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DISSERTATION

MODELS FOR THE LOCATION DECISION FOR
A COMBINED CYCLE POWER PLANT

BASIC PRINCIPLES FOR SOLVING THE DECISION PROBLEM OF THE CHOICE OF LOCATION FOR A FEASIBILITY STUDY OF GAS-FIRED POWER PLANTS

PRESENTED BY: JAN KRÜGER

DIRECTOR OF DISSERTATION: DR. LLUÍS PONS PUIGGROS

TUTOR OF DISSERTATION: DR. LAZARO V. CREMADES OLIVER

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MODELOS PARA LA DECISION DE LOCALIZACION DE CENTRALES TERMICAS DE CICLO COMBINADO

BASES PARA SOLUCIONAR EL PROBLEMA DE DECISION SOBRE LA SELECCIÓN DEL EMPLAZAMIENTO PARA UN ESTUDIO DE VIABILIDAD DE PLANTAS CENTRALES ELECTRICAS UTILIZANDO GAS NATURAL

MODELS FOR THE LOCATION DECISION FOR A COMBINED CYCLE POWER PLANT

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MODELLE ZUR STANDORTENTSCHEIDUNG VON GAS-DAMPF-KRAFTWERKEN

GRUNDLAGEN ZUR LÖSUNG DES ENTSCHEIDUNGSPROBLEMS DER STANDORTWAHL FÜR EINE MACHBARKEITSSTUDIE VON GASKRAFTWERKEN

For my father, Detlef Krüger

> "If this work has a value it consists in two things. First that in it thoughts are expressed, and this value will be the greater the better the thoughts are expressed. The more the nail has been hit on the head. – Here I am conscious that I have fallen far short of the possible. Simply because my powers are insufficient to cope with the task.
> On the other hand the truth of the thoughts communicated here seems to me unassailable and definitive. I am, therefore, of the opinion that the problems have in essentials been finally solved.
>
> And if I am not mistaken in this, then the value of this work secondly consists in the fact that it shows how little has been done when these problems have been solved."
>
> Ludwig Wittgenstein (translation by C. K. Ogden)
>
> Taken from the preface in
> Tractus Logico-Philisophicus

At this point I would like to cordially thank Prof. Dr.Lluís Pons Puiggros for the supervision of the present doctoral thesis. Due to his interest in the advancement of the thesis and his exemplary willingness to help, he has made a substantial contribution towards ensuring the completion of this thesis. I would also like to thank Dr. Lazaro V. Cremades Oliver, Dr. Jose Maria Roqueta, Dr. Aureo Sánchez and Dr. Edgar Harzfeld, who supported a straightforward and uncomplicated examination procedure.

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Above all, I would like to thank my parents, my wife and my children. Without their support and understanding for the number of hours spent in various libraries, which were necessary in addition to my intensive professional activities, the present thesis would not have been possible.

Jan Krüger

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List of abbreviations

ACC	Air Cooled Condenser
c.f.	"conferatur" (Latin)
	compare
ca.	Circa (approximately)
CAPEX	Capital Expenditures
CC	Cost Category
CCGT	Combined Cycle Gas Turbine Power Plants
CCPP	Combined Cycle Power Plant
CHP-plants	Combined Heat Power Plants
e.g.	"exempli gratia" (Latin)
	For example/ for instance/ such as
EBIT	Earnings Before Interest and Taxes
EC	European Commission
ECSC	European Coal and Steel Community
EEC	European Economic Community
EEX	German Electricity Stock Exchange
EIA	Environmental Impact Assessment
EOH	Equivalent operating hours
EP	Electricity Price
etc.	"et cetera" (Latin)
	And so forth
EU	European Union
Euratom	European Atomic Energy Community
FFH	Fauna-Flora-Habitats
GP	Gas Price
HRSG	Heat recovery steam generator
i.e.	"id est^" (Latin)
	That is to say (used to add explanatory information or to state something in different words)
IEA	International Energy Agency

IFRS	International Financial Reporting Standard
IMF	International Monetary Fund
IRR	Internal Rate of Return
LNG	Liquefied Natural Gas
net	"net earnings", (remaining after deductions, as for charges or expenses (opposed to gross))
NGO	Non-Governance-Organisation
NPV	Net Present Value
nr.	Number
OH	Operating Hours
OPEC	Organization of Petroleum Exporting Countries
OPEX	Operating Expenditures
p.	Page
PP	Power Plant
R/P	Reserves-to-Production
ROG	Raumordnungsgesetz (regional development act)
SWOT	Strength Weaknesses Opportunities Threats
VDI	Verein Deutscher Ingenieure
WACC	Weighted Average Cost of Capital
WEO	World Energy Outlook

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1 Introduction to the problem area of the study

1.1 Placement and objectives

„…Due to its technical and planning conditions, the site has a fundamental impact on the further project planning (e.g. building concept) and consequently also on the budget. …" [1]; "…A power plant construction project starts with a decision of the client, who defines the size and the site of the power plant. …" [2];

The tremendous importance of site decisions in power plant construction is consistently emphasized in theory and practice. It is generally justified with the following arguments:

- Site decisions are fundamental strategic decisions;
- Site decisions fix the market (competitive structure, infrastructure, shareholders);
- In the long run, site decisions imply the definition of internal parameters, such as technology of generation, staff and contract design;
- There is a shortage of good sites. A decrease in the number of "lucrative" sites entails an increasing risk of wrong site decisions;
- Site decisions are no longer revisable once the power plant has been erected. This implies, for example, a long-term capital commitment of more than 15 years;
- The turnover achieved by energy companies is decisively determined by external site conditions;
- The selection of sites can hardly be imitated by other energy-producing companies;

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[1] cf. Siemon, Klaus D. (2009) : p. 122 f. : "…Der Standort führt häufig aufgrund seiner technischen und planungsrechtlichen Bedingungen zu grundlegenden Auswirkungen auf die weitere Projektplanung (z. B. Gebäudekonzeption) und damit auch auf den Kostenrahmen. …"

[2] Cf. Strauß, Karl (2009) : p. 113 : „… Am Anfang eines Kraftwerkbauvorhabens steht die Entscheidung des Bauherren. Er legt die Größe und den Standort der Anlage fest. …"

- New sites are the most effective measure with regard to growth and opening of new markets;

The main motives for the search for new sites in the energy industry are therefore the replacement of old power plants, the strengthening of market positions, the lack of growth prospects on the previous location and / or market, tighter regulation on the market, declining margins due to falling electricity prices and rising fuel prices as well as the development of new growth markets.

In view of the advancing technology and international networking, the problem of site selection is increasingly gaining in global importance in today's economy. Motivated by this, site issues have increasingly moved into the focus of economic research. In research activities, emphasis has gradually been shifting to modern planning procedures that primarily originate from the area of investment calculation and financing as well as strategic corporate planning.

The central problem of site planning and site decision is to cover all important site-specific influencing factors, in the following also referred to as criteria, which have a direct or indirect impact on the profits of a company, to summarise and visualise the relations between criteria / influencing factors and the target of the company and to represent them in a model.

The criteria for site determination vary among the different branches of industry.
What they all have in common is that site selection is understood as a part of a long-term strategy to ensure the company's profit maximisation. A profit seeking enterprise will therefore select a site that promises the highest possible return on investments in the future[1].

Both in scientific research in general and in site location research in particular, there are different approaches, depending on the economic focus. This implies that different research objectives and problem-solving techniques are currently existing side by side.

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[1] cf. Management Enzyklopädie (1991) p. 504 ff.

The approaches in the traditional site research literature are characterised by the fact that they attempted to solve the problem under severely restrictive premises. Defining the optimum site was formulated as a cost optimisation problem. Recently, models and approaches have been developed that were based on the latest research findings and mathematical methods. These made it possible to eliminate the restrictive premises and to integrate the relevant influencing factors and their pertinence in the analysis.

In this way, procurement- and cost-oriented criteria have steadily been losing significance in site location research. In return, the necessity to take into account predominantly external, revenue-oriented criteria has risen. Some approaches discussed in site location research are of a more general nature, but the majority of them focus on trading, production and service companies.

In reality, it is apparent that international site decisions are still being made considerably less systematically than national site decisions. Even in theory, no comprehensive approaches for a location policy of international corporations are available, despite the current relevance of this issue. This is especially true of the paradigm of international site planning in the construction of power plants and its definition of scope and demarcation.

One of the main objectives of this thesis it is therefore to draw an "interim conclusion" in terms of site theory, which is important in two respects. One the one hand, it is a prerequisite and starting point for further targeted site location research and theory formation on the assessment of power plant sites, and on the other hand, it is the basis for the solution to central site issues in the planning of gas-steam power plants.

Individual subtasks include analysis and description of the special environment of electricity generation in politics and economy, analysis of the extensive source material in site theory, systematisation and explanation of the key terms and definitions of partial aspects of site theory for energy generation, an overview of essential technical aspects, discussion of individual theoretical components for the assessment of the framework conditions of a power plant site, derivation of a model approach and drawing up and discussion of a specific overview of criteria with a concluding empirical discussion of the criteria identified.

1.2 Structure of the thesis

The globally increasing demand for energy, limited supplies of fossil fuels, increasing greenhouse gas emissions with unforeseeable consequences of the climate change, rising dependence on energy imports, lack of investment in the energy infrastructure and an incomplete internal energy market are key challenges that have to be met by the energy industry in Europe. These aspects are equally important for a potential power plant site, as in this area of tension between the political, economic and / or scientific market players there will inevitably be conflicts of interests with regard to 1) environmental protection, 2) competitiveness and 3) security of supply.
The results of a critical assessment of the energy production sector will be presented in chapters 2, 3 and 4 of the present thesis.

Chapter 2 describes the general global challenges for the energy industry, such as price developments and availability of fuel reserves. Here, the different ways of dealing with the foreseeable potential consequences of continuing excessive CO_2- emissions and the resulting global impact of the greenhouse effect play an essential role.

In the subsequent chapter 3 the interrelation between politics and energy industry within the EU and their interaction in decision-making will be looked at and presented. As it is politics that defines the basic conditions for the energy industry, the future approaches as they are seen by the European policy today are of essential importance.

Assessing future developments requires an understanding of how the existing structures in energy industry and energy policy have emerged. An overview of the major developments and events is provided in chapter 4, with a final critical discussion of the past and potential future development in energy policy.

In chapter 5 the most important site theories and their fundamentals and / or approaches will be explained. These will serve as a basis of the thesis in order to grasp and evaluate the selection of a site as an issue in decision-making. After demonstrating the principles of the theory of site assessment, the major theoretical approaches of site planning and site decision will be represented systematically. The combination of the findings of the theory of site assessment and the theory of site planning provide the basis for developing an international concept model for the site assessment in the construction of a gas-fired power plant.

The subject matter of the present thesis is a gas-steam power plant, which imposes various conditions on its environment in terms of erection and operation. Consequently, planning a model of a site decision involves a certain understanding of these conditions. For this purpose, the key procedures and criteria of a power plant will be discussed and summed up in chapter 6.

This leads to the need of a fundamental distinction and general definition and / or classification of site criteria, which will be dealt with in chapter 7.

In contrast to chapters 5 to 7, which are of a more holistic nature with a descriptive-systematizing focus, chapter 8 deals with the investigation and development of a model analysis as a basis for the assessment of site criteria and their interrelations. In accordance with the goal of developing a basis for solving central site issues, a suitable basic model for the quantitative procedures has been designed, theoretically completed and practically (exemplarily) tested (section 8.1). This forms the basis for a procedure analysis for modelling quantitative criteria (calculable criteria), first considered from a theoretical point of view and then differentiated using the basic model as an example, and for the documentation of their significance in modelling. In the subsequent section 8.2 the applicability and usability of qualitative procedures with regard to qualitative (non-calculable) and quantitative criteria will be discussed. The outcome is a self-developed property and interference matrix. This is the starting point for a more detailed development of an assessment at one site (chapter 9) and an alternative assessment between different sites (chapter 10).

The qualitative assessment criteria that are suitable for the site of a gas-fired power plant will be defined in chapter 9. As a result, individually significant criteria for site selection will be presented, but no claim will be made regarding the completeness of the comprehensively described factors of a power plant site.

In chapter 10 a self-developed modification of the site assessment for a theoretically abstracting alternative assessment will be presented. The basis for this are the deficiencies identified in the previous sections (in theory and assessment procedures) with regard to application and significance.

Using specifically collected primary data, the individual stages of the procedure will be presented in an exemplary fashion in chapter 11, and reference is made to further use of the results of the analysis for a site decision.

For a classification and discussion of the identified criteria for a gas-fired power plant in terms of scientific theory, the essential site areas, in this thesis referred to as subject groups, will be investigated and critically analysed on the basis of a self-designed empirical survey in the subsequent chapter 12.

A summarising discussion of the results of the empirical survey and the findings gained from the investigations will finalise the thesis and offer an outlook on possible further development areas.

1.3 Definition and demarcation of the scope of investigation

Basically, this study focuses on business considerations with regard to power plants. Macroeconomic [1] issues as well as site issues, as they are being discussed in the context of municipal and country-specific development and policy, have remained unconsidered to a large extent. Instead, the present thesis provides the basis for the solution to business-related site issues in an energy-producing company.

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[1] The macroeconomic site theory deals with the distribution of enterprises in the region with targets set to the whole economy, such as optimum factor allocation, creation of regional balances and thus, perfect markets. Through his conceptions for the Euro-Code and his theories on optimum currency areas, e.g. the Mundell-Fleming model, Robert Mundell has made a significant contribution in creating a new scientific basis for the framework conditions in Europe, also with regard to the selection of a site.

Within the framework of the present study, the fundamental theories of site planning and site assessment for power plants are of particular interest and will be dealt with in detail in chapter 5. The investigations pursued in this context are mainly based on German literature sources, which are very systematic and comprehensive in terms of history. In the more recent Anglo-American literature this is reflected with an influence of different trends and specific areas. This current trend towards specialisation can also be observed in the more recent German literature. The risk that is involved in considering all trends, however, is an overflowing complexity which can only be avoided by adequate reduction. Commonalities and differences in relation to other sectors have therefore not been examined and considered in closer detail. Nevertheless, reference will be made to possible interdependences with other fields, where indicated.

Owing to the liberalisation efforts within the EU, the issue of site selection is explicitly considered from an international perspective, this being largely limited to the European Union.

The site question comes up in a very early development stage of a project[1]. The challenge consists in offering real site alternatives first and choosing those which meet the demand of long-term profit maximisation while involving minimum effort. As every alternative which will be shortlisted for a comprehensive feasibility study involves considerable efforts in terms of data acquisition and analysis, unsuitable site alternatives have to be identified and eliminated at an early stage. This early identification and elimination is the purpose of the present thesis.

In practice, decisions are often still made on the basis of imprecise know-how and superficial handling of checklists. The present thesis is intended to help overcome the "lack of theory" in practice and the lack of practical relevance in the area of scientific analysis of power plant sites.

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1 A project is: "…a temporary, relatively innovative, risk-entailing task with a high degree of compexity, which mostly requires special project management (PM) due to its difficulty and importance." Cf. gabler Wirtschaftslexikon, keyword: Projekt; online : http://wirtschaftslexikon.gabler.de/Archiv/13507/projekt-v6.html

The feasibility study is commonly used in investment and system business. It is a preliminary stage for testing the feasibility of a major project and its technical and economic usefulness. The aim is to limit the scope of work involved in the project to be implemented[1].

The feasibility study is the outcome of the first project phase, the preliminary study. It is not part of this thesis, but the follow-up in the further project development.

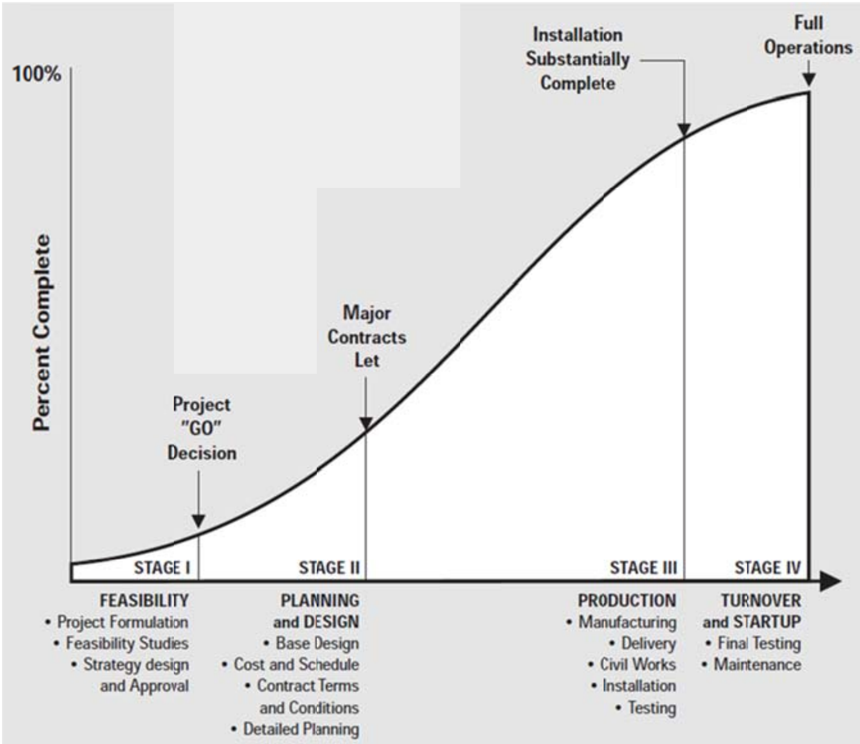

Figure 1-1: Representative Construction Project Life cycle, according to Morris[2]

In the further course of this thesis the designations for the above project phases will be adapted to comply with the construction of a power plant in the following way: (1) pre-development, (2) development, (3) execution, (4) commissioning (see figure below).

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[1] cf. Gabler Wirtschaftslexikon, keyword: Feasibility-Studie, online im Internet: http://wirtschaftslexikon.gabler.de/Archiv/6936/feasibility-studie-v5.html

[2] Duncan, William R. – PMI Standards Committee (1996): p. 14 f.

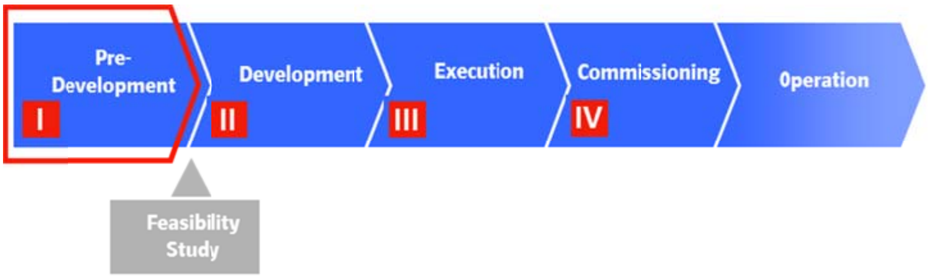

Figure 1-2: Representative power plant project live cycle[1]

From the technological point of view, the subject matter of the investigations carried out for the present thesis, is restricted to a gas-steam power plant. Other technologies may require completely different criteria and their weighting in some points. In the Energy Roadmap 2050 of the European Union gas-steam power plants are regarded as indipendable[2]. Specific characteristics and other technological aspects to be taken into account will be dealt with in the relevant sections.

[1] Authors own graph

[2] "However, as the scenarios show, centralized large-scale systems such as e.g. nuclear and gas power plants and decentralised systems will increasingly have to work together."; "Gas plays a key role in the transition"; "In the Diversified Supply Technologies scenario for example, gas-fired power generation accounts for roughly 800 TWh in 2050, slightly higher than current levels."

cf. Energy Road Map 2050: p. 8; p. 11;

http://ec.europa.eu/energy/energy2020/roadmap/doc/com_2011_8852_en.pdf

2 Challenges in energy economics

Our professional and private everyday life is hardly imaginable without electricity. We use it for lighting, warm water for the shower, computer work and a lot more. Nevertheless, a great number of people know very little about energy supply and only rely on the information that is provided by the press, radio and television. Currently, energy is a highly topical issue with a strong media attention. But this has not always been the case in the past few years, and it may change again. It is only on the basis of technological fundamentals, economic principles as well as political and legal frame conditions in energy economics – and not on the basis of populist discourse – that decisions with regard to gas-based electricity generation, based on project-specific analyses, can be taken.

The focus is on the electricity and gas markets, which are characterised by manifold changes and challenges. To understand the overall context, however, a look at the remaining energy markets is necessary. As physicists in the nineteenth century realised:

> "Energy can neither be created from nothing, nor can it vanish, but can only be transformed from one variety into another."[1]

Equally important is the second law of thermodynamics, which says that with each conversion of energy, its utilisable share decreases. This is especially true of the conversion from heat to electricity. For this reason, the resulting degree of efficiency will always remain under the ideal value of one.

Apart from these technical-physical fundamentals, energy economics is also characterised by economic considerations. What is finally fundamental for competitive energy markets is the motto "The customer is king".

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[1] cf. Dobrinski, Paul et al. (2010): p. 189 ff.

In this context and also in view of the latest developments on the energy and finance markets, the target triangle of (1) economic efficiency, (2) security of supply and (3) environmental compatibility, which is often applied in energy economics, is to be discussed more detailed in a feasibility study[1].

Figure 2-1: Target triangle of energy economics

Currently, there are mainly three aspects which are seen as challenges for international energy economics and therefore also for gas-fired power plants: the *development of energy prices*, the *availability of energy reserves* and the so-called *greenhouse effect*.

The EU directive 27 from 2012 is describing the situation as follow: "… The Union is facing unprecedented challenges resulting from increased dependence on energy imports and scarce energy resources, and the need to limit climate change and to overcome the economic crisis. Energy efficiency is a valuable means to address these challenges.

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[1] All targets set and measured discussed by the EU thus far have been discussed and adopted on the basis of these three aspects. The challenge has always been to find the right balance between the three aspects, as the question: "What is right?" can only be answered in the future, when a result is available, which is, of course, not predictable.

With the European strategy Europe 2020 (http://ec.europa.eu/europe2020/index_en.htm), an increase of the share of energy from renewable resources in the gross final consumption of energy by 20%, an increase of energy efficiency by 20% and a CO_2-reduction by 20% were adopted as common aims. In the Energy Roadmap 2050, a reduction of the greenhouse gas emission by even 80 – 95% (based on the state of 1990) is the envisaged target. To what extent the present bank crisis and the world economy will have an influence on these targets, cannot be predicted accurately.

It improves the Union's security of supply by reducing primary energy consumption and decreasing energy imports. It helps to reduce greenhouse gas emissions in a cost effective way and thereby to mitigate climate change. Shifting to a more energy-efficient economy should also accelerate the spread of innovative technological solutions and improve the competitiveness of industry in the Union, boosting economic growth and creating high quality jobs in several sectors related to energy efficiency. …"[1]

In addition, the effects of the financial crisis and the potential consequences of a possible worldwide economic crisis resulting from it, have to be taken into consideration. This, however, will not be subject of this thesis.

2.1 Price development on the world markets

As a large number of countries receive a very big part of the primary energy they consume, for example gas, from abroad, the development of the world markets are of primary importance for the energy industry and for the development of power plants. With a share of ca. 37% in the total primary energy consumption, mineral oil is still the most important energy carrier (cf. figure 0-2). IEA assumes that the global primary energy demand will grow by 40% between 2009 and 2035. Oil will remain the most important fuel, although the demand for gas will rise the most in absolute terms.

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[1] cf. Energy Efficiency Directive (EED – 2012/27/EU) Was adopted on 25 October 2012, repealing the Energy Services Directive (ESD – 2006/32/EC) as well as the Cogeneration Directive (2004/8/EC), and is to be transposed by all Member States (MS) by the beginning of June 2014.

The new EED Directive establishes a common framework of measures for the promotion of energy efficiency within the Union in order to ensure the achievement of the Union's 2020 20 % headline target on energy efficiency and to pave the way for further energy efficiency improvements beyond that date.

It lays down rules designed to remove barriers in the energy market and overcome market failures that impede efficiency in the supply and use of energy, and provides for the establishment of indicative national energy efficiency targets for 2020.

http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2012:315:0001:0056:en:PDF

It is still customary that the natural gas price is directly connected with the oil price development. This is why the price development of crude oil is obviously very important in gas-fired power plant decisions. The crude oil price, in turn, depends on consumption. For gas-fired power plants, IEA anticipates a major increase, but otherwise notes that renewables and nuclear power account for more than half of all the new capacity added worldwide until 2040.

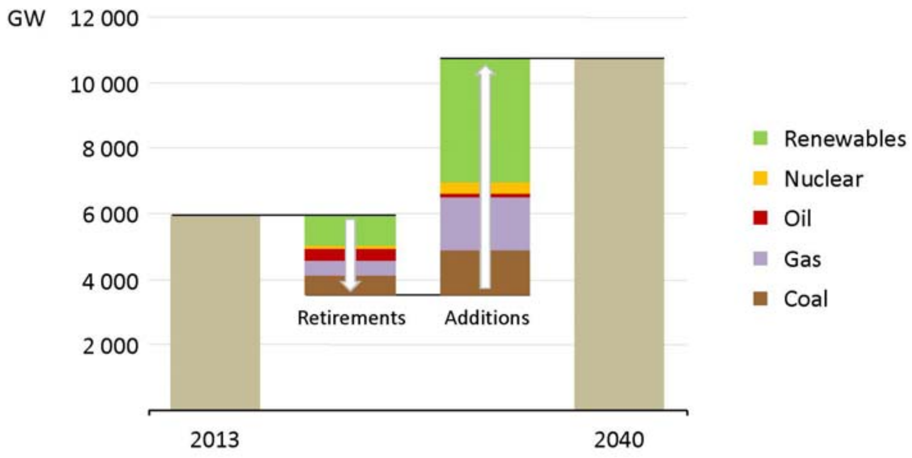

Figure 2-2: Power capacity by source[1]

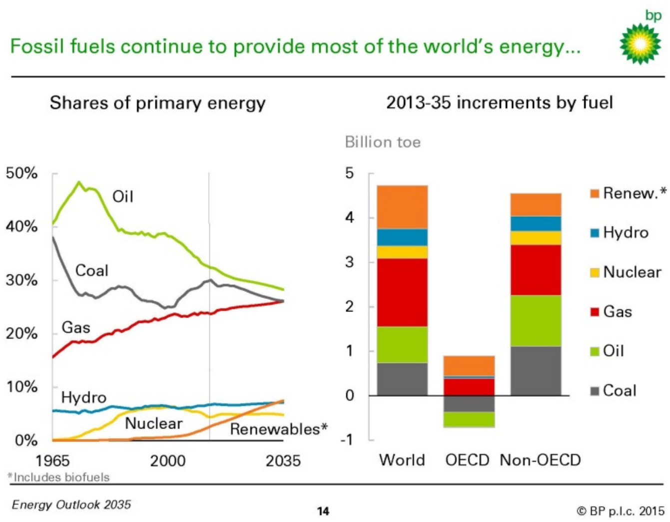

Figure 2-3: Shares of energy sources in the world primary energy demand[1]

[1] c.f. World energy outlook 2014; "… Despite limited demand growth, OECD countries account for one-third of capacity additions – to compensate for retirements & to decarbonize…"; http://www.worldenergyoutlook.org/media/weowebsite/2014/WEO2014_LondonNovember.pdf

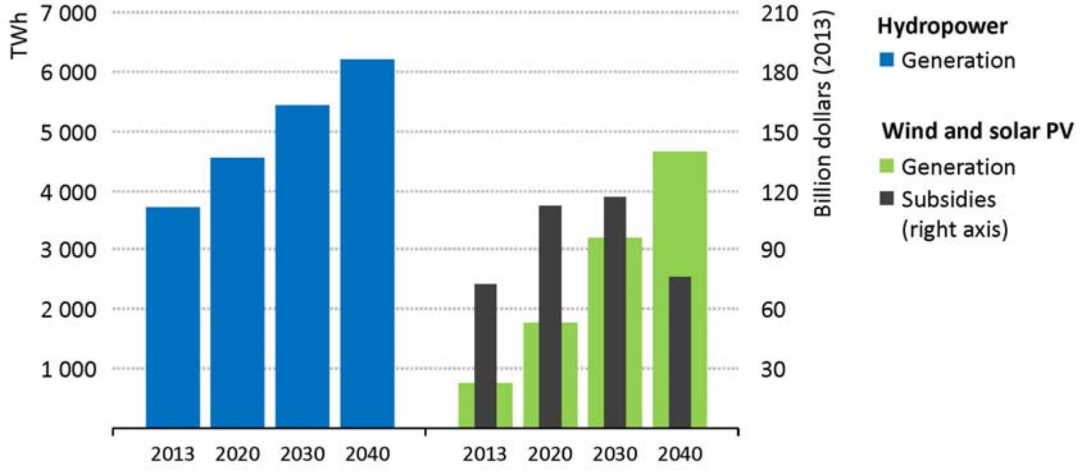

Figure 2-4: Renewables-based power generation and subsidies[2]

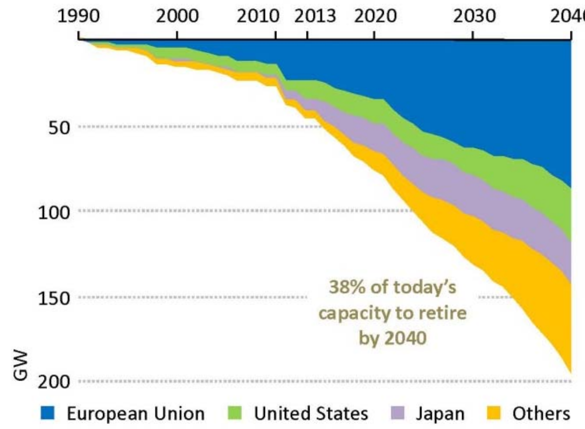

Figure 2-5: Retirements of nuclear power capacity 1990-2040[1]

[1] cf. BP – Energy Outlook (February 2015), p. 16 ff.
Gas gains share steadily, while the shares of both oil and coal fall. By 2035 all the fossil fuel shares are clustered around 26-28% with no single dominant fuel – a first since the Industrial Revolution. Fossil fuels in aggregate lose share but remain the dominant form of energy in 2035 with a share of 81%, down from 86% in 2013. Among non-fossil fuels, renewables (including biofuels) gain share rapidly, from around 3% today to 8% by 2035, overtaking nuclear in the early 2020s and hydro in the early 2030s. Roughly one-third of the increase in energy demand is provided by gas, another third by oil and coal together, and the final third by non-fossil fuels.
http://www.bp.com/en/global/corporate/about-bp/energy-economics/energy-outlook.html

[2] cf. World energy outlook 2014 "… Renewables supply half of the growth in global power demand; wind & solar PV subsidies decline from 2030 as costs fall & recent higher-cost commitments expire…"
http://www.worldenergyoutlook.org/media/weowebsite/2014/WEO2014_LondonNovember.pdf

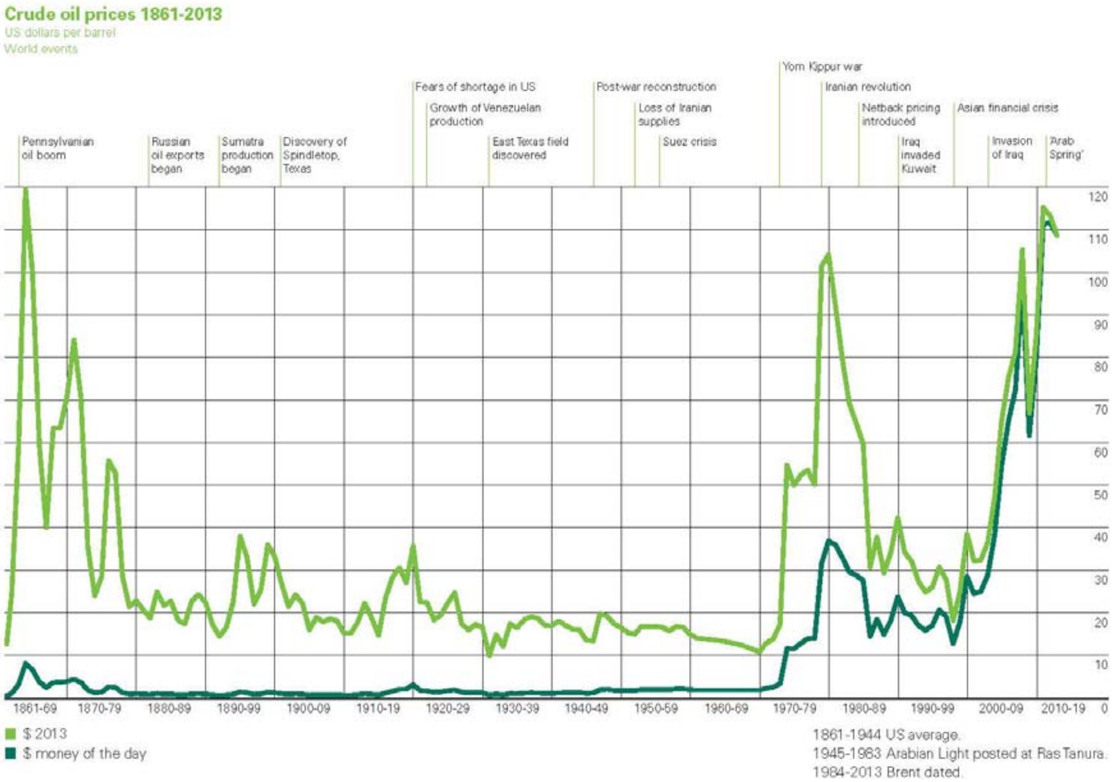

Figure 2-6: Crude oil prices 1861 – 2013[2]

By mid-2011, the nominal oil prices had risen to a record high. Taking inflation into account, oil prices are close to the record prices of the early 1980s, and definitely under the prices of the "oil age". The figure also shows that, in the past, sharp rises in oil prices were always followed by a decrease. This we could recognise at the end of 2014/ beginning 2015. The reason for this is that the price increases, with a time lag, reduced the growth of consumption or the demand, respectively, and finally led to the development of new reserves. Currently, the gas price is determined by the oil price.

[1] cf. World energy outlook 2014 "… Key public concerns include plant operation, decommissioning & waste management http://www.worldenergyoutlook.org/media/weowebsite/2014/WEO2014_LondonNovember.pdf

[2] cf. BP Statistical Review of World Energy June 2014: p. 15 http://www.bp.com/content/dam/bp/pdf/Energy-economics/statistical-review-2014/BP-statistical-review-of-world-energy-2014-full-report.pdf

According to a study of the Federal Ministry of Economics[1], a further rapid rise in international oil prices seems unlikely in the next few years, as today's oil prices are far above the extraction costs of newly opened fields. Unless political conflicts lead to major production losses, e.g. in Iran or Iraq.

Figure 2-7: Gas discovery in the Nile Delta/Egypt: The flame is a clear evidence for the existence of natural gas[2]

The up and down mentioned above can also be observed for hard coal, the second most important energy carrier world-wide, although the amplitudes are not that strong.

For natural gas there has not been a uniform world market price, in contrast to oil and hard coal, as gas cannot be transported easily worldwide. Nowadays, natural gas is normally transported in pipelines, mostly overland. Only shorter distances are covered on the bottom of the sea (possible plans are not being taken into account).

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[1] For small and medium-sized industrial enterprises, a rather "long-term increase, but volatile price trend" is anticipated; cf. Energy costs in Germany – developments, reasons and international comparison (August 2010): p. 131 ff; http://www.bmwi.de/BMWi/Redaktion/PDF/Publikationen/Studien/energiekosten-deutschland-entwicklung-ursachen-internationaler-vergleich-langfassung,property=pdf,bereich=bmwi,sprache=de,rwb=true.pdf

[2] Source:RWE-Dea AG

The transport of liquefied natural gas (LNG) on tankers, however, is increasing, which creates a worldwide uniform market for natural gas.
This can also affect the still customary price control of natural gas by fuel oil in that it will lose its importance in its present form. In gas-fired power plants, however, natural gas could be exchanged by fuel oil and vice versa, which could lead us to assume that the prices per energy unit for both energy carriers will be on a similar level, at least in the long run.

For the operators of power plants and their private and industrial customers, however, it is not only the world market prices that are important. Another significant factor, apart from the world market and import prices, is the costs of transportation and, if applicable, of conversion as well as taxes and levies, which may vary between countries.

2.2 Availability of reserves

When raising the issue of world-market prices, one has undoubtedly to take the availability of energy resources into consideration. In the following, a distinction from the point of view of energy economics will be made between two terms:

Reserves: comprise geological reserves that have been proved and are technologically and economically extractable under current conditions or conditions to be expected in the near future.
Resources: comprise the above reserves as well as further reserves that have been proved, but are currently not recoverable for technological and / or economic reasons. Resources also include geological deposits that have not been proved yet, but are likely to exist.

To characterise and quantify the scarcity of resources, the so-called static lifetime is often used. In English, this parameter is more aptly referred to as "reserve-to-production-ratio", as it can be obtained by dividing the recoverable reserves by the current annual production. In this way the static lifetime indicates how long the currently existing reserves would last without new finds and with prices and extraction remaining unchanged.

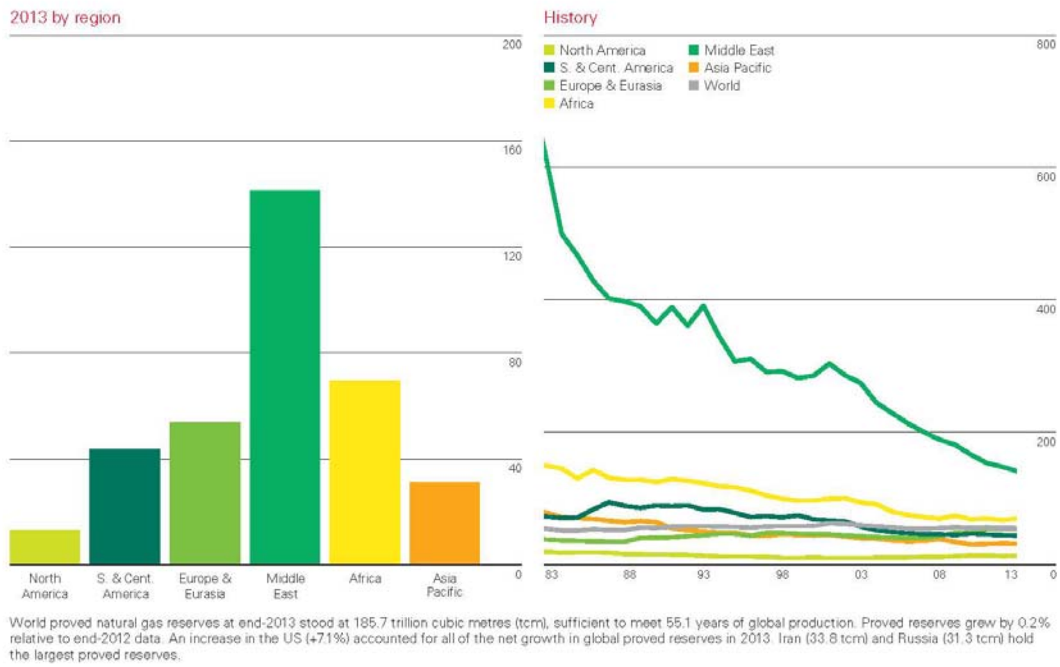

Figure 2-8: Gas reserves-to-production (R/P) ratios[1]

The following table and chart show that, measured by this indicator, crude oil is indeed the scarcest energy source, whereas the reserves of coal are comparatively high.

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[1] Total world proved oil reserves reached 1687.9 billion barrels at the end of 2013, sufficient to meet 53.3 years of global production. The largest additions to reserves came from Russia, adding 900 million barrels and Venezuela adding 800 million barrels. OPEC members continue to hold the majority of reserves, accounting for 71.9% of the global total. South & Central America continues to hold the highest R/P ratio. Over the past decade, global proved reserves have increased by 27%, or over 350 billion barrels cf. BP statistical review of world energy 2014: p. 21; http://www.bp.com/content/dam/bp/pdf/Energy-economics/statistical-review-2014/BP-statistical-review-of-world-energy-2014-full-report.pdf

The table also demonstrates that numbers must not be taken at face value. It is only slightly exaggerated to say that "for 40 years, the oil reserves have been lasting for 40 years".

Year	Raw oil	natural gas	Coal (Hard- and brown coal)
1975	31	42	185
1980	30	44	275
1985	36	51	
1990	44	51	233
1995	45	62	185
2000	43	67	210
2004	43	65	164

Figure 2-9: Static lifetime of fossil energy reserves (in years)[1]

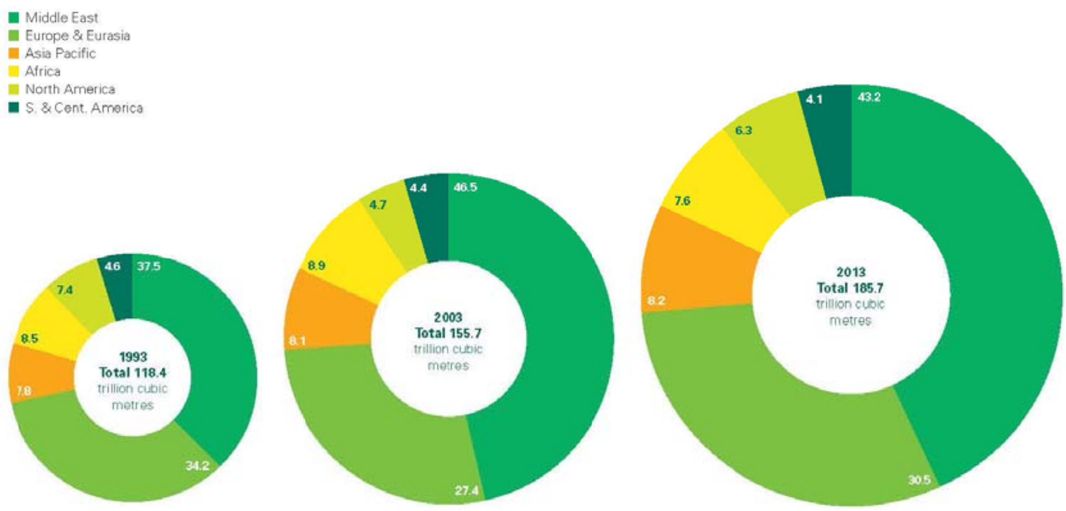

Figure 2-10: Distribution of proved gas reserves in 1993, 2003 and 2013 (Percentage)[1]

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[1] cf. Bundesanstalt für Geowissenschaften und Rohstoffe (BGR) in Hannover [Federal Institute for Geosciences and Natural Resources]. : Annual Report – Reserves, Resources and Availability of Energy Resources 2011/ 2013:
http://www.bgr.bund.de/EN/Themen/Energie/Erdgas/erdgas_node_en.html ;
http://www.bgr.bund.de/EN/Themen/Energie/Erdgas/erdgas_node_en.html
cf. Prof. Dr. Weber, Christopher (2007): p. 13 ff

This implies that in the past decades the consumption of oil and gas reserves have always been more than outweighed by new finds or increased yield from known oil or gas fields.

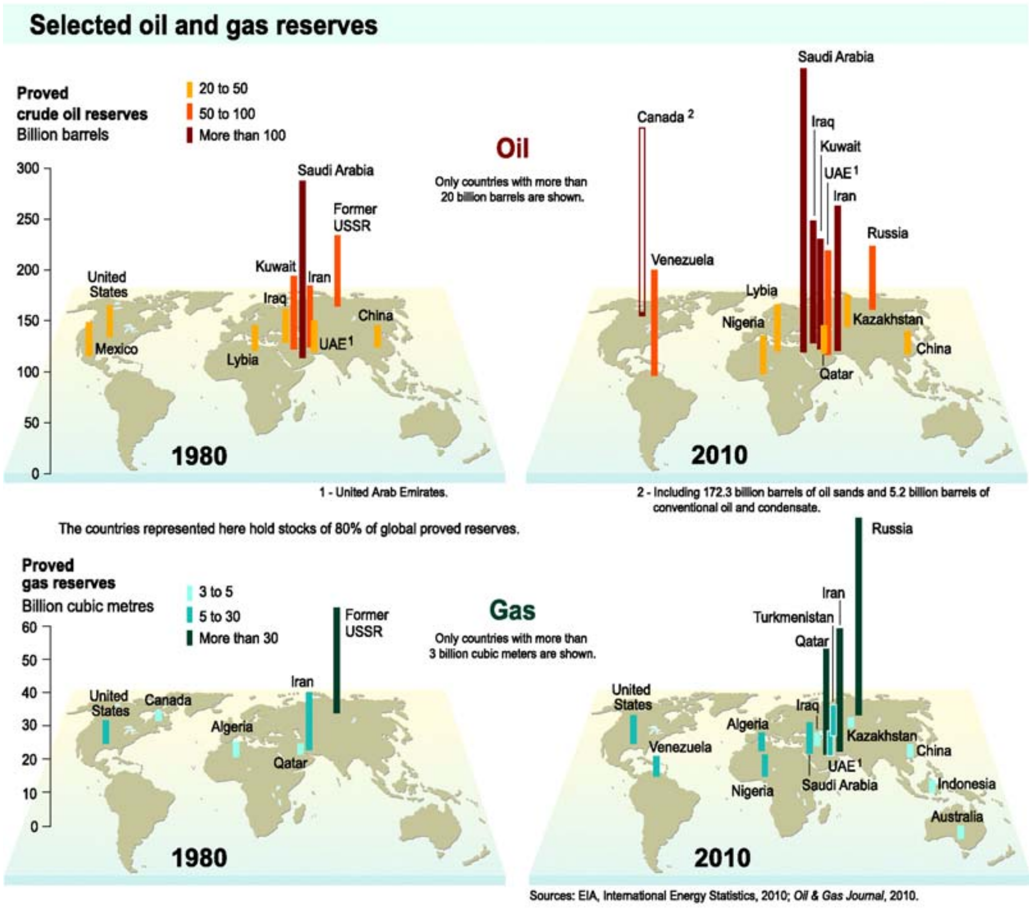

Figure 2-11: Selected oil and gas reserves[2]

In addition, the figures for coal reserves clearly demonstrate that the current price level can considerably influence the lifetime of reserves. In the high-price phase of the 1980s, significantly higher reserves were reported than in the low-price phases of 1995 and 2004. To what extent this can be applied to oil and gas in the future, may be discussed.

[1] cf. BP statistic review of world energy 2014: p. 23

[2] Source of data: European Environment Agency (EEA); http://www.eea.europa.eu/data-and-maps/figures/selected-oil-and-gas-reserves (The European environment - state and outlook 2015 (upcoming 4 March 2015): http://www.eea.europa.eu/soer/2015-pre-launch/upcoming-info)

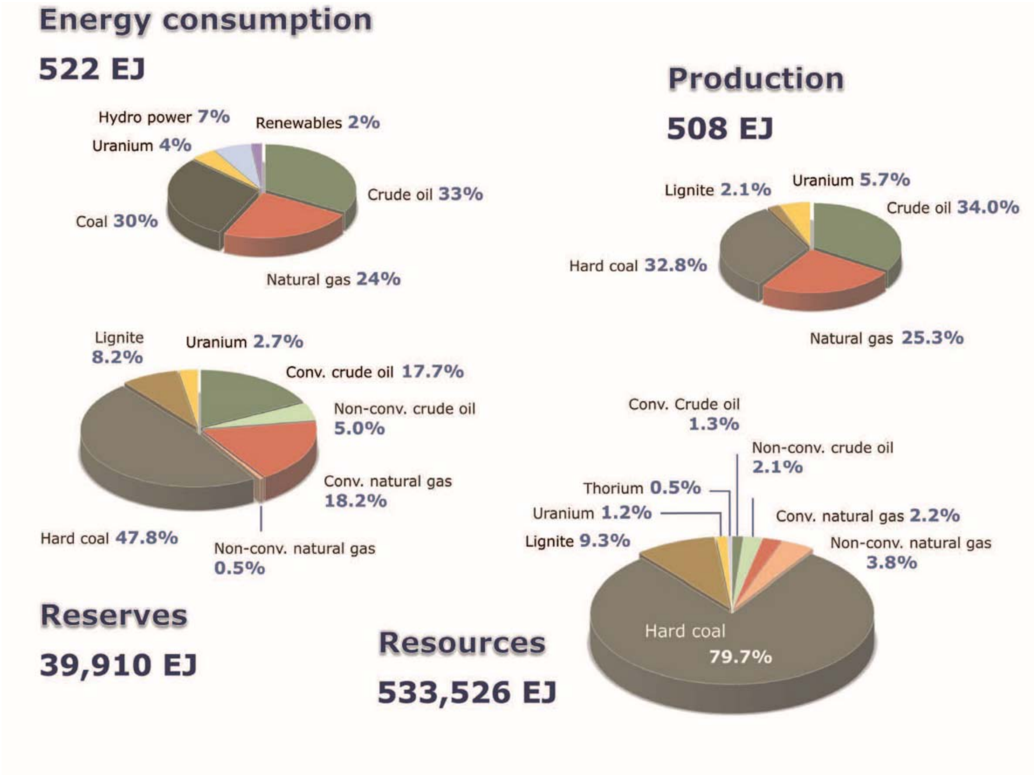

Fig. 4: Global share of all energy resources in terms of consumption (BP 2013) as well as the production, reserves and resources of non-renewable energy resources as at the end of 2012.

Figure 2-12: Global share of all energy resources in terms of consumption (bp 2013) as well as the production, reserves and resources of non-renewable energy resources as at the end of 2012[1]

2.3 Greenhouse effect

In February 2005, following Russia's ratification, the Kyoto Protocol[2] entered into force nearly eight years after it was passed. For the first time, a number of industrialised countries undertook to observe internationally binding emission limits for CO_2 and other greenhouse gases.

The fact that anthropogenic, i.e. man-made emissions of greenhouse gases can make decisive changes to the climate on earth, is now considered as established knowledge by the majority of politicians and, to an extent, also by scientists.

1 cf. Bundesanstallt für Geowissenschaften - Deutsche Rohstoffagentur : Annual Report – Reserves, Resources and Availability of Energy Resources 2014: p. 17

2 Kyoto Protocol Official Site : http://www.kyotoprotocol.com/

However, both the extent of the changes to be expected including their consequences and the countermeasures to be taken are still highly controversial.

In contrast to the emissions of sulphur and nitrogen oxides, which made headlines with acid rain and dying forests in the past decades, downstream technical measures to reduce CO_2-emission cannot be guaranteed at present. Whether the so-called CO_2-separation and sequestration will be able to make a significant contribution to climate protection, still has to be clarified and proved by current research projects. In the Energy Roadmap 2050[1] of the European Union it is already an integral part. But even if this proves to be possible, the implementation of ambitious climate protection targets will impose fundamental changes on the energy industry, as around 90% of the CO_2-emissions as well as considerable amounts of emissions of methane, the second most important greenhouse gas, result from the combustion of the fossil energy carriers coal, oil and gas[2]. A holistic approach to the CO_2-emission of individual power generation techniques would have to take upstream and downstream process chains into consideration. In lignite-fired power plants the emission balance is dominated by the power plant operation. Only two to four per cent of the total emissions are accounted for by the fuel supply. Unlike in wind energy plants, the share of emissions that are connected with power plant construction is negligible.[3] The varying carbon intensity of the different energy carriers is represented in the following chart:

[1] cf. http://ec.europa.eu/energy/energy2020/roadmap/doc/com_2011_8852_en.pdf

[2] cf. Prof. Dr. Weber, Christoph (2007): p. 13 ff

[3] cf. VDI (Verein Deutscher Ingenieure) : BWK Bd. 59 (2007) Nr. 10 http://www.vdi.de/fileadmin/vdi_de/redakteur_dateien/geu_dateien/FB4-Internetseiten/CO2-Emissionen%20der%20Stromerzeugung_01.pdf

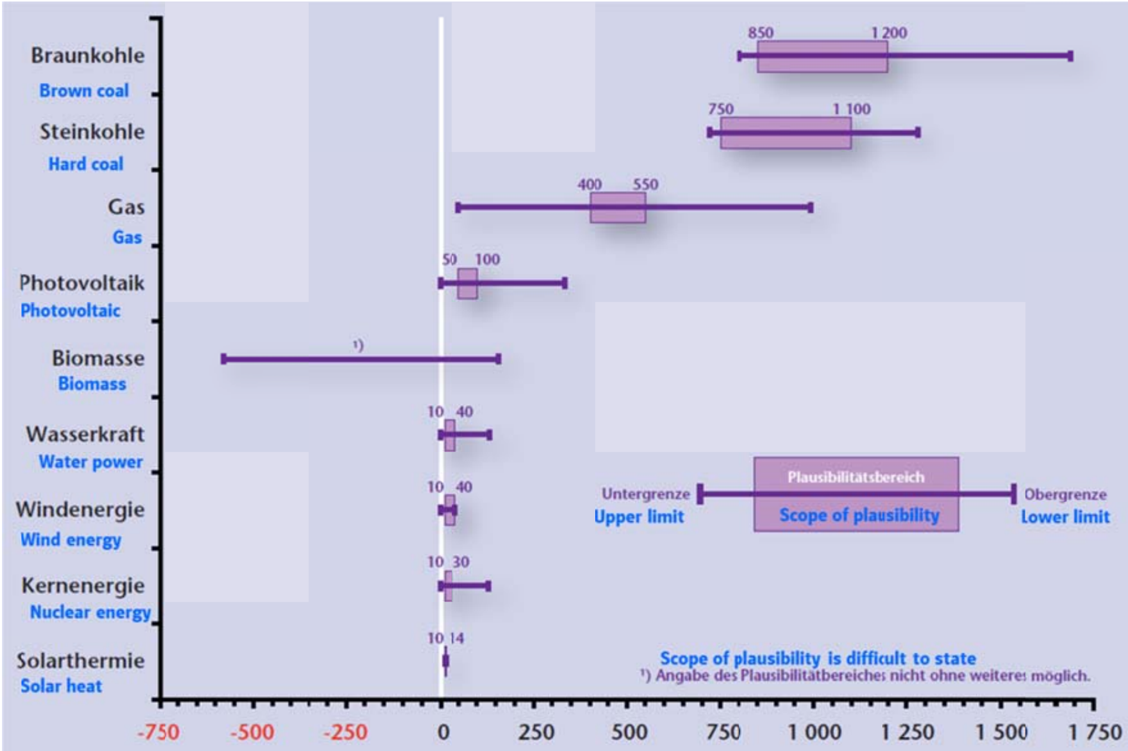

Figure 2-13: Specific equivalent CO^2 emissions [g/kwh][1]

This clearly demonstrates that a change from coal to natural gas can already lead to a significant reduction of the greenhouse emissions. Natural gas, however, is considerably more expensive and more problematic in terms of security of supply. This is because the largest gas stocks are in Russia and in the Near and Middle East. What is more, the transport in pipelines is more susceptible to supply disruptions. For the "CO_2-free" energy sources nuclear energy and renewables, on the other hand, there a number of security concerns and cost questions.

From an economic point of view, the historic overexploitation of environmental resources can only be explained by the fact that the environment was originally considered as a so-called "free good".

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[1] cf. VDI - BWK Bd. 59 (2007) Nr. 10 : p. 50

In the current climate discussion, the question is repeatedly raised, how big the CO_2-emissions of different power generation techniques are. This does not only apply to emissions from the combustion of energy carriers. To capture the energy and CO_2-balance of a technique completely, a holistic approach would be necessary throughout the entire lifecycle. Construction, operation, maintenance and repair of the facility as well as its disposal at the end of its service life require materials and auxiliary power. These upstream chains result in further climate-relevant emissions. The VDI paper presents and compares results from publications on CO_2-emissions from electricity generation.

A free good can, economically speaking, be used free of charge and in virtually unlimited quantities[1].

