raised. It is in red close to 400 million euros. There is a way that money can be raised. It can be done if the economic initiative is higher. Estonia is a tremendous place because we have mineral resources [...] but it's very heavily protected.”

Although Bauert acknowledges the need to preserve the environment, he believes that the economy should be prioritized right now and that nature can absorb the damage caused for the sake of generating revenue. His perspective is therefore reflected in the response matrix as highly preferring positive economic outcomes, strongly rejecting negative economic outcomes and tolerating negative impacts on the environment.

5.2.3. The Ministry of Environment Response Predictions

In the National Development Plan for the Utilization of Oil Shale 2008-2015, the Ministry of the Environment of the Republic of Estonia (2008) details its position on the country’s oil shale exploitation. Despite the governmental agency’s admittance of oil shale’s importance as an energy source in Estonia, it nevertheless calls for a decrease in the amount of oil shale mined. The Ministry of Environment has committed itself to this reduction, citing environmental impacts as well as social impacts linked to the declining health of residents in Ida-Viru county. Its goal is to keep the volume of oil shale mined at or below 15 million tons, less than half the volume mined during the production peak of 31 million tons in the 1980s. The hope is that renewable energies and increased electricity production efficiency can compensate for the reduction in oil shale mining. The plan shows no evidence of concern for the negative economic impact that would result from a decline in oil shale exploitation. Therefore, in the response matrix of the STORM study, the Ministry’s preferences prioritize environmental concerns and remain indifferent towards decreases in economic activity. Because the Ministry expresses concerns for social issues in the National Development Plan, its preferences also reflect a disinclination for reduced employment.

6. Discussion

Through the exploration of various theories and methods, a number of key success factors for resolving wicked problems have been revealed. These factors are combined to form the STORM tool. The Estonian oil shale example illustrates the types of conclusions that can be drawn from a STORM analysis. Despite certain limitations to the method and the Estonian example, STORM nonetheless offers new possibilities for future research and decision-making.

6.1. Key Success Factors for Wicked Problem Tools

As noted in Section 3, complexity related to multiple perspectives and interdependencies differentiate wicked problems from simpler ones. In Section 4, various tools that are currently used for wicked problems are explored, making it possible to identify the key features that make those tools so effective. These key features, which were all incorporated into the new STORM tool described in Section 5, include:

- an organized structure and visual display that helps to make sense of the complexity;
- a common language that allows diverse stakeholders to communicate;
- and a flexible format that enables decision-makers to add information and change their perspective as their understanding of the situation and its interdependencies is refined.

The following subsections explain why these features meet the demands of wicked problem resolution and analyze their implementation in the STORM tool.

Every tool discussed in Section 4 has a different approach for organizing the complexity of wicked problems. While AHP transforms a large number of subjective judgments into a statistical computation whose end result can be a single number, the Mess Map adopts an organized chaos approach in which chunks of information are arranged on a map. While the former method is most likely too reductionist — eliminating all contextual information in order to arrive at an objective number, the latter does not do enough to reduce the complexity — with an end result that leaves the problem just as confusing as it was before the analysis. Therefore, positional analysis and the cluster heat map provide the most useful organizational structures for tackling wicked problems. Both decision trees and matrices allow for a large amount of information preservation while at the same time providing a very disciplined structure that streamlines analysis process. Although the final output of AHP is too reductionist, its ranking system, which comes in at the intermediate stage of the process, offers an effective way deal with a variety of different subjective opinions. Ranking is also used in Söderbaum's (1982) positional analysis, in the context of ranking outcome preferences. Söderbaum's utilization of ranking inspired the rating system used in the STORM method. However, instead of ranking the outcomes from least to most preferable, the STORM tool allows stakeholders to independently rate each outcomes. This allows for a more open-ended and nuanced output that preserves more information about the situation. The STORM method combines Söderbaum's notions with the idea of cluster heat maps in order to organize this increased information in a visually appealing way. These two concepts blend well together as the decision trees are a fundamental part of both of them.

In addition to the decision tree structure, the STORM tool also has a matrix as its base. The matrix is known for making intuitive data quicker and easier to process (Department for Communities and Local Government 2009). Data processing is more efficient because the matrix can categorize and visualize data, acting as a system model that reveals the cause and effect relationships between concepts (Schutt 2012). Indeed, the STORM tool concisely illustrates how the scenarios and the outcomes are connected. The matrix format offers a significant improvement on the messiness of the Mess Map because the relationships are clear and instantly identifiable even to outsiders who are not part of the evaluation process. Moreover, unlike lengthy reports or complicated formulas, the format of the matrix allows a large amount of information to be communicated with one look.

Adding to the efficiency of matrixes is the color coding of heat maps, which are simply a type of matrix. The color coding approach is encouraged by Horn and Weber (2007) who promoted problem resolution through the use of a visual language that creates messages. Color coding has the advantage of transforming complexity into a more understandable form while still maintaining a high level of data. By displaying a visual rendering of a wicked problem expressed through color, stakeholders can more fully comprehend each element as well as as the interrelations between elements can be better comprehended.

One major difference between visual displays and traditional problem solving tools is that visual displays tend to be descriptive instead of prescriptive. Prescriptive problem resolution tools can actually be harmful to the process as they suggest that there is one correct answer. As discussed earlier, this positivist mindset goes against the anti-positivist nature of wicked problems, whose multiple perspectives can lead to a variety of “right” answers. Even AHP and positional analysis fall victim to the desire to prescribe a correct solution. As a result, their final outputs take the form of an optimal choice selected from the range of alternatives within the scope of the study. The selection of a single correct “answer” greatly limits the possibility for further reflection. Lack of further reflection can be dangerous if the implementation of the selected outcome reveals new information about the situation. In such a case, a whole new analysis needs to be conducted starting from square one, as the funnel-like nature of prescriptive tools requires reevaluation of the entire framework when shifts in context are introduced.