Due to its free and unrestricted availability, which mostly implies that virtually nobody can be excluded from using it, there is no (pricing) mechanism acting as a stimulus to use environmental resources economically.

Environmental pollution is, in this case, referred to external effects that are not controlled by the price mechanism. Pollution is a negative external effect, as it impairs, for example, people's health in the form of emissions. This kind of environmental devaluation is a modern version of the 'commons' problem (also called Allmenderproblematik).[2]

In some respects, however, there are also positive external effects. In research and development, for example, companies can often benefit from the experience of others, even if they do not directly acquire a patent.

From a theoretical environmental and economic perspective, environmental pollution can be avoided by introducing a price for environmental goods like for other goods, see EU emission trading.

On the other hand, this leads to the problem that environmental protection is only possible at excessively high costs.

To compete on the global scene, companies will have to aim for a standardisation of the instruments through possibly worldwide harmonisation. This applies in particular to environmental pollution of global nature, such as the emission of greenhouse gases.

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[1] cf. Mankiw, Gregory and Taylor, P. Mark (2008): p. 254 ff.

[2] The problem of the 'commons' (Allmenderproblematik) implies a general theory: As soon as somebody uses a social resource, they immediately diminish its possibility of being used by others. Or, as the Greek philosopher Aristotle put it:" What belongs to many, is treated with less care, as everybody prefers to look after their own private property rather than after common property."
cf. Mankiw, Gregory and Taylor, P. Mark (2008): p.262 ff.

3 Politics and energy economics

The previous chapters have shown that energy economics and energy politics often pursue different objectives at the same time, and that these objectives are, at least partially, in conflict with one another. Which objectives are given priority, is finally a normative question, i.e. a question based on value judgements. These judgements always comprise subjective components, which cannot be proved or disproved objectively, or using scientific methods[1]. However, considerations from economic theory could be useful to carefully weigh up the different objectives and to ensure consistency, i.e. to match the objectives with the means of achieving them.

3.1 Economic policy goals in market economy

From the point of view of economic theory, the energy industry is just a sector of the national economy – measured in terms of the creation of value[2] it is even one of the less important sectors. For this reason, it seems appropriate to transfer principles and findings that were formulated for economics in general, to energy economics and, in a subsequent step, to considerations relating to gas-fired power plants. Exceptions should only be made if the specific characteristics of energy economics and / or gas-fired power plants make the application of general theories difficult.

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[1] Gerhard Wegner even refers to an aporia of the normative theory of economic politics and presents a proposal on how to overcome this aporia. He summarises the result of his theoretical considerations as follows: „At present, the institutions of representative democracy are of such nature that it appears rational for political actors to pursue autonomous economic interests in their competition for votes." “Autonomous“, in this context, means that economic quality standards set to economic politics do not posses a constitutional status. In this way they can be systematically missed.

cf. Wegner (1996): p. 10 ff., 171 ff., 203 ff.; Streit (2005): p. 365 ff.

[2] Value-added calculations, on the one hand, determine the contribution of a business venture to the national product (as the sum of the economic value created in a certain period), and on the other hand, they demonstrate whether and to what amount the value created has resulted in an income.

cf. Schierenbeck, Henner; Wöhle, Claudia B. (2008): p. 754 f.; cf. Brümmerhoff u. Gömling (2011): p. 43 f., 231 ff.

The starting point for the economic discussion of public and other goals is the welfare theory[1], also referred to as 'welfare economics'. The first principle of welfare economics is that functioning competition in a market economy leads to a so-called Pareto-optimal result[4], i.e. any kind of state intervention in a market may improve the result from the perspective of some parties involved, but there will always be losers, who will be in a worse position after such state interventions.

This does not mean, however, that market outcomes are fair. For some participants, the market outcome may imply that they will not be in a position to make a decent living or that it contradicts the society's sense of justice in some other way. State intervention in economic processes can therefore be necessary to realise social value concepts of a fair income distribution.

The second principle of welfare economics, however, specifies that such interventions in the distribution can and should be carried out in a way that does not affect the functioning of the markets for energy and other goods.

Subsidizing energy prices or the construction of environmentally friendly gas-fired power plants, so that the underprivileged can afford to buy fuel for cooking and heating, is an intervention in the energy market which is being practised in several developing countries. From the perspective of welfare economics it might be an act of good intention, but it has no positive effect. Direct monetary support of 'poor households' would be a better option.

From the point of view of welfare economics, general state interventions in the energy industry must therefore be justified.

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[1] cf. Weimann (2006): p. 73 ff.; cf. Streit (2005): p. 17 f., 148 f.; cf. Mankiw / Taylor (2008): p. 159 ff., 231 f.

[4] In this context, the term Pareto –efficiency is used. It describes an investigation made by the economist and sociologist Vilfredo Pareto (1848 – 1923) regarding the following implication: Is there a possibility to treat someone more favourably without placing someone else at a disadvantage. = Pareto improvement;
cf. Varian (2007): p. 17 f.

However, there are some good reasons for such interventions (apart from many bad ones), as the principles of welfare economics are only valid if certain requirements are met.

One of these implies that no so-called external effects exist[1]. Environmental pollution, however, is a typical negative effect, as the polluter harms others without having to bear the costs that may arise.

Another reason for state intervention is market failure due to natural monopolies[2]. Monopoly means that there is only one provider on the market. The term 'natural monopoly' implies that in the competition between several providers a service cannot be offered at a cheaper price, but that, on the contrary, the total costs charged by several providers are higher than by one provider[3]. Such a natural monopoly usually exists in energy transport and distribution networks.

Even if information is distributed asymmetrically (e.g. between seller and buyer), state interventions can improve the general welfare.

From the welfare-economic perspective, however, the state should generally be cautious about intervening in the energy industry. But if it does, it should be guided by the overall objective of welfare economics, i.e. the improvement of the welfare for the whole society[4].

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1 cf. Streit (2005): p. 111 f.

2 cf. Weimann (2006): p. 328 ff.

3 cf. Wöhe (2010): p. 418 f., 453 ff.

4 A certain contradiction between political decisions and interventions in energy economics has been recognised and discussed in the paper of the European Commission of 12 December 2011 in the context of the energy policy until 2050. In the paper, it is openly referred to a risk of fuel poverty in certain classes of society. - cf. Energy Roadmap 2050: p. 19 point (6)
http://ec.europa.eu/energy/energy2020/roadmap/doc/com_2011_8852_en.pdf

3.2 Considerations of decision-making on the basis of the target triangle of energy economics

Being guided by the overall objective, i.e. the improvement of the welfare for the whole of society, is not always common practice in the energy industry. In fact, the model that was used in the past three decades for energy politics and energy economics was the target triangle shown in Figure 2-1[1]

It certainly describes the essential challenges for the energy industry. However, as targets are in relation to each other, every specification raises the question of how to make a choice between the various objectives. For this, the above orientation on the welfare for the whole society can be useful, but will not provide the ideal solution.

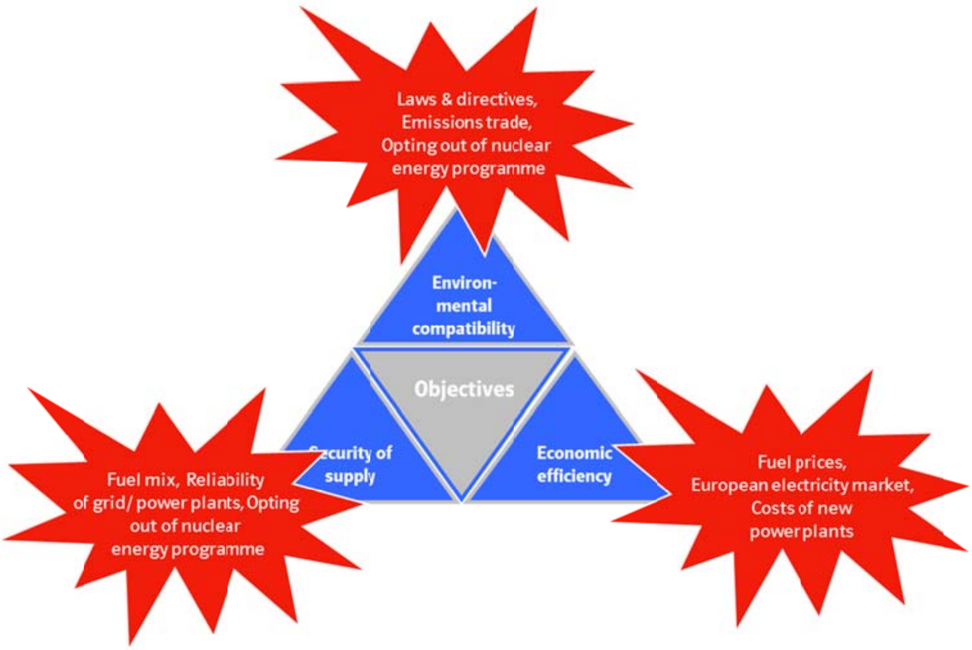

Figure 3-1: Challenges for energy economics from the welfare perspective[2]

[1] cf. page 20 - Figure 2-1: Target triangle of energy economics

[2] Author's own graph

Nevertheless, at least two of the three above objectives are in line with the reasons for a state intervention from the welfare perspective, which were discussed previously. This places them directly in the focus when considering the construction of a gas-fired power plant. To ensure economic efficiency, it is essential that a functioning competition is established, in which market failure is limited by natural monopolies as far as possible. But also the aim of environmental protection legitimates state intervention from the point of view of welfare economics, as the market alone will not be able to eliminate external effects that can occur, e.g. by greenhouse emissions or other environmental problems.

Only for the objective "security of supply", the question arises if and to what extent specific state interventions are necessary to ensure achievement of this objective. In the case of a gas-fired power plant, this is of importance as the supply of primary fuel has to be ensured at any time.

3.3 Functioning competition as a model

In functioning competitive markets all providers will make every effort to offer and sell their products or services at a favourable price. Otherwise they will not survive. It is therefore decisive, whether or in which ways functioning competition can be ensured in the energy industry.

In economic theory, the concept of perfect competition as an ideal market form was a preferred topic of discussion for a long time[1]. However, in the past decades it has become more and more obvious that perfect competition actually only exists as an idealised model in theory, but not on real markets. Essential characteristics of a perfect market are a large number of providers and demands as well as complete information provided to all market participants. Whether it is the car market, the computer or the mobile communications market, or even the bank sector - the number of the relevant providers is limited to a few.

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[1] cf. Wöhe (2010): p.416 ff.

As far as the completeness of information is concerned, it does not mostly exist on the consumers' side. Who knows, for example, the line coverage of mobile communications providers or the advantages or disadvantages of the different tariffs?

Nevertheless, the competition on markets, such as mobile communications, the car industry and many other goods is regarded as effective. From the economic perspective, it is characteristic of an effective competition that the market participants are capable of and willing to introduce innovations and that revenues resulting from these only have a temporary effect, as can be seen with the APPLE-iPad. Having been particularly sought after when it was launched on the market, it was initially offered at a price that must have been well above its production costs. After a certain time, however, other providers caught up and offered similar products.
With this increased choice, iPad-prices will go down and the excess profits of the innovative business APPLE will decrease.

From this, indications of an effective competition or its absence can be derived, for one thing from the market structure, but also from the market behaviour.

‚*Market structure*[1] in this context mainly refers to the number of providers on the relevant market. The smaller the number of providers, the bigger the risk of a non-functioning competition as a result of explicit cartel-like agreements or implicit adjustments of products and services ("collision").
On a large number of markets, however, the number of competitors has a maximum limit due to the minimum size that is necessary for efficient production. In the extreme case it is the natural monopoly[2], where two providers have higher total costs than one. This case often applies to supply networks. As it is a factor for site assessment and it is decisive for the market access, it will be dealt with shortly in the following.
In a functioning competition, the *market behaviour*[3] is characterised by a high degree of innovation dynamics and a pricing that only temporarily deviates from the marginal costs of production.

[1] cf. Jung (2010): p. 344 ff.

[2] cf. Weimann (2006): p. 149 ff.; cf. Hardes and Uhly (2007): p. 219 ff.

[3] cf. Varian (2007): p. 341 ff.

3.4 Networks as " monopolistic bottlenecks"

The networks of electricity and gas, but also for (terrestrial) telephone and the railway are characterised by distinct economies of density as a special case of economies of scale[1]. Supplying a further customer in a given supply area entails additional costs, which are far below the average costs implied in the network construction so far.

In the extreme case, the costs are close to zero, if, for example, only a new house connection at an existing gas pipe has to be installed. Such a situation leads to a natural monopoly that is characterised by a so-called sub-additive cost function[2.] This means that, if two businesses build competing supply networks in one area, this implies higher costs than if only one business is in charge of the supply of the complete area. If, in this situation, businesses are initially in competition, they will undercut each other and make every effort to recover at least a part of their network investments. The competition will end with the insolvency of one business, which will leave one provider as a natural monopoly on the market. This happened, for example, in the USA in the late nineteenth century both in the railway industry and the supply networks. A natural monopoly requires state intervention, especially if a part of the costs are so-called sunk costs, i.e. costs that are lost irretrievably. The costs for lines and networks are mostly sunk costs, because even if the power supply were discontinued, selling off the lines to other regions would hardly recoup the costs.

A natural monopoly with sunk costs represents a monopolistic bottleneck, which also blocks the competition on upstream and downstream markets (such as the generation and distribution of electricity).

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1 Economies of scale take the form of scale revenues. To achieve. Economies of scale….. The most probable result will be at the output rises by the same multiple. But it is also possible that the output level is by an additional share higher than the input growth.

cf. Varian (2007): p. 391 ff; cf. Weimann (2006): p.150 f.

2 The maximum profit of a monopolist is reached when the difference between total proceeds (E) and total costs (K) is at its greatest. The cost function comprises the fixed costs and the variable costs. A model for determining the selling price that maximises profits was developed by Cournot; cf. Wöhle (2010): p.453 ff.

Competition for household electricity customers is not possible, if the electricity cannot be distributed via the lines of the available power supply system. This, however, raises the question of the type of regulation.

A monopolistic bottleneck has to be generally accessible, if competition is to be allowed on upstream and downstream markets. For this reason, non-discriminatory grid access is an absolute requisite, if competition is to be initiated outside the networks, i.e. on wholesale and retail markets, the grid-bound energy carriers.
For this purpose, the European Union had demanded the generation of competition in the electricity and gas sector by the EU Directives[1] of 1996 and 1998. This, however, was hardly implemented in a really constructive manner by any of the member states.

This is why the European Union passed the so-called "Speeding-up Directives"[2] in 2003, as in many countries the progress made in liberalising the electricity and gas markets appeared insufficient. With these directives, all member countries were obliged to ensure the regulated grid access.

The grid access regulation implies the following aspects:

- the organisation of energy enterprises in the sector of grid-bound energy carriers
- the conditions of grid the use by third parties
- the structure and level of the network charges

The regulation is implemented on national levels and can therefore be organised in different ways.

[1] cf. chapter 4.2 The development of a European energy policy
[2] cf. chapter 4.2 The development of a European energy policy

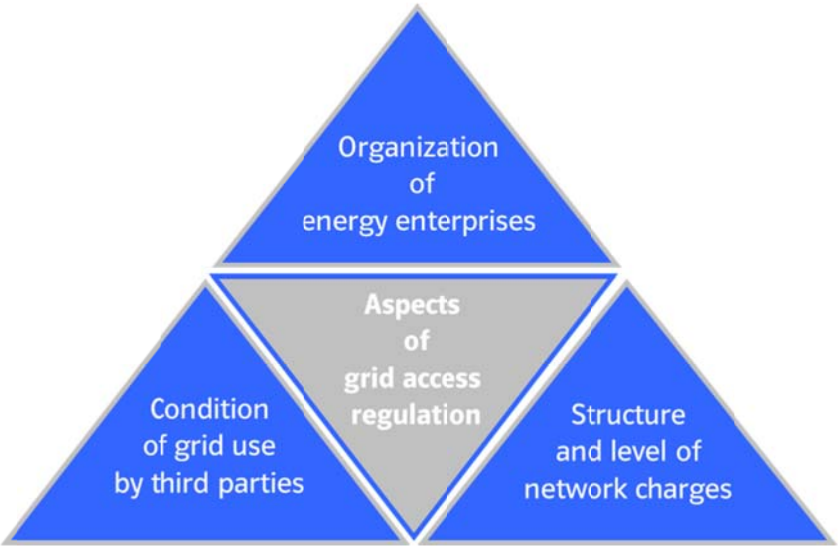

Figure 3-2: Aspects of a grid regulation[1]

3.5 Competition and price development on the European market

In contrast to the grid sector, the liberalisation is meant to establish functioning competition on the wholesale and retail markets for electricity and gas. A characteristic of functioning competition is that prices stabilise at the lowest possible level[2]. If they do not, one or several providers are very likely to exercise market power. However, one should bear in mind that the prices will not take their cue from the short-term marginal costs, at least not in the long term. The producers should rather be able, perhaps after a transition period, to cover their long-term marginal costs, i.e. the costs including investment costs and fixed costs for staff, insurance, etc. by their proceeds.

When competition on the electricity trading market in the European countries began, very low prices were observed, which were close to or partially below the variable costs (i.e. the short-term marginal costs) of the power plants involved. This was a result of overcapacities in production.

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[1] Authors own figure

[2] cf. Schierenbeck and Wöhle (2008): p. 321 ff.

Under these circumstances, older power plants were not able even to cover the annual fixed costs for insurance, staff, etc., so that old capacities were decommissioned in considerable numbers or put in the so-called cold reserve, i.e. preserved in such a way that they can be used, should prices rise again.

This shortage of generation capacities, along with a moderate, but continuous growth in demand in Europe has led to a gradual increase in electricity prices, which began in the second half of 2001. This development was and is still overlaid by stochastic, i.e. coincidental events, which can lead to significant price peaks, owing to the fact that electricity cannot be stored. In France, for example, a cold start of the winter in combination with power plant outages and the aftermath of the insolvency of the American energy vendor Enron in December 2001 resulted in prices that were for first time up to 1,000€/MWh. But also the average monthly price on the spot market reached new peaks. The extremely hot summer of 2003 led to a reduction of the available power plant capacities in the northern part of Europe due to high cooling water temperatures, and to restrictions in river traffic due to low water levels. Together with an increased demand for electricity for cooling and air-conditioning, this resulted in energy price spikes that had never been experienced before.

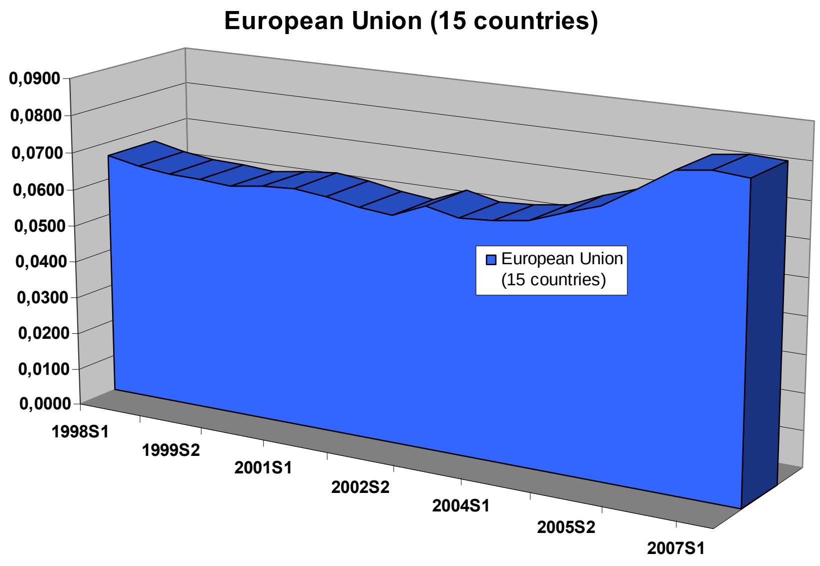

Figure 3-3: Electricity - industrial consumers - half-yearly prices - Old Methodology until 2007[1]

[1] EUROSTAT - Energy Statistics: gas and electricity prices - Old methodology until 2007: http://epp.eurostat.ec.europa.eu/portal/page/portal/energy/data/database

Apart from the shortage of generation capacities, changes in prices for input factors lead to price changes on the wholesale markets. It is especially the prices for hard coal and natural gas that affect the variable costs of power plants, thus causing a rise in wholesale prices for electricity and gas. In addition, the introduction of the trading with CO_2-certificates resulted in the situation that an additional input factor for pricing on the wholesale market became relevant.

Whether market power was exercised in this context, is an ongoing issue of debate in the EU-countries. As this cannot easily be deduced from empirical price data, there are other approaches that are used by competition regulators to derive indications suggesting the exercise of market power. In these approaches, the concepts of the relevant markets are of primary importance.

Germany, for example, renounced price controls and administrative price setting on competitive markets in the past - unlike France - and was very successful at limiting inflation. Finally, such controls are always interventions in the market, and, due to an information asymmetry between state and enterprises, they are hardly efficient. Either the state accedes to the demand of the enterprises, which makes prices controls superfluous, or the state refuses price increases, which would lead to an additional shortage of supply, as it would not be profitable for enterprises to enter the market or remain on it.

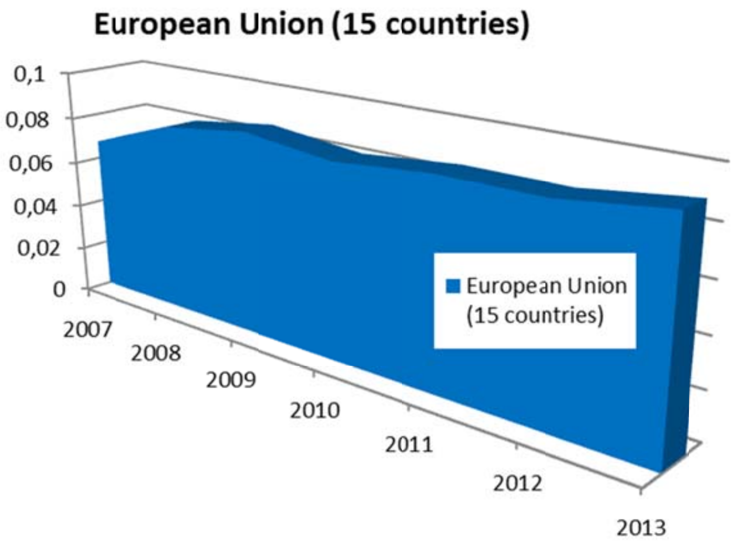

Figure 3-4: Electricity prices - industrial consumers - half-yearly prices - New methodology from 2007 till 2013[1]

[1] cf. EUROSTAT - Electricity – industrial consumers – New methodology (extracted on 03rd of January 2015):

When analysing the market structure, an essential question would be, whether the market power of the big players on the spot market could be effectively limited by well-functioning futures markets, on which larger amounts of electricity can be purchased months or years in advance. On the EEX, the German electricity stock exchange[1], more than 100 traders are registered, and the spot market is in no way limited only to the big producers. This suggests that the big producers indeed have only a limited market power, if any at all.

Figure 3-5 : Press statement of Chancellor Mrs. Merkel at an EEX visit[2]

Analysing the market results reveals the problem that the observed prices depend on a multitude of partly deterministic (calculable) and partly stochastic (accidental) influences. High prices at certain times, such as in 2009[3], are not automatically an indication of market failure, but rather reflect temporary shortages, which can be overcome by the entry of new market participants and / or subsequent expansion of production capacities. Only if market prices remain above the long-term marginal costs for longer periods, can an abuse of a dominant position be assumed. This makes it difficult to provide evidence of such an abuse, all the more since planning and construction times for power stations can be up to three to five years.

http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nrg_pc_205_c&lang=en

[1] cf. EEX website : http://www.eex.com/en/

[2] EEX Press Statement in 2010 : (© Jürgen Jeibmann Photographik Leipzig)

[3] cf. Figure 3-4: Electricity prices - industrial consumers - half-yearly prices - New methodology from 2007 till 2013

In 2005[1], electricity prices rose further as a result of the emission trade. Correspondingly, a large number of new power plants were planned and / or went under construction in the subsequent years. It is therefore to be expected that these additional capacities will limit the electricity price and the market power of traditional providers, at least in the long run.

3.6 Power plant fleet in Europe

In 2012, the EU 28 countries had a total power consumption of electricity by industry, transport activities and households/services of 2.8 GWh[2]. The electricity volume produced in these countries in the same year amounted to 3.3 GWh. The current three major electricity markets in Europe are France, Germany and Britain.

[1] cf. Figure 3-3: Electricity - industrial consumers - half-yearly prices - Old Methodology until 2007 & Figure 3-4: Electricity prices - industrial consumers - half-yearly prices - New methodology from 2007 till 2013

[2] This consumption stands for final energy consumption. This means that the consumption in industry covers all industrial sectors with the exception of the energy sector, like power stations, oil refineries, coke ovens and all other installations transforming energy products into another form. Final energy consumption in transport covers mainly the consumption by railways and electrified urban transport systems. Final energy consumption in households/services covers quantities consumed by private households, small-scale industry, crafts, commerce, administrative bodies, services with the exception of transportation, agriculture and fishing.

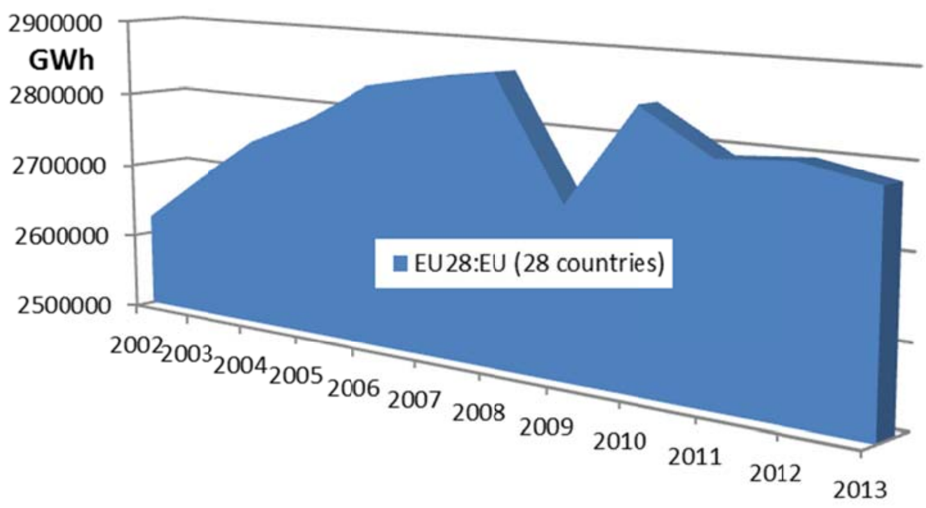

Figure 3-6 : EU 28 Consumption of electricity by industry, transport activities and households/services[1]

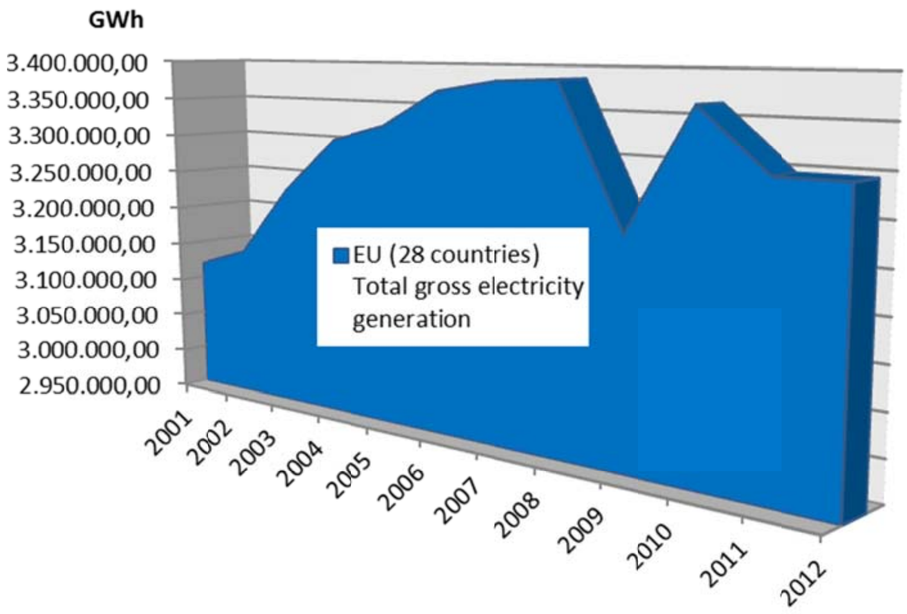

Figure 3-7 : EU 28 Total gross electricity generation[2]

[1] Source of data: Eurostat (ten00094); date of extraction: 02nd March 2015; http://ec.europa.eu/eurostat/tgm/refreshTableAction.do?tab=table&plugin=1&pcode=ten00094&language=en

[2] Source of data: Eurostat (ten00087); date of extraction: 03rd February 2015 http://ec.europa.eu/eurostat/eurostat/tgm/table.do?tab=table&init=1&plugin=1&language=en&pcode=ten00087

The clear surplus electricity produced was necessary to cover the power plants' own consumption and the losses that occur during the transport of electricity.
Considering the economic growth in a number of European countries until the financial crisis and in Spain until 2012, a further increase in consumption would have to be expected for the next few years. However, the long-term implications of the financial crisis in the banking industry and the global economy are not yet foreseeable today.

In the total net electricity generation of the EU 28 countries, nuclear energy, lignite and hard coal, natural gas and hydropower are the most important energy sources.

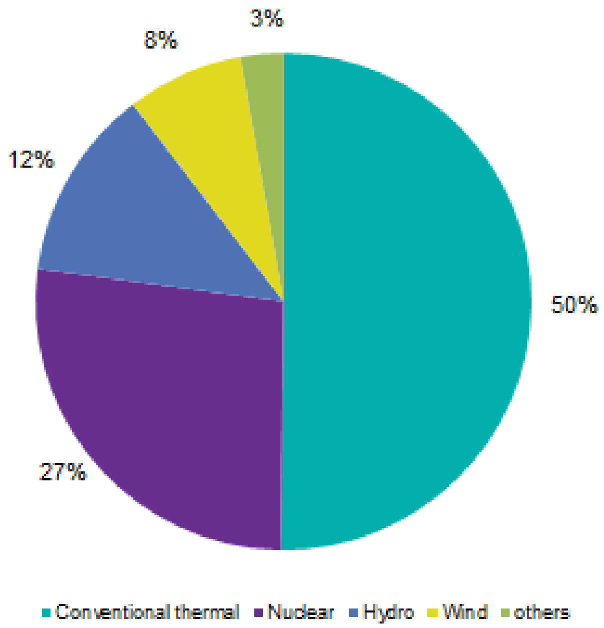

Figure 3-8 : EU 28 Electricity production by source, 2013 (% of total, based on GWh)[1]

This is reflected in the figures of the installed net generating capacity, although they are slightly distorted due to the different annual full load hours. According to statistics of ENTSOE[2], the installed net generating capacity in 2013 amounted to around 916 GW in the European countries.

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[1] cf. Statistical Yearbook of European Commission for Energy 2014;
http://ec.europa.eu/eurostat/statistics-explained/index.php/Europe_in_figures_-_Eurostat_yearbook

[2] ENTSOE = European Network of Transmission System Operators for Electricity; source of data: Statistical Yearbook 2014;
https://www.entsoe.eu/resources/publications/general-reports/statistical-yearbooks/

year	Oil	Coal and lignite	Natural and derived gas	Nuclear	Renewables	Other fuels	Total
1990	224247	1004720	223528	794863	327384	20020	2594762
1991	232093	1010292	217610	819835	341484	18262	2639576
1992	241614	965625	213482	827323	357893	18010	2623947
1993	218847	924790	239393	862173	364890	15757	2625850
1994	214862	927884	270565	858724	376805	17329	2666169
1995	230335	937574	294111	880821	382150	17753	2742744
1996	226300	946763	341198	925939	385287	19696	2845183
1997	214682	893042	394075	937622	396466	20823	2856710
1998	220396	903156	424917	932851	418930	21920	2922170
1999	205263	871400	489128	943384	424655	20345	2954175
2000	181296	925962	512894	944993	448783	22021	3035949
2001	174170	932706	529802	978986	476563	26605	3118832
2002	186503	947243	556812	990196	436486	26638	3143878
2003	171633	996893	603348	995860	440992	25865	3234591
2004	148069	976359	653670	1008437	487930	29107	3303572
2005	142772	951241	704172	997699	495129	34096	3325109
2006	136215	974533	718481	989877	520354	30452	3369912
2007	114506	974600	776724	935277	549786	32399	3383292
2008	108766	890015	825823	937215	594188	30799	3386806
2009	99043	814403	757942	893990	626575	29437	3221390
2010	86777	818992	797752	916610	709565	34693	3364389
2011	72462	840412	733810	906744	705932	35713	3295073
2012	72490	892056	614704	882366	798736	34882	3295234

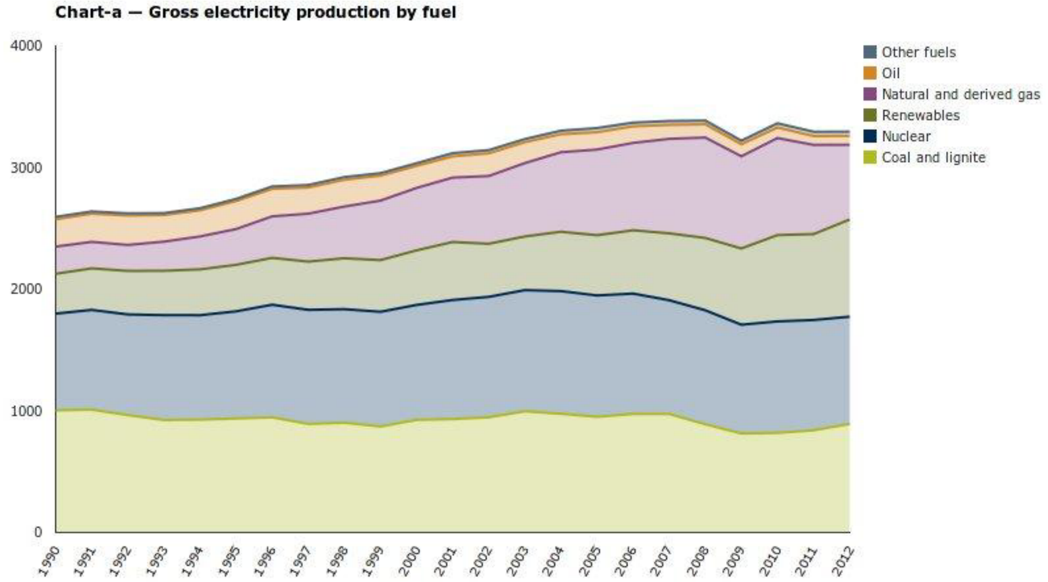

Figure 3-9 : Share of gross electricity production by fuel type in 2012 in GWh[1]

[1] Source of data: European Environment Agency; Created 05 Dec 2013 Published 19 Dec 2014 Last modified 19 Dec 2014, 01:41 PM

Data shown are for gross electricity production and include electricity production from both public plants and auto-producers. Renewables include electricity produced from hydro (excluding pumping), biomass, municipal waste, geothermal, wind and solar PV. The share of renewables presented in the chart is that for production and hence does not correspond to the share in consumption, as required by Directive 2001/77/EC (see ENER 30). The difference between both shares is accounted for by the net balance

On the European electricity markets there is a competition among electricity producers in the area of fuels, which is gradually going beyond the national borders. Nevertheless, the European fleet of power plants is dominated by a few major corporations, which has, for one thing, historical reasons, but is also due to the insufficient liberalisation.

The ten biggest energy companies have an installed capacity of over 50% of the market share.

Utility Company	Electricity sales in TWh (2013)
E.ON (Germany)	704
EdF (France)	530
ENEL (Italia)	296
GDF Suez (France)	290
RWE (Germany)	271
IBERDROLA (Spain)	215
Vattenfall (Sweden)	203
EnBw (Germany)	51

Figure 3-10 : Electricity sales of Europe's largest utility companies in 2013 (in TWh)

According to the EU Green Paper on Energy Efficiency of 2006, the heat-controlled CHP-plants cover 13% of the electricity consumption in the EU. By using heat and electricity, a fuel efficiency rate of up to 90% can be achieved.[1]

between imports and exports of electricity. ‘Other fuels’ include electricity produced from power plants not accounted for elsewhere, such as those fuelled by certain types of industrial wastes. It also includes the electricity generated as a result of pumping in hydro-power stations.
http://www.eea.europa.eu/data-and-maps/figures/share-of-electricity-production-by-5
http://www.eea.europa.eu/data-and-maps/indicators/overview-of-the-electricity-production/assessment-2

[1] cf. RWE – Facts and Figures 2014, p. 9 (ID 151258)

In 2012 the fossil fuels continue to dominate the EU28 electricity mix, albeit a decline of 8.1 percentage points in their share in gross electricity generation from 56% in 1990 to 47.9% in 2012.

Nuclear electricity increased by 11% between 1990 and 2012, at an average annual rate of 0.5%. It is the result of an increase of 1.5%/year between 1990 and 2005 and, since 2005, an average decrease by 1.7%/year. On average, nuclear electricity decreased between 2005 and 2012 in Germany (-6.8%/year), Belgium and Bulgaria (-2.4%/year in both countries) and in the UK (-2.1%/year), whilst it increased in countries such as Romania (10.9%/year), the Czech Republic (3.0%/year) and Hungary (1.9%/year).

The electricity produced from renewable sources increased by 144% between 1990 and 2012 at an average annual rate of 4.1% over this period and at a faster pace (7.1%/year) since 2005. The acceleration observed since 2005 occurred in the context of national and EU renewable energy support policies. In 2012, 46% of the renewable electricity was generated from hydro, 26% from wind, 19% from biomass, 9% from solar and 1% from geothermal.

3.7 Prospects

Both in Germany and in the other European countries, the power plant capacity will have to be renewed in the near future. It is generally assumed that, despite the financial crisis and its effects on the global economy, the total demand for energy will rise by ca. 1.6% annually (WEO, 2011)[1].

[1] International Energy Agency – World Energy Outlook 2011
http://www.iea.org/w/bookshop/add.aspx?id=428

Due to the further increase in consumption and the limited service life of existing power plants, power plant capacities between 300GW (Axpo 2006) and 560 GW (EU Green Paper of 2006)[1] will have to be newly installed in the EU 25 countries until 2030. Despite the financial crisis and the sharp rise in the raw material prices for metals, etc., these assumptions will not change significantly in view of the necessity to renew old fleets of power plants.

In contrast to Germany, the electricity generation in nuclear power plants in Europe will be expanded further or again. The reasons for this include a higher social and also political acceptance in several countries, a different policy framework and the target of reducing CO_2-emission. Measures to achieve this objective include emission trade, which does not only favour the efficient gas and steam plants and the CHP plants as well as the renewable energies, but finally also the nuclear power plants, as these do not emit any or less carbon dioxide per MWh than coal-fired power plants.

Due to the low investment costs per KW of installed capacity, the high efficiency factor, the low CO_2-emissions and the relatively short construction times, a large number of gas and steam power plants are planned or are already under construction in Europe[2]. In order to be sufficiently provided with fuels for the generation of electricity in the future, a lot of countries have been focussing on liquefaction of natural gas (LNG) for several years. The physical properties of LNG facilitate its transport on tankers to the ports of destination and / or power plants, where the natural gas is returned to its gaseous state. Thus, LNG offers a practical alternative to the gas transport by pipelines and a possibility to put the procurement structure on a broader basis. This, in turn, will lead to new alternatives for the choice of sites. Projects like the Baltic pipeline or the Nabuko project offer the prospect of a greater security of supply.

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[1] EU Commission - Green Paper - A European Strategy for Sustainable, Competitive and Secure Energy {SEC(2006) 317};
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:52006DC0105:EN:NOT

[2] In the European Road Map 2050 (p. 11 ff.) they pointed out that „gas plays a key role in the transition. … In the Diversified Supply Technologies scenario for example, gas-fired power generation accounts for roughly 800 TWh in 2050, slightly higher than current levels. With evolving technologies, gas might play an increasing role in the future. …"

Further measures to secure supply include decentralised generation and the use of renewable energies for power generation. The expansion targets of the EU 15 countries of 2004 and the values in each EU member country resulted in an indicative target value of around 20% of the share of renewable energies in the gross electricity consumption for the EU 25 in 2010. The political implementation in the individual EU 25 countries is one of the criteria for the choice of sites for power plant projects within Europe.

Last, but certainly not least, the importance of the international electricity trade for the liberalised electricity market in Europe must be stressed. Apart from the promotion of the Europe-wide competition in the generation of electricity, the existing capacities in the power plant fleet can be used more efficiently in this way. An important prerequisite for the electricity trade, however, is the expansion of the cross-border power transfer capacities between the individual European states. This, in turn, requires good cooperation of all participants on the energy market, which is essential for the development of a power plant fleet in Europe and finally, for the success of each individual company.

4 History of energy economics

4.1 The beginnings of energy economics

The term „energy economics“ refers to the sector of economy which satisfies the demand for energy, i.e. primary extraction (coal, oil, gas, water, etc.) and transformation into secondary energy carriers (power plants, etc.), converts and transfers it and makes it available and usable for production and individual and social consumption[1]. This definition represents above all a general formula, which can solely be applied to the beginnings of energy economics.

Related to the current state of science and technology, energy economics is defined as follows[2]:

> Energy economics focuses on the development and allocation over time of non-renewable energy resources (oil, gas, coal, and uranium), the optimum time to convert them into energy, and the trade-offs between the benefits of the present and future use of these resources. Energy economics is also concerned with the circumstances under which alternative energy sources (e.g. renewable) would be best introduced into the energy system.

Energy economics did not become an independent sector of the economy until the breakthrough of electrification at the beginning of the twentieth century. The foundation for this was laid by the industrial revolution, which began in England in the early ninetieth century. The industrial basis was the increased use of steam engines as a motorised drive for production and transport. According to estimates, the maximum number of steam engines with an average output of ten horse powers that were in operation in England around 1800 was 1000 (which is a total of 10,000 horse powers).

---

[1] cf. Gabler (1997): p. 1116 f.; cf. Institut für Wirtschaftsgeschichte der Akademie der Wissenschaften der DDR (1981): p. 644 f.

[2] cf. International Encyclopedia of Economics (1997): p. 462 ff.

Estimates for the year 1850 suggest that the output of stationary engines in Great Britain amounted to 500,000 horse powers and that of mobile engines – the major share was made up by railway locomotives – 790,000 horse powers.[1]

The use of hard coal as an energy carrier and the improvement of the transport system on rivers, canals and oceans represented an important new basis for energy economics. The differences in the development of energy economics at that time are reflected in the fact that until the end of the ninetieth century, around 30% of the world population made use of approximately 90% of the steam engine horse powers.[2]

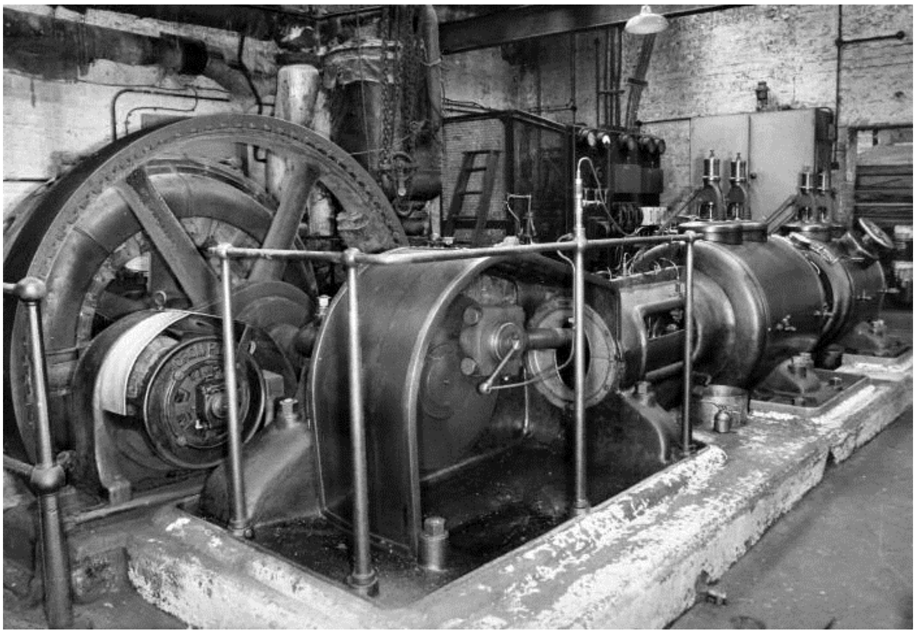

Figure 4-1 : A steam engine used in a factory[3]

The gradual emergence of a demand for smaller engines, however, led to the introduction of a gaseous energy carrier and the development of the combustion engine.

[1] cf. Landes (1973): p. 106 f.; cf. Deane (1979): 72 ff.

[2] cf. Institut für Wirtschaftsgeschichte der Akademie der Wissenschaften der DDR (1981): p. 645

[3] cf. http://www.theschoolrun.com/homework-help/victorian-era http://www.paxmanhistory.org.uk/images/18581CBb.jpg

But the invention of the combustion engine, which was the basis for the automotive vehicle, did not help to solve the contradictions in the classical factories.
It was not until the need to satisfy the energy demand and the impossibility to develop the transmission system further was recognised, that the breakthrough of the use of electricity in production was achieved. In the first stage of the development of electrical engineering, large electric motors were used for the group operation of machine tools, so that a certain reduction of the transmission mechanism could be achieved as an economic advantage[1].

The factory systems and the efforts made to optimise production along with the need for a safe electric lighting system (which had mainly been operated on gas by that time) in the early twentieth century promoted a further advance of electrification. It was also the introduction of electricity which helped the turbine establish itself as a drive for electric generators. Electrical energy and the possibility of its transmission to remote units allowed for a separation of the sites of energy production from those of its use. This resulted in the emergence of new industrial sites – the power plants[2].
The first public electric power station in Europe was built by the Siemens brothers in Godalming (England) in 1881. It was followed by more stations throughout Europe[3] and finally, throughout the whole world.
The construction of hydropower plants at the Niagara Falls in 1902, for example, allowed for a supply of a hitherto unique amount of economically produced electricity. This was one of the decisive factors for a large number of companies to settle down in close proximity.
Implementing schemes of such dimensions required high equity investments in bank dams, power plants and national energy transmission systems, which could mostly be financed only by public sector companies[4]. This has been reflected to the present day by the predominance of single corporate groups or public energy companies in Europe.

[1] cf.. Institut für Wirtschaftsgeschichte der Akademie der Wissenschaften der DDR (1981): p. 646 f.

[2] cf. Albers et. al. (1980): p. 362 ff

[3] cf. Landes (1973): p. 268 ff

[4] cfl. Institut für Wirtschaftsgeschichte der Akademie der Wissenschaften der DDR (1981): p. 649 ff.

4.2 The development of a European energy policy

Following extensive discussions, a chapter on energy policy was finally included in the Draft Treaty Establishing a Constitution for Europe in 2003. According to article 157, the European Union policy on energy aims to[1]:

- ensure the functions of the energy market,
- ensure security of energy supply in the Union, and
- promote energy efficiency and saving and the development of new and renewable forms of energy.

These provisions will not affect a Member State's choice between different energy sources and the general structure of its energy supply, e.g. the question of Germany's opting out of nuclear energy.
The European Union is increasingly influencing national energy policies and their players. The basis for this is provided by a legal framework and its most important players on the European level. The essential laws and political decisions will be briefly explained below[2].

Although the roots of the European Communities are, among others, to be found in the energy sector, due to its significance as an indispensable utility industry, the agreements for the foundation of the European Coal and Steel Community (ECSC from 24 July 1952 to 23 July 2002) [3] and the European Atomic Energy Community (Euratom of 25 March 1957)[4] did not confer comprehensive powers for the regulation of energy economics from the Member States on the Communities.

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[1] cf Europäischer Konvent – CONV 850/03 page 130 Entwurf eines Vertrags über eine Verfassung für Europa : http://european-convention.eu.int/docs/Treaty/cv00850.de03.pdf

[2] cf. Godron Phillip; Tschentscher, Sebastian (2007): p. 59 ff.

[3] cf. http://europa.eu/legislation_summaries/institutional_affairs/treaties/treaties_ecsc_en.htm

[4] cf. http://europa.eu/legislation_summaries/institutional_affairs/treaties/treaties_ecsc_en.htm ; http://eur-lex.europa.eu/en/treaties/dat/12006A/12006A.htm ; http://europa.eu/legislation_summaries/institutional_affairs/treaties/treaties_euratom_en.htm

The Treaty establishing the European Economic Community (EEC) of 1953 did not contain any special regulations for the energy sector, either. Instead, a large number of national regulations on the production, trade and import of energy products dominated the respective energy markets[1].

The threatening raw material shortage connected with the oil crisis in 1973 introduced a closer coordination of the energy policy, though mainly relating to the issue of import and export of raw materials. The basis was article 133 EC Treaty on a common commercial policy of the Treaty on Establishing the European Community[2].

It was not until the European internal market was founded in the late 1980s, accompanied by an increasing liberalisation, that issues on energy policy gained considerable significance. As a consequence, the Treaty of Amsterdam was signed in 1999, which included energy policy in the list of activities of the European Community (Article 3 (lu) EC Treaty)[3].

A decisive factor for the scope for intervention of the EU in the energy policy is the internal market concept of the European Community[4].

> *Art. 14 EC Treaty*[5]
>
> „(1) The Community shall adopt measures with the aim of progressively establishing the internal market…
>
> (2) The internal market shall comprise an area without internal frontiers in which the free movement of goods, persons, services and capital is ensured in accordance with the provisions of this Treaty.

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1 cf. http://www.bmwi.de/BMWi/Navigation/aussenwirtschaft,did=9388.html?view=renderPrint ; also http://eur-lex.europa.eu/de/treaties/dat/11957E/tif/11957E.html

2 cf. http://www.aeuv.de/aeuv/fuenfter-teil/titel-ii/art-207.html

3 cf. http://www.europarl.europa.eu/topics/treaty/pdf/amst-de.pdf

4 cf. European Commission : http://ec.europa.eu/internal_market/index_en.htm

5 cf. http://eur-lex.europa.eu/de/treaties/dat/12002E/pdf/12002E_DE.pdf

(3) The Council, acting by a qualified majority on a proposal from the Commission, shall determine the guidelines and conditions necessary to ensure balanced progress in all sectors concerned."

In the energy sector, the first active steps were taken with the Directive 96/92/EC and 2003/54/EC (electricity sector)[1] and 98/30/EC und 2003/55/EC (gas sector)[2]. The so-called first EU-internal market paved the way for the creation of an internal gas and electricity market in 1996/1998[3].

The internal market had to take into account completely different structures of energy industries, such as the centralist structure in France and the central structure in Germany with its more than 1,500 network operators. At the same time, however, free access to the market was to be granted to all approved customers and providers within the European Community. The majority of the Member States, e.g. Spain, Germany and Great Britain decided to liberalise their energy markets completely, or at least to an extent that was beyond the standards required by the EC. This unbalanced opening of the national markets led to a distortion of competition among the respective market actors. Electricité de France, for example, acquired significant market shares in the major European neighbouring countries, such as Italy or Germany, but remained unrivalled on the more isolated French market, for a long time.

As a consequence of the different degrees of progress in the liberalisation of the national markets, the so-called Directives for Speeding up Liberalisation in the Electricity and Gas Sector were passed on 26 June 2003[4]. The aim of these Directives was a complete opening of the markets while ensuring high standards of public services and maintaining universal service obligations.

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1 cf. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2003:176:0037:0037:EN:PDF

2 cf. Konsolidierte Fassung des Vertrages zur Gründung der Europäischen Gemeinschaft vom 24.12.2002 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2003:176:0057:0057:EN:PDF

3 cf. Institut für Europäische Politik : http://energy.iep-berlin.de/php/1_binnenmarkt_analyse.php

4 Repealing Council Directive 96/92/EG;
cf. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2003:176:0037:0037:DE:PDF ;
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32003L0054:EN:NOT

The two Directives came into force on 4 August 2003. They stipulated that the gas and electricity markets were to be opened for all non-private consumers by July 2004 and for all consumers by July 2007. After these dates, all consumers – enterprises and private households – would have to be guaranteed free choice of their electricity and gas provider on the market. Important elements of the Directive include: (1) Unbundling, (2) Tariffs and (3) Public services.

Major institutional actors include the European Commission, the European Council, the Council of Ministers and, since the Maastricht Treaty at the latest, the European Parliament.
In addition, the EU-Commission appointed regulators as an advisory body, the so-called "European Regulators Group for Gas and Electricity (ERGEG)"[1] in 2003[2]. There is a large degree of identity of actors and targets between the two groupings, although ERGEG, being the official advisory body of the Commission, has a stronger direct, i.e. operative legitimacy.

On 8 March 2006, the President of the Commission, Jose´ Barroso and Energy Commissioner Andris Pieblas submitted the long expected Green Paper[3] "Towards a European Strategy for the Security of Energy Supply[4].

In the Commission's view, the European energy policy was expected to comprise the following six primary areas[5]:

[1] EUROPEAN REGULATORS GROUP FOR ELECTRICITY AND GAS RULES OF PROCEDURE http://www.ergeg.org/portal/page/portal/ERGEG_HOME/ERGEG_DOCS/ERGEG_DOCUMENTS_NEW/INTERNALRULES/ERGEG_RULES-OF-PROCEDURE_05-10-05.PDF

[2] Commission Decision of 11 November 2003 : http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32003D0796:EN:HTML

[3] Green Papers : http://europa.eu/documentation/official-docs/green-papers/index_en.htm

[4] cf. Green Paper - A European Strategy for Sustainable, Competitive and Secure Energy {SEC(2006) 317} : http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:52006DC0105:EN:NOT

[5] cf. Godron Phillip; Tschentscher, Sebastian (2007): p. 67 ff.

- The completion of the internal European electricity and gas markets is to be given priority. In addition, the Commission recommends to set up a European regulator;
- Strengthening the solidarity among the Member states in cases of supply disruption and building up emergency gas stocks;
- Diversification of the energy mix;
- Climate protection measures: Renewable Energy Road Map with specified targets until 2020 and beyond; Action Plan for Energy Efficiency;
- Strategic Plan for Energy Technologies to avoid overlap of national research programmes and to ensure European market leadership in renewable energies (EE) ;
- Common European foreign policy on energy to coordinate the relations, in particular with Russia, due to its strategic role as supplier of raw materials, specifically natural gas, and with the OPEC countries[1].

At its Spring Council meeting on 23/24 March 2006, the European Council basically welcomed the proposals of the Commission. At the same time, the Heads of Government made clear that the Member States would maintain their national sovereignty with regard to energy mix. They announced an increase in the share of renewable energies to 15% by 2015, with special regard to biomass. The proposal of establishing a European regulator was rejected as being too early[2].

[1] OPEC home web site : http://www.opec.org/opec_web/en/

[2] cf Conclusions of the Head of the European Council - Summit of 23./24. March 2006 in Brussels : http://www.auswaertiges-amt.de/cae/servlet/contentblob/338934/publicationFile/3593/EU-Erkl%C3%A4rungBelarus.pdf

Figure4-2 : European Council Summit in March 2007

At the Spring Council meeting 2007, the European Council set new ambitious aims for climate protection. A more integrated EU energy policy, combining measures on European and national levels, was meant to serve these aims[1].

A further step taken at the Spring Council meeting towards liberalisation of the national energy markets was the requirement of an effective separation of energy generation and supply, but no ownership separation. Due to the lack of interest in reorganising the markets, it still took until April 2009 until a compromise allowed the Member States to choose between three unbundling options,(1) the „ownership unbundling“[2], (2) the ISO-[3] and (3) the ITO-model[4].

The increasingly severe financial crisis, as well as the EURO-crisis in a number of European countries has turned out to be an obstacle on the way to a common European energy market.