Consequently, it is important for the tool to maintain a descriptive format that can evolve with the situation, and visual display helps to achieve this. Horn's Mess Map is a prime example of a descriptive visual display that keeps intact all the nuances and complexities of a wicked problem without suggesting that there is a single correct answer. Horn and Weber (2007) attributed the Mess Map's effectiveness to its incorporation of uncertainty and risk. In the STORM tool, uncertainty is expressed through the range of shades in the color code, which can indicate the stakeholder's level of confidence in his or her beliefs. Instead of removing complexity and
uncertainty, the most effective wicked problem tool will embrace complexity. Of course, keeping the information comprehensible is a challenge (as is demonstrated by the Mess Map), so the method of organization is equally important. That is why the STORM tool combines the preservation of nuance and complexity offered by the Mess Map with the data organization techniques of matrices and heat maps. Added to this structure is the ability to integrate data about judgement, thanks to methods inspired by AHP and positional analysis.

6.1.2. Establishing a Common Language

Facilitating open communication amongst stakeholders must be one of the primary goals of wicked problem tools. Because the process of resolving wicked problems often extends across multiple stakeholders, as explained in Section 3.2., the tool must provide a way for bridges to be built between different perspectives. Different perspectives also include the use of different types of data (i.e. qualitative and quantitative) and jargon, but there is no guarantee that other participants will understand such data or jargon. Organizing complexity, as is done in the previous subsection, is the first step towards handling wicked problems. The second step is allowing stakeholders to communicate with each other. By allowing stakeholders to exchange information about the problem in a structured forum, they can achieve greater understanding of a wicked problem that was most likely poorly understood on an individual level before the discussions (Australian Public Service Commission 2007). Therefore, the resolution tool must be able to translate the different languages of the stakeholders into a common language shared by all.

Securing a common language must be done before stakeholders can begin to work towards a common resolution. Stakeholders must be able to discuss the differences in their perspectives in order to overcome those differences. Through the use of a visual tool that is displayed in front of a group of stakeholders, the stakeholders can work through their representations of the problem in a collaborative way, leading to a shared understanding. Conklin (2009, p. 18) highlighted the importance of shared understanding: “Shared understanding means that the stakeholders understand each other’s positions well enough to have intelligent dialogue about their different interpretations of the problem, and to exercise collective intelligence about how to solve it.”

Achieving a shared understanding therefore makes it dramatically easier to agree upon the course of action that should be taken. In the previous subsection, visual displays, ranking and color coding are noted for their organizational benefits. Here, it is clear that they also provide a common language in which the stakeholders can communicate. Using ratings and a color code in the STORM method ensures that all stakeholders express themselves in the same way even if they come from vastly different fields, organizations or socioeconomic backgrounds. Because each stakeholder’s Response Matrix entries are transformed into ratings and then into colors, every participant is speaking the same language. Experts from different fields can contribute to the analysis without requiring the stakeholders to learn each other’s languages. For example, if a chemist were involved in the Estonian oil shale evaluation, he or she might base his or her preferences on the observation of chemical compounds in the atmosphere or ground water, yet these chemistry concepts could be indecipherable to other stakeholders. With the STORM tool, however, this expertise can manifest itself in the form of ratings and colors that are understandable to everyone. The versatility of the tool ensures that it can be adapted for a wide range of uses by various actors.

Another benefit of using a common language is that all stakeholders can feel safe expressing themselves. Establishing a safe space for expression is crucial to achieving mutual satisfaction among stakeholders (Hallsworth et al. 2011). Creating a safe space is important because it is usually painful or difficult to confront challenges to one’s deeply held world-views — as is often the case with stakeholders discussing wicked problems. Checkland (2000, p. 45) shed light on the difficulty of discussing world-views when he said, “We should remember that many people painfully find their way unconsciously to world-views which enable them to be comfortable in their perceived world. Coming along with a process which challenges world-views and shifts previously taken-as-given assumptions, we should remember that this can hurt.” Through a collaborative process that uses a common language, stakeholders can feel safe to discuss their true positions without being hurt. In the case of STORM, technology contributes a lot towards the creation of a safe space. It is recommended that the STORM analysis be completed using web application Google Sheets. That is because the application allows multiple users to modify the spreadsheet containing the matrix at the same time, providing the feeling of true collaboration. Ground rules should be established by the facilitator to that the
Learning and adaptation can only be provided by the whole group. However, putting the tool in the hands of the stakeholders and allowing them all to change it in real-time goes a long way towards making them feel like their opinions count. In this way, a safe space is created for stakeholders to express their true motivations. By conveying their preferences in a structured manner, they also establish legitimacy for their position. Any inconsistencies are easily recognized, so stakeholders are more likely to express their viewpoints clearly and consistently. As the resolution of wicked problems depends on the successful convergence of potentially opposing views, stakeholders must have a way of communicating to reconcile their differences. They must also feel comfortable enough to go through this challenging process. The visual nature of the STORM tool provides this common language while its collaborative possibilities help to build a safe space for expression.