From the end of the Second World War until the present time, the steady increase of electricity consumption has been a dominant conflict factor when dealing with the question of future resources and a common energy policy.

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1 cf. Rat der Europäischen Union : Europäischer Rat (Brüssel) 08./09. März 2007 Schlussfolgerungen des Vorsitzes : http://energy.iep-berlin.de/pdf/Schlussfolgerungen.pdf

2 „ownership unbundling“ = full ownership unbundling

3 ISO-Modell : highly regulated solution of „independent system operator“ (ISO)

4 ITO-Modell : The energy groups maintain their integrated structure. The Member countries undertake to observe certain rules, which are to ensure that the divisions of energy generation and supply are in practice separated from the transmission networks operator.

cf. : http://energy.iep-berlin.de/php/1_binnenmarkt_analyse.php

It seems reasonable to conclude that the energy industry is lagging behind the scientific-technological progress (such as nuclear fusion, decentralised energy supply). A politically intended sustainable technological change, however, currently seems to be possible only at very low rates in European politics.

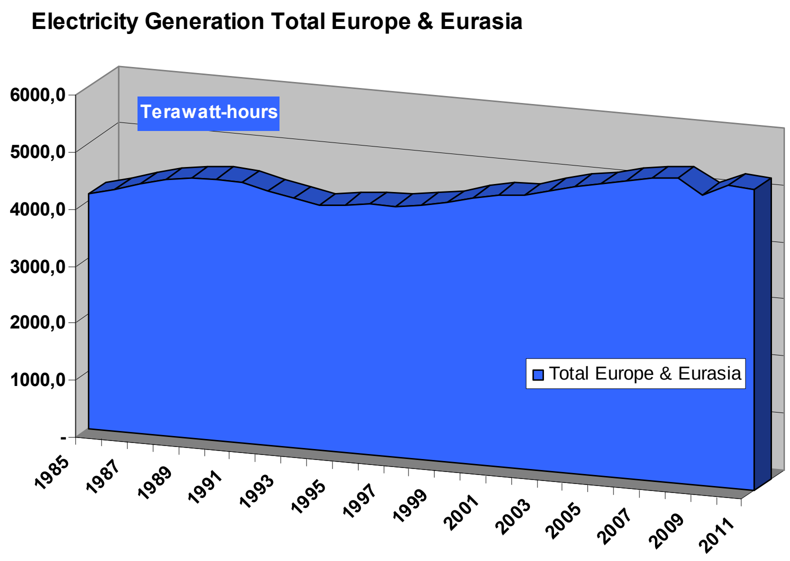

Figure4-3: Electricity Generation in Europe & Eurasia[1]

[1] British Petrol full Excel workbook of historical statistical data from 1965 – 2011; http://www.bp.com/sectionbodycopy.do?categoryId=7500&contentId=7068481

Europe & Eurasia = Austria, Azerbaijan, Belarus, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Republic of Ireland, Italy, Kazakhstan, Lithuania, Netherlands, Norway, Poland, Portugal, Romania, Russian Federation, Slovakia, Spain, Sweden, Switzerland, Turkey, Turkmenistan, Ukraine, United Kingdom, Uzbekistan, some other Europe & Eurasia

5 Site theories

Even in nature, the feasibility or viability of every individual strongly depends on their environment and, therefore, on their location.

Numerous buildings and major achievements in human history depended on coincidence and on people's conscious decision for a location.

In Mesopotamia and in Egypt, it was the rivers which represented a significant factor with regard to infrastructure, security (political stability) and 'land' as a production factor (fertility).

During the Roman Empire, locations were specifically found and developed with regard to their eligibility for establishing new towns and, as a consequence, economic centres for creating public prosperity in the Roman Empire's national economy.

Due to the industrialisation in Europe in the middle of the nineteenth century, the production factors 'man and machine' obtained new mutual interaction and significance. The industrial development increasingly depended on the development and sufficient supplies of energy, such as electricity, coal, etc. This opened up new opportunities for different regions, but also various dependencies in the development and promotion of economic sites.

When considering which region represents the optimum site for a business, a large number of factors have to be taken into account, which are in competition with one another. The micro- and macroeconomic site theories have dealt with these so-called site factors.

For a clear presentation of the site theories, the multitude of theoretical approaches can be differentiated using the classification model developed by Meyer-Lindemann, in which the distinction is made with regard to the key aspects shown in the figure below[1]:

- Theory of site assessment,
- Theory of site effects,
- Theory of site development,
- Theory of regional development

[1] cf. Meyer-Lindemann (1951): p. 29

In the more recent literature, this model is supplemented with the aspect of ‚Theory of site planning'[1].

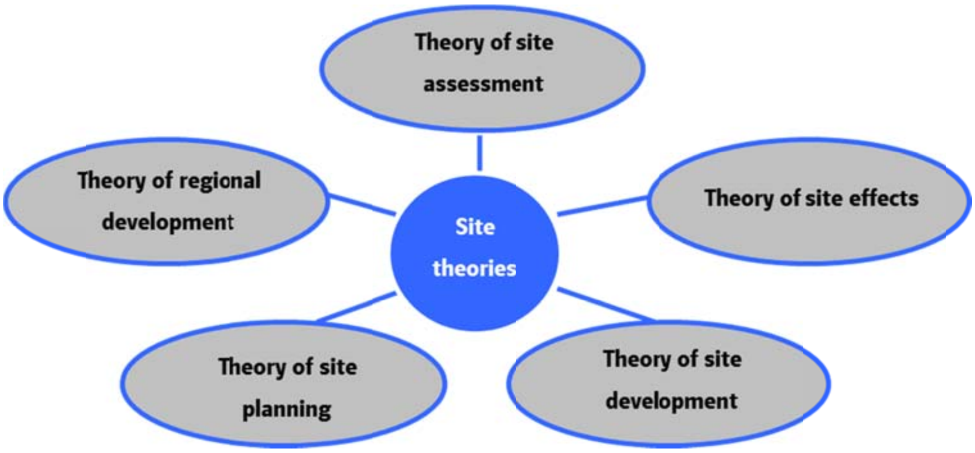

Figure 5-1: Classification model of site theories

The *theory of site assessment* aims at representing and evaluating the factors that are relevant to the decision for a site[2].

The *theory of site effects* describes the economic effects that arise from the choice of a site[3].

The *theory of site development* deals with the question of site formation from a historical point of view, i.e. why sites emerged in specific places[4].

The *theory of regional development* primarily focuses on the aspect of land use[5].

The *theory of site planning* deals with the procedures involved in a site decision, focusing on the individual stages in the process of site decision[6].

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[1] cf. Goette (1994): p. 50

[2] cf. Meyer-Lindemann (1951): p. 30 ff.

[3] cf. Mayer-Lindemann (1951): p. 109 ff

[4] cf. Meyer-Lindemann (1951): p. 143 ff

[5] cf. Meyer-Lindemann (1951): p. 143 ff

[6] cf. Goette (1994): p. 63

For the present thesis, the studies on the theory of site assessment and site planning are of particular interest and will be dealt with in detail in the following chapters.

5.1 Theory of site assessment

The contents and significant approaches of the theory of site assessment will be introduced in the sequence of their historical emergence, and essential findings will be summarized.

A first scientific investigation into economic site considerations was already carried out in 1826. In his article “The isolated state in relation to agriculture and national economy”, Johann Heinrich von Thünen gives proof of the fact that agricultural land use is not exclusively determined by natural soil conditions, but primarily by the distance to the consumption places. As decisive criteria for the choice of a product he identifies distance and cost of transportation.[1]

Alfred Weber’s theory is based on Thünen’s work and is regarded as „…the fundamental theoretical work of the theory of site assessment…”[2] Weber sees the question about the reasons for the choice of a site as the motive for his work. He says that people ”… when choosing a business location, are not simply guided by pleasure or any other irrational motives…”[3]. This is why his efforts were marked by the search for a theory of economic site.

The essential findings of his theory are the definition of the term “site factor”, the differentiation between general and special site factors and the classification in “natural-technological” and “social-cultural” site factors. The term “site factor” is defined as “… clearly distinguished advantage by its nature, which presents itself for an economic activity, if … is performed at a certain place. …”[4].

[1] cf. Thünen (1966): p. 12

[2] cf. Goette (1994): p. 54

[3] cf. Weber (1922): p. 3

[4] cf. Weber (1912): p. 16

According to Weber, this advantage is to be seen as a saving of costs and / or a lower expenditure in comparison with a different place. What he neglects in his considerations, however, is the marketing side, as he nearly exclusively focuses on the transportation costs.

Rüschenpöhler describes two further approaches in his work. He distinguishes between ‘site conditions’ and ‘site requirements’ - two items which, in his view, have to be further differentiated according to their capacity to be calculated.
The criteria which can be calculated, can be fixed in numbers and allow for a simplified collection and evaluation. For the criteria which cannot be calculated, only a qualitative evaluation is possible. In the view of Rüschenpöhler, the criteria which cannot be calculated, were neglected in the site theory at that time, which is a particularly serious mistake, as “their defect of not being specifiable in terms of numbers, must not lead us to lose sight of their true importance”[1].

Behrens’ approach is characterized by the fact that site factors can be systematised, namely according to criteria that are related to sales and provision of services[2]. According to Goette, this systematisation provides the basis for site decisions in an international context[3].

5.2 Theory of site planning

The theory of site planning deals with the representation of the site decision process on the basis of stages. Its aim is to systematise the process in order to meet the demand for a transparent and reproducible procedure.

[1] cf. Rüschenpöhler (1958): p. 66

[2] cf. Behrens (1971): p. 48 f.

[3] cf. Goette (1994): p. 58

5.2.1 Approach of Lüder and Küpper

In their paper, Lüder and Küpper present the results of an empirically based study on the behaviour of major local industrial enterprises[1]:

- initiation of the process of site decision and identification of capacity requirements,
- choosing and evaluating possible sites, which usually comprises two steps, the macro – and micro-site selection, and
- reaching the final decision for the site by submitting the evaluated alternatives to the decision-maker.

The site decision process is initiated and brought into its first stage, when, according to Lüder and Küpper, at least one of the following conditions applies: capacity requirements, excess capacity or site deficiencies with regard to external or internal factors[2].

The motives for site decisions identified by Lüder and Küpper include on-site expansion, shift of operating resources, purchase, new construction, on-site contraction, closure, disposal and relocation[3].

The process of site selection represents the second stage and includes three steps[4]:

- limitation of the number of macro-sites using logical criteria and principles for structuring and search,
- limitation of the number of sites in a pre-selection procedure by mandatory criteria not defined by costs and by principles for structuring and search,
- cost-effectiveness studies and additional analyses for the potential sites on the short-list.

[1] cf. Lüder, Küpper (1983): p. 9 f. „…unternehmensexterne oder – interne Faktoren…“

[2] cf Lüder, Küpper (1983): p. 166

[3] cf. Lüder, Küpper (1983): p. 151 ff.

[4] cf. Lüder, Küpper (1983): p. 177

Lüder and Küpper use the terms macro- and micro-sites. Macro-sites designate considerations concerning large-scale sites, i.e. countries or economic regions, in the evaluation of foreign sites or regions in the search for domestic sites. This classification allows for a first limitation of the search area[1]. 'Micro-site' is the term for the sites that are left after the limitation to a certain region.

The structuring and search criteria are further subdivided into two different types of criteria. The limitational criteria, also referred to as mandatory criteria, describe minimum standards of a site, which have to be met in any circumstance. This allows for a compensation of the substitutional criteria, if necessary. These are further differentiated between "financial substitutional" criteria, which are included in the assessment of cost effectiveness and "non-financial substitutional" criteria, which have to be taken into account in value benefit analyses[2].

The third stage is the final decision for a site, which is not made until a detailed statement of investments by the responsible committee is available[3].

5.2.1 Approach of Goette

Goette describes „… the maximisation of the degree of meeting the degree of satisficing"[4] as the primary aim of the process of site planning, so that the site which best brings the demands in line with the existing conditions can be identified. According to the author, there is no final conclusion as to how many stages are involved in a site decision process, but only that it should comprise a minimum of five stages[5]:

---

[1] cf. Lüder, Küpper (1983): p. 167 und 201

[2] cf. Lüder, Küpper (1983): p. 192 ff.

[3] cf. Lüder, Küpper (1983): p. 170

[4] cf. Goette (1994): p. 254 „…die Maximierung des Anspruchserfüllungsgrades"

[5] cf. Goette (1994): p. 256

- concept stage
- preselection of countries
- macro-analysis
- micro-analysis
- decision

The concept stage is the starting point of the process. In this stage, the goal for the growth of a business and the growth strategy are defined, thus paving the way for the search for a site[1].

For the pre-selection of countries, Goette uses the term „scanning“. In his opinion, the pre-selection of countries is not a standard procedure, as not all countries of the world can be analysed in a comprehensive way, which is why a default selection of countries is available as a rule. This procedure, however, bears the risk of overlooking potential interesting sites. The country pre-selection should be carried out with a few exclusion criteria, which reduce the number of the shortlisted countries quickly and significantly[2].

The macro-analysis initiates the real site decision. Goette subdivides this stage into four further steps[3]:

- the selection of criteria,
- the nature of the information available,
- the processing of information and
- an initial selection.

The challenge of this stage is the choice of the „right“ criteria. Goette distinguishes between two different approaches, which are based on:

- economy-related criteria

or

- business-related criteria.

[1] cf. Goette (1994): p. 257

[2] cf. Goette (1994): p. 260 ff.

[3] cf. Goette (1994): p. 265

General economy-related data are usually easy to obtain, which offers the advantage of a comparison between countries. The disadvantage is that business-specific aspects are not taken into account to a sufficient extent.
This is why Goette recommends an analysis of the business-related data, which, in turn, are subdivided into cost analysis and consideration under market-strategic aspects [1].
When obtaining the necessary information, four aspects have to be taken into consideration: availability, reliability, comparability and up-to-dateness of the information[2]. There are different procedures for processing the information and preparing the initial selection. In this stage, the preferred practice are heuristic procedures, "… which do not aim at an optimum solution, but at finding an acceptable solution at reasonable expense"[3]. Furthermore, these methods offer the possibility to take qualitative and quantitative criteria into account. Examples are the check-list procedure and the value benefit analysis[4]. Goette emphasises the fact that it is not the procedure, but the criteria and the data available, which are decisive for an initial selection[5].

The micro-analysis proceeds from the data made available in the preceding macro-analysis and is basically carried out in the same way as the latter. Some of the potential sites have been discarded at this stage, and more detailed information has to be provided for the remaining sites. This shifts the focus on an increased demand for information at this stage. Furthermore, this stage is characterised by the "… personal or subjective evaluation components…" [6], which are due to the uncertainty about future decisions and the possibly insufficient amount of information. Goette distinguishes between two procedures in this stage – the total and partial analysis. The total analysis attempts to capture and evaluate all influencing factors, whereas the aim of the partial analysis is to narrow them down to a number of essential parameters.

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[1] cf. Goette (1994): p. 265 ff.

[2] cf. Goette (1994): p. 273 ff.

[3] cf. Maier, Tödtling (1992): p. 28

[4] cf. Goette (1994): p. 289

[5] cf. Goette (1994): p. 287

[6] cf. Goette (1994): p. 297

These models normally only consider the quantitative criteria of a site. In order to take the qualitative components into account, the value benefit analysis lends itself[1].
The decision is not exclusively made on the basis of the preceding evaluations. Goette refers to the business instinct of the decision-makers, the behaviour of who also depends on any previous experience with making site decisions[2].

5.3 Site decision process

Further examples can be provided for the designation of the stages in the site decision process. Hummel, for example, has developed a classification system, which subdivides the process into diagnosis, information analysis, pre-selection of alternatives and decision[3].

At this point, however, it is not essential how the single stages are designated, but what they comprise. For the site decision of a conventional power plant, the following four stages can be identified:

- idea or concept stage
- preliminary study
- evaluation of alternatives
- decision stage.

Figure5-2: Stages in a site decision of a power plant

[1] cf. Goette (1994): p. 296 ff

[2] cf. Goette (1994): p. 308 ff.

[3] cf. Hummel 1997: p. 157

The *idea or concept stage* represents the first stage, in which, influenced by internal or external factors, a situation analysis is carried out, on the basis of which the site strategies are defined. For the site decision of a conventional power plant, this means that market opportunities are elicited and investigations are carried out to ascertain to what extent the new construction of power plant capacities is necessary and possible. Possible site strategies were identified by Lüder and Küpper as on-site expansion, shift of operating resources, purchase, new construction, on-site contraction, closure, disposal and relocation[1]. For the site decision of a conventional power plant, only the regional diversification, i.e. new construction and expansion of existing sites (on-site expansion) are of interest as parts of the growth strategy[2]. What capacity is required in which country and which of the above strategies will be pursued, is a strategic decision, which, in practice, is often made in parallel with the site decision process, thus also providing one of the prerequisites for the site decision process.

The *preliminary study* is the second stage in the site decision process of a conventional power plant and is aptly defined by term 'information analysis' chosen by Hummel. Its task is to decide, which kind of information is relevant, depending on the site strategy. This makes clear that the decision for a strategy implies different information requirements. Whereas the aptitude of already existing sites for a power plant sites has already been established, this question will have to be answered when considering a new site.

Lüder and Küpper regard the preliminary study as part of the site selection process, although they do not explicitly emphasise this. In Goettes theory, this second stage can be found as one of the four sections of the macro-analysis.

In order to classify the industry-specific requirements imposed on a site of a power plant for the preliminary stage, reference will be made to the relevance classes for the site factors established by Lüder and Küpper: the "mandatory factors" (limitational site factors) and the "target factors" (substitutional site factors)[3].

---

[1] cf. Lüder, Küpper (1993): p. 151ff.

[2] cf. Hummer (1997): p. 108

[3] cf. Lüder, Küpper (1983): p. 192 ff. „… „Muß-Faktoren" (limitationale Standortfaktoren) und die „Soll-Faktoren" (substitutionale Standortfaktoren)…"

The aim of this stage is the elimination of sites, which do not meet the requirements defined as "exclusion criteria", at an early stage of the decision process[1].
This stage is one of the core areas of the present thesis. The selection and description of the relevant criteria will be dealt with in chapter 9 Project phase „Preliminary study in the site decision process".

The *evaluation of alternatives* represents the third stage and the actual evaluation process and is characterised by an increased demand for information and level of detail that are necessary for the evaluation[2]. This is identical with the microanalysis in Goette's theory and part of the site selection process as described by Lüder and Küpper.
The reduction to the essential criteria for site decisions of a conventional power plant, the evaluation of the quality and quantity of the information in order to evaluate potential sites, will constitute the second major area of this thesis and will be further dealt with in the following chapters.

In the decision stage, in which the actual site decision takes place, all available information and findings gathered in the preceding process have to be reviewed and represented in a transparent and traceable way.[3] As this stage does not constitute the core area of the present thesis, it will be dealt with only to some extent.

5.4 Essential results of the theoretical considerations

The following items for the site assessment of a gas-driven power plant can be identified as important starting points from the history of the site assessment process and the theory of site planning:

[1] cf. Hummel (1997): p. 163
[2] cf. Hummel (1997): p. 163 ff.
[3] cf. Hummel (1997): p. 166 ff.

- The classification into “natural-technical” and “social-cultural” site factors is to be considered as the basis for the differentiation of the special criteria for the site decision of a gas-driven power plant.
- The distinction between criteria that can be calculated and those that cannot be calculated as well as between limitational and substitutional criteria is standardised.
- Heuristic procedures are presented and their use for the information processing in the preliminary study stage is verified.
- The importance of the personal and subjective evaluation components is demonstrated.

6 Power plant process

In this thesis, reference will exclusively be made to combined gas and steam turbine power plants, also referred to as CCGT-power plants. CCGT stands for Combined Cycle Gas Turbine Power Plants.

The working medium in the gas turbine is air and flue gas, in the steam turbine it is superheated steam[1].

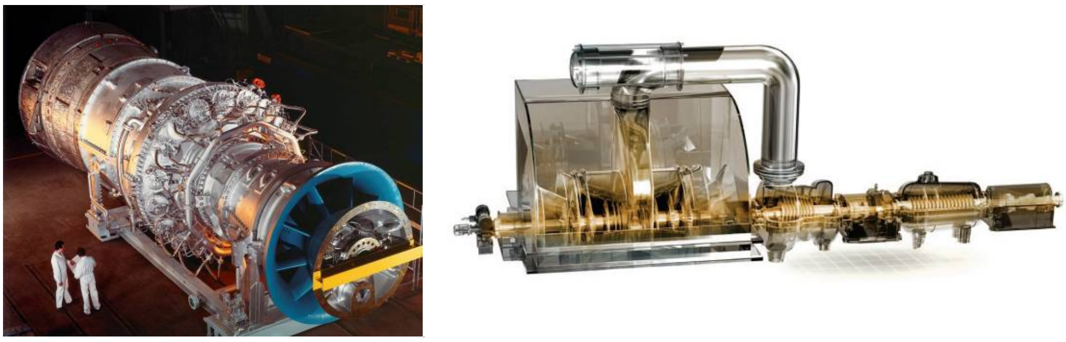

Figure 6-1: Gas and steam turbine of General Electric[2]

[1] For gas turbine cf. Zahoransky (2009): p. 104 f.; for steam turbine cf. (Strauß 2009): p. 120 ff.

[2] GE gas turbine 9FA; GE steam turbine 109DST; cf. http://www.ge-energy.com/products_and_services/products/gas_turbines_heavy_duty/9FA_heavy_duty_gas_turbine.jsp ; http://www.ecomagination.com/portfolio/flex-efficiency

The operating principle of a gas turbine is based on the so-called Joule cycle (named after James Prescott Joule). Comprised air mixes with the fossil fuel gas and is burned in a combustion chamber. The formerly chemical energy is converted into thermal energy, the flue gas. The potential energy of the flue gases generated in this way expands in the gas turbine and is thus converted into the mechanical rotational energy of the turbine.

The diagram in figure 6-2 below shows the main systems based on the energy flow of a combined gas and steam power plant, figure 6-3 shows a simplified thermal flow diagram of a CCGT power plant.

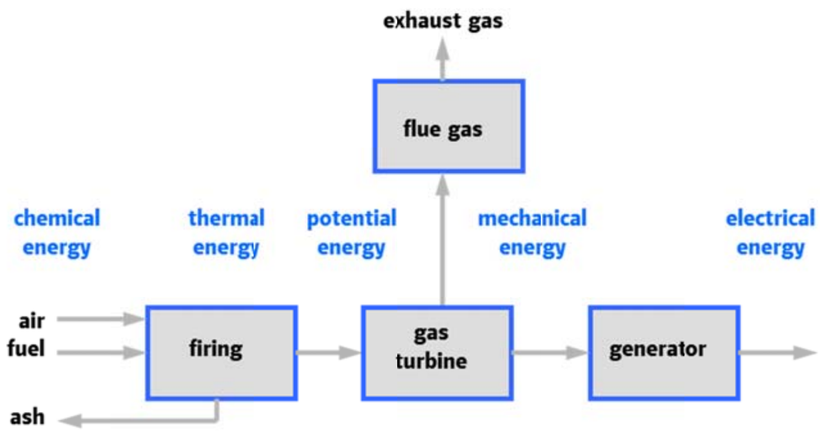

Figure 6-2: Energy diagram of a gas-fired power plant[1]

[1] authors own representation

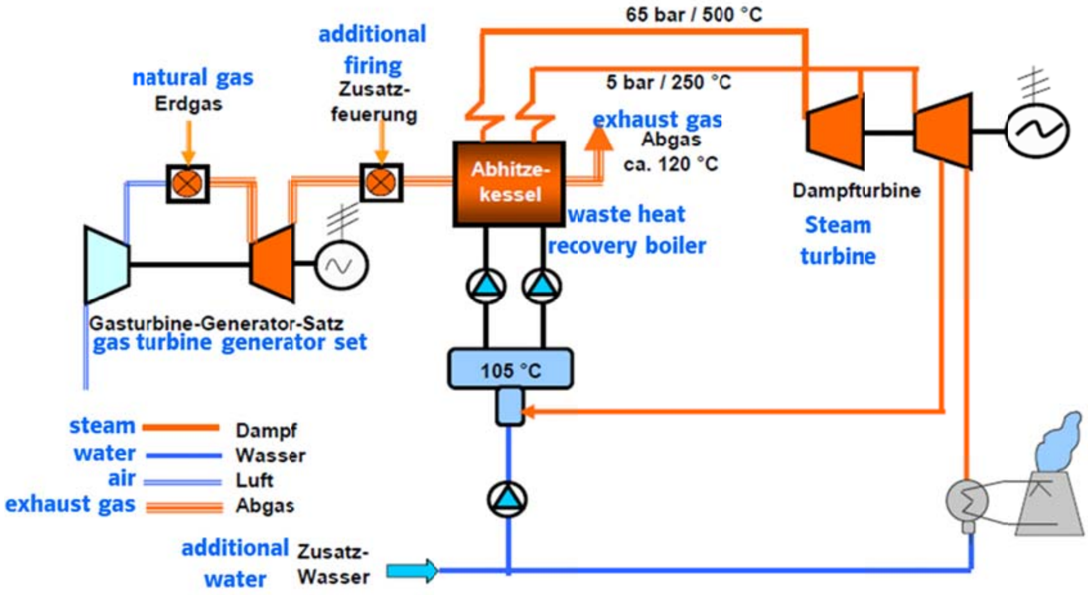

Figure 6-3: Simplified thermal flow diagram CCGT power plant[1]

In the heat recovery steam generator (HRSG), the thermal energy of the flue gases is emitted to the medium contained in the heating surfaces, normally water, to generate steam. The steam expands in the steam turbine and converts the potential energy (steam) into mechanical rotation energy (turbine). Having passed the turbine, the steam is fed into the condenser and liquefied again by extracting the still existing heat, in order to enter the process again.

The diagram in figure 6-4 below shows the main systems, using the energy flow of a steam power plant as an example.

[1] cf Konstantin (2009): p 287 - with own translations

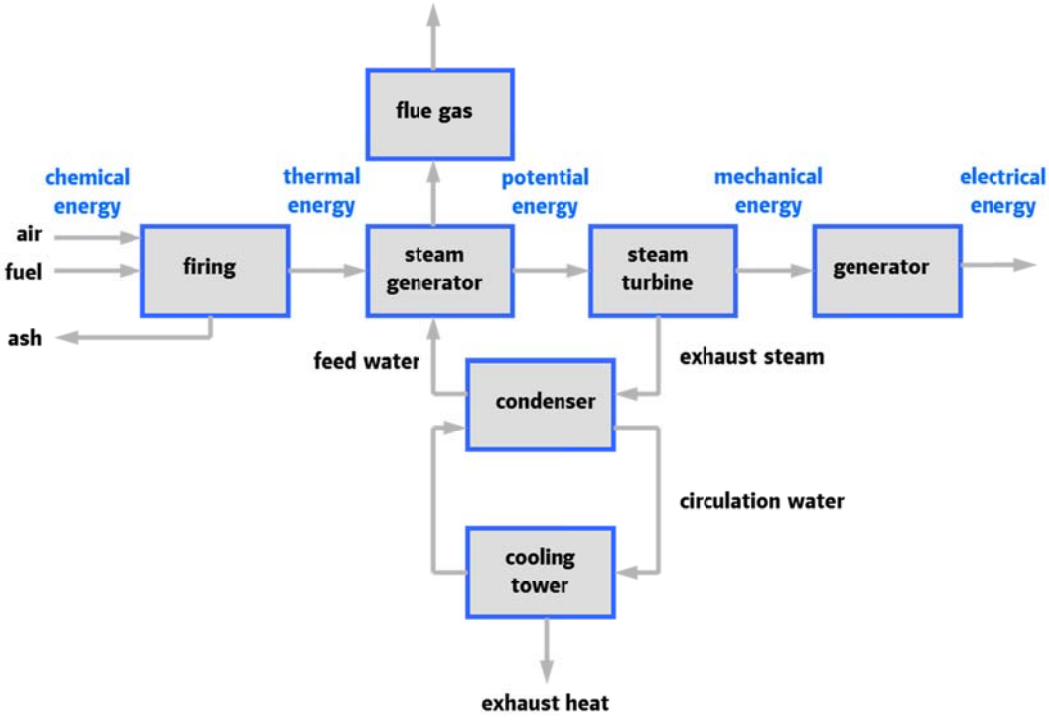

Figure 6-4: Energy diagram of steam power plant[1]

The rotational energy of the gas and steam turbine is converted into electrical current in generators, which is then fed into the electricity grid[2].

In the gas and steam power plants, a distinction is made between multi and single shaft plants. The difference is that, either

- gas turbine and steam turbine drive a common generator, or
- gas turbine and steam turbine each drive their own generator.

The advantages and disadvantages of the two versions are to be found in the investment volume and in their operating behaviour. Figure 6-5 shows the diagram correspondingly extended from the two diagrams above.

[1] author's own representation adapted from Strauß (2006): p. 4

[2] cf. Strauß (2006): p. 99 ff. and cf. Oeding, Oswald (2004): p. 81 ff.

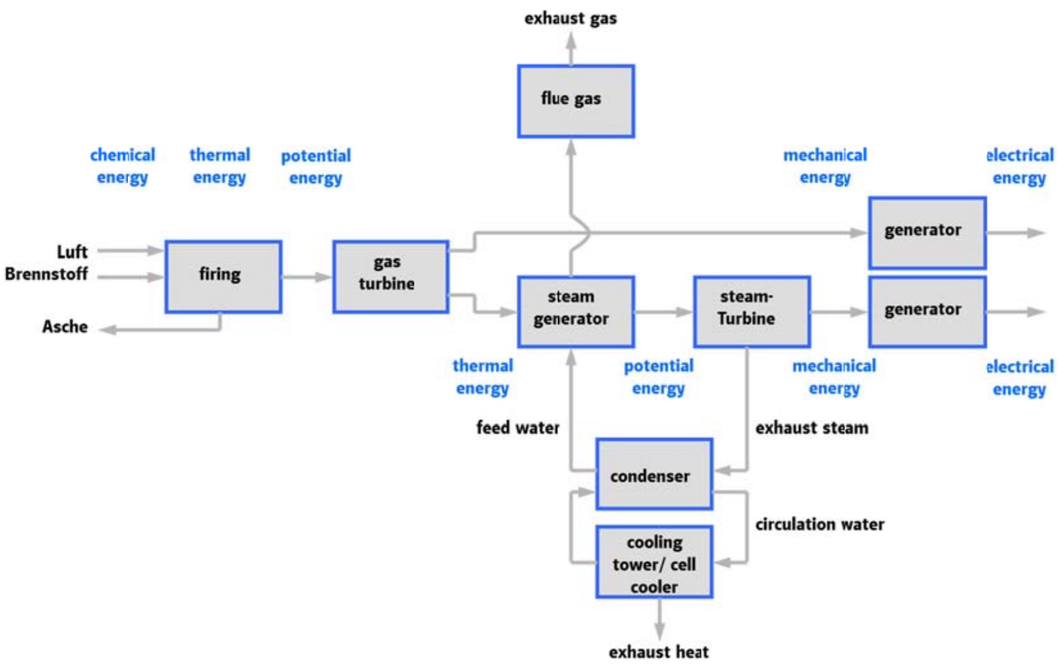

Figure 6-5: Energy diagram of a gas and steam power plant (multishaft)[1]

The aim of this chapter is to describe and illustrate the particularities of combined gas and steam turbine power plants and to stress out the demands that these plants place on their environment and / or their sites. These particularities will be dealt with in the following sections.

6.1 CCGT power plant

A CCGT power plant is a combined power plant of a gas and a steam turbine. The term 'gas turbine' is used because the propulsive medium is a gas[25]. A main feature of a CCGT power plant is, as the name suggests, the use of natural gas as a fuel and the fact that the steam turbine is connected with the gas turbine by a process, i.e. by using the flue gases for generating steam. This results in higher degrees of efficiency than in pure gas or steam turbine processes. Owing to the use of noble fuels, such as natural gas or light fuel oil as back up fuels, no solids develop in the exhaust gas.

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1 authors own representation

2 The word ‚gas turbine' does not originate from the fuel, which can be gaseous, liquid or even solid, but from the gaseous working medium – cf. Zahoransky (2009): p. 120

Energy and cost intensive exhaust gas treatment is generally not necessary, with the exceptional case of very low NOx limit values, which require a catalytic converter.

CCGT power plants combine the thermodynamic advantage of a gas turbine, i.e. heat input at a high temperature (1400 – 1500^{o}C) with that of a steam power plant, i.e. heat release at a low temperature (< 500^{o}C). With this, they offer very flexible application possibilities from both components. The degree of efficiency can still be further increased by heat extraction.

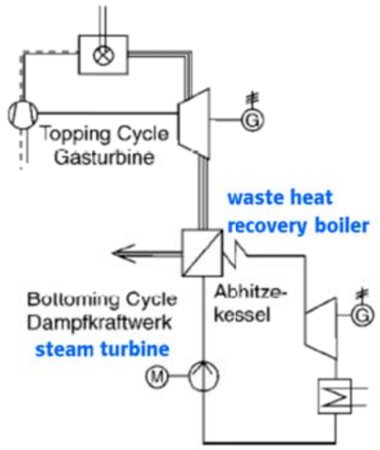

Figure 6-6 : Basic thermal flow diagram of a combined power plant[1]

These factors represent the key reasons why combined power plants of gas turbines and steam turbines (referred to as CCGT) are being increasingly preferred, when power plant capacities are to be extended. In summary, the advantages are as follows[2]:

- highest levels of thermal efficiency
- low CO2 emission
- low fuel costs despite the use of high-quality fluid fuels (natural gas or fuel oil)
- low specific investment costs
- short construction times
- capacity units from ca. 50 MW to over 1,000 MW

[1] cf. Zahoransky (2009): p. 147 f. - with own translations

[2] cf. Zahoransky (2009): p. 147 f.

- high flexibility
- low polluting noise and exhaust emissions
- high level of acceptance by the population

Figure 6-7 : Two CCGT Power Plants, each with two gas turbines in Algeciras (Spain)

Using gas as a fuel directly influences or even severely limits the selection of a potential site from a logistical point of view.

Until a few years ago, the supply of gas was restricted exclusively to the big gas lines. It is therefore not surprising that, for example in the south of Andalusia, near the Maghreb Europe gas pipeline, and in the Medgaz gas pipeline, a strong concentration of installed gas-fired power plant capacity is to be found.

However, due to the increasing construction of LNG-terminals (liquid natural gas terminals), further options have been created, which have resulted in a certain competition between sites for gas-fired power plants.

The overview in figure 6-8 represents the essential subsystems of a CCGT power plant. To reach an optimum degree of efficiency, two energy cycles are used for generating electricity – first, through the combustion of gas and second, through the generation of steam (see also figure 6-5: energy diagram of a gas and steam power plant (multishaft)).

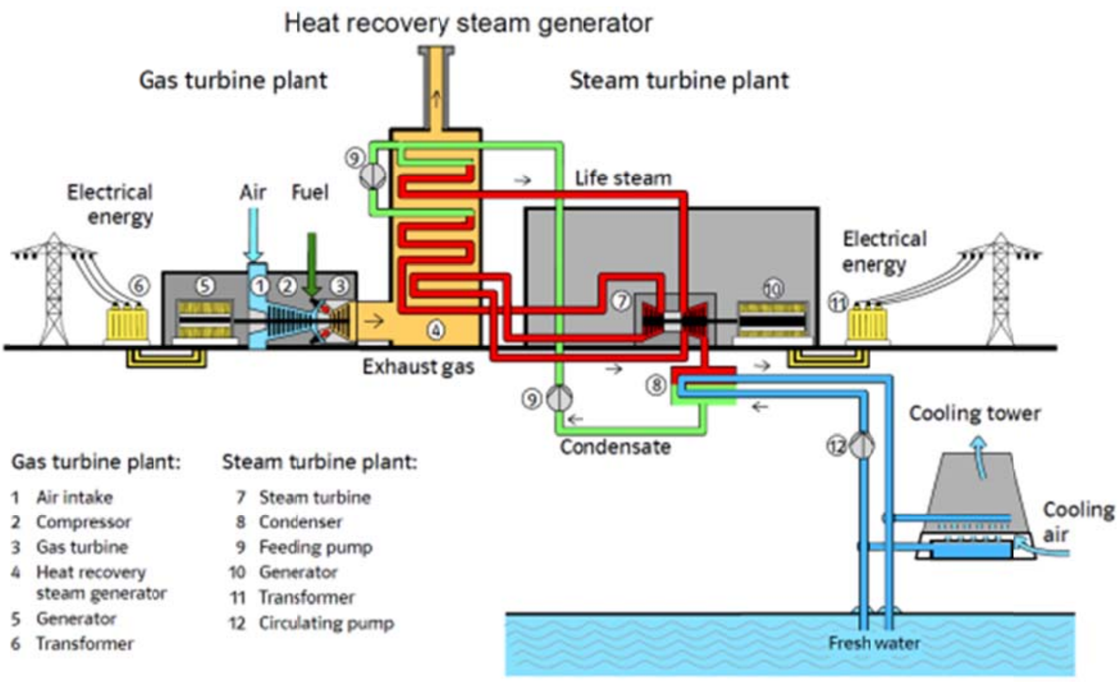

Figure 6-8: Diagram of a combined Cycle Multi Shaft Power Plant[1]

Apart from the availability of fuel that was initially referred to, the site of a gas-fired power plant is also essentially determined by other subsystems necessary for the operation of the plant.

Unlike in coal-fired power plants, the flue gases are not usually cleaned. This implies that no additional subsystems, such as desulphurisation systems (coal) are needed. For this reason, gas-fired power stations might absolutely be found in the close vicinity of residential areas. However, there might be local regulations and requirements that restrict the operation of gas-fired power plants to certain size categories.

The location of the power plant and / or the selection of the site also determine the choice of the cooling system. For gas-fired power plants there are two technical solutions, (1) flow cooling and (2) closed-circuit cooling.
In the procedure referred to as flow cooling or open circuit cooling, the amount of cooling water necessary for re-cooling in the condenser is gathered from a body of water.

[1] Source: SIPICS. PG Fossil Power Generation. 3_3_1_0_1 / a © Siemens Power Generation 2005. All Rights Reserved.

Subsequently, the heated cooling water is redirected in to the water.

The water demand for the flow cooling is approximately 8000 to 12000 m^3/h per 100MW of condensation capacity[1]. This type of cooling offers the highest efficiency of a power plant. Depending on the local laws, these power plants can only be operated on sites, where no impairment of the water body is expected as a result of the heat input[2].

The second cooling type cooling represents a closed circuit, in which the cooling water, after having been cooled down to ambient temperature in a condenser, is used for cooling again. Only the losses of cooling water resulting from evaporation[3] and replaced circulating water[4] are replaced[5].

If the water supply is very poor, the plants can also be cooled dry via an air cooled condenser (ACC). In this procedure, the overall efficiency is the lowest, compared with other cooling methods, and the noise pollution is considerable due to the necessary ventilators, which is a factor that has to be considered if a site near a residential area is taken into consideration.

6.2 Requirements specific to power plants

To demonstrate the requirements to be met by potential power plant sites, the material flows, the dimensions and the environmental impacts will be shown and described in the following, using a 400 MW CCGT power plant as an example. There will also be a basic explanation of the legal planning specifications, which vary depending on the country or region.

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1 cf. Lehmann (1990): p. 52

2 cf. German regulation - VGB Germany (1983): p. 480 ff.

3 The functional principle of the cell coolers that are common today is that the heated water discharged from the condenser is sprayed finely over the individual cells, which creates a large surface. The air flows in the direction opposite to the water. The cooling water is cooled through the evaporation from the heat exchange between water and air. – cf. VGB (1983): p. 484 f.

4 Due to evaporation losses there is a salt accumulation in the cooling water. To keep the salt content constant, the circulating water has to be continuously drained and replaced by fresh water - cf. VGB (1983): p. 489 f.. "…Abflut…"

5 cf.. Strauß (2006): p. 285 f.

6.2.1 Material flows

For a gas-fired power plant, the general diagram of material flows is very concise, showing again the essential material flows of a site to be identified, such as water (cooling and process water), gas, further operational and auxiliary materials and electricity.

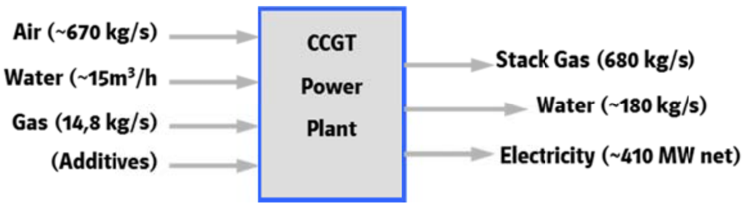

Figure 6-9: Material flows of a 410 MW (net) CCGT power plant[1]

For comparison, the following figure demonstrates the material flows of a coal-fired power plant.

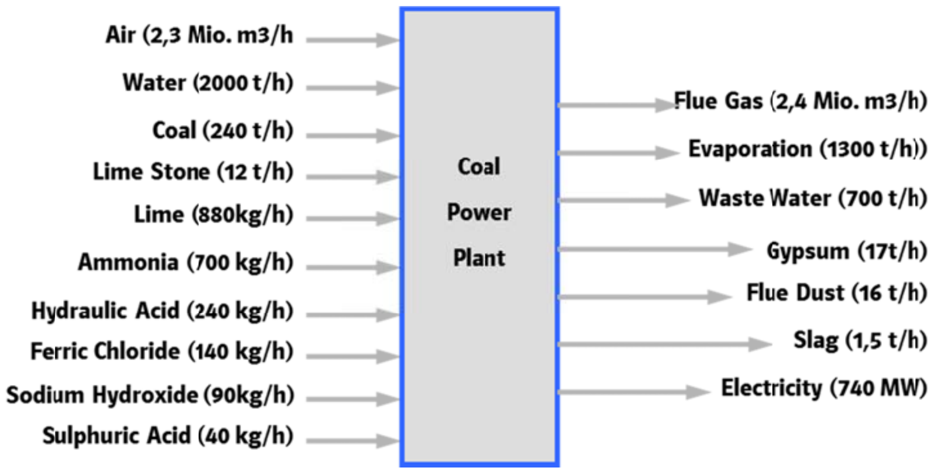

Figure 6-10: Material flows of a 740 MW (net) coal-fired power plant with cooling tower[2]

[1] autors ouwn graph (values are orientated on a power plant in Hungary – commissioned in 2012)

[2] according Strauss (2009): p.23

The average water demand of ~470t/h is valid for the cell cooler operation, i.e. closed-circuit cooling. If flow cooling is used, the demand for cooling water is about ~30.000t/h for a 410 MW gas-fired power plant.

The average fuel demand of a 400 MW CCGT power plant is ~15 kg/s, respectively (natural gas H).

Other essential operational and auxiliary materials include:

- deionised water for the water-steam-cycle
- chemicals for the water treatment (deionised water, raw water, waste water treatment).

It should be noted, however, that their amount is much smaller than in coal-fired power plants.
Unlike in coal-fired power plants, residual products (slurry-sewage water, gypsum, bottom ash and flue ash, etc.) are not produced in a gas-fired power plant.

In order to dissipate the electrical current produced in the generator of the power plant, the current is transformed to the voltage of the grid level, in the generator transformer of the power plant. The European extra high voltage grid is operated on voltages of 380 kV or 220 kV. Via the extra high voltage grid, the electrical energy is carried to the main consumer points. If the power plant capacity is higher than 300 MW, the energy is actually only fed into the extra high voltage grid[1].
There are more maximum voltage distribution networks in other European countries. Russia, for example, has an extensive 750-kV-grid. In Canada and the USA, the operating voltages are 735 kV and 765 kV. Depending on the routing, the closeness or distance to the grid can be a significant cost and time factor (planning, approval, construction) for the quantitative assessment of or the investment in a site (cf. section 8.1 Quantitative procedures).

[1] cf.. Konstantin (2007): p. 329 ff.; cf. Reich Benesch (2007): p. 121 f.

6.2.2 Dimensions and demand of space

To demonstrate the demand of space of the main components of a gas-fired power plant, an existing 400 MW gas-fired power plant in Slovakia (in commercial operation since the beginning of 2011) is used as an example[1].

With a demand of around ~8000 m^2, the majority of the space is required by the turbine house.

For the boiler, an area of ~3800 m^2 is to be taken into account, depending on the design.

The height of a boiler house in a gas-fired power plant can amount about ~25 m and higher (pending on the technology and supplier).

If a cell cooler is necessary for the cooling mode, because no suitable water body is in close vicinity, the dimensions of this would be approx. ~6000 m^2, depending on design and construction.

In gas-fired power plants, the flue gases are discharged via a stack, the height of which can vary strongly, depending on the permit conditions. Heights of 40 to 100 m are absolutely normal.

For auxiliary and off-site equipment, an area of approximately ~10.000 m^2 is to be provided (pending a lot on permission and plant arrangement).

For administration buildings and outbuildings, such as control room, shop floor, warehouse, etc., an area of ~1000 m^2 can be assumed, depending on the philosophy of the power plant operator. For streets, car parks and storage space as well as other sealed surfaces, an area of around ~30.000 m^2 has to be taken into account.

[1] all in the following mentioned dimensions are not normative, real sizes pending on a lot of different factors, e.g. construction license, arrangements, surface characteristic, …

see also appendix 16.21 Example arrangement drawing of a gas fired power plant with closed-circuit cooling

This results in an average space demand of ~40.000 to 50.000 m^2 for a 400 MW gas-fired power plant.

This does not take into account the site facilities and assembly surfaces necessary for the erection of the power plant, for which at least the same surface area has to be estimated.

6.2.3 Environmental impacts

This section deals with environmental pollution, which is a significant aspect in the choice of a site for a gas-fired power plant.
Compared to the conventional fossil power plants, such as coal-driven power plants, a gas-fired power plant is considered as “cleaner”, as there are fewer emissions and process residues, but it still has emissions that have to comply with the appropriate rules and regulations.
Possible adverse environmental affects in connection with the construction and operation of a gas-fired power plant including the land demand and the emissions that are involved, are:

- air pollution
- noise pollution
- waste heat.

Figure 6-11: CCGT Power Plant on the border between industrial area and residential area (Algeciras – Spain)

The German Federal Immission Control Act specifies environmental pollution caused by immissions of large combustion plants as "…air pollutants, noise, shock and vibrations, light, heat, radiation and similar environmental impacts that affect humans, animals, plants, soil, water, the atmosphere as well as other cultural and material assets"[1], [2]. Consequently, immission implies "…the modification of the natural composition of the air, in particular by smoke, soot, dust, gases, aerosols, steams or odorous substances…"[3]. Guided by the idea of environmental protection, the instrument of environmental impact assessment (EIA) has been installed in Europe in order to recognise and estimate possible environmental consequences, with the aim of optimising projects by preventing or reducing any adverse environmental effects[4].

In Germany, the construction and operation of a plant that generates electricity, steam, etc. with a total rated thermal input of more than 200 MW are subject to EIA.

1 cf. BImSchG § 3 Abs. 2 (German Federal Immission Control Act)

2 Each country has its own laws and definitions; in Spain, for example, there is: "Ley de control de la Contaminación - Decreto Supremo No. 374. RO/ 97 de 31 de Mayo de 1976" cf. http://www.prtr-es.es/ - Ministerio de Agricultura Alimentación y Media Ambiente

3 cf. BImSchG § 3 section 4

4 cf. Köppel (2004): p 173 f.; cf. Meyerholt (2007): p. 98 f.f.

Environmental stress must have no adverse effects on natural resources. Adverse effects include, for example, emissions that are liable to cause considerable disadvantages or nuisance to the public or neighbourhood, depending on their type, extent or duration of exposure[1].

An assessment area for environmental impact assessment is usually specified as an area with a radius equal to a multiple of (in Germany to 50 times) the actual stack height. Consequently, the height of the stack has a decisive influence on the selection of a site. If the site in question is located close to a border and the project would have considerable effects on natural resources in an adjoining country, cross-border participation of authorities may be possible or even necessary.

The basis for implementing EIA is the EU-Directive 85/337/EWG[2], which was altered and considerably extended in 1997 and 2001 and has become binding for site decisions in the EU-countries[3].

Furthermore, it has to be checked whether the area is situated in a nature conservation area or whether there are legally protected landscape components or protected habitats on the area.

The EU promotes the development of a „…coherent ecological network of special protected areas in Europe“[4]. Named “NATURA 2000”, this EU-wide protection area is a transnational network with the aim of ensuring the long-term survival of Europe’s most valuable and threatened species and habitats[5].

The basis for these protection areas are the Fauna-Flora-Habitats Directive[6] and the Birds Directive[7].

---

[1] cf. BImSchG § 3 (1)

[2] cf. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31985L0337:EN:NOT

[3] cf. Köppel (2004): p. 175

[4] cf. Habitats Directive, Art 3 (1)

[5] cf. http://ec.europa.eu/environment/nature/natura2000/index_en.htm

[6] FFH- Directive; Directive 92 / 43 / EEC on the conservation of natural habitats and of wild fauna and flora; cf. http://europa.eu/legislation_summaries/environment/nature_and_biodiversity/l28076_en.htm ; cf. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31992L0043:EN:NOT ;

[7] cf. Birds Directive; Council Directive 79 / 409 / EEC of 2 April 1979 on the conservation of wild birds; cf. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31979L0409:EN:NOT

The instrument that was created to check if a scheme or project can have negative effects on a NATURA-2000-area, is the FFH-compatibility assessment. In contrast to EIA, this is not carried out Europe-wide, but restricted to the respective protection areas[1].

The principle governing any intervention in nature is "prevention – reduction – compensation". Any avoidable impairment of landscape and nature must be refrained from in all circumstances. In the event of intrusions in nature and landscape, any unavoidable impairment must be mitigated or compensated for. Such compensation or mitigation measures are to a great extent determined by the responsible local authorities. If unavoidable impairments of nature and landscape cannot be compensated for and / or mitigated in an economically feasible manner or within a reasonable period or if the concerns of nature conservation have priority over the planned measures, this measure is inadmissible. If, for example, interventions destroy biotopes of strictly protected species, these are only permitted, if they are justified by overriding reasons of public interest. Public interest, however, does not exclude necessary compensation.

The laws in the EU-countries should not aim at preventing projects, but at developing gentler methods at the site of intervention and / or selecting more favourable locations and routes for schemes and projects[2].

The management of waters, i.e. the abstraction and injection of water, is governed by the laws established in the EU-countries that implement the provisions of the EU Water Framework Directive 2000 / 60 / EG of 23 October 2000[3], establishing a framework for Community action in the field of water policy.

The following requirements and guidelines for the use of water are specified and have to be observed:

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[1] cf. Köppel 2004: p. 299

[2] cf. Klöppel 2004: p. 71

[3] cf. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32000L0060:EN:NOT - Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy

1. abstraction and discharge of water from surface waters
2. retaining and lowering surface waters
3. removal of solid substances from surface waters, as far as this has an impact on the state of the water or the water run-off
4. introduction and injection of substances into surface waters
5. introduction and injection of substances into coastal waters
6. injection of substances into the ground water
7. removing, extracting, conducting or draining of ground water.[1]

For projects that are subject to EIA, the direct and indirect impacts on the respective site have to be examined and assessed.

6.2.4 Regional development

Apart from environmental impacts by emissions, the consequences of the space demand have to be examined and assessed from the regional development perspective, which is a decisive factor in the approval process of a power plant. Regional development is a complex instrument, which is handled differently in every country. How regional development can function and which planning levels are involved in the regional development process, will be demonstrated using the Federal republic of Germany as an example. The regional development in Germany has to observe the EU-requirements[2].

„The entire land area of the Federal Republic of Germany and its parts are to be developed, allocated and secured by superordinate regional development plans and by coordinating plans and activities of importance for regional development.“[3]

---

[1] cf. German Water Resources Act, § 3 (1)

[2] http://europa.eu/legislation_summaries/development/general_development_framework/dv0003_en.htm

- Local authorities and development assistance

[3] cf. Regional Development Act (ROG), § 1

In Germany, regional development is organised according to the counter-flow principle, i.e. subordinate plans must not contradict a superordinate plan, and the concerns of the subordinate planning level have to be considered when drawing up superordinate plans[133]. The highest planning level in Germany is the federal level, which specifies the norm-based framework by laying down principles and aims for regional development in the Regional development Act[2].

The federal states draw up regional development plans, which "…contain stipulations on the spatial structure…"[3], i.e. specifications on the settlement structure and the routes for the infrastructure.

The planning stage is based on the regional plans, which are to be developed on the basis of the regional development plans and represent the plans of the municipalities and / or associations of local authorities[4].

At municipal level, land-use plans[5] have to be provided "…to prepare and manage the use of the sites for building and other purposes"[6]. There are two types of land-use plans – the "preparatory land-use planning" according to the Master Development and Town Planning Scheme[7] and the "binding land-use planning" according to the zoning plan[8] [9].

Drawing up the land-use plans is in the responsibility of the local authorities, which have to coordinate the plans with the neighbouring municipalities and observe the aims and principles of the regional development scheme[10].

[1] cf. ROG § 1 (3)

[2] = Raumordnungsgesetz – ROG

[3] cf. ROG &7 (2)

[4] cf. ROG § 9 (2) and (4)

[5] = Bauleitpläne

[6] cf. BauGB § 1 (1)

[7] = Flächennutzungsplan

[8] = Bebauungsplan

[9] cf. BauGB § 1 (2)

[10] cf. BauGB § 2 (2)

Since the 2004 amendment of the BauGB (German Federal Building Code), an environmental review has been mandatory when drawing up land-use plans, which ascertains and describes environmental impacts in the form of an environmental report and subjects them to extensive public participation[1].
The environmental report represents the results of the EIA and any other specialised studies, and forms the core of the environment-related information in the procedure[2]. In this way, land-use planning connects environmental impacts with regional development.

Jones et al. describe the approaches and requirements of the environmental impact assessment (EIA) on the regional development in 13 different countries. An analysis of the different procedures shows that the instrument of environmental impact assessment is used world-wide. It is therefore necessary to deal with the country-specific standards and legislations, as these have considerable consequences for assessment of potential sites[3].

6.3 Power plant operation

Gas turbines are preferred

- for covering peak loads and
- in CCGT power plants in the medium-load range.

In oil-producing countries, where a lot of gas is produced, gas-fired power plants are also operated in the base-load mode. When used as peak-load power plant with short running times of a few hours per day, the price of the generated electricity is decisively determined by the investment costs.

[1] cf. BauGB § 2 (4); cf. Hangarter (2006): p. 12, cf. Tändler (2006): p. 23, cf. Sellner et al. (2006): p. 90 f.

[2] cf. Köppel et al. (2004): p. 181 f

[3] cf. Jones et al. (2005): p. 279, cf. Köppel et al. (2004): p. 171

This is why simple plants are becoming more popular, which are based on the simplest process and are generally designed for maximum specific effective work, i.e. a high degree of efficiency[1].

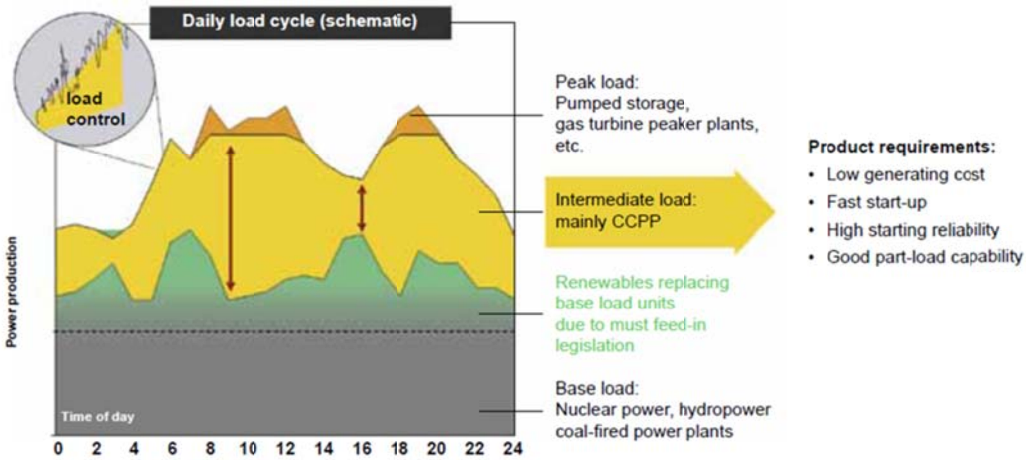

Figure 6-12: Daily load cycle (schematic) and its implications especially for combined cycle power plants[2]

The operation in the medium and peak-load range, on the other hand, includes specific requirements to the control options in the different operation modes and / or load states. Common operation modes / load states are:

- rapid load changes,
- frequent start-ups and shutdowns,
- part-load operation and
- normal operation.

The remuneration of this flexibility varies in the European countries and has therefore to be checked individually for every site. The potential remuneration is important in the assessment of the investment at the respective sites by means of quantitative methods (see also 8.1 "Quantitative procedures").

---

[1] cf. Zahoransky (2009): p. 129 f.

[2] cf. SIEMENS – The Future Role of Fossil Power Generation: p. 3: http://www.energy.siemens.com/hq/pool/hq/power-generation/power-plants/gas-fired-power-plants/combined-cycle-powerplants/The%20Future%20Role%20of%20Fossil%20Power%20Generation.pdf

This flexibility, however, represents a special load on the plant or parts of it. Therefore, certain maintenance intervals have to be observed, just as with cars, both in order to secure the availability of the power plant and to work against the loss of power over the operating years. For this purpose, there are correction curves that are individually developed by every manufacturer. The interaction between operation and inspections is represented schematically in the figure below.

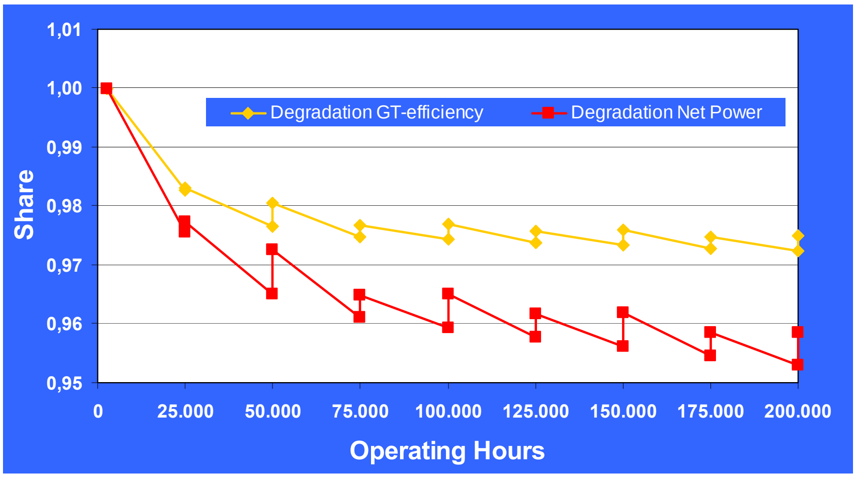

Figure 6-13: Diagram of the degradation schedule of gas turbine and power[1]

Apart from the normal maintenance, there are so-called major inspections. The disadvantage of these inspections is that the power plant, depending on the manufacturer and design, has to be at a standstill for up to one month (or even longer). This is one twelfth of the annual turnover, i.e. around 9% in the respective year, not counting the costs for the inspection itself

The influence of operation and maintenance is taken into account by the determination of the operating hours equivalent to the load (EOH). For this, the different operational events (start-up and shutdown, part-load operation, load rejection, quick start (see figure 7-14, etc.)) and the operating hours are evaluated by using different factors and then added up.

[1] Own graph - based on sample figures

In comparison to steam turbines, gas turbines require a relatively high amount of maintenance, which is due to the high thermal load in the area of the combustion chamber and the expansion turbine. The common intervals for a major inspection of a gas turbine are ca. ~24,000EOH[1], for a steam turbine approximately ~100,000 EOH.

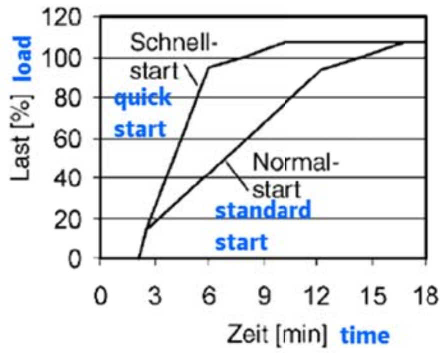

Figure 6-14: Quick and normal start of a gas turbine[2]

It should be noted that the degree of efficiency does not increase linearly during the start-up and shutdown of the plant. Consequently, there are points, even in the part-load range, which represent an optimum of the plant operation. To illustrate this, Zahoransky gives an example in his description of the operational behaviour (see figure 6-15).

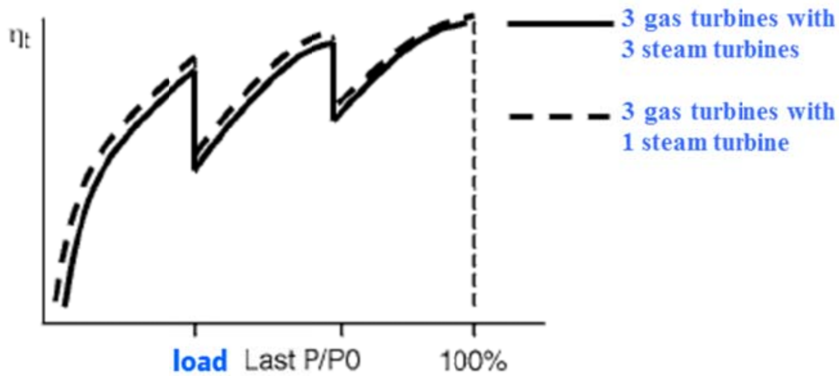

Figure 6-15: Part-load efficiency; CCGT power plant without additional firing with three gas turbines[3]

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[1] EOH = Equivalent Operation Hour; it is a calculated value, as special operating states, e.g. start-up or emergency shutdown are subject to higher wear. One start, for example, can have 20 EOH.

[2] cf. Zahoransky (2009): p. 141

[3] cf. Zahoransky (2009): p. 161

The different operational events are automatically registered in the plant control unit, and each resulting EOH is calculated. The following chart provides an example with the basic principle of the EOH-determination.

Assumptions:

- a start equivalent to 10 full-load operating hours [1].
- inspections every 25,000 full-load operating hours

Operating year	**Operating Hours per year**	**Starts per year**	**EOH**	**EOH cumulated**
1	5000	50	5500	5500
2	6000	40	6400	11900
3	6500	30	6800	18700
4	6000	50	6500	**25200**
5	6500	40	6900	32100
6	6000	30	6300	38400
7	6500	50	7000	45400
8	6000	40	6400	**51800**

Figure 6-16 : Example with the basic principle of the EOH-determination[2]

In practice it is much more complicated to determine the EOH, as reference is directly made to individual components and taken into account in the calculation. For this purpose, every manufacturer provides so-called plan-specific correction curves.

[1] 10 full-load operating hours is a value often used in practice, as it roughly reflects the data given by the different providers on the market.

[2] Authors own chart

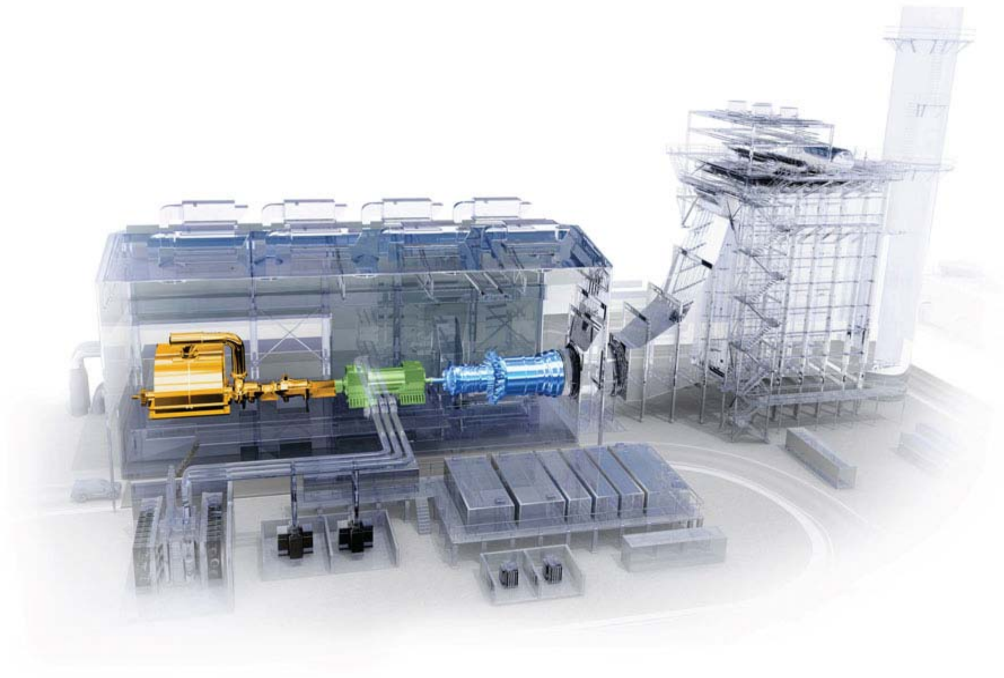

Figure 6-17: General Electric - FlexEfficiency 50 Combined Cycle Power Plant[1] [48]

It is, therefore, in the interest of a power plant operator to keep the operation in an optimum between the variable operating costs[2] plus maintenance costs[3].

Consequently, every power plant operator has to identify their position on what the limit values of costs and revenues are, on the basis of which they are prepared to commission the power plant. In the basic model developed in section 0, reference to this is not made directly, but it does play an indirect role when estimating the working hours and will therefore be illustrated briefly in the following.

The question could be formulated as follows: How high do the revenues have to be in order to cover all power plant costs plus the expected return at a certain number of operating hours?

For this, the first step is to ascertain the fixed and variable power plant costs in the operating time. The sum of all these costs, net of inflation, is referred to as electricity production costs.

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[1] cf. http://www.ge-energy.com/products_and_services/index.jsp

[2] cf. 8.1.1.7 Operating Expenditures, variable: p. 132

[3] cf. 8.1.1.8 Operating Expenditure, fixed: p. 142

According to the so-called “merit order”, the electricity production costs, in particular the fuel costs of a combined gas and steam power plant are too high for base load operation. Merit order means that when the electricity demand increases, the power plant which has the lowest electricity production costs (=marginal costs) will be the next to be connected to the grid. This implies that the use of power plants follows the principle of cost-optimisation. According to Konstantin, the marginal costs are identical with the variable costs[1].

Conversely, this also means that the revenues are not generated below the level of the variable costs.

In the second step, the revenues would have to be high enough so that the variable and fixed costs are remunerated via the operating hours. This is where the speculative element on the electricity market comes into play.

Whether the maintenance costs are proportionately fixed or variable, has to be decided once, see also the schematic representation in the figure below.

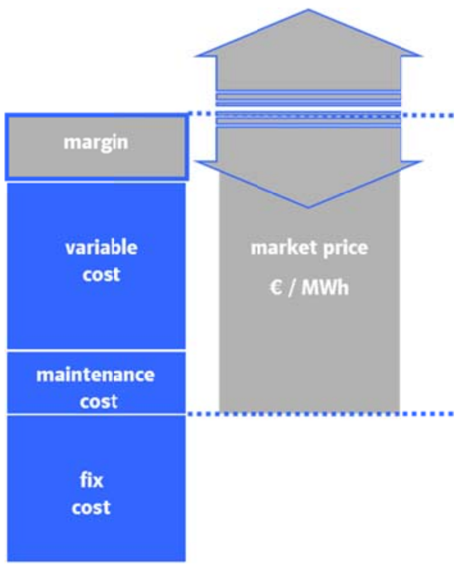

Figure6-18: Schematic representation of the power plant costs compared to the market prices[2]

[1] cf. Konstantin (2009): p. 181 ff., 292 ff.

[2] Author’s own schematic figure

If the maintenance costs are considered as variable costs, the so-called marginal costs, i.e. the costs on the basis of which operators are prepared to connect the power plant to the grid, rise. This entails fewer working hours, but theoretically, higher revenues can be achieved, as the power plant will only be commissioned when the market prices are higher.

The market price curve (with monetary unit per MWh) and the operating hours (max. 8760 per year) in the graph below result from the individual ratios between costs, revenues and working hours.

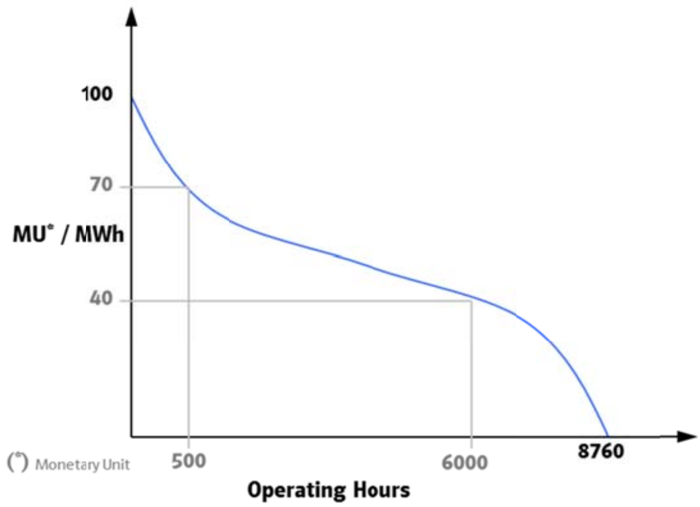

Figure 6-19: Schematic market price curve as a function of the operating hours[1]

[1] Author's own graph

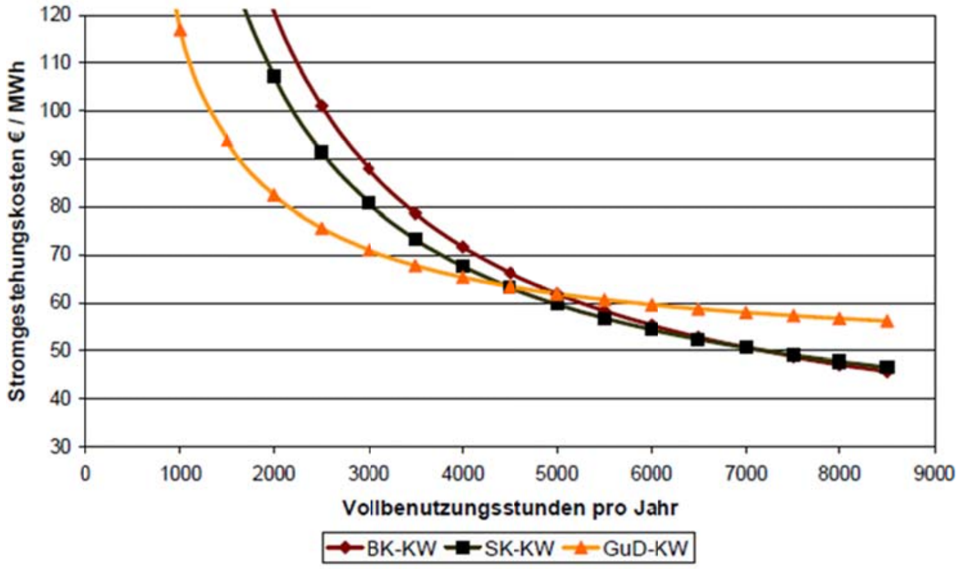

Figure 6-20: Electricity production costs as a function of the utilisation time[1]

Planning and estimating the operating hours of a power plant is therefore connected with a high degree of uncertainty and risk. For this reason, greatly simplified premises were assumed for the basic model in section 0.

6.4 Summary of the requirements on a power plant site

The following essential aspects can be summarised as requirements on a power plant site:

- minimum space demand
- possibilities for cooling water supply
- infrastructure links which allow the transportation of gas as the fuel necessary for the operation
- grid connection for the transmission of electrical energy

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[1] cf. Konstantin (2009): p. 294 –average specific electricity production costs as a function of the utilisation time, according to Konstantin;

On p. 293 Konstantin provides an overall survey of the electricity productions costs in fossil power plants.

- land-use planning that allows the construction and operation of a power plant and / or does not contradict the use as power plant area
- environmental compatibility of the project
- prevention and reduction of claims to protected areas
- qualified power plant staff for flexible operation based on appropriate framework conditions

7 Site criteria for a gas-fired power plant

In the chapter „Site theories“, different designations for the distinction of criteria were presented. The present chapter will define the terms that are necessary for this thesis. This will be followed by a general catalogue of criteria for the “Site decision of a gas-fired power plant” that will be drawn up and systematised using the criteria resulting from the power-plant-specific requirements.

7.1 Definition of terms

As mentioned in the previous chapter, Lüder and Küppers subdivide the criteria in limitational and substitutional factors[1].

7.1.1 Limitational criteria

The criteria identified as limitational factors or mandatory criteria describe minimum standards of a site, which have to be met at all costs. These will later on be referred to as ‘exclusion criteria’. Non-compliance with the exclusion criteria in the evaluation of a site in the further project process means the site is not suitable and leads to its exclusion from the assessment procedure.

1 cf. Lüder, Küpper (1983): p. 192 f.

7.1.2 Substitutional criteria

For the actual site evaluation, which is the basis for the comparison between different sites, the factors referred to as substitutional criteria by Lüder and Küpper are particularly suitable. It is a characteristic of these factors that any unfavourable peculiarities of one factor can be compensated for by favourable ones of another factor[1].

The subdivision into „financial substitutional"criteria and „non-financial substitutional" criteria made by Lüder and Küpper is similar to the terms "criteria that can be calculated" and "criteria that cannot be calculated" used by Rüschenpöhler[2]. There are further terms which are used in literature, such as "general" and "special" factors, as referred to by Weber[3]. Grabow et al. use the term „soft and hard site factors". Soft and hard factors together are supposed to cover the whole spectrum of site decisions. Soft site factors "… have direct implications for the business activities, but they are difficult to measure (!), or facts are, as a rule, overlaid or replaced by assessments"[4].

For the site assessment or creation of a catalogue of a gas-fired power plant, none of the above term pairs will be used in the present thesis. The substitutional criteria will be summarised using the term "qualitative and quantitative criteria" and will later on be comprehended as follows:

- Quantitative criteria can be clearly calculated, and no subjective assessment of the criteria is necessary.[5]
- Qualitative criteria are characterised by the fact that they cannot sufficiently be calculated by mathematical methods and have to be assessed subjectively by decision-makers[6].

---

1 cf. Lüder, Küpper (1983): p. 193

2 cf. Lüder, Küpper (1983): p. 192 f.; cf.. Rüschenpöhler (1958): p. 66

3 cf. Weber (1922): p. 16

4 cf. Grabow et al. (1995): p. 64

5 cf. Hansmann (1974): p. 137; cf. Schill (1990): p. 8

6 cf. Hansmann (1974): p. 137; cf. Schill (1990): p. 8

7.2 Differentiation of site criteria

A classification of the criteria into „natural-technical“ and „social-cultural“ site factors[1] has already been made by Weber. Godau compares seven different classification approaches[2] for site conditions and shows that a basic subdivision can be made into economic, political-legal, natural or geographic and cultural criteria[3].

For the criteria catalogue „Site decision of a gas-fired power plant”, the classification system offered by Godau is adapted for qualitative methods[4] to the “overview of the demands on the site of a gas-fired power plant” presented in a previous chapter as follows:

- area-specific criteria
- technical criteria
- political-legal criteria
- economic criteria
- other criteria

---

1 cf. Weber (1922): p. 20

2 cf.:

Kortüm, B. (1972): Zum Entscheidungsprozess bei privaten Auslandsinvestitionen. Frankfurt a. Main / Beuttel, W.; et al. (1980): Entscheidungsverhalten bei Auslandsaktivitäten: Ergebnisse einer empirischen Untersuchung. München: Florentz / Schüning, H. (1991): Der Einfluß wirtschaftspolitischer Rahmenbedingungen auf das Investitionsverhalten multinationaler Unternehmen. Stuttgart: G. Fischer / Goette, T. (1994): Standortpolitik internationaler Unternehmen. Wiesbaden: Gabler / Autschbach, J. (1997): Internationale Standortwahl. Direktinvestitionen der deutschen Automobilindustrie in Osteuropa. Wiesbaden: DUV Gabler / Hummel, B. (1996): Internationale Standortentscheidung: Einflußfaktoren, informatorische Fundierung und Unterstützung durch computergestützte Informationssysteme. Freiburg i. Br.: Haufe / Freericks, C. (1997): Internationale Direktinvestitionen mittelständischer Unternehmen: Am Beispiel der deutschen Automobilzulieferindustrie in Spanien. 1. Aufl., Berlin: VWF-Verlag

3 cf. Godau (2001): p. 111

4 cf. chapter 8.2 Qualitative procedures

Figure 7-1: 400 MW CCGT Power Plant in Gönyü (Hungary) at river Danube

For an investigation or assessment of a site, the main points have to be further subdivided into sub-items, to which respective criteria will have to be assigned. The criteria mentioned as examples in the individual sub-items either originate from existing criteria catalogues found on the topic "site assessment" or were especially developed for the site assessment of a gas-fired power plant on the basis of the requirements presented in the previous chapters[1].

<u>Area-specific criteria</u>

Area-specific criteria are further differentiated by the sub-items

- size and properties of the area
- ownership situation
- environmental situation
- conflicts relating to previous utilisation.

[1] cf. Arbeitsgemeinschaft Industriebau (2004): p. 17; Diller (1991): p. 42 f.; Fürst et al. (1973): p. 100 ff.; Grabow et. al (1995): p. 68 f.; Hansmann (1974): p. 140 ff.; Seidel (1977): p. 172 ff.; Stahr (1979): p. 110 ff.; Tesch (1980): p. 362 ff.;

Technical criteria

This section describes the requirements for the construction and operation of a power plant from a technical point of view. The criteria to be assessed are

- the situation relating to cooling water
- the access to the mains supply and the mains capacity
- links to the existing infrastructure
- supply and disposal facilities.

Political and legal criteria

The *political situation* has to be evaluated to ascertain to what extent support for or resistance to a power-plant scheme is to be expected. In addition, the pre-requisites for the erection and operation of a power plant relating to planning legislation have to be checked, taking into account the current or future political constellation(s) on federal, regional and municipal levels.

The *legal component* describes the existing legal framework, i.e. the respective legal requirements relating to planning approvals and the compliance with environmental regulations.

Economic criteria

The economic criteria are a *quantitative analysis of the costs* involved in the construction and operation of a power plant on the one hand, and a *qualitative assessment* of the marketing and synergetic potentials on the other hand.

Other criteria

These comprise criteria that cannot clearly be classified under one of the four above categories, but can be related to *several of the categories*, such as local contacts or stakeholder management.

8 Evaluation procedures

There are two basic models - in the following also referred to as procedures - that are used for evaluating a site: quantitative and qualitative procedures[1].

The focus of this thesis is on the representation and evaluation of the qualitative criteria, which are also referred to as non-quantifiable criteria. These criteria represent the major part of the decision-relevant criteria in the selection of suitable sites in this early project or power plant development stage. Qualitative criteria can be used to identify sites and establish their suitability as locations for power plants.

Quantitative procedures check the sites with regard to their economic efficiency. Towards the end of the project development chain, the final site decision should not be made until economic feasibility studies and performance audits have been completed. However, as described in chapter 1.3 on the general project development, we are in a very early stage of a project development process. This implies the probability of a high variance in the technical design and therefore also in the costs, as well as from the perspective of profitability.

Qualitative Procedures	Quantitative Procedures
• checklist procedures • profile method • utility analysis • ranking method • SWOT analysis	• statistical investment calculation procedures - cost comparison method - profit comparison method - profitability comparison method - (static) amortisation calculation • dynamic investment calculation procedures - capital value method - annuity method - internal rate of return method - dynamic amortisation calculation

Figure 8-1: Overview of site evaluation procedures [2]

[1] cf. Kinkel (2003): p. 53; cf. Olfert (2001): p. 31 ff.

[2] Author's own graph based on Kinkel (2004): p. 33

What all the procedures have in common is that they summarise the large number of individual data of a project in a financial measure (ratio), which is to indicate the current degree of target achievement. The quantitative procedures set the focus on the target "profit", the qualitative procedures on the target "benefit". When evaluating investments in power plant new-builds, there are two further targets from a business point of view, which could be involved in the evaluation - liquidity and risk[1].

The procedure for liquidity and risk can be transferred to the decision process of site selection if certain premises are taken into account.

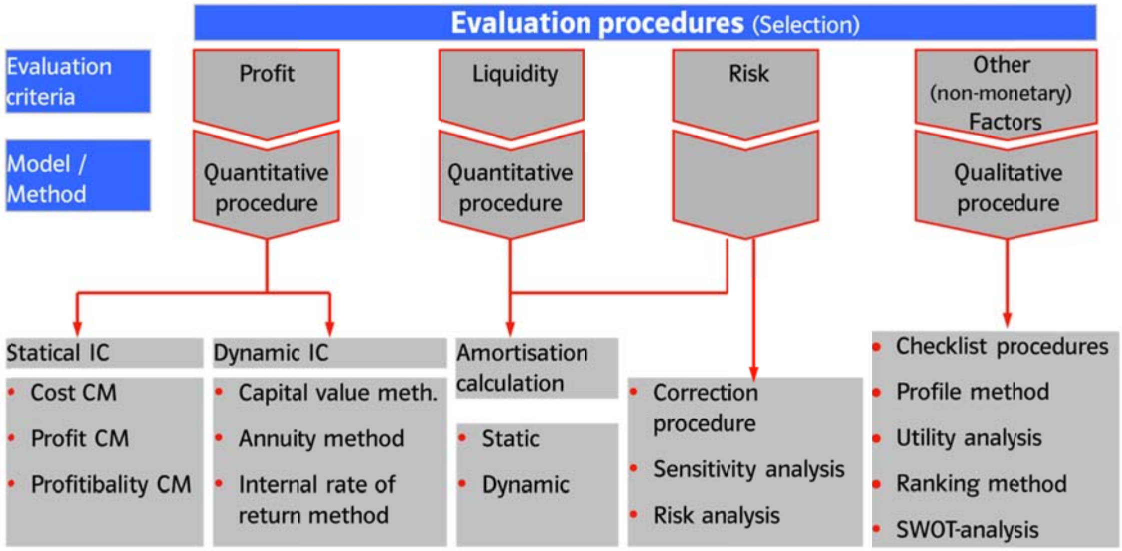

Figure 8-2: System of evaluation procedures for individual decisions [2]

In the following sections the procedures shown in the above figure will be analysed successively with regard to the decision about the site to be selected.

When using the procedures and evaluating them it has to be remembered that every procedure is designed to suit certain application purposes and questions. These will be explained in the following sections, but it should already be mentioned at this stage that not all procedures are suitable for assessing sites.

[1] cf. Mensch (2002): p. 40 ff.

[2] Author's own extended graph based on Mensch (2002): p. 41 f.

To gain knowledge of the profitability of an investment at a certain site, it is necessary, especially for the quantitative procedures, to represent reality in an abstracting form, using a model that is based on certain natural premises [5]. To avoid misinterpretations, section 8.1.1 provides the basis of a model for a simplified investment calculation for a CCGT – power plant and its premises, before the individual procedures and their application purposes are described.

8.1 Quantitative procedures

Quantitative procedures are analytical investment calculation procedures, which in their approach only refer to one (1) investment object and therefore do not directly take account of any possible interdependences among investment objects [1].
In einem Investitionsrechenmodell wiederum könnten unter bestimmten Prämissen zu einem gewissen Grade Interdependenzen mit anderen Marktteilnehmern bzw. Investitionen berücksichtigt werden[2].
A quantitative evaluation applies general calculation methods as a standard for the profitability of investments and from this, draws conclusions about the economic efficiency. It should, however, be noted that the suitability of conveying information on the profitability of investments is judged differently[3].

According to a survey, there has been an increasing preference of dynamic investment calculations over static investment calculations over time, especially in large enterprises[4].
A gas-fired power plant is a clearly definable investment with a relatively precise planning time and service life. What is more, it is an investment over a relatively long period of time (between 20 and 30 years). All these factors are in favour of the dynamic investment calculation procedures.

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1 cf. Seicht (1997): p. 66 ff.

2 See also section 8.1.4 Development potentials of the basic model on page 157

3 cf. Olfert (2001) : p. 57 f.; cf. Wöhe (1993): p. 795 ff.

4 cf. Olfert (2001): p. 220 f.; cf. Mensch (2002): p. 41f.; cf. Blohm et. al. (2006): p. 42 ff

The decisive characteristics and limits of the dynamic investment calculation will be described in one of the following sections by means of examples.

Static investment calculation procedures were very popular in the past, as they are relatively easy to use and procuring information requires comparatively little effort. They do not, however, consider the time reference and / or try to convert the revenues and expenditure in average "period costs" and "period revenues". For a long-term investment, as in the case of a gas-fired power plant, this shortage implies a big danger of misinterpretation[1].

From the point of view of theoretical exactness, this puts the static procedures undoubtedly at a disadvantage compared to the dynamic ones. In relation to the dynamic procedures they could be interpreted as approximation procedures. In order to illustrate this theoretical approximation character, reference will be made to the static procedures after the dynamic procedures have been described.

In theory and practice a large number of procedures for the assessment of investments have been developed. When evaluating and applying these individual procedures it has to be remembered that all quantitative procedures are based on models. For this reason the fundamentals and limits and / or premises of a basic model will be explained in the following section. On the basis of the simplified basic model developed herein, the individual quantitative procedures will then be examined critically.

[1] cf.. Kruschwitz (2009): p. 41 ff.; cf. Seicht (1997): p. 66 ff.

8.1.1 Basic model for the evaluation of a gas-fired power plant investment

The task of an investment calculation is to forecast the financial effects of a planned investment and to compact the gained monetary data so that an investment decision can be made that is in accordance with the objectives[1]. These compacted data in combination with the investment calculation as a basis for an economic appraisal and decision are referred to as “economic efficiency calculation” or “valuation model”.

A model used in investment calculation is an abstract image of reality. Its basic advantage is that it is more suitable to gather information from than reality.

As a general rule, the more precise and complete the model is, the more complex and difficult is its practical implementation. Therefore it is not a perfect reproduction of all details of reality that is required. The relevant components and factors have to be captured in such a way that they are fit for the purpose of solving the problem[2].

The problem will then be solved in the model after certain premises have been specified.

The solution, which is initially merely a model solution, will have to be adapted to the real problem, in this case the decision about the site. This implies interpretation, but also additional consideration of aspects that are relevant, but have not been taken account of in the model (qualitative factors, risks, etc.)[3].

1 cf. Wöhe (2010): cf. 527 ff.

2 cf. Kruschwitz (2009): p. 20 ff.; cf. Mensch (2002): p. 37 ff; cf. Blohm (2006): p. 271; cf. Seicht (1997): p. 64 ff.

3 cf. Kruschwitz (2009): p. 268 ff; cf. Mensch (2002): p. 38 ff

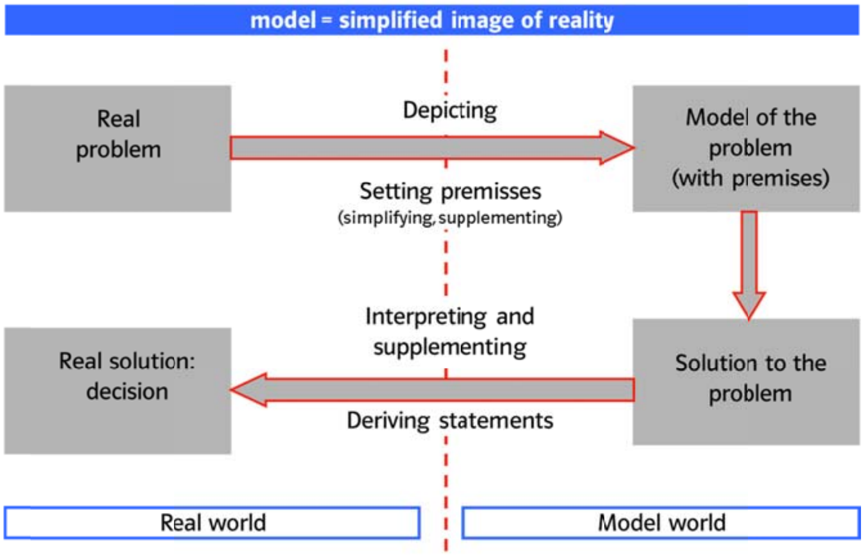

Figure 8-3: Model and reality in quantitative procedures [1]

The challenge in designing a model for a gas-fired power plant is therefore the procurement of information and its manageability in terms of calculation, as well as the "correct" setting of premises.

Investments in a gas-fired power plant are forward-looking. Accordingly, the data that are the basis for its evaluation have to be determined future-oriented rather than by merely importing past and / or actual data.
According to the definition of Mensch, different ways are available for the data forecast of the individual periods (or costs and revenues derived from them), which differ in their forecast quality, but also in the effort and the forecast problems involved in their application[2].

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1 Author's own graph based on Mensch (2002): p. 37

2 Mensch differentiates between five ways of forecast: (1) activities / market forecast, (2) forecast of influencing parameters, (3) detailed trend update, (4) general trend update, (5) (constant) estimated value, cf. Mensch (2002): p.23

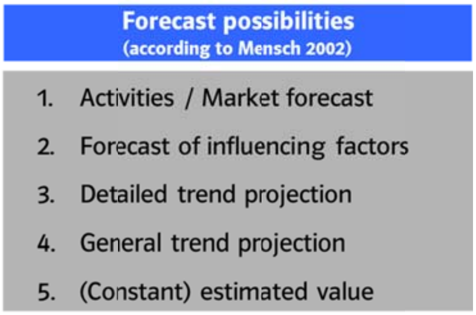

Figure 8-4 : Forecast possibilities

Due to the long forecast horizon for a gas-fired power plant and the associated difficulties in making forecasts, different forecast forms have to be taken into account when designing the model. Depending on the payment amount, a combination and / or staggering may, in certain cases, even prove more relevant for a better reproduction in the model.

The starting point in the modelling process is always the definition of the relevant question. In this thesis, the relevant question is the decision for a site in the project development stage - the feasibility study[1].

To illustrate a quantitative site evaluation, a simplified basic model has been developed, which implies all essential aspects of an investment in a gas-fired power plant while setting the focus on the evaluation of the respective site.
Why has this been done only in a simplified (exemplary) way? What opposes a more precise model specification at this stage is the lack of detailed information. For this reason, the model has to be iteratively and / or continuously adapted to any new information gained throughout the entire process of the project development. Possible development areas will to some extent be discussed in the individual sections on the basic model and in section 8.1.4 "Development potentials of the basic model" starting on page 182.

[1] cf. explanation „feasibility study“ chapter 01 page 13

In the basic model developed herein, the known site aspects of an investment in a gas-fired power plant are interlinked on the basis of economic and financial calculations. The final product will be a profit and loss account (P & L) for a gas-fired power plant, from which all further considerations and comparisons can be derived by using the quantitative procedures.

There is no fixed structure for the reproduction of the site conditions with regard to an investment in a gas-fired power plant. This can vary in the evaluation by different companies, depending on the requirements and priorities.

Basically, there are eight main categories and factors for the reproduction in a basic model and the premises set in it that have to be named and developed: (1) market conditions and competition, (2) capital market, (3) macroeconomic data, (4) main design data of the gas-fired power plant, (5) electricity prices and revenues, (6) investment (CAPEX), (7) variable operating costs and (8) fixed operating costs.

In the following sections on the basic model, reference will be made of these factors with a detailed explanation and discussion.

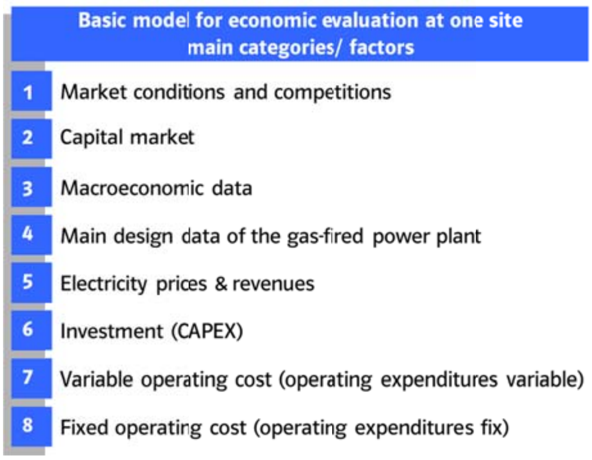

Figure 8-5: Main categories and factors for the reproduction in a basic model[1]

A CCGT (Combined Cycle Gas-Turbine Power Plant) of the 400 MW-class will serve as a basis for the basic model which was developed for the discussion of the quantitative procedures and which will be looked at in the present and subsequent sections.

[1] Author's own graph

The site is a so-called ‘green field’, which means there are no essential infrastructures from previous power plants or similar facilities. The construction literally takes place on a green field.
The service life of the power plant will be assumed to be around 25 years in the first approach. The duration of the project (planning and construction time) will amount to a total of around four (one plus three) years in this model.
No specific site in Europe will be considered. The model is rather intended to serve as general orientation for an evaluation. Therefore, the basic model has been optimised in terms of a pure cash flow basis.
The essential factors and variables to be taken into account will be specified in the following sections.

8.1.1.1 Market conditions and competition

Taking market conditions and competition into consideration would imply a very complex structure of the model. Apart from the methodological difficulties it would hardly be possible to provide a substantiated data and information basis.
For these reasons, the basic model was developed without taking account of any special factors or other mathematical links.

Ways to reduce the risks and uncertainties resulting from this will be mentioned and discussed in section 8.1.4 Development potentials of the basic model.

8.1.1.2 Capital market

The basic model presented herein is based on the premise of the perfect capital market. This implies that the *interest rate* for the debit interest (cost of capital in the case of external financing) and the credit interest (revenues from alternative equity investments) are of equal amount for all partial periods of the complete planning period (flat yield curve)[1]. The capital for such heavy and long-term investments is usually raised at the international financial market. What is more, vision and forecast are especially unreliable at the moment, in view of the continuing financial crisis and low interest rates and their impact.

For evaluating an individual site, the financial market therefore only plays a minor part, or none at all, in the basic model. For this reason, the basic model uses the pure cash flow basis to simplify the procedures, i.e. without involving interest and taxes (see also the explanations on taxes in the following section).

8.1.1.3 Macroeconomic data

In the model, those key figures were considered and summarized which describe the general macro- and microeconomic framework conditions at the site. These imply:

- inflation,
- planning and construction time,
- operating time,
- taxes.

[1] cf. Wöhe (2010): p. 536 ff; cf. Kruschwitz (2009): p. 63 ff

Inflation is the process of general price increases in the period under review [1]. Consequently, the inflation rate R_i (in %) specifies the percentage of the price increase in the respective period. In the model used as an example, this should ideally stay constant over the complete operating time.
The inflation factor R_{if} represents the cumulated per cent increase from the previous period to the period under review, the basis being an inflation factor R_{if} = 100% at the starting point of each period.

$$R_{if(n)} = R_{i(n)} * (1 + R_{if(n-1)})$$

$R_{if(n)}$ inflation factor in year n
$R_{i(n)}$ inflation rate in year n
$R_{if(n-1)}$ inflation factor in year n-1

The *planning and construction time* T_{PC} is the period starting from the feasibility[2] stage via the final construction drawings until the construction and commissioning period of a gas-fired power plant.

The *operating time* T_B is defined as the period of use, also referred to as service life. The service life is counted from the first hour of operation officially ordered by the network operator until the point at which the gas-fired power plant is no longer used for the generation of electricity, i.e. is switched off.
The optimum operating time could be determined using a model, but the result would again only be a model-related one. The wear and tear of the plant, and consequently its operating time depend on different factors, such as the total number of operating hours, the amount of startups and shutdowns (in proportion to which the equivalent operating hours result)[3], the quality of the plant to be constructed, i.e. securing availability and performance at a manageable amount of maintenance, accidents, etc. .

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[1] cf. Gabler (1994): p. 1602 f

[2] cf. explanation on “feasibility study” page 13 ff.

[3] See also section 6.3 „ Power plant operation “on page 87

The real operation on the network is difficult to imagine, so that in practice a minimum operating time is often fixed, independent of all the influencing parameters mentioned above. This procedure will also be adhered to here in the basic model.

The sum of the planning and construction time T_{PC} and the operating time T_B is the *total project term* T_P.

$$T_P = T_{PC} + T_B$$

T_P total project term
T_{PC} planning and construction time
T_B operating time

In addition, a so-called *operating factor* F_B will be defined in the basic model, which will be set to indicate the periods in which the power plant is in operation (and simultaneously serves as an indicator for the depreciation start).

0 = out of operation (depreciation „NO“);
1 = in operation (depreciation „YES“).

The significance of the depreciation in the basic model will be explained in more detail below.

Taxes are "…public charges that a community levies on natural and legal persons in its regional district, through the use of the power of the state at amounts fixed unilaterally and without granting any consideration in return…"[1].
Egner und Henselmann[2] state that taxes become all the more significant, the less the activity is bound to a local market and the more easily the activities can be relocated internationally. However, they also emphasize that the significance of taxation in international site considerations must not be overrated.

1 cf. Gabler Wirtschaftslexikon (2010): p. 2843
2 cf. Gabler Wirtschaftslexikon (2010): p. 2844 f.

Taxation is only one factor among others, and, in addition, it depends on those factors which influence the taxable bases.
The measuring methods for the tax charge can also be subdivided into qualitative and quantitative procedures. Complete comparisons of legal rules perform a qualitative analysis of the fiscal environment of a site, and they are a requisite for several quantitative procedures[1].
These procedures are time-consuming, as the taxable bases are not standardised and, what is more, are (partly) interdependent. In addition, they involve big demarcation problems. The exact attribution of the proportionate tax charges to an individual project imposes enormous difficulties on capital companies[2].
Related to a bigger company as a whole, *taxes* do have an influence, even or particularly from the point of view of a group company. Here, however, the strategic and corporate aspects that are of primary importance are completely different from those to be considered in a pure site evaluation. With the envisaged tax harmonisation within the European Union, reduced importance of tax burden comparisons can be expected.
The focus in the basic model is therefore purely on the economic benefit, i.e. not on the capital formation and taxes, but on the expenditure and income.
Nevertheless, a few essential aspects on taxes were mentioned above for the sake of completeness and a possible further.

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[1] cf. Gabler Wirtschaftslexikon (2010): p. 2845 ff

(1) Qualitative procedures: Complete comparisons of legal rules comprise both local foreign taxation (e.g. tariffs for reinvestment and distribution, taxes on capital, withholding tax, tax consolidation, capital gains taxation, amortisation rules, accrues, losses, subsidies) and the taxation of transnational activities in a foreign country (charging, release, transfer prices, abuse regulations, agreement procedures).

(2) Quantitative procedures:

(a) Tax quotas are determined as the ratio of the tax burden relating to the past and a corresponding reference figure.

(b) Tariff comparisons; As a general rule there are several kinds of income tax and additional levies existing side by side (e.g. trade tax, corporate income tax, income tax, solidarity surcharge, church tax), for which a combined burden on earnings has to be calculated.

c) EMTR (effective marginal tax rates) compare the gross return on investments with the net return of the investor after tax. Effective average tax rates (EATR) relate the final values of input tax and after-tax of an investment to each other.

d) Simulated tax assessments are based on the individual planning of the intended investment activities.

[2] cf. Wöhe (2010): p. 553 ff

Extract from the basic model - macroeconomic data:

For the macroeconomic data in the basic model, the planning time and construction time are summarised in a period of four years. No division was made, as there are no fundamental financial and economic differences in the first approach of a business analysis.

The operating time is assumed to be 25 years.

A constant rate of inflation is assumed after the planning and construction time. The rate of inflation in the planning and construction period, on the other hand, is exemplarily defined as beginning with a high value and falling off afterwards. In practice, possible budget risks can already be taken into account in this way (this will be discussed in section 8.1.4 Development potentials of the basic model.

T_{PC}	planning and construction time:	4 years (from 2011 to 2015)
T_B	operating time:	25 years (from 2015 to 2040)
R_i	rate of inflation :	2 %

Economic Efficiency Model - Combined Cycle Power Plant
Volkswirtschaftliche Daten und Zeitplan

	year		2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
	Dimension	*Indicator*															
Inflation Ri	%		2,80%	2,50%	2,40%	2,10%	2,10%	2,10%	2,10%	2,10%	2,10%	2,10%	2,10%	2,10%	2,10%	2,10%	2,10%
Inflation factor Rif	%		100,00%	102,50%	104,96%	107,16%	109,41%	111,71%	114,06%	116,45%	118,90%	121,40%	123,95%	126,55%	129,21%	131,92%	134,69%
Operating period	year	25 to 2040	0	0	0	0	1	2	3	4	5	6	7	8	9	10	11
Operating factor			0	0	0	0	1	1	1	1	1	1	1	1	1	1	1
Over all project period	year	29		1	2	3	4	5	6	7	8	9	10	11	12	13	14

	year		2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
	Dimension	*Indicator*															
Inflation Ri	%		2,10%	2,10%	2,10%	2,10%	2,10%	2,10%	2,10%	2,10%	2,10%	2,10%	2,10%	2,10%	2,10%	2,10%	*2,10%*
(cumulated)	%		137,52%	140,41%	143,35%	146,36%	149,44%	152,58%	155,78%	159,05%	162,39%	165,80%	169,28%	172,84%	176,47%	180,17%	*183,96%*
Operating time	year		12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Operating factor			1	1	1	1	1	1	1	1	1	1	1	1	1	1	*0*
Over all project period	year		15	16	17	18	19	20	21	22	23	24	25	26	27	28	29

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(yellow)	Manual Entry.
(grey)	Transfer cells from other part

Figure 8-6 : Extract from the basic model – macroeconomic data

8.1.1.4 Main design data

The term “main design data” summarises the essential characteristics and key data of a gas-fired power plant that are important for an investment calculation in the basic model.
These imply:

- Own demand power
- Net output
- Gross output
- Net efficiancy
- Availability
- Full Load Operating Hours

The *own demand power* P_E equals the portion of the total output of a power plant that is necessary for its normal operation, i.e. the energy supply of its own installations and facilities.

The *net output* P_{net} usually refers to the power plant output which is available for marketing after the transformer at the output terminals. In practice, this is often assumed as constant for the guarantee period, but over the subsequent years a deterioration of the efficiency due to ageing has to be taken into account.[1]

The *gross output* P_{gross} is the output which is required to cover the net output P_{net} plus the own demand power P_E. For this, the sum is put in relation to the efficiency, which is normally determined by the manufacturer or established by contract. The gross output, in turn, is the basis for the calculation of the total energy demand for fuel. This energy input usually remains constant over the entire life time of the power plant. What reduces over the years due to wear and tear, however, is the efficiency and therefore the net output of the power.

[1] See also section 6 Power plant process

$$P_{gross} = \frac{(P_E + P_{net})}{\eta}$$

P_E own demand power

P_{net} net output

η net efficiancy

P_{gross} gross output

The *net efficiency* indicates the ratio between the total amount of energy that is produced and the energy that is put in. For the gross efficiency, the own demand power would have been subtracted. In practice, the world's best CCGT-power plants have an efficiency of around 60%. The common standard is between 55% and 58%. Specifications are made by the respective producers in their offers for awarding contracts. As the supplier is not usually known in the early project phase under consideration, the basic model has to proceed from an assumption.

Due to wear and tear caused by normal operation, the net efficiency decreases over the years. Through regular maintenance and exchange of parts, this decrease can be delayed, but not be compensated for. A graph is represented in Figure 6-13, where the zig zag amplitudes reflect the so-called heavy maintenance, in which major parts are serviced and / or exchanged completely. Nevertheless, the deteriorating trend is clearly visible. In the basic model, this factor will be taken into account on a linear basis by means of a percentage ageing factor F_A. Within the two years of guarantee, however, no ageing will be considered. Thus, the basis that results for the calculation of the efficiency in the year n is as follows:

$$\eta_{(n)} = \eta_{(n-1)} * (1 + F_{A\eta(n)})$$

$\eta_{(n)}$ net weighed efficiency net in the year n

$\eta_{(n-1)}$ net weighed efficiency from the year n-1

$F_{A\eta(n)}$ efficiency ageing factor in the year n

The gross output is assumed to be constant in the model. Taking into account the weighted efficiency and after adjusting the gross output formula to the *net output* (for the period after the guarantee) it results as follows:

$$P_{net(n)} = P_{gross} * \eta_{(n)} - P_E$$

$P_{net(n)}$ net output in the period n

η_n net efficiency in the period n

P_{gross} gross output

P_E own demand power

The availability AV is the time in which the gas-fired power plant is ready for operation, related to a unit of time (one year)[1].
A standard calculation is available at the American National Standards Institute under the regulation IEEE STD 762[2].

The use and operation of a power plant with the *Full Load Operating Hours* – in the following simply referred to as *Operating Hours* OH – and the EOHs (Equivalent Operating Hours) that result for the maintenance intervals was already mentioned in section 6.3.
Based on his studies in Europe, Konstantin assumes an average of operating hours up to approximately 7500 hours per year[3].
In view of the increasing build-up of renewable energy sources, this will hardly be possible for medium-load range any longer. Therefore, a more moderate estimate will be assumed in the basic model.
In the following, several basic pragmatic approaches will be listed, which help to find a first OH-value as a basis for further assumptions.

1 cf. Zahoransky (2009): p. 42 ff.

2 cf. also http://www.ansi.org/

3 cf. Kanstantin (2009): p. 290 ff.

A gas-fired power plant is used in the peak-load range and under certain circumstances also in the medium-load range. This means, for a rough estimate, all weekends (around 104 days) and bank holidays (around 10 days) can be subtracted from the total annual balance (around 365 days = around 8760 hours). In addition, days of downtime due to maintenance and other reasons should be taken into account. The number of these might be smaller in the first few years, but will here exemplarily be assumed to be 200 hours. Consequently, the possible number of operation hours of the power plant is calculated as follows:

$$H_{CCGT} = H_{year} - H_{bh} - H_{we} - H_m \mp H_x$$

$$H_{CCGT} = 8760 - (10 * 24) - (104 * 24) - 200 \mp 0$$

$$H_{CCGT} = 5800 \text{ hours}$$

H_{CCGT}	hours of CCGT power plant
H_{year}	total annual hours
H_{bh}	total hours of bank holidays
H_{we}	total hours of weekends
H_m	total hours of downtime due to maintenance
Hx	other influences (e.g. malfunction)

The ageing process of the power plant goes along with a change in the conditions for the Merit Order[1], which means that its use can deteriorate with increasing service life, with the emergence of further power plants or also by law due to preferred technologies (e.g. wind energy in Germany). This aspect has been taken into account in the model by an ageing factor for the OH.

[1] See definition and further details on page 87 ff.

$$OH_{(n)} = OH_{(n-1)} * (1 + F_{AEOH\,(n)})$$

$OH_{(n)}$	EOH in the year n
$OH_{(n-1)}$	EOH in the year n-1
$F_{AEOH(n)}$	EOH-aging factor in year n

When calculating or estimating the OHs, the value of the availability has to be taken into consideration as well. The quantity of adjusted OHs resulting from this is calculated as follows:

$$OH_{ad(n)} = OH_{(n)} * AV_{(n)}$$

$OH_{(n)}$	EOH in the year n
$OH_{ad(n)}$	adjusted EOH in the year n
$AV_{(n)}$	availability in the year n

Extract from the basic model – main design data:

The values to be found in the basic model are selected freely. They are not based on empirical studies or principles. They are necessary for further calculations and also serve, among other things, as a basis for illustrating possible areas of further development and / or factors which, in practice, requires a closer iterative consideration.

Usually, the guarantee conditions apply in the first two years of operation. Consequently, for this period, no “ageing” of the plant can be assumed in the model

P_E	own demand power	= 2 MW_{el}
P_{net}	net output	= 410 MW_{el}
η	net efficiency	= 57%
P_{gross}	gross output	= 723 MW_{el}

Economic Efficiency Model - Combined Cycle Power Plant
Hauptauslegungsdaten

Kraftwerksdaten	year / Dimension	Indicator	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Own demand power/ Eigenbedarfsleistung	MWe	2,00					2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00
Marketable Net Power/ Vermarktbare Nettoleistung	MWe	410,00					410,00	410,00	409,59	409,18	408,77	408,35	407,94	407,53	407,12	406,72	406,31
gross output of power plant/ Bruttoleistung Gaskraftwerk	MWe						722,81	722,81	722,81	722,81	722,81	722,81	722,81	722,81	722,81	722,81	722,81
Efficiency net/ Wirkungsgrad netto	%	57,00%					57,00%	57,00%	57,00%	56,94%	56,89%	56,83%	56,77%	56,72%	56,66%	56,60%	56,55%
Aging factor/ Alterungsfaktor	%	0,1%							0,1%	0,1%	0,1%	0,1%	0,1%	0,1%	0,1%	0,1%	0,1%
Efficiency aged	%						57,0%	57,0%	56,9%	56,9%	56,8%	56,8%	56,7%	56,7%	56,6%	56,5%	56,5%
Availability/ Verfügbarkeit	%	98%					98%	98%	98%	98%	98%	98%	98%	98%	98%	98%	98%
Full load hours	h						2.000,00	5.800,00	5.800,00	5.771,00	5.742,15	5.713,43	5.684,87	5.656,44	5.628,16	5.600,02	5.572,02
aging factor	%	0,5%							0,5%	0,5%	0,5%	0,5%	0,5%	0,5%	0,5%	0,5%	0,5%
Full load hours aged	h						2.000,00	5.800,00	5.771,00	5.742,15	5.713,43	5.684,87	5.656,44	5.628,16	5.600,02	5.572,02	5.544,16
Full load hours adjusted	h						1.960,00	5.684,00	5.655,58	5.627,30	5.599,17	5.571,17	5.543,31	5.515,60	5.488,02	5.460,58	5.433,28

	year / Dimension	Indicator	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Own demand power/ Eigenbedarfsleistung	MWe	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00
Marketable Net Power/ Vermarktbare Nettoleistung	MWe	410,00	405,90	405,49	405,08	404,68	404,27	403,86	403,46	403,05	402,65	402,24	401,84	401,43	401,03	400,63	400,22
gross output of power plant/ Bruttoleistung Gaskraftwerk	MWe		722,81	722,81	722,81	722,81	722,81	722,81	722,81	722,81	722,81	722,81	722,81	722,81	722,81	722,81	722,81
Efficiency net/ Wirkungsgrad netto	%	57,00%	56,49%	56,43%	56,38%	56,32%	56,26%	56,21%	56,15%	56,09%	56,04%	55,98%	55,93%	55,87%	55,81%	55,76%	55,70%
Aging factor/ Alterungsfaktor	%	0,1%	0,1%	0,1%	0,1%	0,1%	0,1%	0,1%	0,1%	0,1%	0,1%	0,1%	0,1%	0,1%	0,1%	0,1%	0,1%
Efficiency aged	%		56,4%	56,4%	56,3%	56,3%	56,2%	56,2%	56,1%	56,0%	56,0%	55,9%	55,9%	55,8%	55,8%	55,7%	55,6%
Availability/ Verfügbarkeit	%	98%	98%	98%	98%	98%	98%	98%	98%	98%	98%	98%	98%	98%	98%	98%	98%
Full load hours	h		5.544	5.516	5.489	5.461	5.434	5.407	5.380	5.353	5.326	5.300	5.273	5.247	5.221	5.194	5.168
aging factor	%	0,5%	0,5%	0,5%	0,5%	0,5%	0,5%	0,5%	0,5%	0,5%	0,5%	0,5%	0,5%	0,5%	0,5%	0,5%	0,5%
Full load hours aged	h		5.516	5.489	5.461	5.434	5.407	5.380	5.353	5.326	5.300	5.273	5.247	5.221	5.194	5.168	5.143
Full load hours adjusted	h		5.406	5.379	5.352	5.325	5.299	5.272	5.246	5.220	5.194	5.168	5.142	5.116	5.091	5.065	5.040

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Figure 8-7 : Extract from the basic model - main design data

8.1.1.5 Electricity prices and revenues

Auf der Umsatzseite sind hier im Grundmodell die erwarteten Erlöse im Kraftwerksbetrieb für die geplanten Betriebsjahre ausgewiesen.