### 6.1.3. A Flexible Format for Iterative Learning and Adaptation

Another key feature that tools for wicked problem should possess is the ability to change and react to the evolving needs of the problem on a spontaneous basis. One reason for this is that the complexity of a wicked problem is so great that stakeholders will necessarily be in a constant state of learning and the problem and its systemic nature. One way to handle the complex system is to make room for stakeholders and decision-makers to learn during the resolution process (Checkland 2000). The learning takes place on various levels. It could represent learning about other stakeholder's positions, fields of expertise or belief systems. It could also represent learning triggered by changes in the situation over time, which obligate stakeholders to reevaluate their positions as well as all of the analysis conducted up to that point. For example, if a new and highly effective type of carbon sequestration suddenly becomes implementable, such a development must be factored into decision processes dealing with emissions. Sustainable development is a volatile field that often depends on the whims of politicians and financiers. Moreover, advances in science and technology are now occurring at a rapid pace. Consequently, decision-making processes related to sustainable development (a type of wicked issue) must be able to adapt to rapid scientific, political and financial changes.

Learning and adaptation can only be provided by a tool that is iterative. One way to make an iterative tool is to provide a model that shapes thinking and is shaped by thinking during a collaborative process that includes all stakeholders. The model is first established using readily available knowledge and judgements, and then stakeholders use that model to gain an understanding of the issue. Then, they suggest ways in which the model could be improved or fleshed out (Department for Communities and Local Government 2009). That is why, with the STORM method, the structure of the Alternative Matrix can be changed in real-time, with the results of changes immediately visible and subject to further spontaneous dialogue. The matrix is also simple enough that new alternatives can be instantaneously added to the left side of the matrix during the course of discussion and evaluated on the spot. Once again, the Google Sheets web application allows these iterations to be completed by any of the stakeholders at any time, with simultaneous modifications possible.

The learning process is crucial for resolving wicked problems due to the fact that, as mentioned earlier, they are often not well understood by stakeholders initially. When it comes to wicked problems, it is preferable to adopt a non-linear process that mimics the learning process that decision-makers inevitably undergo as they explore the issue (Conklin and Weil 2009). Söderbaum (2008) insisted on the importance of stakeholder feedback as part of a learning process. With the proposal of a new, more flexible method such as STORM, no strong differentiation is made between the creation process and the feedback process. The model is continuously iterated and refined in a circular fashion as new feedback, information and perspectives are instantaneously integrated. STORM therefore makes the resolution of wicked problems more agile in a way that traditional problem-solving tools are not. Using a tool in which new information can easily be integrated enables decision-makers to be well prepared for the discovery of unintended consequences related to interdependencies between outcomes. When unintended consequences become apparent, they can be subsequently assimilated into the analysis at any stage, even after the implementation of a scenario. As a result, STORM can help decision-makers to recalibrate and fine tune implementation as well. Waterfall reasoning, as seen in traditional problem-solving tools, leaves no room for iterative processes that allow for the re-evaluation of variables. Once a step has been completed, the focus shifts to the next step, which is based solely on the limited information supplied by the step before it.

Utilizing an iterative tool that can adapt to shifting
The STORM study is therefore helpful in its ability to discuss areas of potential negotiation, in the process. The way to handle differences in ideology is to have the stakeholders talk with each other about the areas in which their ideologies could converge (Söderbaum 2008). In this way, the flexible and modifiable nature of the STORM tool enables its users to adapt the tool as their knowledge of the situation as well as their perspectives change. Such an iterative approach is necessary when handling wicked problems, which are likely to evolve and likely to include interdependencies that could suddenly appear later in the process.

6.1.4. Facilitating Negotiation Amongst Opposing Ideologies

By discussing areas of potential negotiation, stakeholders can attempt to find a mutually agreeable outcome, even if their viewpoints are initially opposed. Because the goal of complex problem resolution is not to find the correct answer but to find “versions of the situation which conflicting interesting can live with” (Checkland 2000, p. 16), negotiation is incredibly important. The STORM tool highlights areas of negotiation since neutral preferences are colored in yellow and more moderate responses are lighter shades of green and red. Therefore stakeholders can immediately spot outcomes in which their ideological opponent might be swayed. Alternatively, stakeholders may cede their position on an outcome if they notice that, for the specific outcome, their preferences are much more neutral than those of their ideological opponents. They may do this in exchange for their ideological opponents agreeing to cede on a different outcome in which the circumstances have been reversed (i.e. an outcome for which the stakeholders have a strong conviction while the ideological opponents are more neutral). These exchanges work in situations where intensity of conviction is mismatched in different areas.

The STORM study is therefore helpful in its ability to convey the intensity of preferences for each outcome. For example, the Reduced Production scenario displays more red hues than the other two scenarios (Fig. 3). These colors indicate that the economic consequences of reduced oil shale production are perceived as more detrimental than the environmental consequences of increased production. One can also see that, in general, the Producer and Geologist are more rigid than the Ministry of Environment, with the former displaying more red and deep red responses than the latter. Knowing the disposition of the ideological opponents in this way assists in the negotiation process. If the facilitator notices that some stakeholders are more rigid that others, this can perhaps be pointed out. In consequence, the rigid stakeholders may elect soften their views or become more open-minded for the sake of fairness. Their rigidity can also be explored in other ways by the decision-makers because it provides insight into the stakeholder perspectives. Decision-makers may decide to accord more influence to rigid stakeholders as their convictions indicate how they may react (i.e. very positively or very negatively) once a given outcome is actually implemented. Going back to Figure 3, it is also apparent that the main contention exists between the Ministry of Environment and the other two stakeholders in the study. The opposing perspectives are particularly evident in the Stable Production scenario, where the Producer and Geologist reject economic harm in favor of environmental harm whereas the Ministry rejects environmental harm in favor of economic harm. Being able to quickly identify the stakeholders whose preferences are opposed allows for a more efficient process, as the decision-makers can focus on getting the main opposing views to come to terms. Through easy identification of areas of contention and areas of potential compromise, the STORM tool streamlines the negotiation process and increases the chances of successful problem resolution.