The *revenues* R_{el} result from the product of the electricity price and the volume of electrical energy generated in this period.

$$R_{el(n)} = EP_{(n)} * V_{el(n)}$$

$R_{el(n)}$	electricity revenues in the period n
$EP_{(n)}$	electricity price in the period n
$V_{el(n)}$	electricity volume of the period n

The *electricity price* EP in the model is an estimated or forecast value. Past data and trends from sources, such as EUROSTAT [1] and stock market information[2] can serve as a basis. Figure 8-8 shows the development of electricity prices in the past few years.
A model should therefore be able to represent possible changes and trends in electricity prices. In the basic model, the electricity price over the years was adjusted by an inflation factor R_{if} (increases in electricity prices).

$$EP_{(n)} = EP_{(n-1)} * R_{if(n)}$$

$EP_{(n)}$	electricity price in the period n
$EP_{(n-1)}$	electricity price in the period n-1
$R_{if(n)}$	inflation factor in the period n

[1] cf. http://epp.eurostat.ec.europa.eu/portal/page/portal/energy/data/database for e.g. gas and electricity prices

[2] cf. http://www.eex.com/en/ (home page)

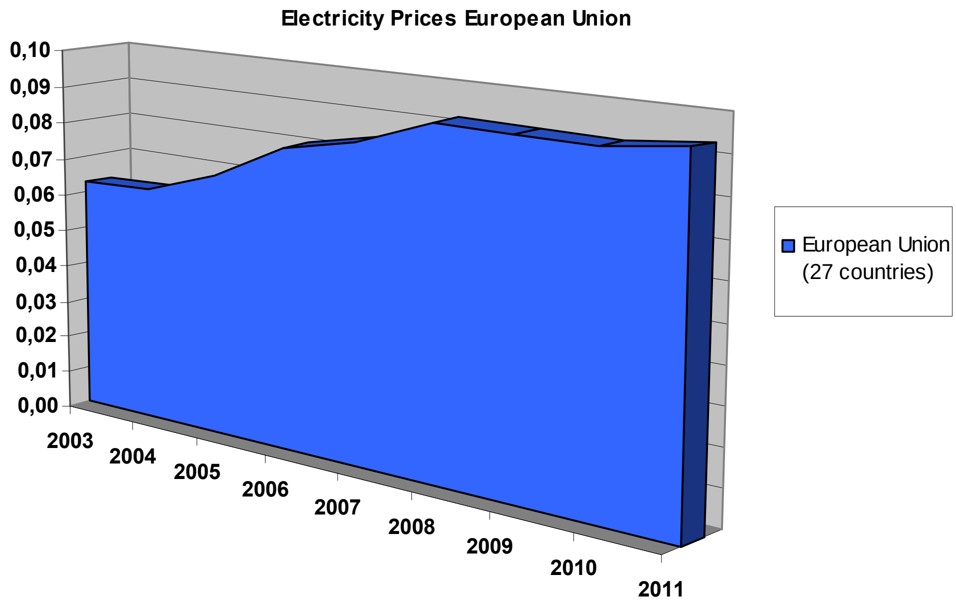

Figure 8-8: Electrical Energy Prices EU 27 from 2003 until 2011– Industrial costumer[1]

The *generated energy* V_{el} is calculated from the output of the power plant and the number of operating hours in the respective year.

$$V_{el\,(n)} = OH_{ad\,(n)} * P_{net}$$

$V_{el(n)}$	generated electrical energy in the period n
$OH_{ad(n)}$	adjusted EOH in the period n
$P_{net(n)}$	net output in the period n

Extract from the basic model – electricity prices and revenues:

At the time n=0 in the guarantee period, an electricity price of around 90 € / MWh was assumed. Exemplarily, the first year of operation was not considered as a full operating year, which would be the case if the commissioning takes place in the summer.

With all these data, all further quantities including the revenues can be calculated using the above relations.

[1] cf. EUROSTAT [nrg_pc_205] and [nrg_pc_205_h]

Economic Efficiency Model - Combined Cycle Power Plant
Umsatz

Umsatz	year / Dimension	Indicator	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Marketable Net Power/ Vermarktbare	MWel						410,00	410,00	409,59	409,18	408,77	408,35	407,94	407,53	407,12	406,72	406,31
Efficiency aged	%						57,0%	57,0%	56,9%	56,9%	56,8%	56,8%	56,7%	56,7%	56,6%	56,5%	56,5%
Availability/ Verfügbarkeit	%						98%	98%	98%	98%	98%	98%	98%	98%	98%	98%	98%
Full load hours adjusted	h						1.060,00	5.694,00	5.655,59	5.627,30	5.600,17	5.571,17	5.543,31	5.515,60	5.488,02	5.460,59	5.433,29
Electricity Price inflated	€/MWh	90,00					98,47	100,54	102,65	104,81	107,01	109,26	111,55	113,89	116,29	118,73	121,22
Electricity Volume	MWhel						803.600,00	2.330.440,00	2.316.457,70	2.302.559,28	2.288.744,24	2.275.012,08	2.261.362,29	2.247.794,40	2.234.307,89	2.220.902,29	2.207.577,12
Revenues Total	€						79.133.020,63	234.304.960,77	237.790.047,77	241.326.971,28	244.916.502,31	248.559.423,29	252.256.528,33	256.008.623,32	259.816.526,16	263.681.066,89	267.603.087,93

Umsatz	year / Dimension	Indicator	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Marketable Net Power/ Vermarktbare	MWel		405,90	405,49	405,08	404,68	404,27	403,86	403,46	403,05	402,65	402,24	401,84	401,43	401,03	400,63	400,22
Efficiency aged	%		56,4%	56,4%	56,3%	56,3%	56,2%	56,2%	56,1%	56,0%	56,0%	55,9%	55,9%	55,8%	55,8%	55,7%	55,6%
Availability/ Verfügbarkeit	0%		98%	98%	98%	98%	98%	98%	98%	98%	98%	98%	98%	98%	98%	98%	98%
Full load hours adjusted	h		5.406,11	5.379,08	5.352,18	5.325,42	5.298,80	5.272,30	5.245,94	5.219,71	5.193,61	5.167,64	5.141,81	5.116,10	5.090,52	5.065,06	5.039,74
Electricity Price inflated	€/MWh	90,00	123,77	126,36	129,02	131,73	134,49	137,32	140,20	143,15	146,15	149,22	152,36	155,56	158,82	162,16	165,56
Electricity Volume	MWhel		2.194.331,88	2.181.166,10	2.168.079,31	2.155.071,02	2.142.140,77	2.129.288,10	2.116.512,52	2.103.813,59	2.091.190,84	2.078.643,82	2.066.172,06	2.053.775,13	2.041.452,57	2.029.203,93	2.017.028,77
Revenues Total	€		271.583.444,19	275.623.003,32	279.722.645,86	283.883.265,46	288.105.769,06	292.391.077,08	296.740.123,63	301.153.856,72	305.633.238,45	310.179.245,25	314.792.868,04	319.475.112,51	324.226.999,28	329.049.564,18	333.943.858,41

Cell Color-Code:	
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Figure 8-9: Extract from the basic model - electricity prices and revenues

8.1.1.6 Investment (CAPEX)

After having captured the model data and numbers for the environment, the investment itself, also known as Capital Expenditures (CAPEX) will now be analysed. This includes the planning when costs will be incurred (investment allocation).

Here, in the basic model, CAPEX costs include all costs which are capitalised and can therefore be depreciated over the life time of the power plant.
For reasons of simplification, the investment was divided into seven cost items CI, with the first four of the factors below forming the largest proportion of the CAPEX.

(1) costs for the general contractor
(2) project management
(3) mains supply
(4) gas supply
(5) governmental compensation measures
(6) Public Relation (PR) & Stake Holder Management
(7) other additional costs

$$CAPEX = \sum_{i=7}^{i} CI_i$$

The investment allocation, i.e. the planning when costs will be incurred, has an influence on the application of the different quantitative procedures with discounting function.
In practice, it is mainly planning expenses and site preparation costs that are incurred in the first year, rather than costs of delivery and services by vendors. In the second year, here in the model the awarding of turn-key-contracts, increased down payments are to be expected in practice, although the on-site work might just have started. Accordingly, the payments are often lower in the last year, when the commissioning takes place. This, however, strongly depends on the negotiating skills of the respective contract partners. From the economic point of view of the investor, it is desirable that the cash flow is as late as possible.

The *costs for the general contractor* are defined as the sum that was agreed on with the general contractor in the turn-key-contract.

The *project management costs* exemplarily represent the costs of the internal project organisation for the coordination of the whole project.

The *electricity and gas supply* of the power plant are listed as separate items in the basic model, as these often represent a significant cost item, along with the costs for the general contractor. Here, a general item for infrastructure would be conceivable as well.

Governmental compensation measures due to the approval procedure have to be expected for all projects. Their amount can hardly be determined in advance, but should by all means be taken into account as a lump-sum figure.
This also applies to costs for *Public Relation* and *Stake Holder Management*.

There are further activities, supplies and services that entail costs which have to be taken into consideration in connection with the investment. In the basic model, these were summarised under the term "*other additional costs*", and include items, such as:

> purchase and development of land, construction site preparation activities (e.g. for turn-key-suppliers), water supply and waste water management, quality assurance measures in the construction stage, administrative fees, local consulting services, facilities of the power plant (office, shop, etc),

to name but a few.

These costs would also include the spare parts for the power plant, unless they have already been agreed upon as being included in the price of the general contractor.

The sum of the CAPEX will be depreciated according to schedule throughout the duration of use. *Writedowns* are intended to cover the depreciation of fixed assets subject to wear and tear, in this case the power plant[1]. . In the basic model, a straight-line depreciation, i.e.an evenly distributed depreciation over the period, is assumed.

[1] cf. Woll (2008): p. 3 ff.

Apart from this, there are further types of depreciation, such as the progressive depreciation. Basically, this depends on the current legislation and the interests of the company.
The straight-line depreciation rate A_{AFA} in the model results from the reciprocal value of the operating time T_B.

$$A_{AfA} = \frac{1}{T_B}$$

A_{AfA}	depreciation rate
T_B	operating time

This results in the depreciation amount $A_{A(n)}$ in the year n:

$$A_{A(n)} = I_{total} * A_{AfA}$$

$A_{A(n)}$	depreciation amount in the year n
A_{AfA}	depreciation rate
I_{total}	total investment

Extract from the basic model - CAPEX:

For the EPC, a total investment volume of 300 million € has been estimated in the first approach.
All major construction measures, such as electricity or gas supply as well as the EPC, were distributed on a percentage basis (40% - 50% - 10%) over the period of three years of construction and commissioning.
In the practice, the remaining investments are to be distributed according to the best possible assessment over the project term.
The writedowns start in the first operating year in 2015 and resulted in a depreciation rate of 4% for an assumed operating time of 25 years.

Economic Efficiency Model - Combined Cycle Power Plant
GuD Invest

Investition	Dimension	AfA period [year]	AfA Satz	Indicator	2011	2012	2013	2014	2015	2016	2017	2018
Faktor Betrieb					0	0	0	0	1	1	1	1
							40%	50%	10%			
EPC contract lump sum	€	25	4,00%	300.000.000			120.000.000	150.000.000	30.000.000			
Zusatzaufwand	€	25	4,00%	8.000.000		0	3.200.000	4.000.000	800.000			
Risc	€	25	4,00%	2.000.000		0	800.000	1.000.000	200.000			
Gasanschluß	€	25	4,00%	5.000.000		0	2.000.000	2.500.000	500.000			
Netzanschluss 380 kV	€	25	4,00%	10.000.000		0	4.000.000	5.000.000	1.000.000			
behördl. Ersatzmaßnahmen	€	25	4,00%	1.000.000		0	0	0	1.000.000			
sonstiges (Medienversorgung Baustelle)	€	25	4,00%	1.000.000		0	333.333	333.333	333.333			
Bauleitung, Projektmanagement	€	25	4,00%	3.000.000		600.000	800.000	1.000.000	600.000			
Summe Investition	€			**330.000.000**		**600.000**	**131.133.333**	**163.833.333**	**34.433.333**			
Abschreibungen												
Abschreibungssatz p.a.	%					0,00%	0,00%	0,00%	4,00%	4,00%	4,00%	4,00%
Abschreibungsbetrag Investition	€								13.200.000	13.200.000	13.200.000	13.200.000

Figure 8-10 : Extract from the basic model – CAPEX

8.1.1.7 Operating Expenditures, variable

The most influential variable expenditures of a gas-fired power plant for generating electricity, here summarised under the term OPEX = Operating Expenditures, are expenditures for:

- gas
- CO_2-emissions (charges and / or certificates)
- cooling water

These three cost types are to be recognised as variable expenditures, i.e. costs that are not incurred during plant outage.

Costs for maintenance and spare parts, which also have a relatively high share, have been assigned to the service costs and not to the operating costs, as the costs that are actually high are subject to longer cycles.

Definition of gas costs

The total gas costs $GC_{tot(n)}$ of a power plant for the relevant year can be determined by multiplying an gas price electrical per operating hour with the adjusted operating hours[1] (see also section 8.1.1.4 Main design data) forecasted for the year in question.

$$GC_{tot(n)} = OH_{ad(n)} * GP_{el(n)}$$

$GC_{tot(n)}$	total annual costs for gas in the year n
$OH_{ad(n)}$	adjusted operating hours n the year n
$GP_{el(n)}$	gas price electrical per operating hour in the year n

The question arises how a gas price is derived.

Determining or fixing the costs for gas in general is very difficult as it would mean a forecast of the future prices for gas traded at the stock exchanges. Therefore, a simplification is required here.

[1] cf. 8.1.1.4 Main design data page 116 ff.

A possible way is described in the following:

First, a current basic value has to be defined for the forecast. This could be done by assuming a mean value of the last averages traded at the stock exchange (see the graph below).

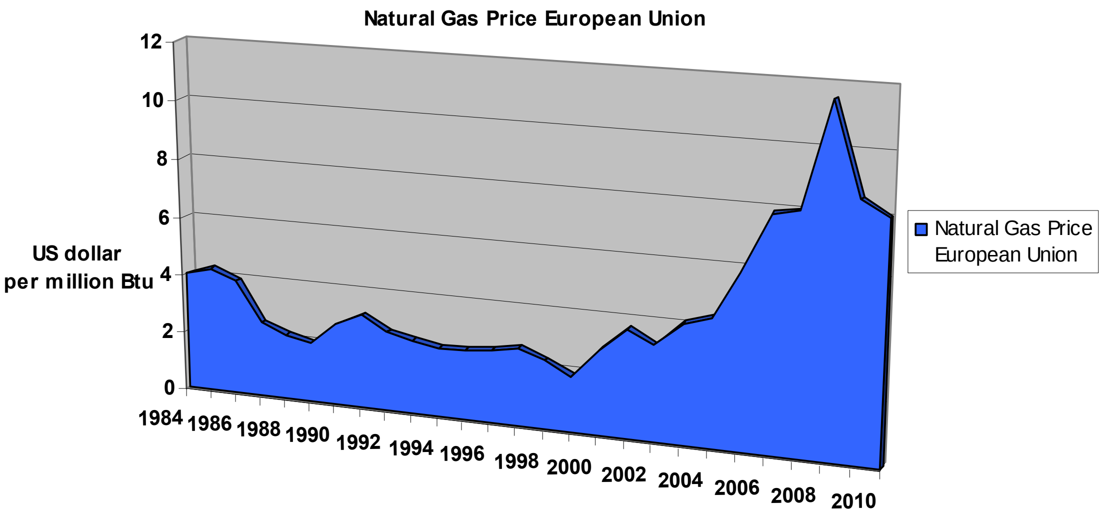

Figure 8-11: Price for the natural gas in the European Union 1984 to 2010[1]

The prices at the stock exchange always refer to the energy content of natural gas. Calculating the gas costs of a gas-fired power plant, however, requires data relating to the electrical power in MW.

The price determination in America, for example, is done in US-dollars per mmBtu (1 million British Thermal Units)[7]. The British Thermal Unit mmBtu corresponds to an energy amount of 1,005.06 Joule.

Another trading centre for gas is the International Petroleum Exchnage (ICE) in London, where the listing is done in British Pence (€) per 100,000Btu.

Using these data, the gas costs in EURO per Giga Joule (€/GJ) can be transferred.

For converting the energy values (GJ) into output values (Mega Watt thermical = MW_{th}), the following transition from physics can be applied[2]:

---

[1] cf. BP (British Petrol) - workbook of historical statistical data from 1965-2010 http://www.bp.com/sectionbodycopy.do?categoryId=7500&contentId=7068481

[2] cf. ABB AG (08/2007): Schaltanlagenbuch komplett – Deutsch

$$1MW_{th} = 3{,}6GJ$$

With the reciprocal value this results for one Giga Joule:

$$1GJ = 0{,}2778MW_{th}$$

Once a decision for a basic value of the gas price has been made, it has to be defined, how this is related to the future in the model. Here, in the model, the future course of the gas costs will be represented via two factors, one of them being the rate of inflation in the year n, $R_{i(n)}$, described above in connection with the macroeconomic data.
However, in order to take the risk of uncertainty into account, a second factor – a so-called Uncertainty Factor (UF) is introduced. This leads to the gas price in the year n ($GP_{(n)}$) as follows:

$$GP_{th(n)} = (1 + R_{i(n)}) * GP_{init} * (1 + UF)$$

$GP_{th(n)}$	pas price thermal in the year n
$R_{i(n)}$	inflation rate in the year n
GP_{init}	initial gas price thermal
UF	uncertainty factor

In order to get from the thermal gas price GP_{th} to the electrical gas price GP_{el}, the GP_{th} has to be multiplied by the electrical output of the power plant generated in one hour. The total output generated in one hour corresponds to the gross output P_{gross} described in section 8.1.1.4.

$$GP_{el(n)} = GP_{th(n)} * P_{gross}$$

$GP_{el(n)}$	gas price electrical per operating hour in the year n
$GP_{th(n)}$	gas price thermal in the operating year n
P_{gross}	gross output

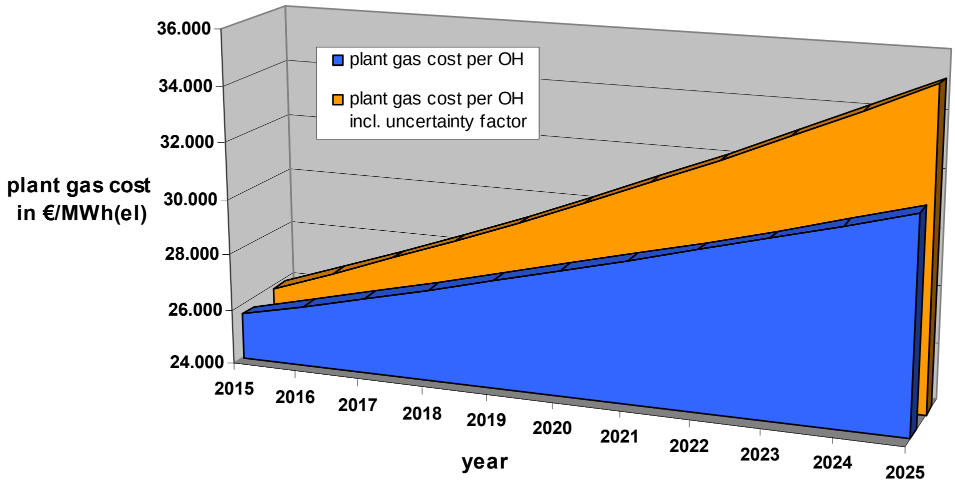

Figure 8-12: Increase of plant gas cost by uncertainty factor out of basic model

Now the total gas costs $GC_{tot(n)}$ can be calculated for the relevant year as described above.

Definition of the CO2 costs

In order to motivate companies to fulfil their objectives with regard to CO_2 reduction, the European Union has introduced so-called CO_2-certificates, which have to be acquired by power plant operators in sufficient numbers, so that the power plant can be operated. These certificates are traded at the stock exchanges.

The annual CO_2-costs of a power plant therefore result from the product of the costs for CO_2-certificates CO_{2cert} and the total emissions of a power plant per year EM_{co2}.

$$CO2_{tot(n)} = CO2_{cert(n)} * EM_{CO2(n)}$$

$CO2_{tot(n)}$	CO_2–emission costs in the year n
$CO2_{cert(n)}$	CO_2–certificate costs in the year n
$EM_{CO2(n)}$	total power plant emissions in the year n

In the past, the costs of CO_2-certificates varied considerably less than, for example, the gas prices. In figure 8-11, a certain downward trend throughout the year 2011 was to be seen. At the turn of the year, however, the prices rose again slightly.

Figure 8-13: European CO2 emission allowances at spot market from 03-2011 until 01-2012[1]

To cover possible fluctuations and trends in the costs for CO_2-certificates, a basic value is to be assumed, which will then at least be multiplied with the inflation rate described in section 8.1.1.3. For further risk minimisation, an additional rate of price increase R_{pi} is introduced in the basic model, which is here assumed to be constant.

$$CO2_{zert(n)} = R_{i(n)} * R_{pi}$$

$CO2_{cert(n)}$	costs of CO_2-certificates in the year n
$R_{i(n)}$	rate of inflation in the year n
R_{pi}	rate of price increase (steady)

[1] cf. CO2 emission allowances at EEX (European Energy Exchange stock market) as per 2012-02-22; https://www.eex.com/de/Marktdaten/Handelsdaten/Emissionsrechte/EU%20Emission%20Allowances%20|%20Spotmarkt/EU%20Emission%20Allowances%20Chart%20|%20Spotmarkt/spot-eua-chart/2012-02-22/0/0/1y

The CO_2- emission values of a power plant are expressed by the manufacturers in grams per kilowatt hour (g/kWh).
As the certificates are usually traded at the stock exchange in EURO per tonne (€/t), the emission value is to be converted into tonnes per megawatt hour (t/MWh).

$$1t / MWh = 1000 g / kWh$$

To define the total emissions $CO_{2tot(n)}$ of a power plant, the stated (or measured) CO_2-emission value EM is to be multiplied by the total gross output per hour P_{gross} in the first step. In the second step, the emission value per hour EM_h is multiplied by the adjusted operating hours $OH_{ad(n)}$ (see also section on "Main design data") to get to the emission value of a power plant for a complete year $EM_{CO2(n)}$.

$$EM_h = EM * P_{gross}$$

$$EM_{CO2(n)} = EM_h * OH_{ad(n)}$$

EM	emission value as stated by the power plant
P_{gross}	gross output
$OH_{ad(n)}$	adjusted operating hours in the year n
$EM_{CO2(n)}$	total power plant emissions in the year n

Definition of the cooling water costs

Another cost factor in the operation of a power plant that should not be underestimated are the costs for cooling water. This particularly applies to warmer regions, where water supply can be problematic at certain times, which makes a forecast for the next decades all the more difficult.

Figure 8-14: 430 MW CCGT power plant in Gönyü (Hungary) at river Danube[1]

The cooling water consumption per hour W_h is to be assumed as constant in the model, as it does not really change over the whole operating life of a power plant. This value is multiplied by the adjusted operating hours $OH_{ad(n)}$, which results in the water consumption in one year. This, multiplied by the cooling water costs per m^3 (€/m^3), results in the total water costs of the power plant WC_{tot} in one year. The charges for cooling water per m^3 are fixed by the local authorities and should be obtained before setting up the model, as their height can vary due to different parameters, even within the same region. Here, in the basic model, the cooling water costs per m^3 are assumed as constant, but can still be inflated.

$$WC_{tot(n)} = W_h * OH_{ad(n)} * WC_{m3}$$

$WC_{tot(n)}$	total water costs in the year n
W_h	cooling water consumption per hour
$OH_{ad(n)}$	adjusted operating hours in the year n
WC_{m3}	cooling water costs per m^3

[1] in commercial operation since May 2011

Extract from the basic model – OPEX variable:

The costs that appear first in the basic model are the costs of natural gas. The basic value for the gas price that was fixed here was 9 €/GJ. The described uncertainty factor was set at 1%.

The costs for the CO_2-certificates are assumed to be 12.5 €/t and are updated with an inflation rate of 1%. The power plant emissions are assumed to be 350 g/kWh.

For the cooling water, a consumption of 27000 m^3/h was taken as a basis. The costs amount to 0.008 €/m^3

Economic Efficiency Model - Combined Cycle Power Plant
Operating Expenditure - variable

year	Dimension	Indicator	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Full load hours adjusted	h						1.960,00	5.684,00	5.655,58	5.627,30	5.599,17	5.571,17	5.543,31	5.515,60	5.488,02	5.460,58	5.433,28
gross output of power plant/ □Brutto	MWel						722,81	722,81	722,81	722,81	722,81	722,81	722,81	722,81	722,81	722,81	722,81
Gas Cost																	
Gas Price	€/ GJ	9,00					9,85	10,05	10,27	10,48	10,70	10,93	11,16	11,39	11,63	11,87	12,12
Gas Price	€/ MWth	32,40					35,45	36,19	36,95	37,73	38,52	39,33	40,16	41,00	41,86	42,74	43,64
plant gas cost per OH	€/ MWhel						25.623,75	26.161,85	26.711,25	27.272,18	27.844,90	28.429,64	29.026,66	29.636,22	30.258,58	30.894,02	31.542,79
Uncertainty factor	%	1%															
Gas Price incl. Uncertainty factor	€/ GJ						9,95	10,26	10,58	10,91	11,25	11,60	11,96	12,33	12,72	13,11	13,52
Gas Price incl. Uncertainty factor	€/ MWth						35,80	36,92	38,07	39,26	40,49	41,75	43,06	44,40	45,78	47,21	48,69
plant gas price per OH incl. uncertai	€/ MWhel						25.879,99	26.687,70	27.520,62	28.379,54	29.265,27	30.178,64	31.120,51	32.091,78	33.093,37	34.126,21	35.191,29
Gas cost per year	€/ MWh						50.724.774,14	151.692.893,58	155.645.092,64	159.700.262,10	163.861.084,75	168.130.313,26	172.510.772,03	177.005.359,06	181.617.047,83	186.348.889,32	191.204.013,96
CO2 cost																	
CO2 certificate cost	€/t	12,5					13,68	13,96	14,26	14,56	14,86	15,17	15,49	15,82	16,15	16,49	16,84
CO2 Teuerungsrate	%	1%					13,81	14,24	14,69	15,15	15,62	16,11	16,61	17,13	17,66	18,22	18,78
CO2 Emissionen	g/kWh	350					350,00	350,00	350,00	350,00	350,00	350,00	350,00	350,00	350,00	350,00	350,00
	g/MWh						350.000,00	350.000,00	350.000,00	350.000,00	350.000,00	350.000,00	350.000,00	350.000,00	350.000,00	350.000,00	350.000,00
	kg/MWh						350,00	350,00	350,00	350,00	350,00	350,00	350,00	350,00	350,00	350,00	350,00
	t/MWh						0,35	0,35	0,35	0,35	0,35	0,35	0,35	0,35	0,35	0,35	0,35
power plant CO2 emissionen	t/h						252,98	252,98	252,98	252,98	252,98	252,98	252,98	252,98	252,98	252,98	252,98
power plant CO2 emissionen	t/year						495.845,61	1.437.952,28	1.430.762,52	1.423.608,71	1.416.490,66	1.409.408,21	1.402.361,17	1.395.349,36	1.388.372,62	1.381.430,75	1.374.523,60
CO2 emission cost	€/year						6.849.410,09	20.483.222,51	21.016.891,37	21.564.464,40	22.126.303,88	22.702.781,50	23.294.278,63	23.901.186,60	24.523.906,92	25.162.851,57	25.818.443,24
Cooling Water																	
Kühlwassereinleitung																	
Kühlwasser/Vbh	t/h = m3/h	27.000															
Cooling water per year	m3/year						52.920.000,00	153.468.000,00	152.700.660,00	151.937.156,70	151.177.470,92	150.421.583,56	149.669.475,64	148.921.128,27	148.176.522,62	147.435.640,01	146.698.461,81
Kühlwasser	€/m3	0,008															
Cooling water cost per year	€						423.360,00	1.227.744,00	1.221.605,28	1.215.497,25	1.209.419,77	1.203.372,67	1.197.355,81	1.191.369,03	1.185.412,18	1.179.485,12	1.173.587,69
SUM operating variable cost							**57.997.544,22**	**173.403.860,09**	**177.883.589,29**	**182.480.223,76**	**187.196.808,40**	**192.036.467,42**	**197.002.406,47**	**202.097.914,69**	**207.326.366,94**	**212.691.226,00**	**218.196.044,90**

Cell Color-Code:	
(yellow)	Manual Entry
(grey)	Transfer cells from other part

Figure 8-15 Extract from the basic model – OPEX variable (a)

Economic Efficiency Model - Combined Cycle Power Plant
Operating Expenditure - variable

	Dimension	Indicator	year 2011 year 2026	2012 2027	2013 2028	2014 2029	2015 2030	2016 2031	2017 2032	2018 2033
Full load hours adjusted	h		5.406,11	5.379,08	5.352,18	5.325,42	5.298,80	5.272,30	5.245,94	5.219,71
gross output of power plant/ □Bruttc	MWel		722,81	722,81	722,81	722,81	722,81	722,81	722,81	722,81
Gas Cost										
Gas Price	€/ GJ	9,00	12,38	12,64	12,90	13,17	13,45	13,73	14,02	14,31
Gas Price	€/ MWth	32,40	44,56	45,49	46,45	47,42	48,42	49,43	50,47	51,53
Plant Gas Price per OH	€/ MWhel		32.205,19	32.881,50	33.572,01	34.277,02	34.996,84	35.731,77	36.482,14	37.248,26
Uncertainty factor	%	1%								
Gas Price incl. Uncertainty factor	€/ GJ		13,95	14,38	14,83	15,29	15,77	16,26	16,77	17,29
Gas Price incl. Uncertainty factor	€/ MWth		50,21	51,77	53,39	55,06	56,77	58,55	60,37	62,26
plant gas price per OH incl. uncerta	€/ MWhel		36.289,61	37.422,21	38.590,16	39.794,56	41.036,54	42.317,30	43.638,02	44.999,96
Gas cost per year	€/ MWh		196.185.633,78	201.297.044,48	206.541.627,61	211.922.852,85	217.444.280,26	223.109.562,66	228.922.448,05	234.886.782,07
CO2 cost										
CO2 certificate cost	€/t	12,5	17,19	17,55	17,92	18,30	18,68	19,07	19,47	19,88
CO2 Teuerungsrate	%	1%	19,37	19,97	20,60	21,24	21,90	22,59	23,29	24,02
CO2 Emissionen	g/kWh	350	350,00	350,00	350,00	350,00	350,00	350,00	350,00	350,00
	g/MWh		350.000,00	350.000,00	350.000,00	350.000,00	350.000,00	350.000,00	350.000,00	350.000,00
	kg/MWh		350,00	350,00	350,00	350,00	350,00	350,00	350,00	350,00
	t/MWh		0,35	0,35	0,35	0,35	0,35	0,35	0,35	0,35
power plant CO2 emissionen	t/h		252,98	252,98	252,98	252,98	252,98	252,98	252,98	252,98
power plant CO2 emissionen	t/year		1.367.650,98	1.360.812,73	1.354.008,66	1.347.238,62	1.340.502,43	1.333.799,91	1.327.130,91	1.320.495,26
CO2 emission cost	€/year		26.491.115,67	27.181.313,88	27.889.494,47	28.616.125,96	29.361.689,08	30.126.677,06	30.911.595,99	31.716.965,17
Cooling Water										
Kühlwassereinleitunç										
Kühlwasser/Vbh	t/h = m3/h	27.000								
Cooling water per year	m3/year		145.964.969,50	145.235.144,65	144.508.968,93	143.786.424,09	143.067.491,97	142.352.154,51	141.640.393,73	140.932.191,77
Kühlwasser	€/m3	0,008								
Cooling water cost per year	€		1.167.719,76	1.161.881,16	1.156.071,75	1.150.291,39	1.144.539,94	1.138.817,24	1.133.123,15	1.127.457,53
SUM operating variable cost			**223.844.469,21**	**229.640.239,51**	**235.587.193,83**	**241.689.270,20**	**247.950.509,27**	**254.375.056,96**	**260.967.167,20**	**267.731.204,77**

	Dimension	Indicator	2019 2034	2020 2035	2021 2036	2022 2037	2023 2038	2024 2039	2025 2040
Full load hours adjusted	h		5.193,61	5.167,64	5.141,81	5.116,10	5.090,52	5.065,06	5.039,74
gross output of power plant/ □Bruttc	MWel		722,81	722,81	722,81	722,81	722,81	722,81	722,81
Gas Cost									
Gas Price	€/ GJ	9,00	14,62	14,92	15,24	15,56	15,88	16,22	16,56
Gas Price	€/ MWth	32,40	52,61	53,72	54,85	56,00	57,18	58,38	59,60
Plant Gas Price per OH	€/ MWhel		38.030,48	38.829,12	39.644,53	40.477,06	41.327,08	42.194,95	43.081,04
Uncertainty factor	%	1%							
Gas Price incl. Uncertainty factor	€/ GJ		17,83	18,39	18,96	19,56	20,17	20,80	21,44
Gas Price incl. Uncertainty factor	€/ MWth		64,20	66,20	68,27	70,40	72,60	74,86	77,20
plant gas price per OH incl. uncerta	€/ MWhel		46.404,41	47.852,69	49.346,17	50.886,27	52.474,43	54.112,16	55.801,00
Gas cost per year	€/ MWh		241.006.510,54	247.285.682,12	253.728.450,92	260.339.079,29	267.121.940,65	274.081.522,33	281.222.428,61
CO2 cost									
CO2 certificate cost	€/t	12,5	20,30	20,73	21,16	21,60	22,06	22,52	22,99
CO2 Teuerungsrate	%	1%	24,77	25,54	26,34	27,16	28,01	28,88	29,78
CO2 Emissionen	g/kWh	350	350,00	350,00	350,00	350,00	350,00	350,00	350,00
	g/MWh		350.000,00	350.000,00	350.000,00	350.000,00	350.000,00	350.000,00	350.000,00
	kg/MWh		350,00	350,00	350,00	350,00	350,00	350,00	350,00
	t/MWh		0,35	0,35	0,35	0,35	0,35	0,35	0,35
power plant CO2 emissionen	t/h		252,98	252,98	252,98	252,98	252,98	252,98	252,98
power plant CO2 emissionen	t/year		1.313.892,78	1.307.323,32	1.300.786,70	1.294.282,77	1.287.811,36	1.281.372,30	1.274.965,44
CO2 emission cost	€/year		32.543.317,40	33.391.199,36	34.261.172,00	35.153.810,86	36.069.706,49	37.009.464,82	37.973.707,57
Cooling Water									
Kühlwassereinleitunç									
Kühlwasser/Vbh	t/h = m3/h	27.000							
Cooling water per year	m3/year		140.227.530,81	139.526.393,15	138.828.761,19	138.134.617,38	137.443.944,29	136.756.724,57	136.072.940,95
Kühlwasser	€/m3	0,008							
Cooling water cost per year	€		1.121.820,25	1.116.211,15	1.110.630,09	1.105.076,94	1.099.551,55	1.094.053,80	1.088.583,53
SUM operating variable cost			**274.671.648,19**	**281.793.092,63**	**289.100.253,01**	**296.597.967,09**	**304.291.198,69**	**312.185.040,95**	**320.284.719,71**

Figure 8-16 : Extract from the basic model – OPEX variable (b)

8.1.1.8 Operating Expenditure, fix

Apart from the variable operating expenditures described above, there are naturally a number of additional costs connected with the start of the operation that have to be considered in the model - the so-called fixed operating expenditures.
These costs can be captured in differently detailed ways. This, as well as the whole model, depends on the manufacturer and / or the requirements of the decision-makers.

The most important types of costs that have to be recorded and / or forecasted for a model are listed in the following. There are many examples of further types of sub-ordinated costs, and as they can vary from plant to plant, further discussion will be renounced here.

(1) personnel expenses
(2) maintenance costs
(3) rent and lease expenses
(4) insurances
(5) fees and charges
(6) administration costs
(7) material costs relating to buildings
(8) expenses for consultancy and service
(9) data processing expenses
(10) other services and external services
(11) demolition and waste disposal
(12) other expenses

With the exception of the personnel costs, a lump-sum calculation is often the most effective approach in practice. However, detailed calculations and derivations can be made for different items. This depends on the relevant requirements.

A lump-sum approach is here understood to be the determination of a certain value for the respective cost category CC, which will then be multiplied by the inflation rate R_i over the life time of the power plant, resulting in the respective forecast value FV.

$$FV_{CC(n)} = CC_{(n-1)} * R_{i(n)}$$

$FV_{(n)}$	forecast value in the year n
$CC_{(n-1)}$	cost level of the cost category in the year n-1
$R_{i(n)}$	rate of inflation in the year n

Even though the lump-sum approach is a very pragmatic one for the majority of the cost categories, the derivation of the *personnel expenses* has to be represented in a more detailed way. There are several reasons for this. First, the personnel expenses are mostly the largest cost item among the service costs. Second, the breakdown of the costs can vary among the different sites due to different priorities and third, detailed documentation is an advantage for the prevention of future discussions relating to staffing policy and internal budget policy, and it creates security.

When determining the amount of the personnel expenses, at least two further factors have to be taken into consideration, beside the number of staff in the power plant:

real wage increases and

inflation.

The easiest way is to form a real wage increase factor RW_{if}, similarly to the inflation factor R_{if}[1]. The total amount of the personnel expenses PE can then be established simply by multiplying the inflation factor R_{if} by the real wage increase factor RW_{if} and the number of employees (NE).

$$PE_{(n)} = R_{if\,(n)} * RW_{if\,(n)} * NE_{(n)}$$

$$RW_{if\,(n)} = RW_i * (1 + RW_{if\,(n-1)})$$

PE(n)	personnel expenses in the year n
$R_{if(n)}$	inflation factor m in the year n
$RW_{if(n)}$	real wage increase factor in the year n
NE(n)	number of employees in the year n
RWi	real wage increase rate per year assumed as steady

[1] cf. chapter 8.1.1.3 Macroeconomic data

The *maintenance costs* that are to be determined as a lump sum comprise all costs for maintenance and servicing, including possible external services and spare parts as well as the normal disposal of waste parts and waste material.

The *rent and lease expenses* cover all contracts relating to premises, buildings or other rented or leased assets.

The amount and kind of *insurance* to be taken out is to be established in advance. The sum can vary strongly from site to site, e.g. due to different geological or political environments.

Fees and charges apply throughout the entire operation time, but their amount can vary and has to be ascertained by inquiring at the relevant authorities.

Administration costs cover all office costs and other costs incurred in administration, except for IT and data processing costs.

The *material costs relating to buildings* arise in connection with the care and maintenance of administration and adjoining buildings.

External expenses for consultancy and service should be captured separately, as this item is often an ongoing issue in practice.

Data processing expenses include all costs for computers, digital appliances and other IT-service costs.

Demolition and waste disposal is an item that covers all provisions made for the dismantling of the power plant after its decommissioning. There is no recommendation concerning their amount, as there are a number of economic and financial factors for the whole enterprise that have to be taken into account. However, it would be wrong to disregard them completely.

Other services and external services cover security services as well as facility care, office cars and all kinds of expert opinion.

Other expenses are a flat cost item that is to be evaluated, in order to plan and take into account unforeseen expenditure, e.g. for training courses or bank charges (payment transactions).
By surcharges or deductions, factors or in the cost item *Other additional charges*, a lack of detailed information on the service costs can be compensated for up to a certain degree.

Extract from the basic model – OPEX fix:

The values applied in the basic model are not based on factual or average values and can therefore vary in terms of real values. The costs assumed here are merely provided for demonstration and illustration services.

Economic Efficiency Model - Combined Cycle Power Plant
Operating Expenditure fix

	year		2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
	Dimension	Indicator															
Unterhaltungssachkosten							2.500.000	2.552.500	2.606.103	2.660.831	2.716.708	2.773.759	2.832.008	2.891.480	2.952.201	3.014.197	3.077.496
Personalkosten																	
Technisches + kfm. Personal	MA					45	45	45	45	45	45	45	45	45	45	45	45
Personalkosten	€/MA		100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000
kum. Reallohnsteigerung p.a.	%	1%	100%	101,00%	102,01%	103,03%	104,06%	105,10%	106,15%	107,21%	108,29%	109,37%	110,46%	111,57%	112,68%	113,81%	114,95%
kum. Inflationsrate			100,00%	102,50%	104,96%	107,16%	109,41%	111,71%	114,06%	116,45%	118,90%	121,40%	123,95%	126,55%	129,21%	131,92%	134,69%
Personalkosten	€/MA			103.525	107.070	110.411	113.857	117.411	121.075	124.854	128.751	132.769	136.913	141.186	145.592	150.136	154.822
Gesamte Personalkosten Betrieb	€			0	0	4.968.510	5.123.578	5.283.484	5.448.382	5.618.426	5.793.777	5.974.601	6.161.068	6.353.355	6.551.643	6.756.120	6.966.979
Mieten und Pachten							100.000	102.100	104.244	106.433	108.668	110.950	113.280	115.659	118.088	120.568	123.100
Versicherungen							200.000	204.200	500.001	510.501	500.002	510.502	500.003	510.503	500.004	510.504	500.005
Abgaben, Gebühren							100.000	102.100	104.244	106.433	108.668	110.950	113.280	115.659	118.088	120.568	123.100
Verwaltungskosten							200.000	204.200	208.488	212.866	217.337	221.901	226.561	231.318	236.176	241.136	246.200
Gebäudesachkosten							100.000	102.100	104.244	106.433	108.668	110.950	113.280	115.659	118.088	120.568	123.100
Beratungs- u. Dienstleistungsaufw.							100.000	102.100	104.244	106.433	108.668	110.950	113.280	115.659	118.088	120.568	123.100
DV-Kosten							100.000	102.100	104.244	106.433	108.668	110.950	113.280	115.659	118.088	120.568	123.100
Übrige Dienst-, Fremdleistungen							100.000	102.100	104.244	106.433	108.668	110.950	113.280	115.659	118.088	120.568	123.100
Entsorgung, Abbruch							50.000	51.050	52.122	53.217	54.334	55.475	56.640	57.830	59.044	60.284	61.550
Übrige Aufwendungen							500.000	510.500	521.221	532.166	543.342	554.752	566.402	578.296	590.440	602.839	615.499
SUMME Leistungskosten	€				0	4.968.510	9.173.578	9.418.534	9.961.781	10.226.606	10.477.510	10.756.692	11.022.363	11.316.737	11.598.037	11.908.488	12.206.327

Cell Color-Code:	
(yellow)	Manual Entry
(grey)	Transfer cells from other part

Figure 8-17 : Extract from the basic model – OPEX fixed (a)

Economic Efficiency Model - Combined Cycle Power Plant
Operating Expenditure fix

	year		2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
	year		2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
	Dimension	Indicator															
Unterhaltungssachkosten			3.142.123	3.208.108	3.275.478	3.344.263	3.414.492	3.486.197	3.559.407	3.634.154	3.710.472	3.788.391	3.867.948	3.949.175	4.032.107	4.116.782	4.203.234
Personalkosten																	
Technisches + kfm. Personal	MA		45	45	45	45	45	45	45	45	45	45	45	45	45	45	45
Personalkosten	€/MA		100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000
kum. Reallohnsteigerung p.a.	%	1%	116,10%	117,26%	118,43%	119,61%	120,81%	122,02%	123,24%	124,47%	125,72%	126,97%	128,24%	129,53%	130,82%	132,13%	133,45%
kum. Inflationsrate			137,52%	140,41%	143,35%	146,36%	149,44%	152,58%	155,78%	159,05%	162,39%	165,80%	169,28%	172,84%	176,47%	180,17%	183,96%
Personalkosten	€/MA		159.654	164.637	169.775	175.074	180.538	186.172	191.983	197.974	204.153	210.525	217.095	223.871	230.858	238.063	245.493
Gesamte Personalkosten Betrieb	€		7.184.418	7.408.644	7.639.867	7.878.308	8.124.190	8.377.746	8.639.215	8.908.845	9.186.890	9.473.613	9.769.284	10.074.184	10.388.599	10.712.827	11.047.174
Mieten und Pachten			125.685	128.324	131.019	133.771	136.580	139.448	142.376	145.366	148.419	151.536	154.718	157.967	161.284	164.671	168.129
Versicherungen			510.505	500.006	510.506	500.007	510.507	500.008	510.508	500.009	510.509	500.010	510.510	500.011	510.511	500.012	510.512
Abgaben, Gebühren			125.685	128.324	131.019	133.771	136.580	139.448	142.376	145.366	148.419	151.536	154.718	157.967	161.284	164.671	168.129
Verwaltungskosten			251.370	256.649	262.038	267.541	273.159	278.896	284.753	290.732	296.838	303.071	309.436	315.934	322.569	329.343	336.259
Gebäudesachkosten			125.685	128.324	131.019	133.771	136.580	139.448	142.376	145.366	148.419	151.536	154.718	157.967	161.284	164.671	168.129
Beratungs- u. Dienstleistungsaufw.			125.685	128.324	131.019	133.771	136.580	139.448	142.376	145.366	148.419	151.536	154.718	157.967	161.284	164.671	168.129
DV-Kosten			125.685	128.324	131.019	133.771	136.580	139.448	142.376	145.366	148.419	151.536	154.718	157.967	161.284	164.671	168.129
Übrige Dienst-, Fremdleistungen			125.685	128.324	131.019	133.771	136.580	139.448	142.376	145.366	148.419	151.536	154.718	157.967	161.284	164.671	168.129
Entsorgung, Abbruch			62.842	64.162	65.510	66.885	68.290	69.724	71.188	72.683	74.209	75.768	77.359	78.983	80.642	82.336	84.065
Übrige Aufwendungen			628.425	641.622	655.096	668.853	682.898	697.239	711.881	726.831	742.094	757.678	773.590	789.835	806.421	823.356	840.647
SUMME Leistungskosten	€		12.533.792	12.849.135	13.194.609	13.528.479	13.893.015	14.246.496	14.631.210	15.005.452	15.411.525	15.807.746	16.236.434	16.655.924	17.108.555	17.552.683	18.030.667

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Figure 8-18 : Extract from the basic model – OPEX fixed (b)

8.1.1.9 Profit and loss statement

After having represented all relevant quantities relating to costs and revenue, the investment calculation model has to be completed with a profit and loss statement.

The profit and loss statement shows the success of the project in a staggered form and the period profit as revenues minus expenses (earnings position)[1].

In practice, the parameter EBIT (Earnings Before Interest and Taxes) has evolved as a performance measure according to IFRS accounting. The EBIT represents the operative earning power of a company, irrespective of the capital structure and tax charges. It therefore indicates the annual surplus/loss adjusted for interest and taxes according to IFRS[2].

sales revenues
- material expenses
- personnel expenses
- other operating expenses
+ other revenues
- depreciation / amortization on fixed assets
+ additions on fixed assets
= EBIT .

According to the premises assumed, interest and taxes have not been taken into account in the basic model[3]. Consequently, the costs, such as the CCPP[4] performance cost PC_{CCPP}, the operating expenditures fixed $OPEX_f$ and the depreciation expense A_A have to be set off the determined revenues R_{el}. Other earnings or write-ups on fixed assets (CAPEX) were not considered for reasons of simplification.

1 cf. Wöhe (2010): p. 802 ff; cf. Jung (2010): p. 1052 ff; cf. Schierenbeck and Henner (2008): p. 661 ff
2 cf. Gladen (2008): p. 71 ff, cf. Krause (2010): p. 16 ff; cf. Wöhe (2010): p. 808 f
3 cf. for taxes see 8.1.1.3 page 112; cf. for interest page 109
4 Combined Cycle Power Plant

$$EBIT_{(n)} = R_{el(n)} - OPEXv_{(n)} - OPEXf_{(n)} - A_{A(n)}$$

EBIT(n)	EBIT in the year n
$R_{el(n)}$	electricity revenues in the year n
$OPEXv_{(n)}$	operating expenditures variable in the year n
$OPEXf_{(n)}$	operating expenditures fix in the year n
$A_{A(n)}$	depreciation amount in the year n

In the profit and loss statement of the basic model, the *write-offs* are still considered as costs for the determination of the EBIT. For the evaluation of the efficiency – by applying the different quantitative procedures – these are eliminated again to calculate the cash flow. The write-off is an accounting quantity, which describes the depreciation of fixed assets values (here the investment) over the useful life (also called life time)[1]. As there are several reasons for write-offs, such as technical reasons due to wear and tear, economic reasons due to market shifts or legal reasons due to legislative measures, these special accounting effects are not supposed to be included in the basic model.

The quantitative procedures (= procedures for the investment calculation) all refer to the so-called free cash flow.

The *free cash flow* is the cash flow available, i.e. an indication of the amount of money that remains for the dividends of shareholders and / or for the repayment of a possible external financing[2].

EBIT
- investments
+ write-offs
= Free Cashflow

1 cf. Woll (2008): p. 3 ff.; cf. Gabler Wirtschaftslexicon (2010): p. 27 ff.

2 cf. Preißler (2008): p. 73; cf. Krause (2010): p. 77 ff.

$$FC_{(n)} = EBIT_{(n)} - CAPEX_{(n)} + A_{A(n)}$$

FC(n)	free cash flow in the year n
EBIT(n)	EBIT in the year n
CAPEX(n)	capital expenditures in the year n
$A_{A(n)}$	depreciation amount in the year n

The free cash flow is the basis for the application of the net present value formula, which is part of the majority of quantitative evaluation procedures. After a short critical model consideration, it will be discussed further in the subsequent sections with reference to the model developed herein.

Extract from the basic model – Profit and loss statement:

The calculation of net present value will be explained in chapter 8.1.2.1.
The IRR was determined using the excel function „IKV“[1].
The annuity will be explained on page 174 in chapter 8.1.2.2.

[1] cf. for further details chapter 8.1.2.3 Internal rate of return method (IRR) on page 155

Economic Efficiency Model - Combined Cycle Power Plan
Profit and Lost Statement

	year		2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
	Dimension	Indicator															
EBIT																	
revenue (Umsatz)	€						79.133.021	234.304.961	237.790.048	241.326.971	244.916.502	248.559.423	252.256.528	256.008.623	259.816.526	263.681.067	267.603.088
OPEX variabel	€	gas costs; CO2; cooling water					57.997.544	173.403.860	177.883.589	182.480.224	187.196.808	192.036.467	197.002.406	202.097.915	207.326.367	212.691.226	218.196.045
peronnel costs (Personalaufwand)	€			0	0	4.968.510	5.123.578	5.283.484	5.448.382	5.618.426	5.793.777	5.974.601	6.161.068	6.353.355	6.551.643	6.756.120	6.966.979
OPEX fix - personnel cost	€	Instandhaltungskosten		0	0	0	4.050.000	4.135.050	4.513.399	4.608.180	4.683.732	4.782.091	4.861.295	4.963.382	5.046.394	5.152.368	5.239.348
amortization (Abschreibungen)	€						13.200.000	13.200.000	13.200.000	13.200.000	13.200.000	13.200.000	13.200.000	13.200.000	13.200.000	13.200.000	13.200.000
EBIT	€			0	0	-4.968.510	-1.238.101	38.282.566	36.744.678	35.420.141	34.042.184	32.566.264	31.031.759	29.393.971	27.692.122	25.881.353	24.000.716
GuD Invest	€			600.000	131.133.333	163.833.333	34.433.333	0									
Free Cash Flow	€			-600.000	-131.133.333	-168.801.844	-22.471.434	51.482.566	49.944.678	48.620.141	47.242.184	45.766.264	44.231.759	42.593.971	40.892.122	39.081.353	37.200.716
present value (Barwert)	€			-555.556	-112.425.697	-134.000.346	-16.517.175	35.038.170	31.473.619	28.369.385	25.523.482	22.894.526	20.487.863	18.267.824	16.238.824	14.370.132	12.665.395
commulated present value	€			-555.556	-112.981.253	-246.981.599	-263.498.774	-228.460.604	-196.986.985	-168.617.600	-143.094.118	-120.199.591	-99.711.729	-81.443.905	-65.205.080	-50.834.948	-38.169.553
Kalkulationszinsfuß	€	8%															
NPV (Net Present Value) Kapitalwert	%	8,00%		23.567.325	bis 2040												
IRR (Internal rate of Return interner Zinsfuß	%			9,17%	= 3 Jahre (Bau-/Planungszeit) + 26 Jahre (Laufzeit)												
Annuity/ Annuität	€			2.112.069	2.112.069	2.112.069	2.112.069	2.112.069	2.112.069	2.112.069	2.112.069	2.112.069	2.112.069	2.112.069	2.112.069	2.112.069	2.112.069
present values of annuity	€	23.567.325		1.955.620	1.810.759	1.676.629	1.552.434	1.437.439	1.330.962	1.232.372	1.141.085	1.056.560	978.297	905.830	838.732	776.603	719.077
cummulated present value of annuity	€	23.567.325		1.955.620	3.766.378	5.443.007	6.995.441	8.432.880	9.763.842	10.996.214	12.137.299	13.193.859	14.172.156	15.077.986	15.916.718	16.693.321	17.412.399

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Figure 8-19 : Extract from the basic model – profit and loss statement

8.1.1.10 Option Heat extraction as an option

Depending on the location of the power plant, there is a potential for increasing its profitability by using marketable residual heat for district heating supply or process steam. In section 9.3.3 Decision-relevant criteria in the preliminary study this was mentioned as one of the evaluation factors. The danger implied in a singular evaluation as described in section 9 is that this fact is considered as crucial along with a number of other criteria, with the consequence that a business opportunity might not be taken into account in compliance with its potential relevance. Therefore, an additional monetary evaluation is to be recommended in this case.

Supplementing the model described in the previous sections, the basic calculative approach will be illustrated below, using the extraction and use of the generated heat as a source of heating as an example.

The calculative illustration and/or calculation in the model follows the principle of a normal economic efficiency calculation. On the one hand, the revenues and on the other hand, the costs are to be determined. It should be noted that the modelling described in the following refers to a so-called power-operated power plant. In this case, ‘power-operated’ means that for the operation of the plant, the power coefficients on the market are a significant factor. For this reason, the determination of the proportional costs in considering heat is restricted to the variable costs, as fixed costs arise from the operation of the power plant as such, and the power plant is here supposed to serve as a premise primarily for electricity generation. Therefore, in each scenario, the proceeds from electricity generation have to cover the fixed costs as well.

First of all, some assumptions and variables are necessary for the calculation, which will be specified below.

The first variable to be determined and/or fixed is the *maximum extractable thermal heat* QE_{th}. This can be derived from manufacturer specifications. Another option is that the possible marketable heat output is assumed as initial value, which, in practice, would have to be adapted to the technical capabilities of the plant.