6.2. Analysis of the Estonia Example

The STORM study conducted herein illustrates how a visual display can give insight into a wicked problem. With one glance, it can be surmised that the first scenario (Increased Production) is generally the most favorable option of all three scenarios, as it is the one with the most shades of green. In the example of Estonian oil shale, performing a STORM analysis allows several other conclusions to be drawn. First of all, it is evident that not all of the stakeholders hold the same values. While the Producer and the Geologist give priority to economic and social factors, the Ministry of Environment gives priority to environmental factors. Although the ideological orientation of the Ministry is predictable, the orientation of the
Geologist was much more unexpected. If the stakeholder discussion of this study were to take place, it would be interesting to dig deeper into the seemingly counter-intuitive conflict between the Geologist — who is also a geoheritage consultant — and the Ministry of Environment.

These surprises are part of the beauty of this new method. As an anti-positivist tool, STORM allows the participant to craft his or her own reality, which is then expressed through the matrix. These realities may be completely different from what decision-makers were expecting. Furthermore, the independent realities of all of the stakeholders can be compared and contrasted in order to gain insights about the situation. In the oil shale case, such a comparison suggests that the crux of the wicked problem is triggered by the dichotomous nature of environmental and economic factors. The Producer and the Geologist from the STORM study are primarily concerned with maximizing the value of oil shale for political and economic reasons, and they demonstrate little concern for environmental factors. The Ministry of Environment, on the other hand, is exceedingly occupied with the environmental factors. Given the mission of this ministry, as declared in its title, that is not surprising. What is surprising is the exclusion of interest in economic issues, despite the Ministry's nature as a governmental institution. By way of comparison, the website of the U.S. Environmental Protection Agency (EPA) discusses at length the economic benefits of hydraulic fracturing (United States Environmental Protection Agency 2014), even though it is a source of energy that is, from an environmental perspective, at least as controversial as shale oil. Despite the environmental concerns, the U.S. EPA announces on its website an acknowledgment that the energy gained from hydraulic fracturing is important to the U.S. economy. Instead of pledging to decrease drilling, as its Estonian counterpart has done with oil shale mining, the American agency gives itself the role of ensuring that drilling is done in the safest and most beneficial way possible. The Estonian Ministry of Environment, on the other hand, places relatively little importance on economic interests and encourages the reduction of shale oil mining despite its importance to the Estonian economy. If the U.S. EPA can be seen as having a conciliatory relationship with economic interests, the STORM tool shows that the Estonian Ministry of Environment has an antagonistic relationship with economic interests.

It is not necessarily a bad thing to have an antagonistic position, but it does illustrate the contrarian stance of the Ministry of Environment in Estonia. The Ministry is standing up against the economic interests that have long held dominance over public policy. The Ministry is taking a position that will have detrimental effects on the Estonian economy at a time when the country's inhabitants wish to increase their standard of living. In this way, the Ministry can be seen as obstructing the prosperity of Estonia in order to defend the environment. Such a conclusion is logical as Estonia is a member of the EU, and the European Union imposes strict regulations to protect the environment even at the cost of economic strength. Perhaps economic sacrifice is required in order to bring greater sense of balance to economic, social and environmental issues in Estonia. It was made clear in Section 2.3.3. that some Estonians believe that the country's nature is abundant enough to absorb damage, but is it fair to sacrifice nature in this way? From a social perspective, oil shale has shaped the country in good ways (employment and knowledge capital) and bad ways (ethnic tension), but it now seems that the social contribution of oil shale is mostly positive, seeing as the actions that led to ethnic tension are no longer possible. Ultimately, it is up to the Estonian government to decide which scenario is right for Estonia. Should the country attempt to find a happy medium between economic growth and environmental protection, or should the country align itself with its European allies by being a staunch protector of the environment?

The implied answer is that the government seeks to be a protector of the environment; otherwise, the Ministry of Environment would not have the latitude necessary to completely deprioritize the economy. Conversely, the Producer refers to the government as being eager to extract all economic value from oil shale. There is therefore confusion among the stakeholders about the real objectives of the government. Through discussion, and perhaps by consulting other government representatives from different agencies, these objectives can be clarified. That is another benefit of the STORM tool. By unraveling how different stakeholders interpret the same concepts — “government objectives” — the roadblock that prevents them from resolving the conflict can be discovered. The Producer and the Ministry of Environment both perceive themselves as carrying out the will of the government, yet their response matrices are dramatically different. For this reason, it is necessary to ask the government to clarify its position. Once the government's objective is clarified, the STORM tool could be reiterated in order to take into account this new information.
This clarification is especially important for the Producer, who is quoted as saying that he simply follows the instructions of the government. If it turns out that the government is actually as environmentally minded as the Ministry's position suggests, the Producer's response column could look very different. In this way, the STORM tool allows stakeholders to hone in on points of contention and misinterpretations of concepts. In Estonia, that means clarifying seemingly contradictory government objectives and picking a side in the fight between an abundant nature and an struggling economy.

6.3. Limitations

As this thesis encompasses both the development of a new problem resolution tool and a practical example of how the tool could be used, the Limitations section is divided into two subsections. The first subsection covers the limitations of the tool itself, and the second subsection covers limitations of the practical example.

6.3.1. Limitations of the STORM Method

The STORM method relies heavily on stakeholder preferences. Although this is a common way of analyzing decisions, there are some pitfalls to relying so heavily on human judgement. For example, people have been shown to display positive bias toward choices that are related to something with which they are already familiar. They are also more easily influenced by experiences that have recently occurred than they are by what has happened further in the past (Department for Communities and Local Government 2009). Such biases are a natural part of the human experience and can never be completely eliminated. Moreover, fear of such bias is not enough to negate all of the advantages that come from integrating stakeholder preferences in the STORM tool. The benefit of the STORM method is that it does not obscure bias by reducing stakeholder inputs to a single number (as is the case with AHP). Instead, the tool exposes each stakeholder's nuanced position in front of a group of peers and opponents. In such a forum, potential biases can be challenged and then either justified or admitted and subsequently rectified.

The problem of bias also hints at a larger problem of legitimacy for the STORM tool. The danger of an anti-positivist approach is that an abundance of unfounded opinions may cause the results to lack legitimacy. The stakeholders must therefore be aware that their ratings should be based on logical, justifiable assessment. For this reason, it is recommended that an independent analyst complete the matrix as well. Just as Söderbaum (2008) called for independent analysts who could be held accountable for the final result of his Positional Analyses, STORM analysts are the managers of legitimacy for the entire study. The analyst's matrix can then be used as a benchmark to which the stakeholder's matrices can be compared. There will most likely be differences between the benchmark matrix and the stakeholder matrices, and that is perfectly acceptable. In these cases, it is not assumed that the analyst has the "correct" answer. Instead, the reasons behind these differences should be identified and evaluated to ensure that the proper facts or reasonings have been used during the selection of preferred outcomes. As long as a position can be legitimately supported, it has its place within the larger STORM study comprised of the positions of many stakeholders. In the cases where the position cannot be legitimately supported by facts or reasoning, it should be modified.

Another limitation of the STORM method is that it requires stakeholders to be cooperative during the discussion and negotiation process. They do not all need to agree with one another, but they do need to be willing to find common ground. Because the tool itself does not output a specific answer, it is up to the stakeholders — along with the facilitator, independent analyst and decision-makers — to interpret the evaluation and arrive at a mutually agreeable resolution. Alternatively, stakeholders may realize that their visions will never converge and that no one is willing to compromise at all. At that point, the STORM tool will not take them any further. However, in such situations, it is doubtful that any tool could come up with an output that would make all of the stakeholders happy. If the resolution process fails due to uncooperative stakeholders, then it is likely that the decision-makers will be obliged to pick a side. When that happens, they can still use the insights acquired during the STORM evaluation and discussion process to inform their decisions.
6.3.2. Limitations of the Estonian Oil Shale Example

The most challenging limitation faced during the research of the Estonian oil shale example was gaining access to information about stakeholder preferences. Contacting and acquiring interviews with knowledgeable stakeholders was very difficult because most individuals contacted simply did not ever reply back. Most stakeholders contacted were reluctant to open up to an outsider who is trying to get information on potentially sensitive topics. As a result, the number of interviews conducted were limited. The STORM tool adapts nicely to these types of situations because data gained from interviews can be easily blended with data gained from other sources, as had been done with the Estonian example.

The second limitation is also linked to a lack of access to stakeholders. Because the actual resolution phase of the STORM tool relies on stakeholders coming together in a group discussion setting, the example used in this thesis only illustrates the first phase of the process. In order to get the full effect of the tool, there needs to be a collective will to address a specific problem. Decision-makers, stakeholders and other collaborators must plan and participate in discussions because they want to find a resolution, and the motivation must come from them. It cannot be imposed by an outside party, like a researcher, because the method's success hinges on the stakeholder's desire to cooperate. However, even the first phase of the Estonian example provides useful insights about the nature of the wicked problem and the possible next steps that should be taken.

6.4. Future Research

The STORM method offers a highly versatile tool that has been specially developed to respond to the most pressing needs of wicked problems. Therefore, future research should focus on using the tool in as many practical applications as possible. That includes group discussions and would ideally result in a mutually agreed upon resolution to the wicked problem. Although the focus of this thesis was on wicked problems in the sustainable development context, the tool could just as easily be used for wicked problems in other fields as well. The tool works best with the involvement of those who have the power to actually implement the chosen outcome. Therefore, the most useful research will include that type of participant. It should also include a range of stakeholders who represent all of the affected interests.

One interesting possibility for the STORM tool that could be explored in the future is the use of dynamic presentation software to compare Response Matrices. Using software like PowerPoint, a series of Response Matrices created by various participating stakeholders, analysts or decision-makings could be shown one after another. Using dissolving transitions to move from one matrix to the next would create the visual effect of one matrix morphing into another matrix as they are projected in from of the discussion group. Such a dynamic presentation could highlight the differences between perspectives.

7. Conclusion

When investigating the nature of wicked problems through various theories, it becomes evident that multiple perspectives and interdependencies significantly contribute to the complexity of the issue. The most effective tool for wicked problems can therefore integrate multiple viewpoints within an organized visual framework that is easy to comprehend and easy to modify. This is exactly what has been achieved with the development of STORM. Whereas the loss of information is one of the main flaws of traditional decision-making tools, the STORM method of analysis preserves the nuances of the stakeholders' preferences and, thereby, their ideological orientations. The output of the STORM tool has been tested using the Estonian oil shale situation as a case study. This example illustrates how the color-coded matrix format of the method makes it easier to identify areas of contention and possible negotiation. In this way, stakeholders can work towards a converging vision of the problem and the resolution.