A second variable is the so-called *power loss indicator* CLR_{th_el}. This is a variable through which the maximum extractable heat (thermal) can be converted into the heat loss (electrical). For this purpose, the maximum extractable thermal heat is multiplied by the power loss indicator[1]. The resulting electrical output at the heat loss P_{cl_el} is the basis for the determination of the variable costs (see below in this section) and the remaining marketable electrical output of the power plant at a maximum heat P_{net_th}. For the latter, the electrical heat loss is simply to be subtracted from the gross output.

$$P_{cl\_el} = QE_{th} * CLR_{th\_el}$$

P_{cl_el}	electrical output at heat loss
QE_{th}	extractable thermal heat
CLR_{th_el}	power loss indicator

[1] The power loss indicator describes the loss of electrical output and/ or work (power loss) due to heating steam extraction as compared to condensation in the exhaust heat capacitor, related to the CHP net heat production. The power loss indicator rises with the increase of the steam parameters of the extracted heat and with the vacuum in the exhaust heat capacitor. It is furthermore influenced by the technical capabilities for the control of the heat extraction. Particularly relevant is the control and regulation of the extraction capacity and temperature, also in dependence of the block load. The power loss indicator is therefore no invariable. Favorable in terms of thermodynamics and profitability are the lowest possible values, as long as they are accompanied by high efficiency and utilization rates.

Usual values in district heat production range between 0.1 and 0.2 (power loss / CHP-net heat production) and for process steam extraction (in general 2 to 30 bar) between 0.2 and 0.35.

c.f. Arbeitsgemeinschaft für Wärme und Heizkraftwirtschaft – AGFW – e.V. : document S_FW_A_1102 „Zertifizierung von KWK-Anlagen“; https://www.agfw.de/

$$P_{net\_th} = P_{gross} - P_{cl\_el}$$

P_{net_th}	marketable electrical output at maximum heat
P_{gross}	gross output[1]
P_{cl_el}	electrical output at heat loss

The next step is to determine the variable costs for the heat generation. These are basically made up of the costs for natural gas and CO_2.

As indicated above, any further variable costs will be implied in the power plant operation for reasons of simplification.

The *costs for natural gas* are simply to be calculated for the share of the electrical output that relates to the heat generation. This results in the costs for natural gas (GC_{heat}) from the ratio of the marketable electrical output at the maximum heat (P_{cl_el}) to the gross output (P_{gross}) multiplied by the total annual costs for gas in the year n ($GC_{tot(n)}$) [2].

$$GC_{heat(n)} = \frac{P_{cl\_el}}{P_{gross}} * GC_{tot(n)}$$

$GC_{heat(n)}$	gas costs for heat generation
$GC_{tot(n)}$	total annual costs for gas in the year n
P_{gross}	gross output
P_{cl_el}	electrical output at heat loss

A practicable approach for the determination of the *CO_2 costs for heat generation* (CO_{2heat}) is the ratio of the marketable electrical output at maximum heat (P_{net_th}) to the gross output (P_{gross}), multiplied by the CO_2 emission costs in the year n.

$$CO_{2heat(n)} = \frac{P_{cl\_el}}{P_{gross}} * CO_{2tot(n)}$$

[1] see also gross output on page 128

[2] See also total gas costs $GC_{tot(n)}$ on page 142

$CO_{2heat(n)}$ CO_2 costs for heat generation

$CO_{2tot(n)}$ CO_2 emission costs in the year n

P_{gross} gross out put

P_{cl_el} electrical output at heat loss

The other variable costs of the power plant have to be deducted, according to the same principle, proportionately from the heat generation. For this, the first step is again to establish the ratio of the marketable electrical output at the maximum heat (P_{cl_el}) to the gross output (P_{gross}). The next step would be to multiply this ratio with the other variable costs, in our basic model represented as cooling water costs ($WC_{tot(n).}$ The result is the *variable total water costs for the heat generation.* It is important to note that the variable costs depend directly on the operating hours. In the basic model discussed here, this has already been taken into account by the determination of the exemplary total water costs per year ($WC_{tot(n)}$).

$$WC_{heat(n)} = \frac{P_{cl\_el}}{P_{gross}} * WC_{tot(n)}$$

$WC_{heat(n)}$ total water costs for heat generation

$WC_{tot(n)}$ total water costs in the year n

P_{gross} gross output

P_{cl_el} electrical output at heat loss

If, specifically for the heat generation, *other variable costs for heat generation* $VC_{heat(n)}$ are to be expected that are clearly separable from the normal power plant operation, these could be taken into account, e.g. by a cost factor for variable heat costs VCF_{heat} via the adjusted Operating Hours $OH_{ad(n).}$ Such a cost factor for variable heat costs could, for example, amount to 0.2 €/$MWh_{thermal}$ (or 0.2€/P_{cl_el}, respectively).

$$VC_{heat(n)} = P_{cl\_el} * OH_{ad(n)} * VCF_{neat}$$

$VC_{heat(n)}$	other variable costs for heat generation
P_{cl_el}	electrical output at heat loss
$OH_{ad(n)}$	adjusted Operating Hours in the year n
VCF_{heat}	cost factor for variable heat costs

The *variable total costs for heat* $VC_{tot\_heat(n)}$ are the sum of the variable components of the costs for heat discussed above.

$$VC_{tot\_heat(n)} = VC_{heat(n)} + WC_{heat(n)} + CO_{2heat(n)} + GC_{heat(n)}$$

$VC_{tot\_heat(n)}$	variable total costs for heat generation
$VC_{heat(n)}$	other variable costs for heat generation
$WC_{heat(n)}$	total water costs for heat generation
$CO_{2heat(n)}$	CO_2 costs for heat generation
$GC_{heat(n)}$	gas costs for heat generation

To determine a so-called gross heat margin $GM_{heat(n),}$ the sum of the variable heat costs $VC_{tot\_heat(n)}$ is to be subtracted from the revenues from the sale of heat $R_{heat(n).}$

$$GM_{heat(n)} = R_{heat(n)} - VC_{tot\_heat(n)}$$

$GM_{heat(n)}$	gross heat margin
$R_{heat(n)}$	revenues from the sale of heat
$VC_{tot\_heat(n)}$	variable total costs for heat generation

The *revenues from the sale of heat* result from the remuneration for the heat supply $R_{sp\_heat(n)}$ (in EURO per $MWh_{thermal}$) and the heat quantity marketable to the customer QE_{u_th} (in MWh thermal). The amount of remuneration or the selling price of heat $R_{sp\_heat(n),}$ respectively, can be verified using existing heat supply contract in a similar context.

$$R_{heat(n)} = R_{sp\_heat(n)} * QE_{u\_th}$$

$R_{heat(n)}$	revenues from the sale of heat
$R_{sp\_heat(n)}$	remuneration for the heat supply
QE_{u_th}	heat quantity marketable to the customer

The *marketable heat quantity* $QE_{u\_th(n)}$ is calculated in two steps. First, the generated total heat quantity in the year n $QE_{tot\_th(n)}$ is to be determined taking into account the adjusted Operating Hours.

In the second step, the general losses, e.g. during heat transmission to the end customer, or other heat management costs, are to be taken into account via a so-called heat loss factor QEF_{th}. A usual value in the field is ca. 20%.

$$QE_{tot\_th(n)} = QE_{th} * OH_{ad(n)}$$

$$QE_{u\_th(n)} = QE_{tot\_th(n)} * QEF_{th}$$

$QE_{tot\_th(n)}$	generated total heat quantity in the year n
QE_{th}	extractable thermal heat[1]
$OH_{ad(n)}$	adjusted Operating Hours in the year n
QE_{u_th}	heat quantity marketable to the customer
QEF_{th}	heat loss factor

In an overall analysis, the proportional revenues from the sale of electricity and heat and their costs have to be brought together to prepare the respective profit and loss account with the respective cash flow.

Once again, it should be emphasized that the main concern of the model developed herein is to check if the power plant fits into the electricity market. In this model calculation, heat is to be considered as an upside. Accordingly, the extractable heat is also technically limited by the turbines for heat generation (see also power loss indicator).

[1] see also page 162

Another possibility for specification would be, for example, to consider a mix of different kinds of steam with a different remuneration structure in the model, such as process steam and thermal heat.

8.1.2 Dynamic investment calculation

This section deals with the classical dynamic investment or efficiency calculation, which includes the following:

1. the capital value method
2. the annuity method
3. the internal rate of return method and
4. the dynamic payback calculation.

Each method will be reflected in terms of its validity in the developed basic model, in order to re-emphasise the essential aspects for the preparation of a decision.

8.1.2.1 Capital value method (Net Present value - NPV)

The capital value of an investment is the difference between the net present value of the investment-related deposits and the investment-related withdrawals [1].

Based on an adequate rate of return i and an investment period t_0 (= date of the decision) until t_n (= end of investment), the capital value formula is – in a simplified way – defined as follows[2]:

$$K_0 = \sum_{t=0}^{n} (E_t - A_t) * \frac{1}{(1+i)^t}$$

[1] cf. Olfert (2001): p. 210 ff; cf. Wöhe (2010): p. 541 ff

[2] cf. Wöhe (2010): cf. 541 ff

K_0	capital value
E_t	deposits in the year t
A_t	withdrawals in the year t
i	adequate rate of return

The adequate rate of return i can be based on the capital market or on the financial situation of the company. In this way, return expectations of equity investors can be taken into consideration, which can be further extended by using possible risk add-ons. This interest can also be referred to as weighted interest on capital and is to be found in the WACC-approach (Weighted Average Cost of Capital[1].

NPV-calculation in the basic model

	Share in the total capital	Interest
Long-term outside capital	80%	6%
Long-term equity capital	20%	16%

$$WACC = \frac{80*6\%}{100} + \frac{20*16\%}{100} = 4{,}8\% + 3{,}2\% = 8{,}0\%$$

In the basic model, the net present value that results for the investment after discounting over the entire life time (here 25 years) of the power plant, amounts to around 24 million €.

As soon as the investment in the power plant construction extends over several years = periods, this has to be discounted as well, as can be seen in the model.

As the capital value is positive, the investment would have to be classified as profitable in this case. What is still missing now, is the comparison with the capital value at a different site. The site with the higher value would then be the more profitable one.

[1] cf. Olfert (2001): p. 254 ff; cf. Schierenbeck (2008): p. 465 ff.; cf. Wöhe (2010): p. 577 ff.

8.1.2.2 Annuity method

According to the premises set in the basic model, this procedure is also based on the assumption of a perfect capital market (i = debit interest = credit interest) and the assumption that there are no interest rate fluctuations during the planning period. The capital value method identifies the investment result as growth in assets (K_0>0) or depreciation in assets (K_0<0) respectively, related to time t_0.
The annuity method as a second classical procedure is merely a variation of the capital value method. It converts the capital value into uniform (equal) annual payments (annuities[1]. The following applies:

$$A = K_0 * \frac{i * (1+i)^n}{(1+i)^n - 1}$$

A	annuity
K_0	capital value
i	adequate rate of return
n	total number of periods = years

Annuity method as applied in the basic model:

Given :	K_0	=	23,6 Mio. €
	i	=	8%
	n	=	29 years (25 years construction time + 4 years planning and implementation)

This results in an annuity of around 2.1 million € for the example of the basic model.

Compared to another project site, the investment with the highest annuity would be the more profitable one.

[1] cf.. Wöhe (2010): cf. 544 ff.; cf. Kruschwitz (2009): p. 80 ff; cf. Blohm (2006): p. 70 ff.; cf. Schierenbeck (2008): p. 413 ff.

If the duration is shorter, but the annuity equal, the project with the shorter duration is more profitable, as replacement investments can be made, which create additional added value.

8.1.2.3 Internal rate of return method (IRR)

The internal rate of return method is also connected with the capital value method in a certain way. It is different in form from the latter in that it shows at what percentage the capital tied to the investment project yields interest. This percentage is also called internal rate of return r.

The approach of the internal rate of return method is, in a sense, the reversal of the capital value method. To determine the internal rate of return r, the formula for the determination of the capital value K_0 is used, which is set to zero. Then the imputed rate of interest costs i is replaced by the profitability quantity r[1].

$$K_0 = \sum_{t=0}^{n} (E_t - A_t) * \frac{1}{(1+r)^t} = 0$$

K_0	capital value
E_t	deposits in the year t
A_t	withdrawals in the year t
r	internal rate of return

Solving the equation for r leads to considerable mathematical problems and can possibly result in several solutions or no solution at all[2].

In practice, the program Excel offers the special function “IKV”, which delivers an approximate value for this equation by interpolation.

[1] cf. Wöhe (2010): p. 546 ff.; cf. Schierenbeck (2008): p. 414 ff.

[2] cf. Jung (2010): p. 830 ff.; cf. Wöhe (2010): p. 547 ff.

However, manual linear interpolation or, as shown in the example below, graphic interpolation is possible as well.

Graphic solution for the internal rate of return in the basic model

The following approaches are used for the graphic approximation method:

- In the basic model, an adequate rate of return is defined (e.g. 5%), which results in a capital value smaller than zero.
- Then, an adequate rate of return is selected, which results in a capital value greater than zero.
- By linear interpolation, the rate of return is determined in the diagram, which results in a capital value equal to zero.

Internal rate of return r [%]	Capital value [EURO]
5%	107,9
15%	-70,4

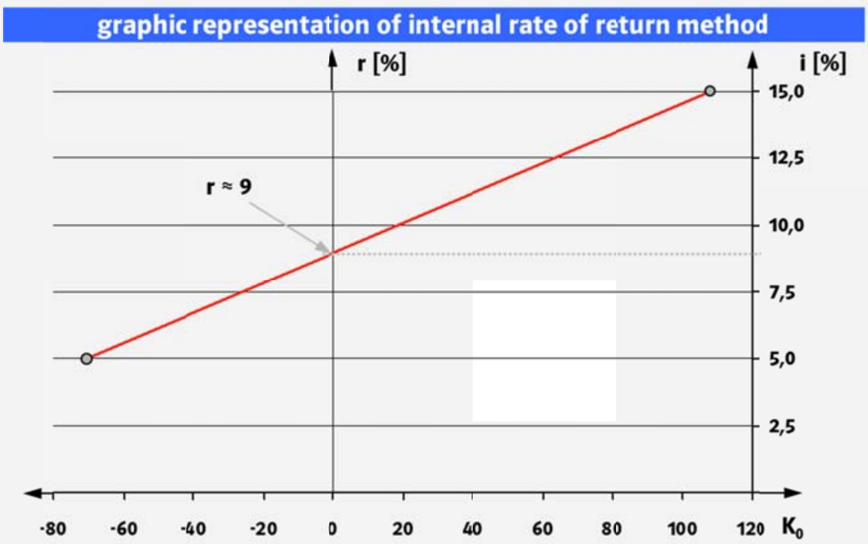

Figure 8-20: Graphic interpolation in the basic model

8.1.2.4 Dynamic amortisation calculation

In the dynamic amortisation calculation (as well as in the static version), the net present values of the investment return flows (discounted with the capital cost rate or WAAC, respectively) are cumulated over the time in which the return flows have covered the investment expenditure, until the amount of the total investment is reached.

Dynamic amortisation in the basic model

For the example of the basic model, Figure 8-19 shows that the net present value of the cumulated expenditures (invest) and returns with the net present value of the cash flows of the 18th year exceeds the investment expenditure of 330 million EURO.

When making comparisons with other sites, the investment which has the minimum payback period would be the more profitable one.

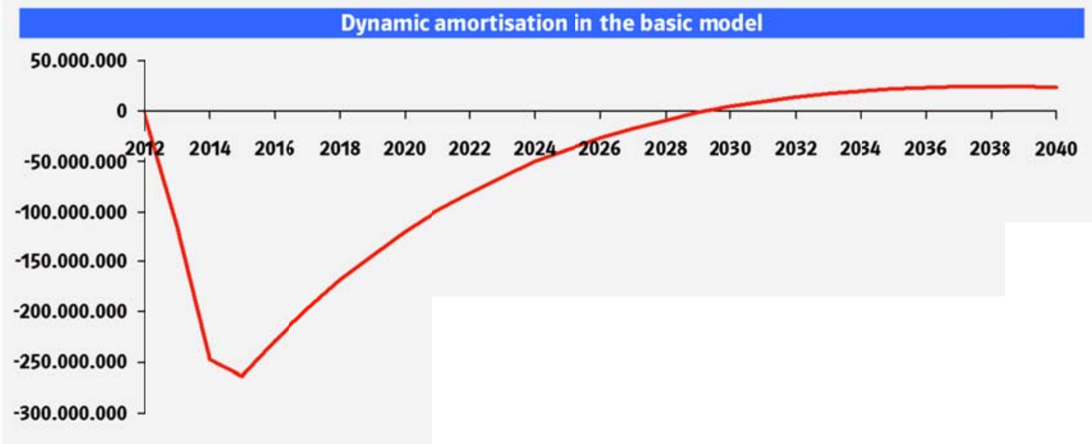

Figure 8-21: Dynamic amortisation curve in the basic model

8.1.3 Static investment calculation

Static investment calculations are popular in practice, because they are relatively easy to handle. The reasons for this are to be found in their characteristics[1]:

- They are only related to one period.
- They do not take into account interdependencies.
- They are based on costs and revenues.

These characteristics, however, are at the same time their drawbacks. The term "static" results from the fact that it does not, or only partially, take account of the different timing of payments-in and payments-out and, what is more, only consider one planning period[2]. This renders them unsuitable for an investment decision or an economic efficiency indication relating to a gas-fired power plant.

The static procedures include:

- cost comparison method
- profit comparison method
- profitability comparison method
- (static) amortisation calculation

For the sake of completeness, they will be briefly presented from a theoretical standpoint in the following sections.

8.1.3.1 Cost comparison method

The cost comparison method is the simplest of the static investment calculation methods. It does not consider the positive success component (revenues), but completely focuses on the negative success component (costs) instead.

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[1] cf. Olfert 2001: p. 72 ff

[2] cf. Jung (2010): p. 813 ff; cf. Blohm et al. (2006): p. 42 ff

Hence, the revenues have to be equal in all investment alternatives under consideration at the different sites.
In certain circumstances, this can mean in the final analysis that not even the most cost-effective investment alternative can ensure a profit[1].

Type of costs	**Invest I_1 Site 1**	**Invest I_2 Site 2**
OPEX fix	…	…
OPEX variabel	…	…
Amortisation (write-offs)	…	…
Total costs	**K_1**	**K_2**

Figure 8-22: Diagram of the cost comparison method

8.1.3.2 Profit comparison method

A profit comparison for a gas-fired power plant is, if at all, only possible in a highly idealised way, which puts its significance into question. One aspect, for example, is that equal average costs and equal average revenues have to be assumed in all periods. This is not realistic in view of an operating life of a power plant of 25 to 30 years.
Therefore, an average of the values ascertained in the model will be used for reasons of illustration, and, in this way, an average period will be formed[2].

According to the profit comparison method the respective profits are determined for the site and / or investment alternatives by subtracting the average costs from the average revenues.

[1] cf. Kruschwitz (2009): p. 35 f; cf. Wöhe (2010): p. 531 ff; cf. Olfert (2001): p. 149 ff
[2] cf. Olfert (2001): p. 147 ff.

Tied-up capital or different service lives are not taken into account in the profit comparison method[1].

The profit definition is:

$$G = E - K$$

G	profit
E	revenues
K	costs

Example on the basis of the basic model:

Given:	E	= 284 EURO
	K	= 269 EURO

The profit for the investment at site 1 amounts to 15 EURO.

8.1.3.3 Profitability comparison method (Return on Investment)

The static profitability calculation establishes a connection between the profit and the capital employed.
For an assessment of the return on investment and a more accurate assessment of the minimum return, this method even includes the earnings before interest in the calculation[2].

[1] cf. Mensch (2002): p. 52 ff.; cf. Jung (2010): p. 820 ff.
[2] cf. Kruschwitz (2009): p. 35 ff.

The profitability definition is:

$$R = \frac{G}{K} * 100$$

R	profitability
G	earnings before interest
K	capital expenditure = investment

Example on the basis of the basic model

Given:	G	=	15 EURO
	K	=	330 EURO

The profitability for the investment at site 1 amounts to 4.5%.

8.1.3.4 (Static) amortisation calculation

The question that will be answered here is how many periods it takes until the payments for the investment are set off by cash inflows, i.e. have amortised by returns on capital. The basis for this are always positive returns and average profits[1].

The payback period is defined as follows:

$$A = \frac{I}{G}$$

[1] cf. Wöhe 2010: 533 ff.; Jung 2010: 823; vgl. Kruschwitz 2010: 37; Schierenbeck 2008: 404 ff.

A	payback period in years
I	investment total = capital expenditure = CAPEX
G	average profit for the period

Example for the payback period A on the basis of the basic model

Given: I = 330 EURO
G = 15 EURO

The payback period amounts to 22 years.

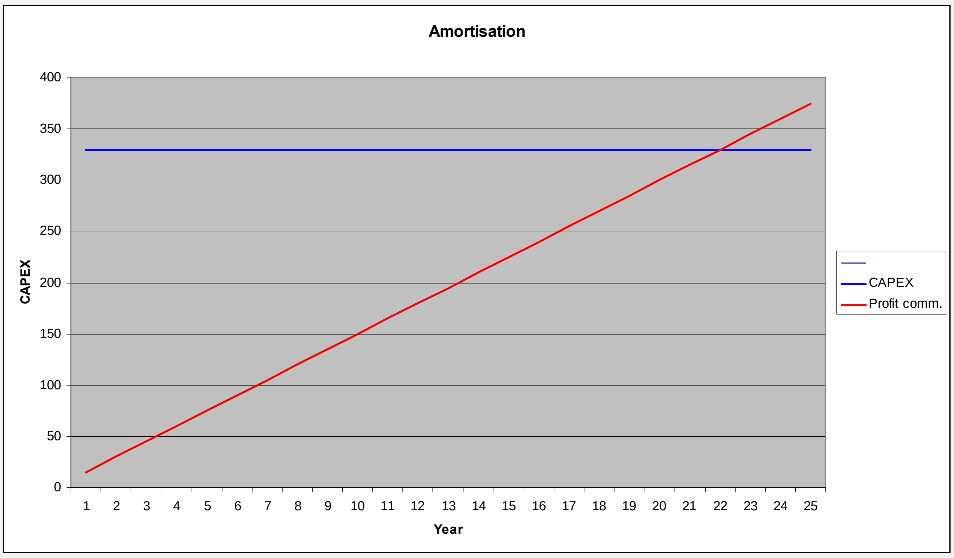

Figure 8-23: Graphic representation of the cumulated returns

8.1.4 Development potentials of the basic model

Due to its partly unrealistic simplifications, the basic model for an economic efficiency or investment calculation presented in the previous sections has to be criticized in many respects.

Three key points of criticism are:

1. There is no global perfect capital market, on which any given amount can be borrowed or invested at a uniform interest rate.
2. It is difficult, if even impossible, to forecast pro-rata amounts of payments-out and payments-in for an investment to be evaluated.
3. There is no perfect anticipation. Investments involve risks.

The fact that particularly rigorous premises were set in the basic model is based on the following two reasons:

- First, for the site under consideration, priority is given to the aim of a maximum asset and income in comparison to other sites.
- Second, it is useful to keep to the core of the problem of simultaneous investment and pure electricity generation planning.

The core is to be seen in the fact that for simultaneous investment and electricity generation planning, suitable and manageable payment calculations have to be developed by formulating suitable target figures and additional conditions (here conditions for power generation = OPEX fixed and variable[1].

Consequently, further criticism and therefore also further development potentials of the model can focus on three points, which are:

- its premises
- the problem of information gathering
- the controllability of the information in terms of mathematical calculation.

The uncertainty regarding possible future environmental scenarios (= economic development) leads to multivalued investment results, also referred to as stochastic investment models[2]. This is inevitably connected with the risk of wrong decisions, which lead to specific investment risks. Consequently, it has to be the task of an advanced economic efficiency calculation to explore the uncertainty range and hence, improve the basis for evaluating an investment site.

This can be done by using various procedures.

[1] cf. definition and explanation in chapter 8.1.1.7and 8.1.1.8

[2] Vgl. Wöhe 2010: 562 ff.

The three most important procedures and approaches that take account of this uncertainty are:

- the correction procedure
- the sensitivity analysis or the critical-value procedures
- the risk analysis

These will be briefly introduced and discussed subsequent to the criticism of premises.

Uncertainty or risk, respectively, are always linked with the probability of their occurrence or non-occurrence. A mathematical consideration using the theoretical approaches of the probability theory could also underline the validity of the results in the model.

In this context and in preparation of all further discussion of possible development potentials or points for optimisation, an old rule should be recalled:

(!) Simple planning calculations are cost-effective and practicable, but inaccurate.

(!) Sophisticated planning calculations are more precise, but more time-consuming and therefore, more expensive.

8.1.4.1 Criticism of premises

It is appropriate to categorize the criticism of the premises in the same way as they were developed in the basic model:

- market conditions and competition
- capital market
- macroeconomic data
- main design data
- electricity prices and revenues
- CAPEX,

- OPEX fixed,
- OPEX variable and
- profit and loss statement.

<u>a) Market conditions and competition</u>

What was represented herein was only the electricity generation of a gas-fired power plant. However, since there have been efforts of the EU to liberalise the European electricity market, the selection of a site has to take account of the behaviour and investment plans of the competitors on the market and also the political tendencies. This is a special challenge, considering the long planning period. On the positive side, though, it has to be mentioned that price formation has been established via the power exchange market in a way that the exertion of influence by individual competitors can be ruled out.

The assumption in the basic model was that of an independence between projects. This could be true as a premise related to the investing company alone, but completely excludes the behaviour of other electricity generators acting on the market. Planned projects or projects which are already being realised can influence the efficiency calculation in many ways, and their parameters can affect both costs and revenues[1].

Not only projects, but also other strategic decisions and measures or results on the market can exert a positive or negative influence on the environment under consideration. With the help of the game theory [2] such possible environmental scenarios can be reflected and mathematically examined.

The different technologies on the market and their future importance and / or development trends were already dealt with in sections 2 and 3.

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[1] One aspect ist he merrit order – cf. definition on page 92

[2] The game theory considers situations, in which two or more individuals act as so-called players, taking decisions independently of one another. What is special about this is that the success of every player does not only depend on their own decisions, but also on those of the other players; cf. Wirtschaftslexikon – Handelsblatt volume 10 (2006): p. 5 and 353 ff.

b) Capital market

Kritik am vollkommenen Kapitalmarkt wurde schon Eingangs des Kapitels festgehalten. Ist diese Prämisse nicht haltbar, so wird die Rentabilität einer Investition bei der Kapitalwertmethode und Annuitätenmethode verzerrt wiedergegeben.

In the past, however, the approach of a perfect capital market was absolutely justified, as a large number of power suppliers were often able to undertake their investments by equity financing or as ("smaller") part of overall credit line. In this case the investment would have to be weighed against the lost interest.

Following the financial crisis and the changes in the energy sector, more and more large energy companies have experienced difficulties in the financing and / or liquidity supply for major projects, especially with regard to the splitting of risks. It can therefore be observed that an increasing number of power plant projects are being implemented in partnerships or with investors. This, however, calls for a higher degree of transparency and a precise financial and liquidity planning prior to a decision.

To reflect imperfect capital markets, various refinements of the classical dynamic calculations have been developed, which include[1]:

- the final asset value method
- the debit interest method
- the market interest method of the investment calculation.

However, none of these three methods finally reflects reality, as they also only follow model approaches[2].

Already in the early 1950s, the Dean model3 was developed, which can be easily handled in terms of calculations.

It aims at taking into account the interdependence of investment and financing decisions. But also this model has a number of limitations[4].

---

[1] vgl Schierenbeck/ Wöhle 2008: 389 ff

[2] Cf. Schierenbeck/ Wöhle 2012: 440 ff.

[3] vgl. Olfert 2001: 114 ff; Mensch 2002: 225

[4] The criticism of the Dean model focused on two points – cf. Wöhe (2010): p. 557 f; cf. Mensch (2002): p. 230 ff

c) Macroeconomic data

As a reminder, these summarise[1]:

- inflation
- construction and planning time
- operating time and
- taxes.

In the basic model, a very complex world was reflected in a highly simplified way, which led to a reasonable and easily manageable calculation.

Further data can be captured and considered herein, but it is always important to consider which factors exert a real influence on the investments and how precisely these can be reflected in the model.

It would make sense to separate the planning period and the construction time, if this is absolutely necessary from the controlling point of view, or if certain relevant tax or other effects have to be taken into consideration. This is relevant, for example, if already during the construction time considerable revenues are earned, which can be the case if several gas-fired power plants are being built simultaneously at one site or if the commissioning time or test phase of the power plant are extended. It is common that already in the test phase electricity is delivered to the grid, which is mostly remunerated to a certain extent.

The operating life of a gas-fired power plant in Europe is often more than 20 years. This largely depends on

- the interests of the investors
- what is taken as a basis for the calculation
- the technical requirements and the real operation

(1) Entrepreneurial activity implies permanent willingness to pay. Being a static model, the Dean model is limited to an assessment at a specific time, neglecting possible payment surpluses over time.

(2) The assumption that the reflux of capital from the planned investments can be invested at its internal interest rate, is not normally a realistic proposition.

[1] see explanation in section 8.1.1.3 Macroeconomic data

The right time for a discussion of a replacement will therefore not be elaborated further here, as this time is too long away to make a reliable forecast. This should be done in the last three to five years, when sufficient data are available from the past and a more precise forward-looking calculation is possible. Provisions for dismantling, however, should be made all the same, as shown in the basic model.

Constant rates of inflation are not necessarily realistic, but useful here to illustrate the main features of an economic efficiency analysis in the basic model. Considering different inflation rates in the individual periods would be a possible further step in the investigation. This could definitely lead to new insights for the consideration of one or more power plant sites. This uncertainty has, at the latest, to be included in the considerations within the risk analysis and possible political changes, e.g. by including a time risk in the data quality.

Tax rates apply to all market participants equally and cannot be influenced. Especially in foreign projects, they have to be scrutinised at least once throughout the project period for a comparison of sites. Appearing in person at the authorities can definitely be very useful and informative. Due to the long consideration period, there is also a degree of uncertainty here, which should be included later in the evaluations when further risk analyses are carried out.

The reasons why the basic model does not include taxes in the site assessment were already discussed and explained in section 8.1.1.3 on page 127. Tax charges tend to be fairly steady. When comparing two sites in the same country or region, these can be rated as a minor influencing factor, as they are equal for both.

If, however, despite the difficulties, the proportional amount of the tax burden of an investment project under review has been forecast with a simulated tax assessment, a complete payment tableau can be created by comparing the implementation version with the omission version[1].

[1] Vgl. Kruschwitz 2009: 112 ff

The simulated tax assessment provides relatively precise planning results, but implies a great deal of planning effort. For this reason, ways were sought for a simplified, model-related consideration of taxes in the investment calculation. The best-known and simplest calculation method is the so-called standard model with taxes on income[1].
In addition, there are the interest model and the net method[2].

To ignore inflation would at least mean to assume a so-called homogenous inflation, which would not reflect the real relations on the market between the value of a commodity and its price level.

d) Main design data

Some of the data summarized here, such as net efficiency, net and gross power output, availability, and, to a certain extent, own demand power, are general technical data that are provided by suppliers or that can be directly derived from them.

Therefore, the specifications provided are only of a general nature and can have a positive or negative influence, depending on the environment, such as altitude or average cooling water temperature.
This means that for some main components, data with a fairly high accuracy are available. These are, however, not always the direct result of a real total power plant output. What happens here is a multiplication of the accuracy/inaccuracy-classes on the one hand. In addition, an optimum interaction of the individual components can be assumed in theory, but it still has to prove itself in practice. The uncertainty on this point is especially high at this early stage of the project development and the technical concept development.

[1] cf. Wöhe (2010): p. 554 ff. This model can be characterised in brief as follows:

- K_s, the capital value after taxes, is determined according to the capital value method.
- On a perfect capital market there is a standard adequate target rate i.
- There is only one general tax on income which covers all investments in the private and corporate sectors with a proportional tax rate.
- Taxes have to be paid at the end of each period. In case of losses, the Tax Office pays a tax refund at the end of the loss period.

[2] cf. Jung (2010):p. 857 ff.

In a model calculation, the correction procedure [1] and the sensitivity analysis [2] could be useful here.

An example for enhancing the accuracy of the information by including further technical and other parameters with an extended computational effort is the degree of efficiency. The *degree of efficiency* is described in the basic model as linearly decreasing around a certain factor. In reality, however, the degree of efficiency of a gas turbine and thus, of the whole power plant, follows a zig-zag curve[3], which is caused, for example, merely by the regular maintenance intervals [4]. General experience shows that an increasing degree of efficiency entails a rise in investment costs[5]. If a high degree of efficiency is to be maintained over the entire life of the power plant, a sufficient number of maintenance measures are required, which, in turn, have a negative effect on the availability of the plant. An optimum in the model can be investigated by a sensitivity analysis.

A forecast concerning the full-load hours is very difficult to make, as it can vary strongly among the different sites. The problem is aggravated by promotional laws, which give renewable energies priority over fossil power plants.
Uncertainty in the assumptions can be reduced by the correction method.
The risk can be minimised by in-depth market analyses and an additional combination of correction method and sensitivity analysis towards a certain risk corridor.

<u>e) Electricity prices and revenues</u>

This forecast is, apart from the gas price forecast, probably the most difficult one in a model, as it depends on a variety of parameters that cannot usually be influenced by the company and are not only of a regional nature.

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[1] cf. section 8.1.4.2 on page 169

[2] cf. section 8.1.4.3 on page 170

[3] cf. Figure 6-13: Diagram of the degradation schedule of gas turbine and power

[4] Maintenance intervals directly depend on the number of the so-called start-ups and shut-downs of the power plant and the real number of hours of operation; see also section 6.3 Power plant operation

[5] cf. Strauß (2009): p. 32 ff

However, it must also be pointed out that prices within the EU are shaped by the electricity exchange and therefore apply equally to all sites throughout Europe.
Here too, the correction method can be used to counteract the risk to a certain extent. The uncertainty of the assumptions, however, remains the same.
The decision can be supported by a sensitivity analysis in the form of different environmental scenarios[1], i.e. different economic development trends.

f) Investment (CAPEX)

Nevertheless, all assumptions are related to the future and therefore entail a degree of uncertainty which cannot be determined with any more accuracy. For this reason, two additional items should always be included in the investment overview:

- contingencies
- risks.

Contingencies are a budget for events or risks that have not been known or reported so far. Therefore, only a lump-sum value is to be defined, for practical reasons as a percentage. This is finally based on knowledge gained by experience.
The risks are identified possible events in the project planning and implementation stages with a negative effect, which have to be valued on a cost basis and taken into account in the total CAPEX.

In the following, an overview of the generic power plant costs (marked with the most important parameters of fossil power plants), based on Konstantin (2009)[2] is provided.

1 cf.
Figure 8-27: Exemplary illustration of the influence of external causes on possible environmental states
[2] cf. Konstantin (2009): p. 293 ff.

Position	Unit	Typ of power plant			
		BK-KW	SK-KW	GuD-KW	GT-KW
Technical parameters					
Gross electricity output	MW	1.100	700	400	150
Share of gas turbine	MW	0	0	260	150
Captive power demand	%	5,5%	7,4%	1,5%	1,0%
Net electricity output	MW	1.040	648	394	149
Combustion heat performance	MW	2.311	1.408	703	436
Net electr. degree of efficiency	%	45%	46%	56,0%	34,0%
Fuel, trading unit	-	BK / t	SK / T	EG / MWh	EG / MWh
Heating value per trading unit	MJ / kg	10,5	29,3	-	-
Emissions per MWh fuel	kg / MWh_{th}	410	342	202	202
Emissions per MWh electrical	kg / MWhel	911	743	360	594
Technica- economic data					
Construction time	Monate	48	36	24	12
Calculated service life	A	35	35	25	25
Imputed reate of interest, incl. tax on earnings, real	%	7,5%	7,5%	7,5%	7,5%
Fuel price in Hu	€ / MWh	4,31	9,54	23,88	29,31
Operating staff	Personen	80	70	30	5
Personnel expenses	T€ / (Pers. a)	90	90	90	90
Maintenace costs, fixed (relate to EPC-price)	% / a	1,6%	1,5%	0,7%	0,5%
Maintenance costs, variable	€ / MWh_{el}	0,00	0,00	3,00	3,00
Operating supplies/ Waste disposal	€ / MWh_{el}	1,65	1,3	0,50	0,50
Insurance / Overheads	% / a	0,5%	0,5%	0,5%	0,5%
Free allocation CO_2-EB *)	1 / MWh_{el}	633	633	308	308
Assumed costs for certification per t CO_2	€ / t	30	30	30	30
Capital expenditures					
Specific investment	€ / kW	1.500,0	1.200,0	530,0	400,0
Purchase price	Mio. €	1.650,0	840,0	212,0	60,0
Owner-engineering services, other expenses 7.5%	Mio. €	123,8	63	15,9	4,5
Decommissioning costs 0.5%	Mio. €	8,3	4,2	1,1	0,3
Construction interest rate on EPC-price 1,05	Mio. €	164,1	47,6	10,5	1,6
Energy and emission balance for typical serice life					
Full load hours *)	h / a	8.250	7.500	7.500	1.000
Electricity generation, net	GWh / a	8.580	4.860	2.955	149
Fuel consumption	GWh / a	19.066	10.560	5.273	438
CO_2-Emmissions, total	kt / a	7.817	3.612	1.065	88
Procurement of CO_2-EB from the market	kt / a	2.386	535	155	43
Elecricity production costs					
Fixed costs	**Mio € / a**	**204,2**	**103,0**	**27,1**	**7,1**
Capital costs	Mio € / a	158,6	77,8	21,5	6,0
Maintenance 1.0%	Mio € / a	29,4	14,0	1,6	0,3
Personnel (1% / a increase rate, real) 1,0%	Mio € / a	8,0	7,0	2,9	0,5
Insurances/Overheads	Mio € / a	8,3	4,2	1,1	0,3

Position	Unit	Typ of power plant			
		BK-KW	SK-KW	GuD-KW	GT-KW
Variable costs	**Mio € / a**	**194,3**	**135,7**	**142,4**	**14,9**
Fuel	Mio € / a	82,2	100,7	125,9	12,8
Maintenance contract	Mio € / a	26,4	12,6	10,3	0,7
Operating supplies / Waste disposal	Mio € / a	14,2	6,3	1,5	0,1
Costs for CO_2-certification	Mio € / a	71,6	16,1	4,6	1,3
Sum Annual costs	**Mio € / a**	**398,5**	**238,7**	**169,5**	**22,0**
Specific costs	**€ / MWh**	**46,45**	**49,12**	**57,35**	**147,69**
Service costs	**€ / (kW*a)**	**196,35**	**158,98**	**68,78**	**47,46**
Labour costs	**€ / MWh**	**22,65**	**27,92**	**48,18**	**100,23**

*) According to German Allocation Law

Figure 8-24: Overview of generic costs of fossil power plants[1]

g) Operating Expenditures variable

The three cost items summarised here, such as gas costs, CO_2-costs and cooling water costs represent the major share of the variable costs. But for a planning period of nearly 30 years even these three items are subject to uncertainty.

Apart from these, there are further parameters, e.g. the operating supplies, which mostly have little impact on the variable overall cost structure, so that they can be considered negligible in the basic model.

In normal production plants, the personnel costs are usually considered as variable. This cannot easily be done in the operation of a power plant. For reasons of safety, trained staff has always to be available, even during standstill. What is more, the staff is too specialised to be temporarily occupied elsewhere or to be made redundant.

There are no reliable forecasts as to how the economic situation will develop over such a long period. Consequently, the only way to cope with uncertainty in the efficiency calculation and to narrow down the uncertainty corridor and / or simulate possible decision scenarios is the application of the methods presented in the following sections.

1 cf. Konstantin (2009): p. 293 ff.

h) Operating Expenditures fix:

The costs summarized in the basic model are, by their nature, somewhat more predictable, but, on the other hand, significantly lower in relation to the OPEX variable. Planning and scale of distribution of expenses can vary, depending on the controlling requirements within the company, and have therefore to be refined in later stages of development.

If the planned inflation rate, as it was assumed here in the basic model for the cost progression, is sufficient, has to be assessed in the individual case.

8.1.4.2 Correction method

The correction method is a widespread, simple approach for taking into account the (risk-) uncertainty of investment projects. For every important target- or input quantity, the original estimate is furnished with a risk supplement or risk deduction, respectively, in accordance with the principle of commercial prudence.

In the basic model presented here, this possibility was added exemplarily to the CAPEX variable, e.g the gas prices were combined with the uncertainty factor, CO_2 with the inflation rate or the degree of efficiency with the ageing factor.

Estimated input value	Security correction	Corrected input value
GP_{el}	will be increased	GP_{el}^{*}
CO2	will be increased	$CO2^{*}$
η	will be decreased	η^{*}
X?	? will be shortened?	$X?^{*}$

Figure 8-25: Supplements and deductions in the correction method[1]

[1] Authors own schematic chart

This heuristic planning procedure, however, shows considerable deficiencies[1]:

- flat-rate estimation of the risk without analysing the cause
- risks may be double-counted
- If the focus is on an unfavourable future development without considering possible opportunities, lucrative investment sites might be discarded.

8.1.4.3 Sensitivity analysis

The sensitivity analysis starts where the deterministic procedures of investment calculation mentioned above end. It can therefore be considered as a supplement to these procedures.
The sensitivity analysis is based on the assumption that the significant input quantities can vary around a certain value. Based on this first estimate of the input quantities, two questions are to be answered by a systematic variation of the values[2]:

1. Which input quantities have a particularly strong influence on the output quantity?
2. Within which limits can the values of the input quantities vary, without the necessity to change a profitability decision taken previously?

Consequently, the correction method could be considered as a kind of first case.

Related to the basic model, a possible question could be: Which is the lowest electricity price at which the NPV is just barely positive?
Or, which is the highest CAPEX at which the NPV is just barely positive? Etc.

The sensitivity analysis is not a decision rule. It does not provide any clear indication for the selection of the best site alternative[3].

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[1] cf. Jung (2010): p. 861 ff; cf. Schierenbeck (2008): p. 445 f.;

[2] cf. Wöhe (2010): p. 563 f.

[3] Vgl. Kruschwitz 2009: 323 ff.

But it can help to fathom out the influence of the uncertainty about the future environmental situation on the upcoming site decision.
In this respect it makes an important contribution to managing the site risk, especially in combination with the risk analysis presented in the following section.

8.1.4.4 Risk analysis

Managing the uncertainty problem can be further facilitated by risk analyses. Whereas the sensitivity analysis focuses on the input factors, the risk analysis investigates the risk structure of the output quantity. Using combined variations of the input quantities, the risk analysis aims at determining a probability distribution of the output quantity.

In the following, the approach will be explained in the basic model using the determination of the net present value (NPV) as an example.
The net present value is to be determined by using the formula described earlier[1].
For reasons of simplification, it is assumed that the values of the input quantities, such as electricity prices, CAPEX, OPEX, gas prices and CO_2-prices and the WACC depend on four imaginable developments of the environment U and that the investor is in a position to indicate probabilities of occurrence of the relevant environmental states. The investor has to decide in favour of one probability of occurrence. This is because they are entrepreneurs and thus, take an active part in shaping the corporate policy.

If one calculates the net present value for all conceivable environmental states, one obtains a probability distribution, i.e. a statement on the probability in which a specific net present value is to be expected.

A brief explanation of an approach for the *deduction and determination of different environmental states* will be provided in the following.
Different environmental states have different external causes and different effects on the calculation model to be used for the determination of the capital value.

[1] cf. page 152

External causes for the change of an environmental state (related to EU27) include:

- global economic development
- gas consumption
- competition on the gas market
- electricity consumption
- environmental measures (e.g. CO_2 targets)
- nuclear power development
- capacity of power plant suppliers
- global new construction project activities

Guidance on possible developments and future evaluations is offered by different sources, such as reports of the International Energy Agency (IEA) [1] the American EIA, or the International Monetary Fund IMF[2], etc.

These different external causes have a different impact on the model parameters. The input quantities with the biggest influence on the basic model can be summarised as follows:

- electricity prices (EP)
- gas prices (GP)
- CAPEX and
- OPEX.

To estimate the effect of the external causes it is necessary to reflect on the extent of their influence on the environmental states.

As an illustration of the principle, four environmental states will exemplarily be described in the following.

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[1] cf. IEA : http://www.iea.org/stats/regionresults.asp?COUNTRY_CODE=30&Submit=Submit; International Energy Outlook : Golden Age of Gas (17.01.2012): http://www.worldenergyoutlook.org/docs/weo2011/WEO2011_GoldenAgeofGasReport.pdf ; International Energy Agency : World Energy Outlook press presentation : http://www.worldenergyoutlook.org/docs/weo2011/homepage/WEO2011_Press_Launch_London.pdf;

[2] IMF (International Monetary Fund) - Home Page : http://www.imf.org/external/index.htm;

Here too, the estimated effects and the extent of influence strongly depend on subjective factors and estimates, as the following example will show. The crucial question is how these subjective questions are dealt with when assessing the risk and making the decision.

In addition to the environmental state described in the basic model, future environmental states U will be assumed with the following premises:

Environmental state U	Description	Effect on the model
1 Global bank crisis	• Prolonged effects of the bank crisis = very small economic growth (only Asia and South America) • Power consumption values stagnant in EU27 • Less stringent rules on CO_2-reduction • Regulations for electricity prices being kept at a low level in EU27	EP = → GP = ↗ CAPEX = ↘ OPEX = ↘
2 Green scenario	• Internationally agreed CO_2-reduction • Broad acceptance of nuclear power (except for Germany) • Expansion of renewable energy business; decline of fossil power plants • Increase of efficiency of gas-fired power plants • Increased use of gas-fired power plants • Strong energy market regulations in EU27	EP = ↗ GP = ↗ CAPEX = ↗ OPEX = →
3 Linear development	• As described in the example of the basic model	as given in the example →
4 Global high economic growth	• Positive economic development, increased energy consumption and prices • Kyoto Protocol will not be renewed • Global epansion of energy generation • Low level of energy market regulation	EP = ↗ GP = ↗ CAPEX = ↑ OPEX = ↗

Figure 8-26: Example of the definition of future environmental states [1]

[1] Authors own chart

EP	electricity price
GP	gas price
CAPEX	Capital Expenditures (Invest)
OPEX	Operational Expenditures

To illustrate the effect of the external causes shown in the above figure, it is necessary to reflect on the extent of influence of the external causes on the environmental states. The basic model serves as a kind of base line in this case, i.e. a basic assumption or assessment.

In the following, the possibility of a graphic representation will be shown:

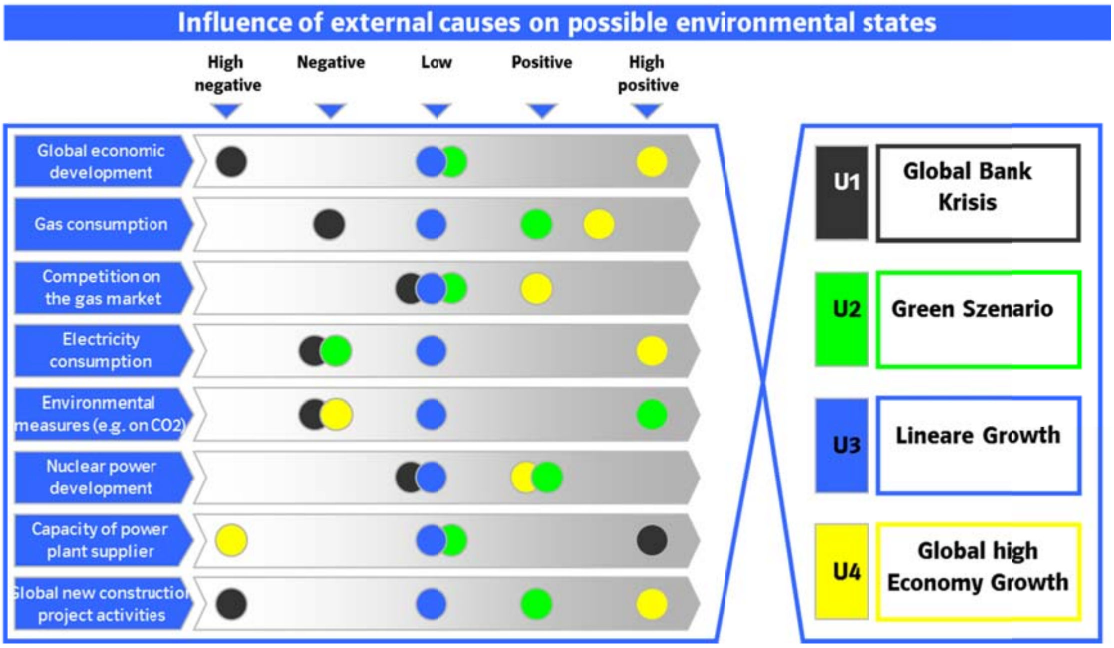

Figure 8-27: Exemplary illustration of the influence of external causes on possible environmental states

If one calculates the net present value for all conceivable environmental states, one obtains a probability distribution, i.e. a statement on the probability in which a specific net present value is to be expected.

Environmental state	U1	U2	U3	U4
Relative probability of occurrence w *)	0,25	0,3	0,35	0,1
Expected net present value in GE	**- 20**	**0**	**+ 25**	**+ 45**

*) investor's own estimate

Figure 8-28: Example of a probability distribution of the net present value

The probability distribution suggests the risk profile of the site alternative with the respective investment. From the risk profile, the degree of probability can be deduced, at which a certain minimum net present value can be achieved.

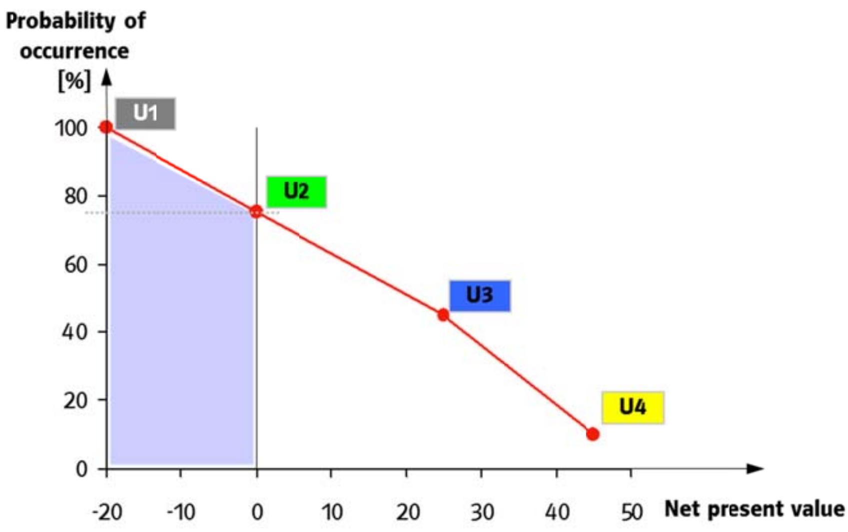

Figure 8-29: Example of a risk profile[1]

Figure 8-29 shows that at the side under consideration, a non-negative value can be expected with a probability of 75%. The probability value of 75% results from the sum of the probability of occurrence of the four net present values in Figure 8-28which do not have a negative sign.

[1] Authors own chart

For a decision-maker who tends to be more willing to take risks, the prospect of ending up in the negative territory with a probability of 25% may not be an obstacle, but for the "risk-averse" decision-maker this would be a reason for declining the site and / or the whole investment.

In any case, the risk profile with its reference to the subjective risk tolerance provides practical assistance in making an investment decision.

If one proceeds from the assumption that companies have to decide between several, e.g. three mutually exclusive sites (investments) A, B and C, the overview developed in Figure 8-28 would have to be extended by the other sites. As one of the simplest models from decision theory, the Bayes theorem, also referred to as μ- rule (expected value μ), will be provided for comparison[1].

Environmental state	**U1**	**U2**	**U3**	**U4**	**Expected value μ**
w	**0,25**	**0,3**	**0,35**	**0,1**	
A	**- 20**	**0**	**25**	**45**	**8,25**
B	**2**	**5**	**10**	**25**	**8,0**
C	**-60**	**-5**	**50**	**100**	**11**

Figure 8-30: Example of a result matrix for three alternative site investments

The choice that has to be made according to this pattern is between:

- a low expected value and a low risk and
- a high expected value and a high risk

If a risk-neutral decision is made, the investment at site C would have to be given priority, according to the μ- rule.

[1] The μ-rule, also referred to as Bayes theorem, proceeds from a neutral decision-maker in terms of risk tolerance. Risk tolerance is the subjective willingness of a decision-maker to accept uncertain outcomes when choosing a possible action. In reality, a risk-averse attitude is prevalent. This is why economic theory assumes a risk-averse attitude in models; cf. Wöhe (2010): p. 96

If, however, the investor is risk-averse, the decision-maker would tend to prefer site B. For the evaluation of alternatives for action under risk, there are decision rules derived from decision theory. These are meant to provide the decision-maker with instructions which match their individual risk tolerance[1].

The risk analysis is mainly judged as positive and is also attractive in practice, especially for the evaluation of large-scale projects, such as the construction of new power plants.

Criticism mainly concerns the determination of the values of input quantities. As these are estimates, they are highly subjective and therefore difficult to verify objectively[2]. This problem can hardly be avoided in a forward-looking procedure and model.

8.1.4.5 Summary on the basic model

The dilemma of model calculation between reality and model, accuracy and effort (data availability) has become obvious again.
For this reason, the economic efficiency calculation with such a long planning horizon can only serve as some kind of guidance or *indication* for a site decision.

In the final analysis, every decision is and will be an entrepreneurial decision with an inherent risk.

---

[1] cf. Wöhe (2010): p. 97 ff.;
For making *decisions with a risk*, the decision theory distinguishes between three decision rules:
(1) μ-rule (Bayes theorem); (2) (μ,δ-rule; (3) Bernoulli principle
For making *decisions with uncertain expectations*, the decision theory distinguishes between five decision rules:
(1) Laplace rule (rule of the insufficient reason); (2) Minimax rule (Wald rule); (3) Maximax rule; (4) Hurwicz rule (pessimism-optimism rule); (5) Savage-Niehans rule (rule of the smallest regret)

[2] cf. Wöhe (2010): p. 566 f.

8.2 Qualitative procedures

8.2.1 Checklist procedure

Checklists represent lists of evaluation criteria. They form the basis of a site evaluation and allow for a transparent representation of the criteria relevant for a decision and for a systematic assessment of the potential sites[1]. The approach in using checklists can be subdivided into three steps:

1. determination of the criteria relevant for the decision
2. evaluation of the individual criteria and
3. forming an overall assessment on the basis of the individual assessments[2]

The advantages of the checklist procedure are their easy manageability or feasibility, respectively. What is more, qualitative and quantitative criteria can be assessed equally. By using a checklist it can be determined if a site fulfils the minimum requirements. This renders the procedure suitable for a pre-selection from a number of potential sites[3].

Disadvantages are that defining the criteria that are to be considered as relevant remains subjective and that the manageability diminishes with increasing number and level of detail. Assessing the sites among each other is just as impossible as the representation of interactions in complex matters[4].

[1] cf. Hummetenberg 1981: 32 und vgl. Lüder 1986: 35

[2] cf. Hummel (199): p. 241; cf. Brockfeld (1997): p. 91

[3] cf. Kinkel (2003): p. 66; cf. Hummel (1997): p. 241 f.; cf. Brockfeld (1997): p. 91 f.

[4] cf. Hummeltenberg (1981): p. 32 and cf. Hummel (1997): p. 241 f.

8.2.2 Profile method

In the profile method it is assumed that a site is most likely suitable, the more the requirements on a site (best profile) correspond with the properties of the potential sites (property profile). Similarity indeces are calculated, the results of which provide a statement on the deviation of the sites to be evaluated from the required profile. In the evaluation system developed for this method it is not the highest, but the lowest value that indicates the most suitable site[1]. The procedure is carried out in six steps:

1. The prerequisite for using the method successfully is the definition of objectives[2].

2. The relevant criteria are compiled in the form of a comprehensive criteria catalogue. Care is to be taken that no criteria are omitted, in order to avoid that their effects are taken into account incompletely. In addition, the criteria have to be independent from one another, so that multiple measurements due to overlapping are avoided[3].