Traditional tools with step-by-step approaches are not adequate for dealing with wicked problems because they require a positivist approach that seeks the “best” solution. The STORM tool acknowledges that often there is no “best” solution in an objective sense. There is only the outcome that is the most appealing to the stakeholders involved. When dealing with wicked problems, the most that decision-makers can hope for is an outcome that makes the best of a complex situation, having taken into consideration the interconnections between the relationship and the various stakeholders involved. The STORM tool breaks down wicked problems and enables the stakeholders to negotiate a
resolution that comes closest to the preferred outcome as defined by the collective in an iterative manner. As a result, this method has the potential to be applied to a variety of complex problems that have heretofore been left unresolved.

8. References


March 2014].


United States Environmental Protection Agency, 2014: Natural Gas Extraction - Hydraulic Fracturing [Online]. United States Environmental Protection Agency Washington D.C. Available at:


Appendix I: Interview with Heikki Bauert

Jeannette Spaulding (interviewer, JS): Could you begin by telling me a bit about your background?

Heikki Bauert (interviewee, HB): I started as a student in Estonia. But when there were signs of regaining independence at the end of the '80s and some funds opened to scholars from the Soviet Union, so I was able to attend a 3-month summer school in Hungary. Then a couple of the summer students got the opportunity to do research in the States for two years. So I ended up in North Carolina at the University of Chapel Hill in the Department of Environment Sciences. This was actually a disaster to me because I was a scholar but at this point Estonia had just gotten its first computers and at Chapel Hill they wanted me to do mathematical modeling of leakage to the soil from petrol stations. I was absolutely not able to handle this one. But across the street was the geology department so I just sneaked over and found a nice professor and made it on the master's program. When I got back to Estonia, things had really changes. It was the middle of the '90s when we were a free country again but very much in a miserable economic state with miserable means. When the Estonian currency was taken into use, every person was able to convert Russian rubles and to get $100 US dollars. Every single person started with $100 US dollars in life, as an independent Estonian.

Around 2005, I went back to my roots in geology. I started to apply for EU funded international projects as a lead partner. I got successful and I have been a lead partner and have run two projects on geo-tourism. So this is just the background.

JS: How do you view the importance of oil shale in geo-heritage terms versus its importance in economic terms? How do you weigh those two?

HB: Well, geo-heritage here in Estonia is in its absolute childhood. I have to also clarify that there is one word whose meaning I really don't understand at all and I am absolutely unable to write any sentences where this word is used and this word is sustainability. An absolutely impossible term for me to use. But oil shale, since it was taken into use in the beginning of last century, which was in 1916 or 1918 the first mines were opened, it's so good in quality, our kukersite oil shale. And good in the sense of its calorific value, which is considerably less than coal, but the advantage of the kukersite oil shale is its organic matter is extremely economically good because it yields oil very well. There might be oil shales which have the right organic content but it is very difficult to get oil out of those rocks. But this one is an exceptionally good source to get oil. Oil processing started around World War II. The percentage of oil shale mined to be converted into oil was quite low up until 20 or 30 years ago. Usually it was just directly burned like coal in furnaces to get electricity. Having this kukersite oil shale has been a tremendous advantage, and was when we gained independence because every country needs energy and we were able to use our oil shale. Which was not the case with Latvia, when all the water power plants or Lithuania who had this nuclear power plants which shut down and right now they have to get electricity elsewhere. We have been independent and this was the reason why we got a pretty good head start at regaining this independence in 1991.

JS: You mentioned having a problem with the word "sustainability." Could you explain why that is problematic for you?

HB: Because I don't know how to use this word properly. As a manager of EU projects, I know that it's very wise to write this term in almost every document you put together. But I have to admit I have been extremely incompetent in using this term.

JS: So in your word with the EU, you see how much they emphasize sustainability and want to protect the environment in all of their projects?

HB: The first project was doing supplementary education materials for geography teachers on the geology of the local area. And the second was this geology project with Uppsala University which was geo-tourism oriented and this project to provide well-written material to local officials and local tourism offices to deliver this knowledge to attract potential tourists, particularly from abroad.

JS: When you are looking at the next geo-heritage project to do — for example, we visited the Kohtla-
Järve museum — is anything like that on your radar?

HB: Well, we have great ideas about the projects, but there are all these people behind. You should start with people, you should know that there should be a task force or a team to get together. Because I think, like in every other country, the problem is that you may have good ideas but there are issues that are quite often political and particularly the local politicians. I mean like politicians at the parish level. They may just screw things up very easily because they don't have the big picture.

JS: Right. And is the museum popular? You mentioned that during the best years it gets 30,000 visitors?

HB: Well I just checked the numbers and it was something like several hundred less than 24,000 last year. Quite substantial anyway. This museum has been very well funded. They have put funding into that other building which was converted into the main exhibition area in addition to the underground part. This is not a real museum. They are using the word museum but it is more like an attraction area. Museum means that they are doing some collecting, which they do not do. So they word is used in a very loose form.

But the oil shale area. Yes, I think that there might be a future. You can attract interest in some key people in this area. For example the Saaremaa island we will be visiting. They had some local money to work out a sort of strategic management plan for the islands. And we had a contract, we did the work, but it turned out that this was just a political agenda. We had the recession a few years ago... And there are three levels in Estonia: there is the country, there are counties and there are parishes. Saaremaa has 14 parishes and they are united under a formal umbrella. And because of the recession they did not want to pay this umbrella a contribution. And the one woman who worked, she was quite old already and she just invented a great idea for us to be the consultant. But at the first meeting where all the parish leaders were sitting around the table, and we were just sharing our ideas about what we should do and how to arrange the work and just explaining what the job should be and what the end goal is to UNESCO. Later on, I just learned that two parish leaders had already signed a document that they had already established the geo-workers. I was at a large convention and I read in the newspapers that the agreement was already done. Not even knowing at all what was supposed to be done, why, its financial management and so on. This was just a political play by one person.

JS: And just going back to something you said about oil shale, that its not very interesting from a geological perspective.

HB: Oil shale is of extreme economic importance here. From a geological point of view, it has been studied. Not thoroughly studied, but in order to study anything you need to apply and you have let's say those guys in Uppsala, they are doing early life, origin, radiation. Those are like the magic key words that will get you funding. But just saying that you want to do something with oil shale, you will never get funding. There are no people, also, in this area except those who are somehow involved in an engineering way.

JS: Yeah, because I read that there is a lot of research done on processing and developing cleaner techniques, but not as much research done on the geological level.

HB: No, nothing geological. The resources they are known. The research could maybe be about the origin and how the organic matter was accumulated, but this stuff is not really studied.

JS: I'm not sure if you have an opinion on this because it is not really in your professional scope, but do you have any opinion on the environmental impact of processing oil shale and burning it?

HB: Yes. Estonia is a country that is densely covered by all sorts of nature reserves. Almost 20% of all land area is some sort of nature reserve. Which is good in one way, but at the same time, what I've learned is the world has changed a little bit. Which means we may have clean nature, but the local people they need to produce something or offer services in order to make a living. This could be one way to make a living. Just being involved in some sort of using the local minerals. But here it is absolutely a political decision. Right now we have an environmental minister, one woman, who says that our priority should be just frogs, birds and butterflies. They are emphasizing through all kinds of political investigations of mining as causing all sorts of enormous harm to the nature. Actually, we don't see that much is harmed in nature because if we were in, let's say, desert area in Africa, if you dig a hole it stays as a hole in the ground for maybe 100 years. Here, it's in such a climate that everything will be restored by nature. Trees
will take over, grasses will take over by themselves very, very fast. Oil shale is not has been exploited for 100 years, but we have enormous resources of phosphorite here. Right now we have a new government which is more left than the previous one. The Ministry of Environment declared that no drilling will be permitting for geological investigation on phosphorite because we want to be absolutely sure that our ground water will be safe. Estonia is very densely drilled. It is like Swiss cheese here. Because this phosphorite has been investigated in the '60s and '70s, kukersite oil shale, so in Estonia there could be like 10,000 drill holes done. We don't have cases that any geological investigation caused any groundwater pollution, it's impossible. You may, in some case, mix two water levels together, but that's it. Nature balances here. The water is not just staying on the inside. The water is coming down in the rain, then it percolates through, and then it's mixed anyway. At some point it may be in wells or close to the river. And there is no problem. But the Ministry of Environment is taking a very rigid position about geology and mining. At the same time, which I really dislike, is that people proudly announce, "Oh we are getting several hundred millions of euros to protect our nature in Estonia." This is just money that we have not earned. This money comes from Sweden, it comes from Western European countries. This is their tax money that we are using here, and this is not fair play at all. Our economy should generate that much tax money that can be used. These are just donations to us, and okay, donations can be taken but not in a proud way: "Oh, thanks, They're giving us several hundred million for the next five years just to protect frogs." This is what I really don't like about the Ministry of Environment because we have mineral resources. In Europe, there is economic competition. In Europe, we can use our resources and we know everything should be in balance. Right now it is out of balance. We cannot just make the goal that Estonia is a big nature reserve because the people are just managing here. The average pension received here is 300 euros per month. People can barely survive with this amount. At the same time the pension fund is already in red because taxes are not coming and taxes cannot be raised. It is in red close to 400 million euros. There is a way that money can be raised. It can be done if the economic initiative is higher. Estonia is a tremendous place because we have mineral resources, we have forest, and we have a good climate and land areas for agriculture. But it's very heavily protected.

And right now the Ministry of Environment wants to create a new, large nature reserve in central Estonia. The problem is that for building quality limestone in Estonia there are just five or six deposits of this kind of limestone that have the right properties. If it is exploited, the resources will provide tax money, let's say at this year's prices, it will generate 100 million euros tax money. But woman from the Ministry of Environment wants to make the reserve just to carve her name in the stone and then the nature reserve requires all sorts of expenses to keep it up. Those expenses are not small ones.
Appendix II: Interview with Olavi Tammemäe

Jeannette Spaulding (interviewer, JS): Could you please explain your role at Eesti Energia and how you came to be in that role and how you see your contribution to that company?

Olavi Tammemäe (interviewee, OT): About my role in Estonian Energy. You know that Estonian Energy is a big state-own company? And it consists of a lot of different enterprises. If we are talking about the oil shale related value chain, then it starts with mining activities, then power generation or electricity generation in two big plants: Estonian power plant and Baltic power plant. Also, the oil industry, which is situated physically very close to the Estonia power plant at Auvere, which is about 20 kilometers from Narva. Then in the Estonian Energy big group, there is also a part dealing with the electricity network. Part of that still belongs to Estonian Energy. Then there is also the renewable energy section. Then we look separately at a power plant deals mainly with domestic waste incineration. And there is also a big technology enterprise that actually builds a big portion of equipment that we need in our different enterprises starting from the mining sector to the oil plant sector. My department is providing centralized environmental services to all existing enterprises in the Estonian Energy group. That means that I have all together 21 specialists, who are working in Ida-Viru or here in Tallinn. And some people work between Ida-Viru and Tallinn.

JS: And when you say you have specialists, are they assigned according to the type of energy or is it according to the source? For example, oil shale?