3. The task is to weight the features in order to take account of the fact that the criteria are of different importance for the achievement of goals[4].

4. Establishing a scale of assessment. Uphoff chose a scale from one (insufficient) to seven (excellent)[5].

5. The actual evaluation takes place in this stage. The result is a property profile for each site[6].

---

[1] cf. Uphoff (1978): p. 133; cf. Siebert (1990): p. 93

[2] cf. Uphoff (1978): p. 136 f. and p. 148 ff.

[3] cf. Uphoff (1978): 136 f. and p. 152 ff.

[4] cf. Uphoff (1978): p. 136 ff. and p. 158 ff.

[5] cf. Uphoff (1978): p. 136 ff. and p. 166 ff.

[6] cf. Uphoff (1978), p. 136 ff. and p. 179 ff.

Criteria	Profile values	Location A							Location A							Location A						
		Insufficient	Deficient	Sufficient	Satisfactory	Good	Very good	Excellent	Insufficient	Deficient	Sufficient	Satisfactory	Good	Very good	Excellent	Insufficient	Deficient	Sufficient	Satisfactory	Good	Very good	Excellent
K1		1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
K2		1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
K3		1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
K4		1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
K5		1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7

Figure 8-31: Examples of property profiles[1]

6. Based on the established property profiles, a similarity index is ascertained and subsequently represented in the form of a ranking[2], where the lowest value shows the lowest deviation from the optimum site[3]. In order to take account of the changes in the economic, political and technological conditions, the procedure offers the possibility to define different scenarios by differently weighting the identified criteria[4].

Two points can be identified as disadvantages. The procedure is very work-intensive and depends very strongly on how the factors are weighted. The result is a dimensionless figure, which cannot be interpreted meaningfully.

It is advantageous that, owing to the possibility to develop different scenarios, future developments can be taken into consideration and represented. This scenario consideration, however, implies a still greater effort. To obtain an overall assessment, weighting is also required for the assessment of the scenarios.

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1 Author's own graph based on Uphoff (1978): p. 190

2 The change index (A_j) is ascertained for each potential site (j) according to the following formula (cf. Uphoff 1978: p. 199 and cf. Hummel 1997: p. 251):
The root of the sum of the squares of the individual criteria weights (g_i) multiplied by the difference of the profile values of the ficticious best profile (P_i) and the respective property profile (P_{ij}).

$$Aj = \sqrt{\sum_{i=1}^{n} \left[gi * \left(Pi - Pij\right)\right]^2}$$

3 cf. Uphoff (1978): p. 136 ff. and p. 190 ff.

4 cf. Uphoff (1978): p. 237 ff.

The higher the number of criteria and scenarios, the lower the influence of misjudgements.

8.2.3 Utility analysis

The utility analysis can be seen as a further development of the checklist procedure. It is used for the structured assessment of alternatives, taking into account different preferences[1]. It is carried out in five stages:

1. Compilation of the decision-relevant target criteria. In order to record the criteria systematically, it is recommendable for a multitude of criteria to summarize them in subject groups[2].

2. Definition of the weighting factors in accordance with their importance for the decision. Although weighting is always subjective, there are method that help systematise the procedure and make it comprehensible[3].

3. Assessment of the expressions of criteria. For this purpose, values are assigned to the respective criteria according to a defined measuring scale. There are nominal[4]- ordinal[5]- and cardinal scales[6] [7].

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[1] cf. Szyperski and Winand (1980): p. 155 and Lüder (1986): p. 36 f.

[2] cf. Seidel (1977): p. 129 f.; cf. Blohm, Lüder (1991): p. 176 f.

[3] An example of this is the so-called method of successive comparisons, in which the importance of the individual criteria is ranked by reciprocally comparing the criteria - cf. Seidel (1977): p. 129 f., p. 132 ff.; cf. Blohm, Lüder (1991): p. 178 ff.

[4] Nominal scales make a distinction only according to whether objects are equal or unequal, i.e. equal numbers mean equal expression of characteristics - cf. Szyperski and Winand (1980): p. 100.

[5] Ordinal scales are assigned the expressions of characteristics of a category, and distinction is made as to whether they are bigger or smaller, i.e. the categories are arranged in a sequence - cf. Szyperski and Winand (1980): p. 100

[6] The characteristics of the cardinal scales are referred to as metric scales and comprise the interval and ratio scales - cf. Szyperski and Winand (1980): p. 99

[7] cf. Kinkel (2003): p. 67 f. and cf. Hummel (1997): p. 246 f.

4. Usually, the partial utility values are assessed using cardinal scoring scales, where the highest score is awarded to the best possible expression of the criterion to be assessed[1]. If an expression of a criterion cannot be determined for all potential sites, this criterion should not be assessed[2].

5. Evaluation of the partial utility values of the criteria to be assessed and summarising them to gain an overall result. In doing so, the different weighting of the criteria has to be taken into account. The total utility value (N_j) of the site to be evaluated (j) is determined by adding the partial utility (n_{ij}) multiplied by its weighting (g_i)[3].

$$N_j = \sum_{i=1}^{n} n_{ij} * g_i$$

N_j	total utility value
n_{ij}	partial utility
g_i	weighting

6. Evaluation of the profitability of alternatives. For this, the decision-maker compares the individual total utility values N_i with the required level[4].

Drawbacks of the procedure are its weak points in terms of methodology, the selection of the decision-relevant criteria and their weighting as well as ensuring the independence of the criteria from one another with regard to contents. The result itself is a dimensionless figure, which has always to be seen in direct correlation with the criteria and weightings and which is interpretable. A comparison of the results from the utility analysis with monetary values, such as costs and revenues is not reasonably possible.

1 cf. Bitz et. al. (2005): p. 165 and cf Seidel (1977): p. 138

2 cf. Hummel (1997): p. 245

3 cf. Kinkel (2003): p. 68 and cf. Blohm, Lüder (1991): p. 186 f.

4 cf. Blohm, Lüder (1991): p. 187 f.

The coordination work that is necessary for implementing the process gives the decision process the necessary transparency in order to be understandable and therefore verifiable for third parties[1].

The advantage of the utility analysis lies in its ease of application, the possibility to consider both qualitative and quantitative factors and thus, to weigh them up against one another. The definition of the criteria and their weightings requires dealing with the demands and targets.

8.2.4 Ranking method

The principle of the ranking method is based on the assignment of ranking values for the respective target criteria with the aim of establishing a ranking of potential sites. Just like in the approach of the utility analysis, the decision-relevant criteria and their weighting have to be determined first. The expression of the characteristics are then compared by using an ordinal scale, and evaluated.

For all n criteria, a value number (W_{nm}) is formed from the respective ranking value (R_{nm}) and the criteria weighting (G_n). Ranking values are integers from one to n - n being the number of sites under evaluation. The site which complies best with the characteristics of the relevant criterion is assigned the ranking value one, whereas the site with the lowest target compliance is given the last ranking number[2].

$$W_{mn} = R_{mn} * G_n$$

W_{nm}	value number
R_{nm}	ranking value
G_n	criteria weighting

1 cf. Kinkel (2003): p. 68 f.; cf. Hummel (1997): p. 258 f.; cf. Lüder (1986): p. 40

2 cf. Olbert (1976): p. 132 ff.; cf. Hummel (1997): p. 252; cf. Hummeltenberg (1981): p. 32 f.

The total value of each site (N_m) to be used for the site evaluation of the m sites can be calculated by adding their value numbers. The site with the lowest total value is the best alternative[1].

$$N_m = \sum_{j=1}^{n} W_{mj}$$

N_m	total value of each site
W_{mj}	value numbers

This method allows for a comparative site evaluation, which, however, takes in no way account of the size of the distances between the ranking numbers, i.e. how much better or worse a criterion is pronounced.

In order to represent the quality characteristics of the criteria, the ranking method can be modified by calculating the ranking (R_{nm}) as follows[2]:

$$R_{nm} = \frac{comparitively\ best\ value}{comparitively\ worst\ value}$$

This modification, however, is only possible if the evaluation criteria can be expressed numerically, and does not permit an assessment of the qualitative characteristics. To represent the qualitative criteria and their quality characteristics in the modified procedure, replacement characteristics (so-called indicator characteristics) had to be formed, which can be assessed quantitatively[3].

Disadvantages of this procedure are, as in the utility analysis, methodological problems, i.e. the selection of the decision-relevant criteria and their weighting as well as ensuring the independence of the criteria from one another with regard to contents.

---

[1] cf. Olbert (1976): p. 133 f.

[2] cf. Olbert: (1976): p. 137 ff.

[3] cf. Olbert (1976): p. 139

Its advantage, i.e. its easy use and the possibility to take both qualitative and quantitative factors into account, is only relevant in the “non-modified” version of the ranking method[1].

8.2.5 SWOT analysis

The SWOT analysis is a tool of strategic management and is primarily used to adapt to changes in the operating environment. The term SWOT analysis means:

Strength – **W**eakness- / **O**pportunities – **T**hreats - Analyse

and stands for the two main categories[2]:

- analysis of strengths and weaknesses = corporate analysis
- analysis of opportunities and threats = environmental analysis

The *analysis of strengths and weaknesses* (corporate analysis) serves to compare the current position or products of the company with the position or products of competitors. In this way, the strengths of the company itself can be shown and the fields of action identified which are to be adhered to or further extended. The options for the weaknesses identified can either result in a defensive exit strategy or an offensive growth strategy[3].

The *analysis of opportunities and threats* (environmental analysis) identifies the outside environment and market conditions which affect the company’s current situation and its products.

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1 cf. Hummeltenberg (1981): p. 33f.

2 cf. Arbeitsgemeinschaft Industriebau (2004): p. 19; cf. Bitz et al. (2005): p. 346; cf.. Freiling, Reckenfelderbäumer (2007): p. 315 ff.; cf. Welge, Al-Laham (2003): p. 318; cf Steinmann, Scheyögg (2005): p. 173;

3 cf. Bitz et al. (2005): p. 346 and cf. Hanssmann (1995): p. 270

The positive possibilities for development are considered as opportunities, the negative as threats. These considerations are assessed with regard to their importance and their probability of occurrence[1]. An environmental analysis includes the following elements[2]:

- macroeconomic environment
- technological environment
- political and legal environment
- sociocultural environment
- natural environment

In the SWOT analysis, the findings of the analysis of strengths and weaknesses and that of opportunities and threats are brought together to derive statements on strengths and weaknesses in the light of future development opportunities[3].

As mentioned above, the SWOT analysis is an instrument of strategic management. A site decision is a strategic decision, which can be objectified by this tool and represented in a transparent fashion. This is achieved by examining the overall situation of a site, identifying its strengths and weaknesses and reflecting them on future developments, i.e. opportunities and threats.

The disadvantage involved is the fact that this method is not suitable for comparing sites among each other.
The advantage is that not only the current situation, but also the development of environmental conditions is to be included in the consideration and assessment.

Within the Theory of Strategic Management, various other models have been developed.

[1] cf. Bitz et al. (2005): p. 346 and cf. Welge, Al.Laham (2003): p. 318 f.

[2] cf. Steinmann, Schreyögg (2005): p. 178

[3] cf. Bitz et al. (2005): p. 347

In the LCAG model developed by the Harvard Business School[1] the SWOT analysis was extended by two further elements. In the present thesis, which focuses on a single site of a project of a specific organisation, this approach will be taken account of in that appropriate criteria have to be defined and evaluated.

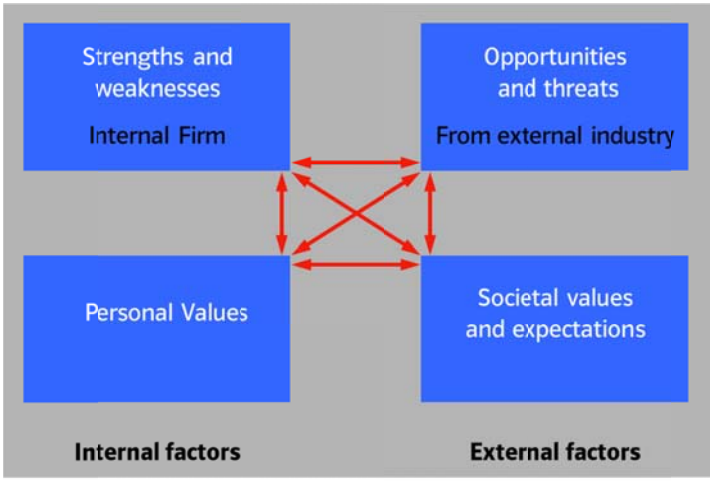

Figure 8-32: Elements of the LCAG model[2]

[1] The LCAG model was developed into a series of analytical processes which managers might use in thinking about firm strategy. Whereas the original approach by Ansoff (1965) suggests little consistency and structure in its concept, a closed framework of reference has been available at the latest since the influence of Porter (1981). The key characteristic of the LCAG model is the conceptual separation of the two main categories of strategy formulation and strategy implementation. The LCAG model as a basic model for rational, decision-oriented approaches of a strategic management was fundamentally criticised and disputed, especially by Mintzberg (1990 – "Mintzberg-Ansoff-controversy"); cf. cf. Falkner and Campbell (2006): p. 241 ff.; cf. Welge and Al-Laham (2012): p. 33 ff.;

[2] cf. Falkner and Campbell (2006): p. 241 ff.

8.2.6 Summary of qualitative evaluation procedures

There is a multitude of qualitative evaluation procedures, none of which can be regarded as the most suitable one. Every procedure has its advantages and disadvantages (see Figure 8-33 below). The aim of site evaluation should be to determine and apply the most suitable or a combination of suitable procedures, depending on the respective requirement, in the different stages of the site decision process.

	Checklist procedure	**Profile method**	**Utility analysis**	**Ranking method**	**SWOT-analysis**
Clarity of the results	Decreasing with increasing number of criteria	Yes	Yes	Yes	Yes
Manageability	Very simple	Very difficult	Difficult	Simple	Simple
Definition of minimum requirements	Possible	No	Yes	No	No
Evaluation of sites among one another	Not possible	Yes	Yes	Yes	Yes
Qualitative/ quantitative criteria measurable	Possible	Yes	Yes	Yes	Yes
Transparency and traceability of results	Yes	Yes	Yes	Yes	Yes
Taking future developments into account	No	No	No	In the modified version	Yes
Other	Suitable for pre-selection of sites	Dimensionless figure as result, not interpretable		./.	./.

Figure 8-33: Overview of evaluation procedures [1]

[1] Author’s own representation

In conclusion, it is apparent that the weak points of the procedures lie in the subjective definition of the decision-relevant criteria and their weighting. The effect of this subjective component, however, can be reduced by involving several people in the evaluation process and forming collective instead of individual judgements[1].

[1] cf. Blohm, Lüder (1991): p. 174

9 Project phase „Preliminary study in the site decision process“

The project phase preliminary study comprises the following tasks for the site decision process:

- summarising the criteria relevant for a site decision in a catalogue of requirements, in which their significance for the site decision is described in detail
- differentiation of the criteria listed as relevant in terms of whether they are criteria for exclusion or not
- disclosure of the source and evaluation of the quality of the criteria

The catalogue developed in the present preliminary study forms the basis for a first rough evaluation of a potential site and for all subsequent steps in the site development. The aim of the preliminary study is to minimise the number of potential sites (a maximum of two to three) and, in this way, to establish the basis for a decision on a budget release for the further development and preparation of a feasibility study[1].

9.1 Evaluation procedure for the preliminary study

The suitable instruments for the phase of the preliminary study are the checklist procedure and the utility analysis.

At the very early stage in the search process for suitable sites, 15 to 20 sites may be available for selection. Such a large number of sites can easily be reduced by using the *checklist procedure* and by establishing criteria for exclusion (also called show stopper). Arguments in favour of the checklist procedure are the possibility to evaluate quantitative and qualitative criteria, the high degree of clarity and transparency in the site evaluation processes.

[1] See also project phase description in section 1.3 and 5.3

Evaluating or comparing sites is not possible with the checklist method. If, after examining the criteria for exclusion, a larger number (n>5) of potential sites remains for evaluation, the utility analysis is the most suitable evaluation procedure.

The *utility analysis* makes it possible to compare sites. Usually, no detailed investigation results or results that have been confirmed by expert opinions, are available in the preliminary study phase. This means that the evaluation basis for all sites can be regarded as comparable. Using the utility analysis as described in the previous chapter, i.e. by first determining the weighting factors and subsequently evaluating the expressions of criteria by means of a scale, the sites that are suitable for a detailed investigation can be identified on the basis of the total utility values obtained. It is not advisable to fix the number of sites that are suitable for an alternative evaluation in the first place. The selection should rather be made subject to the overall result.

9.2 Comparative requirements

To conduct a comparative evaluation it is necessary to define the significant comparative requirement. For the site decision of a gas-fired power plant, the following requirements, among others, can be essential:

- Time of realisation
- Costs of implementation

Depending on the main requirements, different criteria are particularly relevant to the decision. If the main requirement for the evaluation of alternatives is to reach a specific time of realisation, the criteria that involve timing risks are of special significance. One of these, in particular, is the situation with regard to planning and regulatory approval. This is, for example, because the potential areas are not indicated as power plant areas in the respective levels of land use planning, which may require time-consuming amendment processes. Even the political situation can become a time-critical criterion, if it gives rise to delays in taking planning decisions prior to elections or in the case of unfavourable majority circumstances.

A necessary network expansion (both electrical and gas) has to be judged equally critically from the point of view of time and regulatory approval.

The costs of implementation can sharply increase as a result of adjustments to be made in the facility planning due to existing legally protected biotopes or ground contamination on the area. The lack of infrastructure required for the operation of a power plant would also entail a considerable increase in the costs of implementation.

Consequently, before an alternative evaluation can be performed, it has to be defined which requirement will be the decisive basis for the comparison.

9.3 Decision-relevant criteria in the preliminary study

9.3.1 Checklist procedure in the preliminary study

The checklist procedure is meant to examine the sites with regard to their suitability using the criteria for exclusion listed below. A definition of the fundamental comparative requirement is not necessary at this stage. Mainly those criteria are examined on which a statement can be made without contacting official bodies, such as authorities, etc. In addition to making inquiries, on-the-spot visits are mandatory. Apart from the fundamental suitability of the area and the technical minimum standards, special attention is to be paid to avoiding restrictions with regard to regulatory approval and possible objections against the project, e.g. the environmental situation, environmental risks and competing uses in the immediate vicinity.

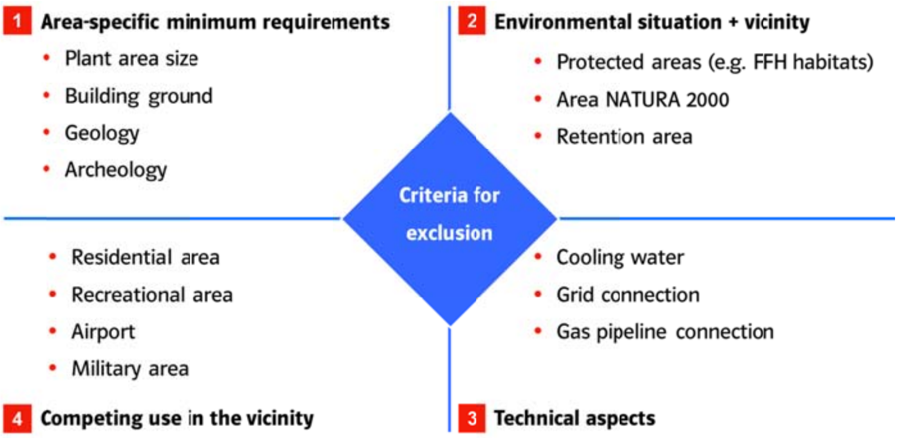

Figure 9-1: Criteria for exclusion in the checklist procedure

Area-specific minimum requirements:

- Is the area sufficiently large for the planned project?
- Does the building ground meet the requirements for a gas-fired power plant project?
- Is there a possibility of mining subsidence damages?
- Are there archaeological sites on the ground or in the immediate vicinity?

Environmental situation on the area and in the vicinity

- Are there protected areas (FFH habitats, bird sanctuaries)?
- Are there NATURA 2000 habitats in the vicinity of the potential area (< 1 km)?
- Is the area in a retention area [1]

Technical aspects:

- Is a cooling water source available, i.e. sea, river, lake or canal?
- Is there a grid connection in the neighbourhood of the potential area?
- Is there a gas pipeline or an LNG terminal in the vicinity of the potential area?

[1] Area that can be flooded in the event of high water level and, in this way, helps decrease the water level

<u>Competing use in the vicinity:</u>

- Are there residential areas directly adjacent to the potential area?
- Are there recreational areas directly adjacent to the potential area?
- Is there an airport in the immediate vicinity of the potential area?
- Is there a military area in the immediate vicinity of the potential area?

9.3.2 General overview of the utility analysis in the preliminary study

After sites have been eliminated from further investigation following the check for exclusion criteria, substitutional criteria are to be included for the comparison of the potential sites.

Figure 9-2: Phases of the utility analysis in the preliminary study

<u>Phase 1</u>

In accordance with the approach in the utility analysis described in section 8.2.3, the decision-relevant criteria are defined and, if necessary, summarised in subject groups. The criteria listed before in connection with the checklist procedure remain part of the utility analysis and are complemented by further criteria. This catalogue of criteria forms the basis for the site evaluation in the phase of the preliminary study.

It is important to note that statements can be made on these criteria and that they can be evaluated without having established contact with authorities or official bodies.

The special significance of each subject group and the required scope of investigation will be described in detail in section 9.3.3.

Phase 2

The task of this phase is to fix the weighting factors for the individual subject groups. This is done in compliance with the comparative requirement defined before.

Criteria weighting	**Weighting factor (g_i)**
Very high significance; Large to very large influence on the potential of the site.	5
High significance; Moderate to large influence on the potential of the site.	4
Normal significance; Average influence on the potential of the site.	3
Minor significance; Below-average to low influence on the potential of the site.	2
Weak significance; Insignificant to very weak influence on the potential of the site.	1

Figure 9-3 Criteria weighting – description of the weighting factors

Phase 3

An evaluation of all criteria listed in the catalogue takes place. Figure 9-4 illustrates an example of a possible structure of an evaluation catalogue.

The individual criteria (K_i) of the site to be evaluated (j) are partly subdivided further into subitems (U_i). These criteria (K_{ij}) and their subitems (U_{ij}) should be described first and then evaluated. A description of the subitems is necesssary for an in-depth evaluation of the criterion and allows for a traceability of the evaluation on the lowest common denominator. For the evaluation of the criteria and subitems, values will be assigned, depending on the expressions in accordance with the defined cardinal scale. This could be defined as shown in Figure 9-5.

Criteria value	**Evaluation factor (BF)**
Fully meets the requirements and / or no risk or conflict can be recognised.	5
Meets the requirements almost entirely and / or no or only a minor risk or conflict can be recognised.	4
Meets the requirements satisfactorily and / or a potential risk or conflict can be recognised.	3
Meets the requirements only partially and / or a high risk or conflict can be recognised.	2
Hardly meets the requirements and / or a very high risk or major conflict can be recognised, or no information is available.	1

Figure 9-4: Criteria values – description of evaluation factors

<u>Phase 4</u>

This phase serves to generate the subject group results (corresponds to the partial utility values in section 9.3.3) of the criteria to be evaluated. The subject group result (SG_{ij}) is calculated from the results of individual criteria evaluations (K_{ij}) within the individual subject group.

$$SGij = \frac{\sum_{i=1}^{n} Kij}{n}$$

SG_{ij} subject group result

K_{ij} criteria evaluation

Evaluation criterias		Criteria description	Evaluation result
Area specific			8,2
Size of the area	… large for the planned project?		3,0
	How large is the potential area?		3,0
Ownership status	Is the purchase of land possible without any difficulty on the basis of the present ownership?		1,7
	How many owners does the potential area belong to?		1,0
	Who are the owners of the potential area?		2,0
	Is the area in privat… or public ownership?		2,0
Properties of the area	Does the building g…nd meet the standards of a power plant project?		3,5
	Kind … tion)?		3,0
	Is the …		4,0
Environmental situation and conflicts relating to past use			3,0
Environmental situation	Are there any environmental risks that oppose the suitability of the site for the construction of a power plant?		3,0
	Can floods be expected on the potential area?		4,0
	Can earthquakes be expected on the potential area?		2,0

Subject group

Criteria

Sub-items

Sachgruppen-ergebnis (SG_{ij})

Criteria evaluation (K_{ij})

Figure 9-5: Example of the structure of an evaluation catalogue

<u>Phase 5</u>

The individual results can be summarised in an overall result by means of a matrix, as illustrated in Figure 9-6. This comprises the formation of a total utility value (N_j) of the site to be evaluated (j) by adding the subject group results (SG_{ij}) multiplied by the defined weighting factors (g_i).

$$N_j = \sum_{i=1}^{n} SG_{ij} * g_i$$

N_j	total utility value
SG_{ij}	result of the subject group
g_i	weighting factor

Location	Total information amount	Area specific criterias					Tecnical criterias				Political and regulatory criteria					Economic criterias								Other criterias				
		Size of the area	Properties of the area	Ownership status	Environmental situation	Conflicts relating to past use	Cooling water situation	Network access	Network capacity	Fuel transport capacity and infrastructure	Political situation	Situation with regard to planning law	Competing land use	Environmental conditions	Situation regarding regulatory approval	Construction costs	Operating costs	Redispatch	Marketing opportunities	Energy market prospects	Potential synergies	NPV (Net Present Value)	Tax system	Local contacts	Stakeholder analysis	Structure of the region and the country	Corporate strategy	Workforce
Criteria weighting																												
Location 1																												
Location 2																												
Location 3																												

Figure 9-6: Example of a result matrix[1]

The matrix forms the basis for the utility analysis, i.e. the evaluation of the different sites. When the results of this evaluation are available, the phase of the preliminary study in the site evaluation process is completed. For further steps it is necessary to define the sites that are suited for further investigations in the alternative evaluation. This is done on the basis of the results listed in the matrix.

9.3.3 Decision-relevant criteria in the preliminary study

Ownership status
• Number of property owners • Kind of property • Private or public property

Special importance

The prerequisite for implementing a project is purchasing land, which is usually complicated by an increasing number of owners. If the site in question is in public ownership, the possibility of a political interference should not be underestimated.

[1] see also annex

Scope of investigation

By consulting land registers, information has to be obtained about how many and, in particular, which owners the property belongs to. Based on this information, the likelihood of sale by the owners has to be estimated. This investigation should be conducted by a third party in order to avoid disproportionate price increases.

Environmental situation
• Trees or shrubs on the area (potential biotopes) • Standing or flowing water bodies on the area (potential biotopes) • Habitats of protected species on the area (Red List) • Specially protected sites on the area (FFH-areas)

Special importance

The existence of biotopes or protected areas on the area implies that, in accordance with the principle of avoidance, deduction and compensation, increased efforts with regard to plant installation planning are to be expected before the land can be claimed. What is more, if nature conservation and landscape protection concerns are considered to be a priority, the project may turn out to be unreliable. Besides the possibility of failure, this would entail long and extensive investigations, which may result in cost-intensive requirements with regard to plant design.

Scope of investigation

In order to be able to assess the environmental situation accurately, it has to be examined, based on the location on the map, if protection areas as mentioned above exist on the potential area. In addition, at least one on-site inspection by an expert should be conducted. This is particularly important as existing protected areas are not always displayed in the maps or the factual situation differs from the map display. What is decisive for the procedure, however, is the actual situation on the site.

Conflicts relating to past use
• Possibility of mining subsidence damages • Suspicion of ground contamination • Archaeological sites

Special importance

If there are mining subsidence damages, the area cannot be used for the erection of a power plant. If there are archaeological sites in the immediate vicinity, the time and effort involved in the construction of the power plant are likely to increase, or there is the possibility that the area will not be designated as a power-plant area in the zoning procedures that might still be pending. The existence of contaminated sites can entail extensive and cost-intensive soil remediation, which, in addition, involve the risk of time lags.

Scope of investigation

The area is examined according to the location on the map with regard to mining and archaeological sites in the vicinity. The on-site inspection has the task to compare the map situation to the factual situation. In this context it may be recommendable to establish contact with the local authorities or with associations or scientists.

Cooling water situation
• Level of average annual temperature of the cooling water source; maximum cooling water temperature • Cooling water supply ensured as required, even under extreme conditions (record flood levels, low water levels, etc.) • Restrictions of use of the cooling water source (existing, future)

Special importance

The availability of cooling water is a key prerequisite for the suitability of a location as a power plant site, as the waste heat produced has to be released by means of a cooling water source. For the technical design of the power plant it is necessary to have knowledge of the quantities of cooling water and / or the possible temperature gains[1] of the cooling water sources. If it can be foreseen that the required quantities of cooling water and / or the temperature gains considered as necessary from the technical point of view are temporarily not available, this has to be taken into account at an early stage of the planning process. An alternative for a gas-fired power plant would be a cell- or condensate cooling system. This option, however, would involve a considerable drop in efficiency.

In the case of a coal-fired power plant, restrictions in open circuit water cooling could result in a cooling tower, which may give rise to acceptance problems in the public. In CCGT power plants, restrictions in the warming of water bodies could lead to operational restrictions (especially in summer time).

The utilisation of cooling water is regulated by a water law approval procedure. This procedure can vary among different countries and regions.

Scope of investigation

It has to be checked if there are measuring points in order to obtain information about temperature profiles in the past few years. If there are further users of the cooling water sources (e.g. at rivers or coastal sections), such information or even existing heat load plans could be obtained from these. If no records are available, temperature measurements, which would permit estimations, should be carried out internally.

Furthermore, a check should be made on whether any existing users have planned expansion projects which would entail additional cooling water demand.

[1] also called “temperature rise” or in German = “Aufwärmspanne”

Network access and network capacity
• Distance of the network connection point in the ultra-high voltage network • Possible voltage levels in the environment • Existing investigations on the regional network expansion • Situation relating to the transition network • Transition network capacity • Planned network expansion measures • Required network route and critical areas / settlements / nature conservation areas • Network congestion through competing use (e.g. wind)

Special importance

Without a power supply network, the generated electricity cannot be transported. Grid expansion measures are subject to very long planning periods and are procedures that are difficult to assess, especially in the light of land use planning, environmental compatibility and public acceptance. The longer a line route to be built and the higher the number of potential land owners through whose properties the line is to run, the higher the risk that this can lead to considerable delays in the construction of the line, to massive cost increases or possibly even to the failure of the procedure.

Scope of investigation

In order to be able to assess the existing grid situation, this is to be checked by means of power system simulations. Information with regard to planned future power plant projects and renewable power generation projects (wind parks) has to be obtained to judge the grid situation anticipated in the longer term. The best way to find out about the grid situation is to consult the local network operators about a network connection. In order to assess the chances for implementing a line new build to some extent, potential routes have to be examined with regard to ownership structure, actual land use and existence of protected landscapes.

Infrastructure links
• Distance to the fuel source gas • Accessibility in the construction phase • Spare space for the construction phase • Opportunities for the power plant staff

Special importance

For the operation of a power plant, a sufficient gas supply is necessary. Gas pipelines mostly run a few kilometres away from the power plant site. New pipelines are normally extended only by the gas grid operators as far as the power plant site. The financing models can vary among the different countries.

Areas designated for pre-assembly, which are often larger than the actual power plant areas, should be made available for the construction phase.

For greenfield projects, new staff is to be recruited. The environment of the power plant should meet the demands of the staff.

Scope of the environment

The existing gas grid situation is to be checked. A close coordination with the gas grid operator and a gas grid simulation calculation are absolutely necessary. A new gas pipeline project has to be negotiated with regard to deadlines, technical and commercial issues with the operator in advance.

Roads and ways to the power plant grounds are to be checked and, if necessary, a possible extension agreed on with the local authorities, also with regard to environmental conditions.

Owners and ownership structure of neighbouring plots are to be evaluated in order to identify possible risks relating to a temporary utilisation.

Political situation
• Support or resistance by politics • Possible politically motivated changes in the requirements on the power plant project in the foreseeable future

Special importance

Local political bodies as planning representatives are responsible for the preparation and implementation of the land utilisation for building and other purposes. This is to be done in coordination with the neighbouring communities and forms the basis for the power plant projects including their respective infrastructure. Without a legal basis with regard to planning approval procedures, new building projects cannot be implemented. A project can be affected by supra-regional political interests, especially during election campaigns.

Scope of investigation

It is important to examine which party is currently governing with what majority, since when it has been governing, and when the next elections (on communal, state and federal level) will be held, as this may result in a new political line. The election programmes are to evaluated in terms of their statements about energy policy. Talks are to be conducted in order to assess the mood with regard to support or opposition (stakeholder management).

Situation with regard to planning law
• Power plant projects possible in accordance with regional planning requirements at national, regional and municipal level • Regional planning law requirements at national, regional and municipal level • Potential area is defined as power plant area in the federal-state planning, the regional and municipal planning

- Conflicts between power plant projects and requirements of the federal-state planning, the regional and municipal planning
- Possibilities of adjustment of and alterations to the requirements of the federal state planning, the regional and municipal plan in favour of the power plant project

Special importance

The planning law forms the basis for potential new building projects. If the potential areas are not designated as power plant areas at the different planning levels or if even contradicting utilisations are planned, it would at least take more time to provide the legal basis for the planning. However, there is also a possibility that the project fails due to the planning law requirements.

Scope of investigation

The existing planning levels are to be examined with regard to the statements and regulations on energy supply and / or power plants. It has to be assessed if, under the present circumstances, a new building project is feasible and, where indicated, what amendments may be necessary at which planning levels. Furthermore, the time and cost expenditure that is involved in such amendments has to be defined.

Competing land use

- Residential areas in the immediate vicinity
- Recreational areas in the immediate vicinity
- Airport in the surrounding area
- Military areas in the vicinity

Special importance

The project has to fit into its environment and be based on the existing utilisations and their requirements. Residential and recreational areas are characterised by very low sound emission limits. In the surrounding area of airports there are altitude restrictions. Military areas can involve restrictions and additional risks for transportation and routes of the network or pipeline.

Scope of investigation

The immediate vicinity has to be examined with regard to existing utilisation. Effects and importance of the surrounding land use for a power plant project have to be described in order to assess the requirements on the potential area.

Environmental conditions
• NATURA 2000 areas (FFH habitats or bird sanctuaries) in the immediate vicinity

Special importance

Given the fact that, pursuant to the law, environmental pollution caused by the construction and operation of a power plant must not have adverse effects on natural resources, the direct and indirect impacts on natural resources and their interdependencies are to be checked and assessed. Special attention is to be paid to impacts on the cross-border nature conservation and species protection.

Scope of investigation

It has to be investigated if, according to the map, there are NATURA 2000 areas within a radius of the fiftyfold height of the stack (author’s own estimate) as the highest point of a gas-fired power plant.

Furthermore it is to be checked if potential NATURA 2000 areas are located on the investigation area, which have not yet been registered at the EU. This is necessary because what counts in a case of doubt is the factual area status and not the location on the map.

Situation regarding regulatory approval
• Licence application (e.g. at the Ministry of Economic Affairs and Energy) necessary for (1) the construction and (2) operation of the power plant • Necessity of a transboundary environmental impact assessment (close to borders, i.e. < 10 km; distances have to be checked in the individual case)

Special importance

Due to different requirements and examination priorities, transnational procedures impede the processing and preparation of the documents. They may extend over a longer period, e.g. due to different interests.

Scope of investigation

It has to be ascertained if there have been similar procedures in the vicinity or if similar procedures are currently taking place. In addition to the examination of the political and planning situation in the country, in which the project is to be implemented, these criteria have to be recorded for the adjacent country as well.

Construction costs / operating costs
• Additional costs that exceed the costs involved in the erection of a power plant at all sites (purchase of land, remediation of contaminated sites, purchase of compensation areas, infrastructure development, costs of network connection and / or network expansion)

- Amount of recurrent operating costs on the potential area (gas transportation and provision costs, charges for cooling water supply, CO_2-certificates)
- Potential local businesses for the construction phase and for supporting the future power plant operation

Special importance

The efficiency of the project is decisively determined by the costs.

Scope of investigation

The costs of the construction of a power plant are normally to be regarded as similar, with the exception of the local specifics. What is important are the costs exceeding the pure investment costs, such as site-specific costs incurred for the infrastructure development. These costs have to be estimated and assessed.

The operating costs are decisively determined by the gas costs and the charges for cooling water supply. They have to be determined at the earliest possible stage.

Marketing opportunities

- Possibilities of direct power supply to contiguous industries
- Possibility to provide contiguous industries, e.g. with process steam
- Possibility to provide adjoining residential and industrial estates with district heating

Special importance

The efficiency and acceptance of a project are considerably increased by its connection to local industries and / or district heating supply.

Scope of investigation

The exploitation of marketing opportunities with local industries is to be investigated. In addition, it has to be examined if an integration into an existing district heating supply or the expansion of a district heating supply is a reasonable option.

Stakeholder analysis
• Possible objections to or rejection of the project by local residents (assessment of the project by the residents) • Possible objections to or rejection of the projects by politics (assessment of the project by politics) • Possible objections to or rejection of the project by non-governmental organisations (NGO) (positioning of the NGOs in relation to the project)

Special importance

The acceptance and support of the project by residents, politics and associations is an important key to the implementation of a power plant project.

Scope of investigation

Opinion surveys and investigations are to be conducted to find out about the current atmosphere within local and transregional associations and organisations. On the basis of the information obtained, a communication strategy is to be developed, which is based on the information required by the parties involved.

Environment / other influencing factors
• Sufficient availability of skilled personnel • Possibility of extreme climatic conditions • Possible social conflicts in the region or possibilities for the promotion of social projects

- Compliance with the general corporate strategy

Special importance

Particularities in the environment of the power plant or in the region can be advantageous for a project, but can also cause its failure.
A project outside the corporate strategy is not supported without resistance.

Scope of investigation

The particularities, i.e. aspects that are especially advantageous for the project and possible limiting factors are to be identified and quantified by using generally accessible statistics and press releases. This applies particularly to a project outside the corporate strategy.

10 Alternative evaluation

For the alternative evaluation, all evaluation results compiled by then are available. By this time, not more than five sites should remain in the evaluation process. The aim at this stage of the preliminary study is an improvement of the information situation, in order to:

- represent a comparable basis for evaluation,
- achieve better comparability and
- establish exclusion criteria, which could not be recognized so far.

10.1 Evaluation procedures

The evaluation procedures preferred for this phase are the utility analysis and the SWOT-analysis. To carry out site evaluations, the availability of data is especially indispensable in the stage of the alternative evaluation. In order to be able to assess the criteria in a criteria catalogue[1], a wide range of data from different sources is required. The sources that are stated are secondary and primary data acquisitions[2]. Goette lists four criteria for the handling of data, which are decisive for an evaluation and especially for a comparison of sites[3]:

- the availability
- the reliability
- the comparability and
- the topicality.

[1] cf. Appendices criteria overviews in sections: 16.1 Overview „Area-specific criteria“; 16.2 Overview „Technical criteria“; 16.3 Overview “Political and regulatory criteria”; 16.4 Overview “Economic criteria“; 16.5 Overview „Other criteria“

[2] cf. Goette (1994): p. 273 and cf. Freiling, Reckenfelderbäumer (2007): p. 156

[3] cf. Goette (1994): p. 273 ff.

In order to be able to assess the reliability of the data it is necessary to state their source. A comparison of data is only possible if the sources are known and information on the topicality can be provided.

Utility analysis

In order that the different quality of the data within the framework of a utility analysis can be assessed, it is indispensable to state the source of the data. This is to be evaluated using a factor for data quality before it is integrated into the evaluation as weighted. For evaluating the data, “data categories” are defined, to which the available data are to be assigned.

Evaluation criterias		Criteria description	Evaluation result	Information factor (0,5/1,0/1,5)	Information result	Description of information sources
Area specific						
Size of the area	Is the area sufficiently large for the planned project?					
	How large is the potential area?					
Ownership status	Is the purchase of land possible without any difficulty on the basis of the present ownership?					
	How many owners does the potential area belong to?					
	Who are the owners of the potential area?					
	Is the area in private or public ownership?					
Properties of the area	Does the building ground meet the standards of a power plant project?					
	Kind of ground (soil composition)?					
	Is the surface plane?					
Environmental situation and conflicts relating to past use						
Environmental situation	Are there any environmental risks that oppose the suitability of the site for the construction of a power plant?					
	Can floods be expected on the potential area?					
	Can earthquakes be expected on the potential area?					

Figure 10-1: Example of an evaluation chart for an alternative evaluation

SWOT-analysis

The SWOT-analysis should be complementary to the utility analysis, in order to view the sensitivity of the criteria, i.e. assess if the currently existing framework conditions can be projected to the future, and, if this is not to be expected, when and what kind of change can be anticipated.

10.2 Decision-relevant criteria in the alternative evaluation

As a decisive difference of the phase of the alternative evaluation compared to the preliminary study it can be stated that no criterion is particularly decision-relevant by itself. The following criteria turn out to be decision-relevant in the alternative evaluation phase:

- the result of the overall evaluation of the site in comparison to the other sites and
- taking account of the quality of the data.

10.2.1 Modified utility analysis in the alternative evaluation

In order to take account of the situation of equivalent criteria and the possibly existing different sources and qualities of data, the system of the utility analysis described in section 9.3.2 will be modified and adapted to the requirements in the alternative evaluation phase. The modified utility analysis will be carried out in ten phases on the basis of the already described criteria catalogue[1] that is subdivided into subject groups.

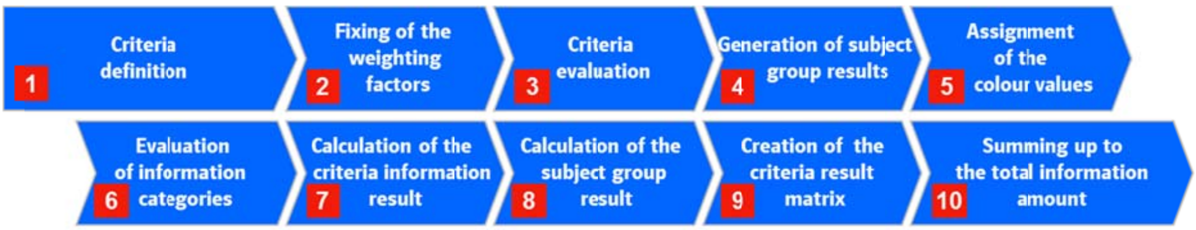

Figure 10-2: Phases of the utility analysis in the alternative evaluation

<u>Phase 1-4</u>

These phases are carried out in the same way as the approach described in section 8.2.3 Utility analysis and section 9.3.2 General overview of the utility analysis in the preliminary study.

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[1] see also Figure 9-5: Example of the structure of an evaluation catalogue

Phase 5

The approach will be changed in that colour values (see Figure 10-3) are assigned to the subject groups (SG_{ij}). The colour values of the respective subject group result will be transferred into the result matrix (see Figure 11-2).

Sachgruppenergebnis (SGij)	Zugehörige Farbwerte
5,0 – 3,7	GRÜN
3,6 – 2,3	GELB
2,2 – 1,0	ROT

Figure 10-3: Colour values of subject group results [1]

Phase 6

The quality of the data is assessed for each criteria sub-item and / or each criterion according to the classification system represented in Figure 10-4 and subsequently evaluated using an information factor (IF).

Information categories	Information factor (IF)
Data are based on own estimates and are checked by third parties from the same enterprise (e.g. competent departments)	0.5
Data are proven by third parties in the same enterprise (e.g. competent departments) and / or by informal or unofficial talks with authorities..	1.0
Data are proven by investigations (e.g. external expert opinions) and / or officially confirmed (authorities).	1.5

Figure 10-4: Information categories – description and evaluation[2]

1 Author's own graph

2 Author's own graph

Phase 7

Phase 7 takes into account the information quality in the evaluation procedure. This is done by multiplying the respective sub-items (Uij) by the information factor (IF) awarded in phase 6. A mean value is calculated from the results of the sub-item evaluation. The result is the criteria information result (KI_{ij}). If there are no sub-items, the criterion will be directly multiplied by the information factor (see Figure 10-5).

$$KI_{ij} = \frac{\sum_{i=1}^{n} U_{ij}}{n} * IF$$

KI_{ij} criteria information result

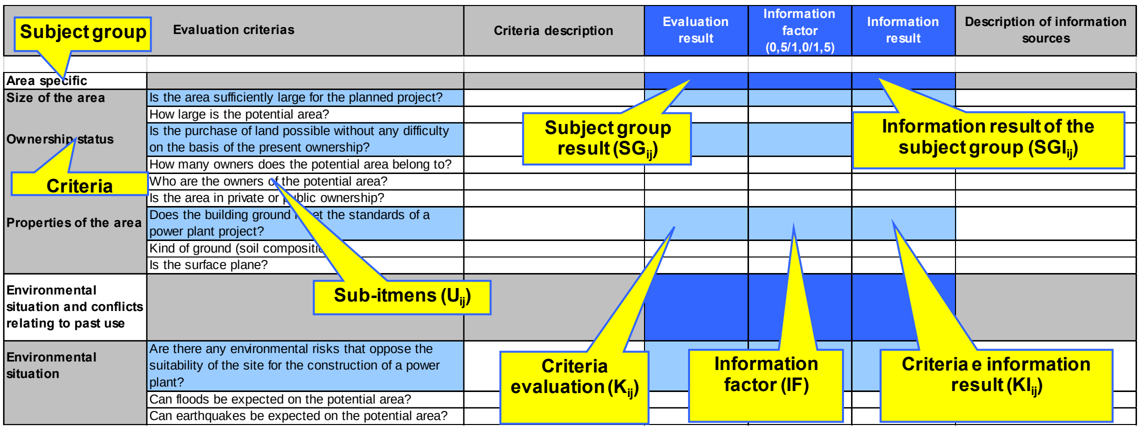

Figure 10-5: Overview of the evaluation table in the alternative evaluation [1]

Phase 8

The mean value from the criteria information results (KI_{ij}) ascertained in phase seven is calculated. This mean value represents the information result of the subject group (SGI_{ij}).

[1] Author's own graph

$$SGI_{ij} = \frac{\sum_{i=1}^{n} KI_{ij}}{n}$$

SGI_{ij} information result of the subject group

Phase 9

The transfer of the available information results of the subject groups (SGI_{ij}) to the result matrix constitutes the main focus of this phase. In addition to the already available colour values of the subject group results, these results are entered into the matrix.

Phase 10

Summing up the information results from the subject groups (SGI_{ij}) to the total information amount (NI_j) constitutes the final part of the modified utility analysis.

$$NI_j = \sum_{i=1}^{n} SGI_{ij}$$

NI_j total information amount

An exemplary result of the modified utility analysis is represented in Figure 11-2: Questionnaire result matrix of „Site evaluation example“. By combining colours with numerical values in the representation, different kinds of information are provided simultaneously:

- The coloured representation of the matrix fields conveys an overall impression and allows for a comparison of the results or partial results of the different sites.

- The numerical values support the coloured display of the results and allow for an estimation of the respective evaluation results with regard to their robustness or reliability. The possible result range is between the numerical values 0.5 and 7.5.

Possible attributes of numerical value parameters will be explained in the following graph.

7,5	Fully meets the requirements and/or no risk or conflict is recognizable. These assessments are confirmed by official information. This evaluation is very „robust“. Best possible result
5,0	Fully meets the requirements and/or no risk or conflict is recognizable. These assessments are partly confirmed by official information and /or expert opinions and are based only to some extent on own estimates. These evaluations can therefore be regarded as “robust”. Good, “robust” resulr
2,5	Fully meets the requirements and/or no risk or conflict is recognizable, but this assessment is not confirmed by official information and/or expert opinions, but is exclusively based on own estimates and is therefore not very “robust”. Not reliable result
4,5	Meets the requirements satisfactorily, and /or a potential risk or conflict is recognizable. These evaluations are confirmed by official information and are very “robust”. The risk or conflict is therefore assessable. Very„robust“ result.
3,0	Meets the requirements satisfactorily and /or a potential risk or conflict is recognizable. The assessments are *partly* confirmed by expert opinions and are only based on own estimates to some extent. They can therefore be regarded as “robust”. The evaluations, potential risks or conflicts are assessable. Satisfactory result
1,5	Meets the requirements satisfactorily and /or a potential risk or conflict are recognizable. The assessments are *not* confirmed by official information. The evaluations, potential risks or conflicts cannot be assessed as “robust”. Unsatisfactory result
1,5	Barely meets the requirements and /or a very high risk or conflict exist. These assessments are confirmed by official information. This evaluation is very “robust”, and the risk or conflict is therefore clearly identified. Poor result

1,0	Barely meets the requirements and /or a very high risk or conflict exist. These assessments are partly confirmed by official information and /or expert opinions and are only based on own estimates to some extent. They can therefore be regarded as "robust". The evaluations, potential risks or conflicts are assessable. Very poor result
0,5	Barely meets the requirements and /or a very high risk or conflict exist. The assessments are not confirmed by official information. The evaluations, potential risks or conflicts cannot be assesses as "robust". Poorest result

Figure 10-6: Attributes of numerical value parameters „modified utility analysis"

10.2.2 SWOT-analysis in the alternative evaluation

The SWOT-analysis can be used for a sensitivity examination of the criteria, i.e. an assessment if the currently existing framework conditions can be projected to the future, and if not, what kind of change is to be expected and when.

The SWOT-analysis is to be carried out in addition to the utility analysis. Its task is to provide a compacted supplement to the criteria evaluated in the modified utility analysis. This is done by representing the strengths and weaknesses of the respective site and by comparing them with the changes to be expected, i.e. the chances and risks.

The SWOT-analysis should be used with the following criteria in particular:

- criteria for which a change in the framework conditions is likely to happen or cannot be excluded and
- criteria which show a high risk or conflict potential (red fields)

These include, for example, network access, competing use and the political situation (including NGO[1]).

[1] NGO = Non Governance Organization

A next step towards the determination of decisive fields in which a SWOT-analysis should be carried out is taken by summarizing the weighting factors and the information factors of their criteria in a common matrix.

		Criteria weighting (influence on site potential)				
		weak	minor	normal	high	very high
Information factor (Information security)	high	**0,5**	**1,0**	**1,5**	**2,0**	**2,5**
	medium	**1,0**	**2,0**	**3,0**	**4,0**	**5,0**
	low	**1,5**	**3,0**	**4,5**	**6,0**	**7,5**

Figure 10-7: Criteria Weighting & Information factor matrix[1]

This matrix supports the decision for more detailed analyses with criteria in which the combination of lower information security and higher weighting is critical, i.e. associated with a higher risk potential. For these criteria, weaknesses and risks are to be defined using a SWOT-analysis in order to determine measures to reduce them, if necessary.

Possible attributes of numerical value parameters will be explained in the following graph.

1 authors own matrix

Attribute	Description
O.5 – 2.4	From the combination of the weighting (=significance) of the criterion for the suitability of the site and the corresponding validity of the information available, *no* or only *insignificant* risks or conflicts are to be expected. Can be managed by routine procedures
2.5 – 4.8	From the combination of the weighting (=significance) of the criterion for the suitability of the site and the corresponding validity of the information available, risks or conflicts are *likely to be expected*. Further investigation is recommended
4.9 – 7.5	From the combination of weighting (=significance) of the criterion for the suitability of the site and the corresponding validity of the information available, risks or conflicts *are to be expected*. Further analysis investigation is not recommended

Figure 10-8: Attributes of numerical value parameters „criteria weighting & information factor matrix„

Transferred to the criteria overview of the example AA in appendix 16.6 to 16.10 the coloured scheme shown in Figure 11-2 results.

11 Example of a site evaluation

The practical implementation of the system shown in the present thesis is effected using a site comparison of three virtual gas and steam power plants, in the following referred to as AA, BB and CC.

The requirements on and the framework conditions for the site are as follows:

- The sites are in located in Europe, but in different countries.
- On one site, a gas and steam power plant is currently being run, which will have to be replaced.
- Another site has the potential for the construction of a future second power plant.
- The third site offers very good conditions for the access to the electricity and gas grids.
- The comparative requirement is the implementation time

11.1 Example of an alternative evaluation

As there are three different sites, AA, BB and CC, with different starting positions, the alternative evaluation is carried out.

Essential differences between the virtual sites a:

Location	Short description
AA	• decomissioning of an existing old power plant, brownfield; • partial use of the existing infrastructure • sea-water cooling

Location	Short description
BB	• very large land area available, greenfield, preparatory work for the construction of a possible second power plant is to be included in the planning • long distance to the gas and electricity grid connection • river-water cooling
CC	• limited size of land area, but sufficient space for a gas and steam power plant • direct connection to the electricity and gas grids • No direct cooling water connection (cell cooler recommended)

Figure 11-1: Site example description

A detailed evaluation according to the criteria catalogue is carried out by assumptions using these three simulated sites as examples. An overview of the assumptions in detail and their short descriptions is to be found in the appendix.[1]

The summarized result of the evaluation of the above three sites for a gas and steam power plant is shown in Figure 11-2.

Location	Total evaluation Value (SGij, Kij and Uij)	Area specific criterias					Tecnical criterias				Political and regulatory criteria				
		Size of the area	Properties of the area	Ownership status	Environmental situation	Conflicts relating to past use	Cooling water situation	Network access	Network capacity	Fuel transport capacity and infrastructure	Political situation	Situation with regard to planning law	Competing land use	Environmental conditions	Situation regarding regulatory approval
Criteria weighting															
Location AA	18,1	3,3	3,3	5,0	3,5	3,8	3,8	4,9	4,6	4,4	1,8	4,0	2,5	3,3	3,8
Location BB	16,2	5,0	2,0	2,5	2,9	3,8	4,2	2,7	4,3	2,9	2,5	3,7	3,0	3,3	3,3
Location CC	16,8	2,0	3,3	3,3	4,4	4,2	2,0	2,8	4,0	4,6	2,5	3,8	4,5	4,0	3,4

Location	Economic criterias								Other criterias				
	Construction costs	Operating costs	Redispatch	Marketing opportunities	Energy market prospects	Potential synergies	NPV (Net Present Value)	Tax system	Local contacts	Stakeholder analysis	Structure of the region and the country	Corporate strategy	Workforce
Criteria weighting													
Location AA	3,8	3,6	2,3	1,8	3,0	2,3	4,0	3,8	4,3	2,0	3,7	4,0	5,0
Location BB	2,0	3,1	3,3	1,8	3,0	1,5	3,7	3,0	3,7	3,0	3,7	4,5	3,3
Location CC	2,2	3,6	3,3	2,3	3,0	1,3	3,7	3,8	2,7	3,0	4,0	4,0	3,7

Figure 11-2: Questionnaire result matrix of „Site evaluation example“[2]

[1] exemplary location AA in the appendix 16.6 to 16.10

[2] same matrix is shown in appendix 16.12 Questionnaire result matrix of „Site evaluation example“

11.2 SWOT analysis of an alternative evaluation

On the basis of the modified utility analysis, a SWOT analysis would have to be carried out in addition. What should be considered are, on the one hand, the criteria, for which a change in the framework conditions is likely to take place or cannot be ruled out and, on the other hand, those which show a high risk or conflict potential.

An exemplary result of the developed criteria weighting and information factor matrix is represented in Figure 11-3. The colours indicate criteria fields, in which further actions are to be taken according to the result parameter attributes described in Figure 10-8.