OT: I have different teams. One team is dealing directly with the mining sector. They are situated in Jõhvi. Jõhvi is a town in Ida-Viru county. Then another team which is situated mainly in Ida-Viru as well is dealing with power generation and oil plants. Their chief is part time in Tallinn and part time in Ida-Viru. So every week drives to Ida-Viru and spends at least three days. Then we have people in Tallinn covering plants, covering the technology industry and our electricity network part and also renewable plants. Then I have my right hand who is Tõnis Meriste and he is dealing with development. I mean new projects — new environmental development projects but also oil industry development questions together with our plans in the US and Jordan. So in the team I have specialists mainly in Jordan and also partly in Tallinn dealing with environmental questions with the Jordan project. And there is a separate team working in the US with the US project, and they are regularly reporting to me and Tõnis. And we have meetings in order to find solutions for the problems raised during their work. So there are a lot of things to do.

JS: I see. So my research focuses on oil shale mining and production of energy through this source. I was wondering if you could describe your goals as an environmental manger with regard to oil shale?

OT: Our main target is to supply our oil shale value chain enterprises with adequate environmental permits. This means giving input in order to keep our internal capacity on a level that we will be able to fulfil all environmental requirements. As you know, oil shale is a fossil fuel and from the European Union direction — and of course we can see that all environmental requirements started from there — are getting stricter and stricter. And these requirements have been incorporated into our internal environmental legislation. That means that we are very much aware about what is going on and what is coming. We need to know what kind of plans have been discussed and agreed on, considering the long term perspectives. I mean, 2020 and onwards, up to 2030.

JS: And do you feel like Estonian Energy is in a good position with regard to the long-term goals — 2020 and beyond?

OT: How to tell you? Everybody who is dealing with fossil energy is in quite an interesting situation now in Europe. Not only in Europe, other countries outside Europe as well. Talking about oil shale, it is a fossil energy resource which is state-owned. The state owns that resource. And now it is very much up to the state politics whether to produce — or how to produce value. How to get value out of that oil shale. Oil shale itself as a fuel doesn't have any value because oil shale does not have any international market right now. So the value will be produced only through some production activities. Whether to produce electricity or oil or whatever else that could be of value. If somebody tells us that Estonian Energy has made some decisions following certain past ways, I would like to tell you that we are following very strictly the owner. I mean, Estonian Energy is also state owned and our owner gives us directions and we
are fulfilling these. My primary objective is to do this in a way that all environmental requirements are followed, all rules are followed, and that we have the capacity to do this in the long term. So this is very simply our description of what is going on here. So you asked whether we are in good shape or how we feel here — you know, very recently the new strategy was announced and that means that step by step during the next decades we are moving the oil shale usage from electricity, from power plants where we are primarily burning oil shale in order to produce electricity. Step by step we are moving this usage to oil production. More and more, for electricity production, we are using the oil retort residues.

JS: Is that because it's easier to export?

OT: It means that we are giving oil shale more and more value through oil production. We are using the residues from oil retorting for electricity production. And the calculations are showing us, while doing this during the next decades, we are capable of switching things in a way that the primary production would be oil shale oil and the secondary production would be electricity. That means that, from different environmental perspectives, a lot of carbon will stay in oil. From a climate change legislation point of view, oil shale usage will become more and more friendly to the environment.

JS: Is that related to new technology for plants. For example, I've seen that there is a transition taking place from the Enefit 140 plants to the Enefit 280 plants. Is that linked to what you are saying?

OT: Yes, those to things are related. The technology is getting better all the time. If you have noticed what has happened in the electricity generation part, then you have possibly noticed that there is a new technology related to circulation burning units. And the environmental performance of that unit is far better than the old ones. If you look at the available data about the new Auvere plant, which is right now under construction, which is going to produce 300 megawatts per hour, then you can see that all technical data is much better than data from the old plants. And we have designed this new plant in a way that 50% of the energy capacity produced from that plant is using biomass. So that plant could produce up to 50% biomass instead of oil shale. This is also a huge change.

JS: So it sounds like you are preparing to step down from having oil shale as the primary source of energy in Estonia, looking towards when that can be transition to a more sustainable, renewable type of energy.

OT: I would say it a little bit differently. We are stepping back from having the primary usage of oil shale be electricity production. That the primary usage will be switched to oil production. But we are still looking forward to using all available oil shale resources, what is possible to use, in order take out from that resource as much value as possible for the state. And that will be switched in a way that, in the first place we produce oil, and from the side products — from the oil retorting side products — we are not just throwing these products away or letting this into the air. We produce from that electricity. And that means from primary electricity production, we are switching step by step to primary oil production followed by electricity production.

JS: Okay, I see. Well, it looks like it is time to wrap up the interview. Just a final question about the numbers from the oil production: is that going to be something that I would see in your CSR reports?

OT: Yes, you would see all the available numbers in our annual reports. But talking for example now about the new plants — you mentioned Enefit 280, which is currently in the hot commissioning stage — that we should produce about 1.9 million gallons of oil shale oil followed by 75 million cubic meters of retort residue. That means that the electricity generation capacity of that unit will be 35 megawatts and oil shale consumption is calculated around 2.3 million tons per year. In a first stage of oil plant development plans, we are looking forward to building four new plants. And we will see what is going on then because it takes years and years to complete the plan and it is quite difficult to foresee and to calculate the future trends because this has been so unpredictable. There is a big portion of political willingness that could mean large-scale change. Also the investment climate in that field. And we have to consider it.
Appendix III: Mess Map Example
Appendix IV: Heat Map Example

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Appendix V: Cluster Heat Map Example

Cluster heat map by the Biomedical Computation Group (2009, “Use of Heatmaps in Phylogenetic Analysis”)