Location	Total evaluation Value (SGij, Kij and Uij)	Area specific criterias	Tecnical criterias	Political and regulatory criteria	Economic criterias	Other criterias
		Size of the area Properties of the area Ownership status Environmental situation Conflicts relating to past use	Cooling water situation Network access Network capacity Fuel transport capacity and infrastructure	Political situation Situation with regard to planning law Competing land use Environmental conditions Situation regarding regulatory approval	Construction costs Operating costs Redispatch Marketing opportunities Energy market prospects Potential synergies NPV (Net Present Value) Tax system	Local contacts Stakeholder analysis Structure of the region and the country Corporate strategy Workforce
Criteria weighting		3,3	3,6	3,7	3,5	3,2
Location AA	2,8	2,3	2,2	3,4	3,3	2,7
Location BB	4,1	3,5	4,6	5,2	4,4	2,6
Location CC	3,1	2,4	3,6	2,6	3,8	3,1

Figure 11-3: Example of a criteria weighting and information factor matrix

The evaluation of the critical fields from the information and weighting factor facilitates the prioritization of the critical criteria, for which the strengths and weaknesses should be analysed in more detail.

Only the description of the strengths and weaknesses can make them really transparent and comprehensible and allows a comparison of the individual sites in a next step.

12 Empirical study on the criteria weighting

The main target of the chapters 9 to 11 was to provide and discuss a profound overview of the identified criteria and the application possibilities of evaluation methods and to develop new methods. It was noted here that an evaluation always contains an individual component of the person who carries it out. This means that different significance is assigned to the criteria.

In this chapter, the hypothesis or theory[1] will be investigated, on the basis of an empirical study, if and to what extent a site evaluation of the site criteria summarized in subject groups differs if this evaluation is made by different people and if an "empirically proven" statement can be derived[2].

In the following sections, the practical question of data acquisition and the approaches for the preparation and analysis of the data will be described. The approaches and methods known from literature will, to some extent, be mentioned and explained, where appropriate. An overview about the main characteristics of the investigation(s) can be seen in the picture below (see Figure 12-1).

After discussing the different possibilities of data acquisition and evaluation, the results of the survey will be analysed and discussed. Here, different results will be linked, where appropriate, in order to investigate possible influencing factors and/or tendencies in weighting site criteria. This is also referred to as ambiguity feature (see p. 261… section 12.1.3).

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[1] As a theory never proves to be "true", i.e. science can never reach the truth and there are, therefore, no "levels of probability" (Popper 1966, p. 223) of hypotheses or theories, the competition of theories is endless and the result are even more explanatory, general theories. cf. Albers et al. (2009) p. 3 f.

[2] In this context, Schnell et al. discuss the problem of separation of statements that are to be interpreted empirically meaningfully from empirically "meaningless statements". Popper solves this problem easily: if statements are potentially falsifiable and not purely analytical (e.g. mathematics, which has no statement about reality, i.e. no empirical statement), they are empirically meaningfully justifiable sentences. The potential falsification is therefore identical with the distinction criterion: "An empirically scientific system has to be able to flounder over experience." (Popper 1976: p. 15); cf. Schnell et al. (2008) p. 73 f.

Aim of the study	Population	Observation unit	Characteristic and / or variable	Possible result
Determination of the weighting of power plant site factors	Selected groups of people with a relation to power plant sites	One person	X = weighting of the criterion	Significance: 1 – weak 2 – minor 3 – normal 4 – high 5 – very high
Information on the characteristics of the person	Selected groups of people with a relation to power plant sites	One person	Y= Characteristics of the person	Y- Distribution matrix from decision-making responsibility and practical experience
Information on value concepts	Selected groups of people with a relation to power plant sites	One person	Z = Tendency of the value concept	Favours power plants Neutral towards power plants Opponent to power plants

Figure 12-1: Characteristics of the empirical study on the criteria weighting

12.1 Data collection and approaches towards processing and evaluation

12.1.1 Empirical research methods

The term ‚empiricism' stems from Greek and means experience, empirical science[1]. Consequently, empirical science is nothing more than a systematization of learning by experience. "Science is organized knowledge" – a sentence which is said to originate both from Immanuel Kant and from Herbert Spencer.[2]
Albers et al. differentiate between four basic types of research, (1) descriptive research, (2) exploratory research, (3) empirical test and (4) prescriptive, advisory research[3].

In line with the nature of the task set in the present thesis, the tools for the "empirical test" are to be used, which is more to be assigned to the area of quantitative empirical research. Generally, empirical research based on experience can be subdivided into two strands, the large-scale, quantitative and the small-scale, qualitative empirical research.

In qualitative research, the focus is on the carefully selected individual case. Instead of analysing statistics, it is the interpretation of individual observations that is decisive[4].

[1] cf. Brockhaus Enzyklopädie (1988) p. 355

[2] cf. Behnke, Joachim; Behnke, Nathalie (2006) p. 53 f.

[3] cf. Albers et al. (2009) p. 6 f
Albers et al. attempt to provide a description of the methods of empirical research that is neutral in terms of economics and social sciences. Additional literature can be found in works on the methods of empirical social research (e.g. by Schnell / Hill / Esser) or on empirical economic research (e.g. Hübler), statistics (e.g. Hartung) as well as works on econometrics (e.g. Davidson / Mackinnon).
An econometric investigation is aimed at four main purposes: (1) testing an economic theory, (2) structural analysis for planning or decision purposes, (3) political simulation and (4) prognosis. cf. Eckey / Kosfeld / Dreger (2011) p. 2 f.

[4] Qualitative research in the form of case studies is applied in areas with a low level of knowledge and is aimed at gaining more in-depth understanding of the complex real phenomenon. On the basis of past

By adequately connecting the individual interpretations, findings can be produced, which, however, do not meet the requirement of representativeness. Qualitative approaches normally refer to social and aesthetic research areas, where social interaction and structures within a society are to be investigated[1]. Qualitative empirical research attempts to be as close as possible to the subject of investigation by covering the full bandwidth of connections, e.g. of social fields.[2]

Reference is made to perceptions and statements of the object of research which reveal the individual meanings. Figures and measurable data, however, are not able to provide adequate information in that respect.

Another characteristic of qualitative empirical research is the openness within the research process. At the beginning there is no pre-designed theory, which is applied to the object to be investigated. This can be interpreted as strength, but also as weakness, depending on the object of investigation.[3]

Adapted from the model of natural science, quantitative empirical research approaches are based on the acquisition of data, mainly through questionnaires, or on observation. They are usually guided by hypotheses and theory. Events are quantified, i.e. represented in figures. For the calculation of frequencies, the data obtained in this way are statistically evaluated with the purpose of verifying or refuting a previously made hypothesis. Quantitative research often proceeds from a small group, which is deemed to be representative for the research issues in question, and then draws deductive conclusions for a larger group.[4]

---

explanations and / or in-depth understanding, the scientist formulates hypotheses which are supposed be valid beyond the investigated cases. cf. Albers et al. (2009) p. 6.

[1] cf. Schnell et al. (2008) p. 7 ff.

[2] cf. Bryman (1988) p. 61 ff.; Atteslander (2008) p. 10 ff.

[3] cf. Hartung (2009) p. 310 f.

[4] cf. Bamberg/ Boll (1998) p. 6 f.; Hartung (2009) p. 4 f. and 314 ff.;

“Samples may be drawn from a DGP (data-generating process) just as they may be drawn from a population.” cf. Davidson/ Mackinnon (2009) p. 30 ff.

“Guiding principles of research (planning) are the clear separation between causes and results, clear operationalization of theoretical connections, the measurability and quantification of phenomena, the formulation of investigation directives which allow for a generalization of results and establishing generally applicable laws.” cf. Flick (1998) p. 10 ff.

It is exactly this approach that was pursued in the present empirical study.
The general procedure and the subsequently applied method will be dealt with in the following section.

12.1.2 Data collection methods for the empirical study

Before empirical data are available and hypotheses can be tested, substantiated data collection is necessary. In economic and socio-scientific research, procedures, such as the interview or the written survey are widely used for this purpose.
There are two ways to obtain data – collecting new data (primary data) or drawing on available data, which have already been collected for other research purposes (secondary data)[1].
The newly developed matrix of the site criteria summarized in subject groups was described in detail in the previous sections. It has been found that no suitable secondary data exist in this context and primary data have to be collected in this case. The most important form of data acquisition is the interview, which, in turn, is only an umbrella term for several data acquisition methods. An instrument for the standardized interview is the questionnaire. An overview of the various methods of data acquisition is provided in Figure 12-2.

[1] cf. Bamberg / Baur / Knapp (2011) p. 8 ff.; cf. Albers et al. (2009) p. 49 ff.
There are two disadvantages of the secondary data: first, they may, in terms of their content, not always be suitable for the research problem in question and second, the lack of knowledge of the way the data were collected and analysed, may make a final judgement on the data quality impossible.

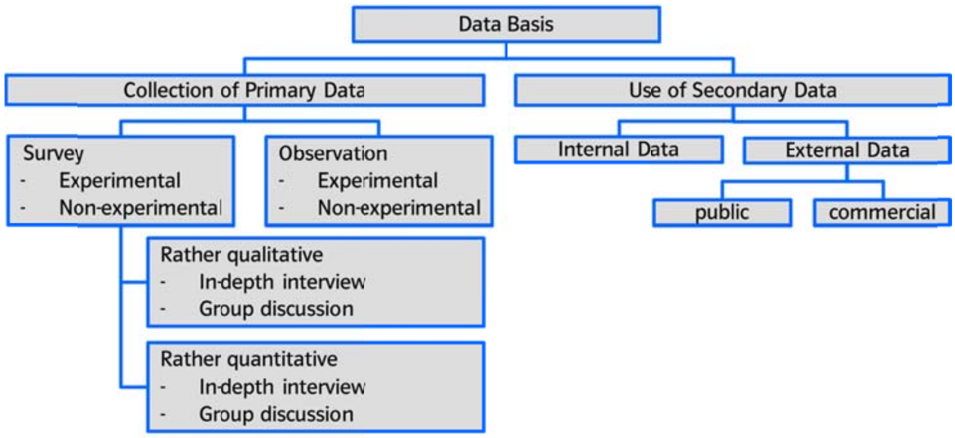

Figure 12-2: Methods of data acquisition[1]

For the empirical study carried out for this thesis, the written survey[2] was identified as the most effective way. The answers of the respondents are hardly influenced in this kind of survey, and therefore provide largely undistorted results. Influences from the cover note, the design of the questionnaires and the topic of investigation tend to be negligible. The time needed for collecting the data is very well calculable, i.e. limited. Due to a target-oriented choice of respondents, a fairly high representativeness[3] can be reached. However, representation problems can arise due to a low return rate.[4] A summary of the advantages and disadvantages of the individual survey techniques is provided using the different criteria in Figure 12-3.

[1] Author's own graph based on Albers et al. (2009) p. 50 f.
Every method of data acquisition has its advantages and disadvantages. According to Maria Kaya (in Albers et al.), the choice of the acquisition method should be made dependent on essential factors, such as: (1) the investigation project, (2) the target group, (3) the required information quality and (4) the restrictions in terms of time and costs.

[2] In the literature, the email survey is assigned to the internet survey or the written survey. However, it has more the nature of a written survey rather than that of an internet survey and is therefore assigned to the former in this thesis.

[3] In this context, Schnell / Hill / Esser refer to the validity as the central quality criterion of a measurement. cf. Schnell / Hill / Esser (2012) p. 154 ff.

[4] According to Hartung, the return rate varies between 10% and 80%, based on empirical values. cf. Hartung (2009) p. 310

Evaluation criterion	Written survey	Telephone survey	Personal interview	Internet survey
Data accuracy	very high	medium to very high	medium to very high	very high
Amount of data to be collected per case	low	medium to very high	very high	very high
Flexibility	low	medium to very high	very high	high
Representativeness	low to high	high	very high	very high
Costs per case	very low	low	medium to high	high
Time required per case	medium	low to very low	medium to very high	low to very low
Bias of interviewer	very low	high	very high	very low

Figure 12-3: Advantages and disadvantages of survey techniques[1]

In the following, the characteristics of the questionnaire developed herein will be explained in more detail, such as the specification of the questions and their number, the formulation of the questions and their order. The questionnaire is accompanied by a cover note, which specifies the purpose, the inquirer and the answering procedure.

A certain success in increasing the return rate is attributed to the cover note. Hartung recommends not to keep it too personal, but also not too impersonal.
The questionnaire developed within this thesis was sent by email. On the other hand this offers the possibility to specify the topic, the inquirer and the procedure for completing the questionnaire at the beginning in a more impersonal introduction. On the other hand, the concern can be explained in a more personal manner in the introductory text of the email. Below there is an example of an email text. The standard introduction can be found in the appendix, section 16.16 “ Questionnaire for the empirical investigation of the criteria weighting ”.

[1] Author’s own graph based on Albers et al. p. 54

The email survey offers two further advantages. First, an outlook reminder can be set directly in the email, which automatically reminds the respondent of completing the questionnaire at a self-determined time. Second, a reminder can be created and sent out by email very quickly.

Krüger, Jan

Von:	Krüger, Jan	
Gesendet:	Dienstag, 4. September 2012 19:34	
An:	[redacted]	
Betreff:	WG: Doctoral thesis // Questionnaire	
Verlauf:	**Empfänger**	**Gelesen**
	[redacted]	Gelesen: 04.09.2012 21:44

Dear Mr. [redacted]

I would be very pleased when you would spend 20 minutes of your limited time to support me in my dissertation.
I'm writing the dissertation at the University UPC (Universitat de Politécnica de Catalunya) in Barcelona, Spain.

In my doctoral thesis I deal with the question of a possible adaptation and extension of the existing classical site theories to the new construction of power plants, in particular to gas and steam power plants.
For this purpose I collect empirical data. The attached questionnaire contents several questions to verify my thesis.

Dissertation Jan Krüger_Questi...

I know you have own experiences in new build and plant operation in Hungary and their special circumstances.
So I'm hoping that you give me the chance to participate on your experiences and opinions by filling out the attached questionnaire.

It would be very helpfully if you could send the filled out questionnaire until the end of September!

Thank you very much in advance for all your interest, efforts and the support!

With kind regards / Saludos Cordiales / Mit freundlichen Grüßen
Jan Krüger

[redacted]

E.ON New Build & Technology GmbH, Sitz/Registered Office: Gelsenkirchen, Amtsgericht/District Court Gelsenkirchen, HRB 3171,
Vorsitzender des Aufsichtsrats/Chairman of the Supervisory Board: Prof. Dr. Klaus-Dieter Maubach,
Geschäftsführer/Board of Management: Dr. Donald Weir (Vorsitzender/CEO),
Dr. Ralf Güldner, Gerhard Seibel, Erik Zizow

Figure 12-4: Example of a cover note of an email and standard introduction to the questionnaire

When *formulating and arranging the questions*, various aspects should be considered in advance in order to guarantee meaningful data and a practicable data preparation with subsequent data analysis.

In science, quantitative data collection is understood to be the attempt to measure (quantify) characteristics and their significance, such as the opinion of people on power plant sites[1]. The measurement, referred to the specific case of investigation, is the assignment of a real number to the identified site factors by a selected group of people. In statistics this is known as the so-called random sample.[2] The people selected for this study are all in a certain professional relation to the object of investigation - a power plant and its site factors. This increases reliability[3]. Correspondingly, a certain extent of previous knowledge can be presumed to be a given factor when formulating the questions for the data collection[4]. However, as these professional relations differ in their degree and nature, data on the environment and the background of the respondents have to be collected as well, in order to be able to examine possible correlations when analysing the data[5]. It may also be presumed that, due to certain personal general attitudes to power plants and environmental values, the site factors are evaluated differently.

This results in three essential sections for the questionnaire developed herein:

(1) General data on the person;

(2) Data collection on the evaluation of the site factor and

(3) Value orientation with regard to power plants and environment.

---

[1] cf. Albers et al. (2009) p. 65 ff.

[2] The question, which respondents will finally be included in the data acquisition, facilitates the investigation and representation of the problem in the theory of sampling. cf. Hartung (2009) p. 18, 269 ff; Schlittgen (2008), p. 276 ff., Kähler (1995) p. 165 ff.

[3] Reliability is understood to be the trustworthiness of a test; see also Hübler (2005) p. 37 ff; Albers et al. (2009) p. 137 ff;

According to Schnell / Hill / Esser, “reliability” can also be understood to be the extent to which repeated measurements of an object with one measuring instrument yield the same results. cf. Schnell / Hill / Esser (2008), p. 151 ff.

[4] This is also referred to as empirical relative; structurally integer representations are also referred to as morphisms. cf. Schnell / Hill / Esser (2008) p. 138 ff.

[5] In this context, this is also referred to as so-called categorical data. According to Andreß, categorical data are variables which have a limited number of expressions (categories, such as e.g. the sex of a respondent); cf. Andreß / Hagener / Kühnel (1997) p. 1 ff.

The different character of the question sections also goes along with different scales representations of the results. Here, scales are to be understood to be aggregated answer formats of a data collection[1]. They decide which evaluation methods are possible.
Different possible scale types and their measuring levels (possible unambiguousness)[2] can be seen in the following figure.

Specified characteristic					
Scale type	**Zero point**	**Distances**	**Ranking**	**Identity**	**Example**
Nominal scale	no	no	no	yes	Participation in the approval process of criteria weighting
Ordinal scale	no	no	yes	yes	
Interval scale	no	yes	yes	yes	Time
Ratio scale	yes	yes	yes	yes	Length

Figure 12-5: Unambiguousness of scale types[3]

The questions raised in sections one and three of the herein developed questionnaires offer, on the one hand, the possibility of differentiating the equality between the respondents, providing so-called nominal scales. On the other hand, they offer the possibility of a ranking, which is referred to as ordinal scales[4].
A ranking with regard to the question asked has also to be made up in the second section of the questionnaire (=ordinal scales).

[1] According to Schnell / Hill / Esser, a scale is a homomorphous mapping of an empirical to a numerical relative. A homomorphous image is an irreversibly unambiguous assignment of a number to several objects. cf. Schnell / Hill / Esser (2008) p. 139f;

[2] The measuring level of a scale becomes the higher, the fewer transformations of the measured values are admissible. As a general rule, the higher the measuring level, the higher is the information content of the measurement. cf. Schnell / Hill / Esser (2008) p. 144;

[3] Author's own graph based on Schnell / Hill / Esser (2008) p. 144;

[4] According to Hartung, this type of scale already has a higher level than the nominal scale, the values of which differ in their intensity and can be arranged according to the strength of the intensity. cf. Hartung (2009) p. 16 f.;

The formulation of the questions in the first section of the questionnaire for the empirical study should provide information about the following person-related details: (1) professional relation, (2) possible leading position in a site decision-making process, (3) professional experience and experience in the energy sector and (4) experience in site decision processes.

In the second part of the questionnaire, questions are replaced by situations which have to be evaluated. In a pilot test with three representative test persons it turned out that for the data collection planned for the present study, understanding and validity[1] for a personal evaluation is much higher in a description of a situation of the individual items than in an identical preformed question. The arrangement and sequence of the individual situations followed a stringent system for a preferably distortion-free weighting.

For this, the following pattern was used:

(1) All five different subject groups (cf. definition in section 9.3) are addressed six times;

(2) The five subject groups are repeatedly described in a situation in blocks of five, in which the sequence can vary;

(3) Distributed over the blocks of five, all subject groups are addressed three times positively and three times negatively.

The following figure shows the second survey section with a graphic representation to visualize the survey system / matrix.

[1] Validity is here understood to be the quality of the validity of the measurement; see also Hübler (2005) p. 37 ff; Albers et al. (2009) p. 137 ff;

According to Schnell / Hill / Esser, the validity of a measuring instrument is understood to be the extent to which the measuring instrument actually measures what it is supposed to measure. cf. Schnell / Hill / Esser (2008) p. 154 ff.;

15 x	(red)	negativ
15 x	(green)	positiv
political	(red)	3 x
	(green)	3 x
technical	(red)	3 x
	(green)	3 x
economically	(red)	3 x
	(green)	3 x
Area-specific	(red)	3 x
	(green)	3 x
any other	(red)	3 x
	(green)	3 x

Figure 12-6: Survey system for the five subject groups of site criteria[1]

In the last – the third – part of the survey, possible attitudes to power plants and environmental policy were recorded using quotations and direct opinion poll. Topics relating to environmental and power plant issues were, if possible, addressed alternately in order to avoid distortion of data due to a repetition of topics[2].

When *defining the questions* in sections 1 and 3 of the survey, the aim was, with as little effort and expense as possible, to gather a maximum of relevant information on the person which could form decisive factors for the weighting of a power plant site from different perspectives.

In section two of the survey, the content is already clearly defined according to the possible summary developed in chapter 9 and illustrated in figure 9-6. Only the individual situation that is described in the questionnaire and that addresses the individual subject group, is freely formulated for the empirical study.

The *number and scope of the questions* were limited so that the survey on the weighting of the site subject groups will produce a maximum of comprehensiveness and variation and / or transparency. Including the general introduction, the personal details, the subject group weighting and the opinion and attitude polling, answering the questions should take between 15 and 20 minutes.

[1] Author's own graph out of evaluation model; for further details question wise see appendix chapter 16.17 Survey system for the five subject groups of site criteria

[2] In this context, Maia Kaya in Albers et al. speaks of a so-called halo-effect, i.e. a question "radiates" on the following, which is then no longer answered neutrally. cf. Albers et al. (2009) p. 54 f.;

The time limitation, along with the compactness, is supposed to help increase the readiness of the respondent to complete the questionnaire.

A few general rules-of-thumb and hints on the formulation of questions and / or statements are attached in the appendix section 16.22.[1]

12.1.3 Analytical method of the empirical study

Prior to the actual analysis and preparation of the data of the study, a rough overview of the basic methods will be provided in the following.
A more complex and detailed discussion and investigation taking into account all known mathematical and statistical methods is not the aim of the present study. However, reference to appropriate literature sources and theory will be made where required.

The data analysis and interpretation carried out in the present thesis comprises the following steps:

a) Frequency distribution using figures and parameters
b) Relations of results and values (such as location parameters)
c) Connections between characteristics (ratios)

The first choice for structuring the data of the survey in a clear and transparent way is the table and the chart. The significances of the characteristics for the metric and ordinal characteristics measured here can be arranged by size. Furthermore it seems appropriate to calculate the number of investigation units in which the significance of a characteristic was observed (e.g. the weighting) and to display it graphically, e.g. in different bar charts. This is referred to as frequency distribution of the single variables.

[1] cf. Schnell et. al. (2008) p. 336 ff, p. 354

The summarised presentation of the frequency distribution of all variables in a diagram represents a marginal counting[1]. In the present thesis, reference is mainly made to the relative frequency.

It can also be advantageous to describe large volumes of data roughly by using a few characteristic values. Firstly, centres, so-called location parameters or measures of location[2] can be determined and secondly, indicators of the variation of the significances can be calculated (e.g. the size of the range which covers all weightings). In the literature, this is also referred to as scattering[3] (e.g. the size of the range that comprises all weightings). The most frequent parameters used in this study are the mean value[4] and the modal value. Scattering indices were only formed and discussed in this study when reference was made to specific significance ranges. It did not seem useful to compare simple indices of the scattering with each other.

The question could be, for example, how many per cent of the weighting of all respondents are accounted for by how many per cent of the respondents. Is the lowest weighting perhaps accounted for by a very small number of respondents? When determining such significances of characteristics/properties, this is referred to as concentration[5].

---

[1] cf. Schnell/ Hill /Esser (2008):p. 431 ff.

In frequency distribution, distinction is made between absolute and relative frequency. The absolute frequency of x_n is understood to be the number of property values that match the characteristic x_j. The relative frequencies state the proportion of the statistical units, in which the nth significance was measured; cf. Eckey/Kosfeld/Türck (2008): p. 31 ff.; cf. Hartung (2009): p. 20 ff;

[2] The measure of location is a measured value which states a “centre” of the observation value in an appropriate way. cf. Hartung (2013) p. 31; cf. Eckey/Kosfeld/Dreger (2002) p.41 ff.;

[3] Scatterings or scattering indices are quantities that are related to suitable measures of location and that represent a characteristic feature of a distribution. The most common include

a) The average deviation (a statement how far an individual measured value deviates, on average, from the mean value of the totality of measured values),
b) The variance (mean value of the squared deviations of the individual values from the mean value of the distribution) and
c) The standard deviation (the root of the variance of a distribution of amounts of data);

cf. Behnke, Joachim; Behnke, Nathalie (2006) p. 132 ff, 279 ff,288 ff.; Schlittgen (2013) p. 51 ff.;

[4] The mean value states the average significance of all measured values. It is also referred to as arithmetic mean or average value. cf. Bourier (2013) p. 78; cf. Schlittgen (2013) o. 41 ff.;

[5] This can definitely be presented in graphical form, which did not seem useful within the present study.

So-called ratios[1], also referred to as indices, however, reflect the ratio of a certain group of people, such as High Management, to the total number of the respondents. These could also reveal tendencies in the weighting of groups of people.

In the survey, data on several characteristics were collected simultaneously (e.g. working years, professional position, environmental values, etc.) These individual characteristics[2] can, in combination, be summarised to an ambiguity characteristic. This could produce new statements on the concentration or ratio.

Finally, the findings of the above presentation are, where possible and meaningful, transferred to single tendential parameters, which serve to prove the hypothesis and to represent general tendential rules.

Recognizing a connection between two or more characteristics is considered essential in operational practice[3]. When investigating the connection between two characteristics, this study focusses on the questions:

a) is there a connection at all and
b) of what particular form is this connection[4].

Taking into account the objective of the study or the statistical question, respectively, further methods of statistical analysis and evaluation have been waived in the interest of a fact-based interpretation.

12.2 Analysis and discussion of the empirical study

In the following, the concrete results of the empirical study will be graphically represented und discussed in sequence.

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[1] cf. Bourier (2013) p. 119 ff.;

[2] This is also referred to as one-dimensional characteristics.

[3] cf. Bourier (2008): p. 195;

[4] A further question that could be discussed is that of the strength (intensity). Methods from science include the regression and correlation analysis.

As already explained in section 12.1.2, the first and the last part of the survey focussed on general information on the group of people and/or attitudes and personal values and principles. Following a differentiated consideration of the relevant profiles that can be derived, these are related to the results of the scale investigations, where appropriate.
Each statement is discussed and evaluated in terms of its relevance and derivable tendencies.

Unfortunately, the *response rate* of the completed questionnaires could not be increased above average, despite the use of different media, such as telephone, email, etc. With 52% it is, however, still above the general empirical values[1].

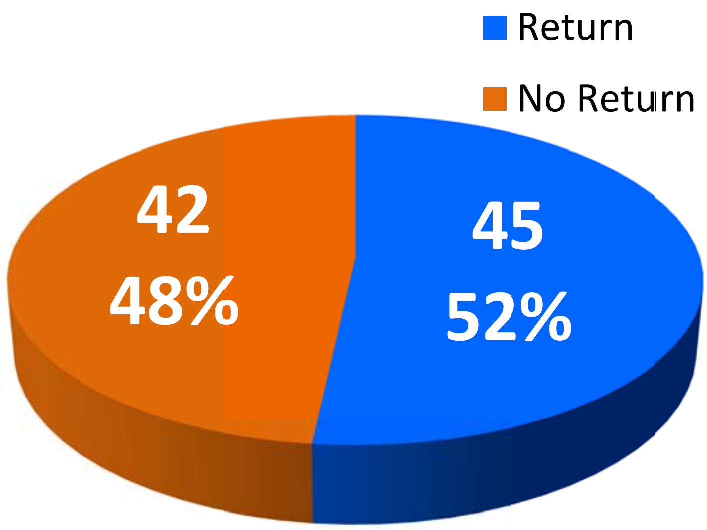

Figure 12-7: Response rate of the completed questionnaires

[1] cf. chapter 12.1.1

12.2.1 General information on the group of people

In this section, the answers of the first part of the questionnaire "General nature" will be evaluated. Apart from the basic consideration, further options for evaluation and possible optimizations for improving the significance will be provided.
The first question of the questionnaire was meant to ascertain the *professional background* of the respondent[1]. Unfortunately, no questionnaires were returned from representatives of areas not directly related to the energy sector, such as politics, authorities and universities. This is why there is a general concentration in the areas of construction and operation of power plants and the energy sector, with more than half of the respondents belonging to the power plant construction area. Such a result restricts the evaluation of tendencies and their significance throughout different groups of respondents.
The first question already revealed one weakness of the questionnaire. As was established later, there was a deviation among the individual respondents regarding the criteria based on which they grouped themselves into the different categories. At the end of this section 12.2.1, an additional set of questions with a different assignment introduced subsequently, will be presented for a partial calibration of the result.

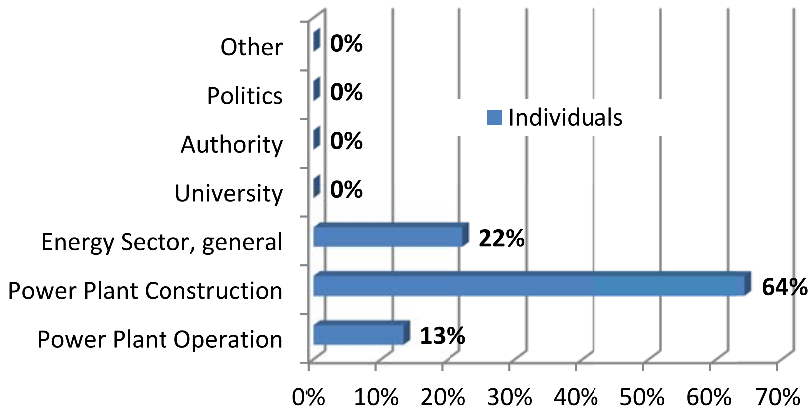

Figure 12-8: Percentage distribution of the respondents over the areas of business

[1] cf. chapter 16.16 Questionnaire for the empirical investigation of the criteria weighting; p. 337

The next query was on the *professional status*[1]. Here too, it turned out that the personal classification and assessment differs among people of verifiably equal professional status. However, in the additional query, a tendency towards the supposedly higher position could be recognized afterwards. In the same way, the distribution of people presents itself beyond the professional status with a more strongly growing share distributed over the different management levels. Finally, 42%, i.e. nearly half, grouped themselves into the senior level management. Conversely, this would mean that there can be a concentration of the respective group of people when the correlation between professional status and the weightings is being analysed. Such an influence, however, does not restrict an overall assessment and will therefore be pursued and discussed further, where appropriate.

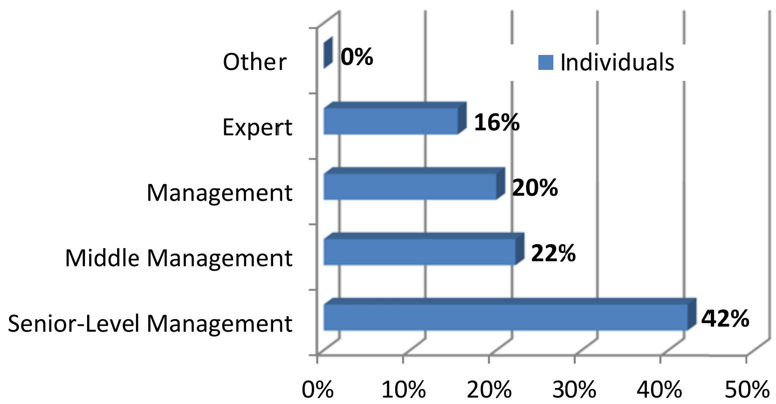

Figure 12-9: Percentage distribution of the respondents over the occupational positions

When querying the *professional experience*, specific information was requested on the proportion of the working years in the energy business, apart from the general working years[2].

It turned out that the generation with a high number of working years (>20 years) was strongly represented with 55%. It is also interesting to note that especially in this group of 55%, only 2.2% worked outside the energy sector for more than five years. As it can be seen, this proportion shifts in the group of people with fewer working years. Whether it makes sense to bring this group together with the 15 years' working experience and below, in order to get a balanced distribution for further evaluations, will be analysed and discussed again in section 12.2.3 " Specific analyses".

[1] cf. chapter 16.16 Questionnaire for the empirical investigation of the criteria weighting; p. 337

[2] cf. chapter 16.16 Questionnaire for the empirical investigation of the criteria weighting; p. 337

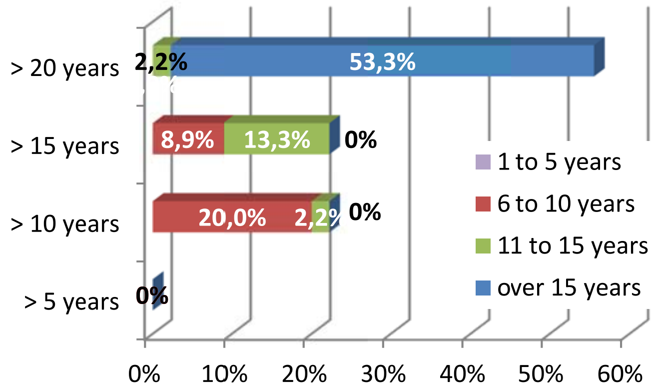

Figure 12-10: Percentage distribution of the respondents over the work experience groups (in years)[1], with the proportion of working years in the energy business (in years)[2]

		Years of professional experiance			
		> 5 years	> 10 years	> 15 years	> 20 years
Years in the Energy business	1 to 5 years	0%	0%	0%	0%
	6 to 10 years	0%	20,0%	8,9%	0%
	11 to 15 years	0%	2,2%	13,3%	2,2%
	over 15 years	0%	0%	0%	53,3%

Figure 12-11 : Distribution matrix over the work experience groups (in years)[3], with the proportion of working years in the energy business (in years)[4]

The last question on the professional practice profile[5] was about the respondents' *experience in power plant approval processes* (independent of technology). Here, too, there was a balance between 1.) those who have more approval experience, i.e. were involved twice or more times, and 2.) those who have no experience or were involved only once at the most. Among the respondents there was a balanced proportion between those with more experience and those with restricted experience in power plant approval processes.

[1] % is related to total number of questionnaires

[2] The portion on professional years is indicated by the different colors

[3] % is related to total number of questionnaires

[4] The portion on professional years is indicated by the different colors

[5] cf. chapter 16.16 Questionnaire for the empirical investigation of the criteria weighting; p. 337

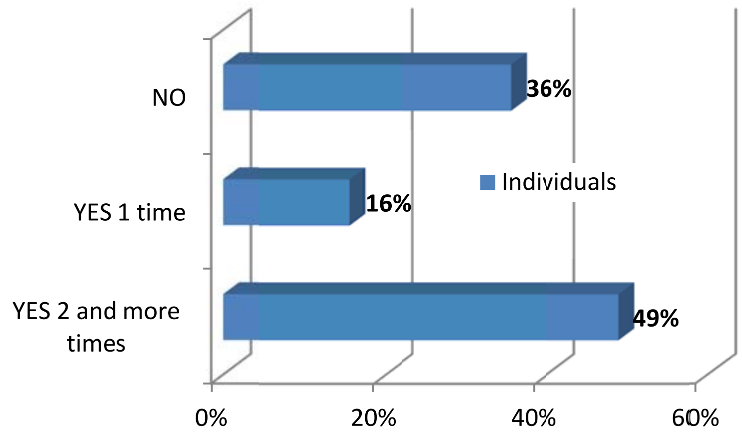

Figure 12-12: Distribution of respondents over the groups with work experience in power plant approval processes (independent of technology)

As described at the beginning of this section on p. 265, there are no statements and/or evaluation possibilities from the professional environments that are not directly related to the energy business, such as universities, authorities, politics and others. The limited significance of the information on the professional status was already indicated. For this reason, the respondents who had already provided answers were contacted again to obtain a more detailed description on their professional status and their essential experience. This was done by a short personal interview or by telephone or in some cases also by email. The second survey resulted in a new classification of or assignment to the following professional categories:

- managing directors
- engineering
- plant project development
- plant operation
- general project management
- commercial project management

In order to prevent a personal interpretation by the respondent, as it was recognisable with other queries, the classification was not done by the respondents themselves, but by the interviewer. One of the key factors for the assignment was, apart from the current position, the fact where or in what area/on what position the most experience was gained in the past. Therefore it was aimed to put groups of people together by applying supposedly equal standards in terms of their experience gained.

Figure 12-13 shows the result of this additional survey, a fairly balanced distribution relating to the groups mentioned above. In this way, the relevance of a correlation derived from this appears to be more representative than in highly distortive distributions.

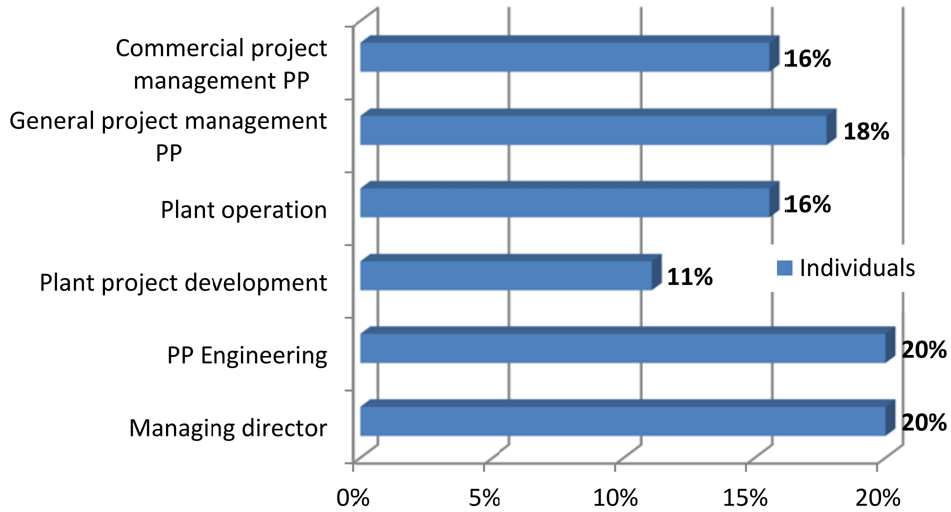

Figure 12-13: Percentage distribution of the respondents over the professional categories[1]

12.2.2 Overall analysis

Prior to a more differentiated investigation of the evaluation of the site criteria in terms of groups of people or attitudes, this section provides an undifferentiated overview of the tendency of the evaluation or weighting of the individual criteria defined in advance. Here it can be seen that none of the criteria investigated shows a particularly strong above-average criteria weighting and, therefore, deviation from the others. On a scale from 1 to 5, the maximum average deviation between the criteria is only 0.5 (see Figure 12-14). Individual evaluations, however, show a maximum deviation of 4[2].

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1 referred to the total number of respondents

2 One of the respondents rated the criterion of the maximum weighting with 5 and another respondents weighted the same criterion only with the factor 1

This would lead to the conclusion that criteria weighting is not necessary or does not make sense, as it appears that in a sufficiently number of persons - with different experience, and from different areas of responsibility, but from the same professional environment, here the energy sector – there is a tendency towards an equal weighting of the different criteria. To what extent this thesis is still valid after a more specific consideration of the circle of persons questioned will be investigated in section 12.2.3.

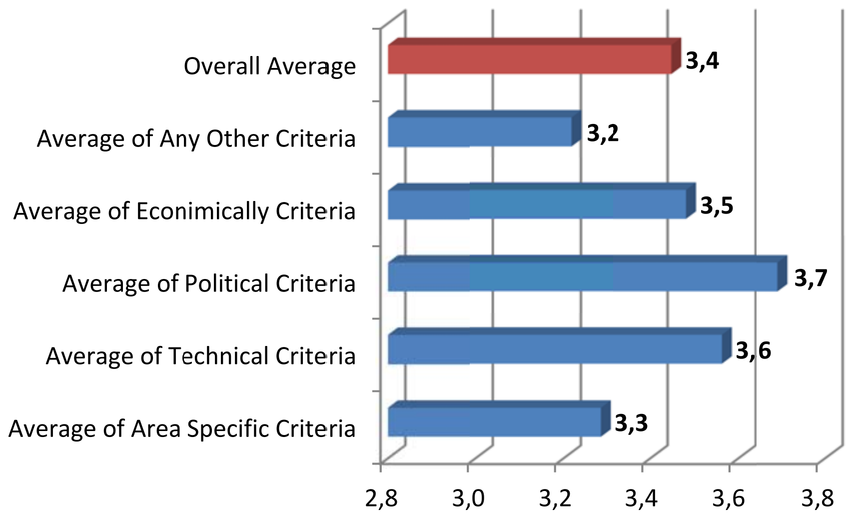

Figure 12-14: Average criteria weighting

From Figure 12-14 it could be derived as a slight tendency that the highest weighting and therefore also the biggest risk potential is to be seen for the political criteria, whereas the area specific criteria and any other criteria were weighted less or considered as slightly less important.

A further tendency can be derived from the differentiation between positively and negatively described criteria. No major deviations from the average evaluation can be seen (see Figure 12-15), but a clear tendency. Aspects with a negative wording were weighted higher for all criteria, than was the case for the same criterion with a positive wording.

In this way it can be generally concluded that, when establishing a site criteria catalogue and describing the individual factors/aspects, care has to be taken that these are formulated consistently positively or consistently negatively. Any mixing would lead to a distorted result.

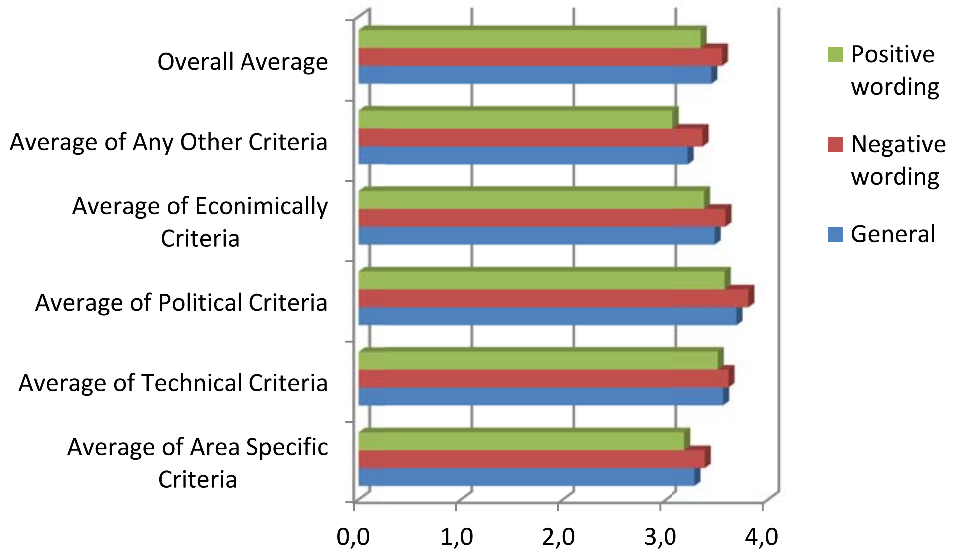

Figure 12-15: Overall overview of the tendencies in the evaluation for positive and negative wording of the criteria to be weighted

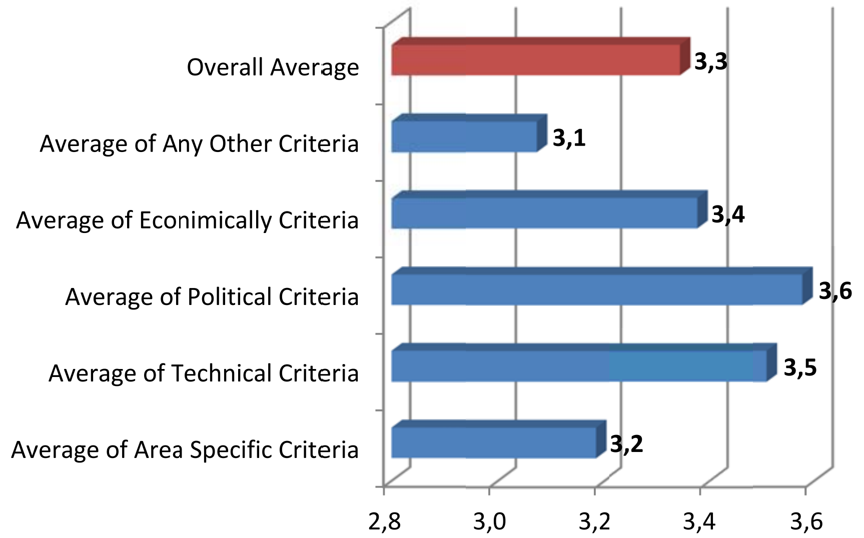

Figure 12-16: Tendencies in the evaluation for positive wording of the criteria to be weighted

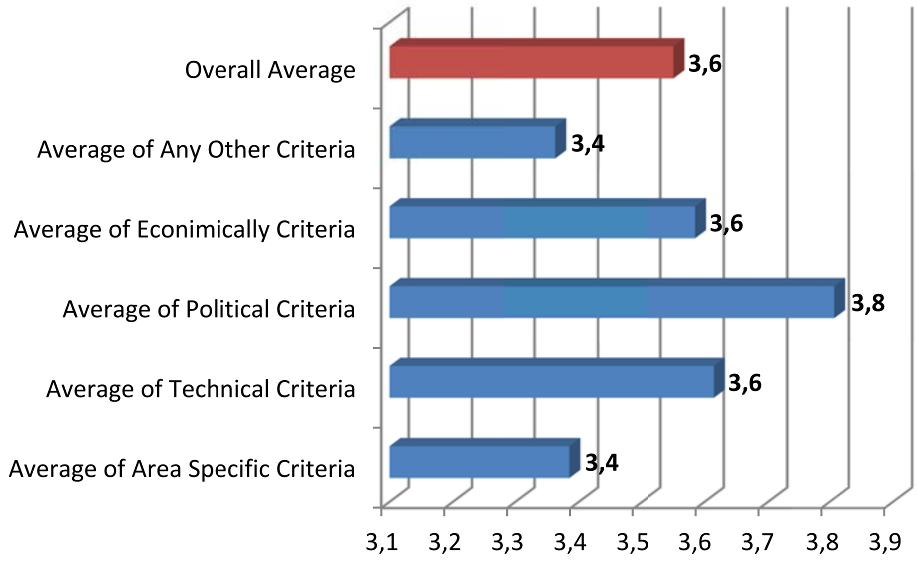

Figure 12-17: Tendencies in the evaluation for negative wording of the criteria to be weighted

Whether there are larger differences in the groups of people interviewed and what their nature is will be analysed and discussed in the following section.

12.2.3 Specific analyses

As already mentioned at the beginning of the chapter on the empirical study, one section of the questionnaire serves for a general classification of the respondents and another section for the evaluation of basic attitudes towards (gas) power plants and/or towards the energy business and the environment.

In this section, by an ambiguity feature analysis possible correlations between a group of people and their attitudes on the one hand and the criteria weighting on the other hand will be investigated[1]. The significance and representativeness of the groups of people from part 1 of the questionnaire were already discussed in section 12.1.1. Therefore, further investigations mainly focussed on the different professional categories[2].

[1] also referred to as analysis of ambiguity features (see explanations in section 12.3 on page 299”)

[2] cf. section 12.2.1, feasibility study p. 240

For this purpose, the first step involved investigating the details from the "General information on the group of people" and measuring them against the weighting. Subsequently, the opinions and evaluations on selected energy-related issues and quotations recorded in the questionnaire were discussed.
A certain trend of an interdependence between personal experience and attitude on the one hand and a criteria weighting on the other hand will be recognisable, but is in none of the cases distinctly pronounced.

Looking at the weighting over the various *areas of business* (see Figure 12-19) it can be seen that the group of respondents which is related to the construction of power plants attaches a significantly greater importance to the political criteria than the respondents from the areas of power plant operation or the energy sector in general. The latter put their focus more on the technical criteria. What all three groups have in common is that they did not rate area specific criteria and any other criteria as the most important criteria. Consequently, a tendency towards weighting certain factors more or less can be recognized between the different areas of business. However, there might be criteria that are assessed relatively congruently. Economic criteria, for example, were not rated as exceptionally important in all groups.
It should also be noted that the average weighting over all criteria of the respondents from the "Plant construction" and the "Energy sector, general" is equal despite unequal weighting of the different individual criteria, such as "Technical criteria" (3.4 >-< 3.8) and "Political criteria" (3.8 >-<3.7) (see Figure 12-18).

Plant Operation	Plant Con-struction	Energy Sector, general	University	Authority	Politics	Other
3,1	3,5	3,5	0,0	0,0	0,0	0,0

Figure 12-18 : Overall average weighting over all criteria in terms of the professional environment

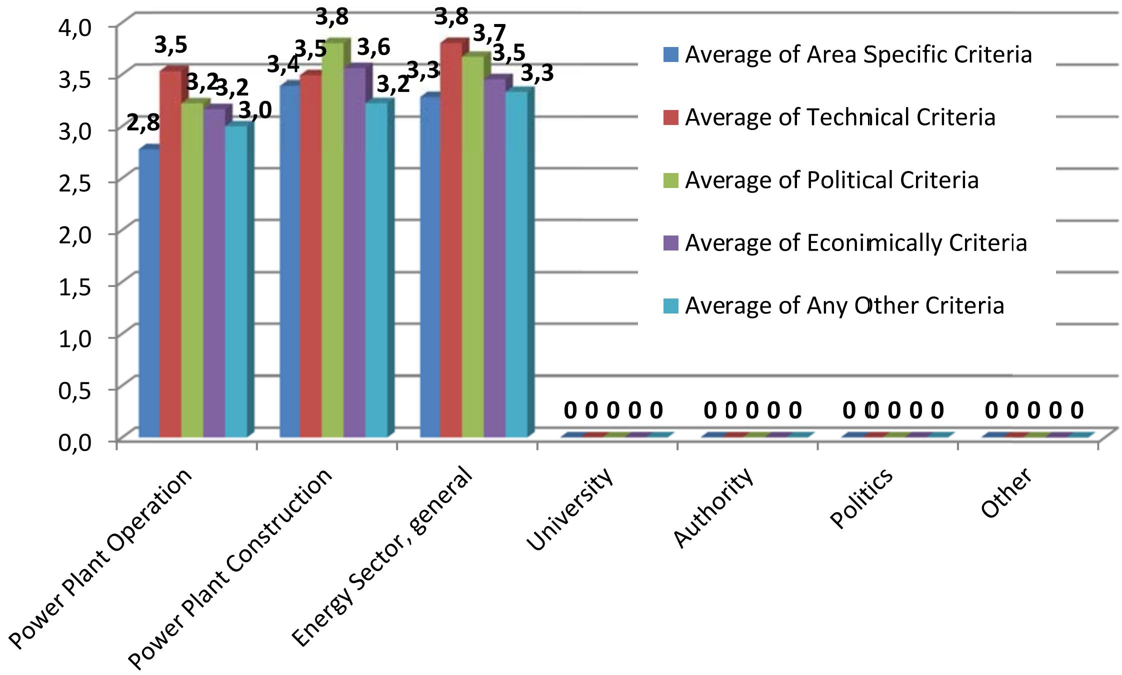

Figure 12-19 : Criteria weighting in terms of the different professional groups

Looking at the different *occupational positions* reveals a different distribution of the weighting. But here too, the political criterion was the one with the highest rating in three out of four occupational positions. As for the average weighting, there are also tendencies of coherence among the different positions (see Figure 12-20). This, however, is a false conclusion, as the individual weightings differ considerably from one another (see Figure 12-21).

Why, in contrast to the trend of the other groups, the economic criterion ”Management” was obviously rated as the most important, cannot be clearly established. This would require further psychological investigations.

Senior-Level Management	Middle Management	Management	Expert	Other
3,3	3,8	3,2	3,8	0,0

Figure 12-20 : Overall average weighting over all criteria in terms of occupational positions

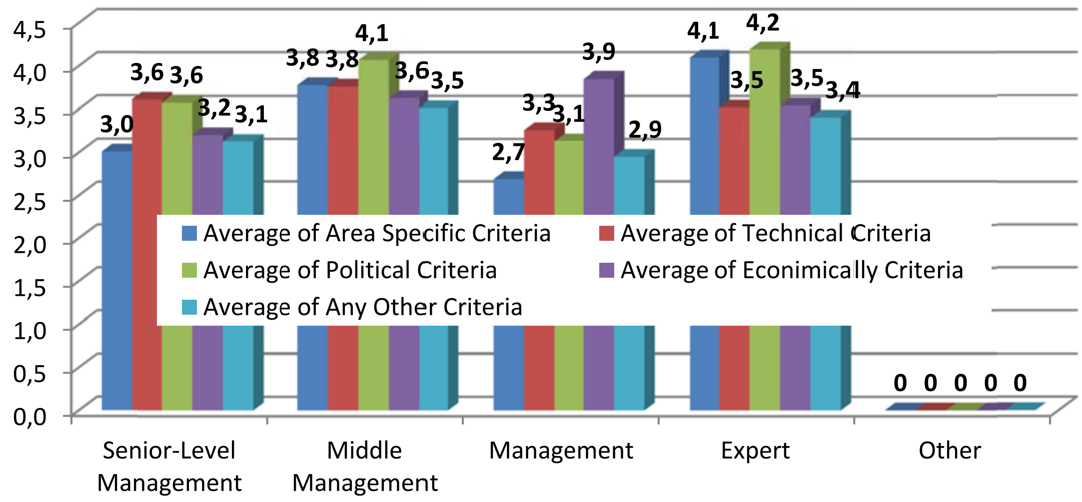

Figure 12-21 : Criteria weighting in terms of different occupational positions

The fact that the political criteria are rated higher, mainly by the group with more professional experience, becomes also evident in the category "Professional experience".

In the group of respondents with the least professional experience, special focus is repeatedly put on the economic criteria, which are rated considerably higher (cf. Figure 12-23). This would allow the conclusion that there is a tendency towards a particularly strong weighting of economic criteria among the respondents with less professional experience (here around 15 years and under). Consistent with the reasoning that the respondents with less professional experience do not necessarily fill a higher professional position, this should be reflected here, too. Figure 12-24 confirms this assumption. With around 80%, the proportion of respondents from the normal management and the expert group clearly outweighs the respondents (blue bar) with fewer years of professional experience.

Putting together two groups of respondents, as already discussed briefly in 12.2.1 "General information on the group of people" would therefore not make sense.

> 5 years	> 10 years	> 15 years	> 20 years
	3,3	3,3	3,7

Figure 12-22 : Overall average weighting over all criteria in terms of professional experience

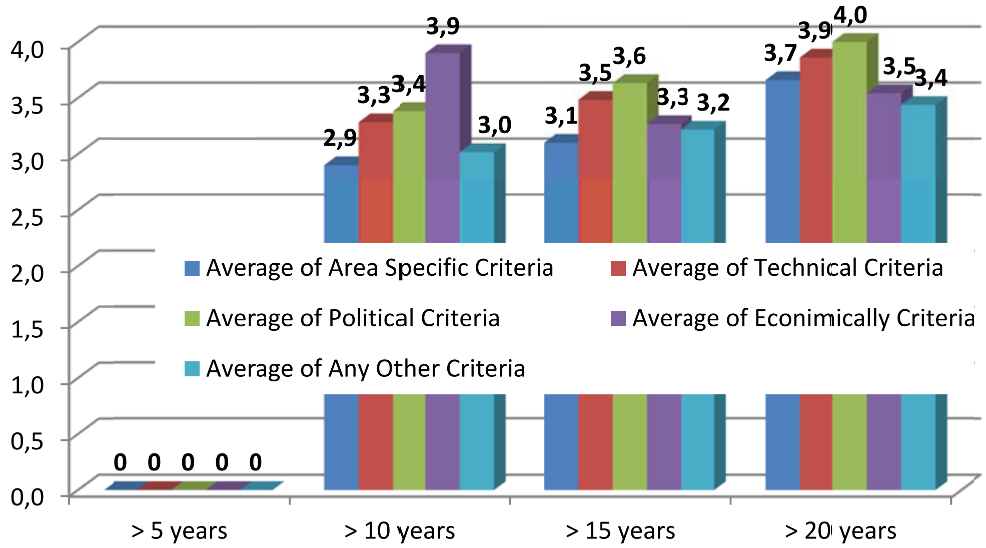

Figure 12-23 : Criteria weighting in terms of different degrees of professional experience (in years)

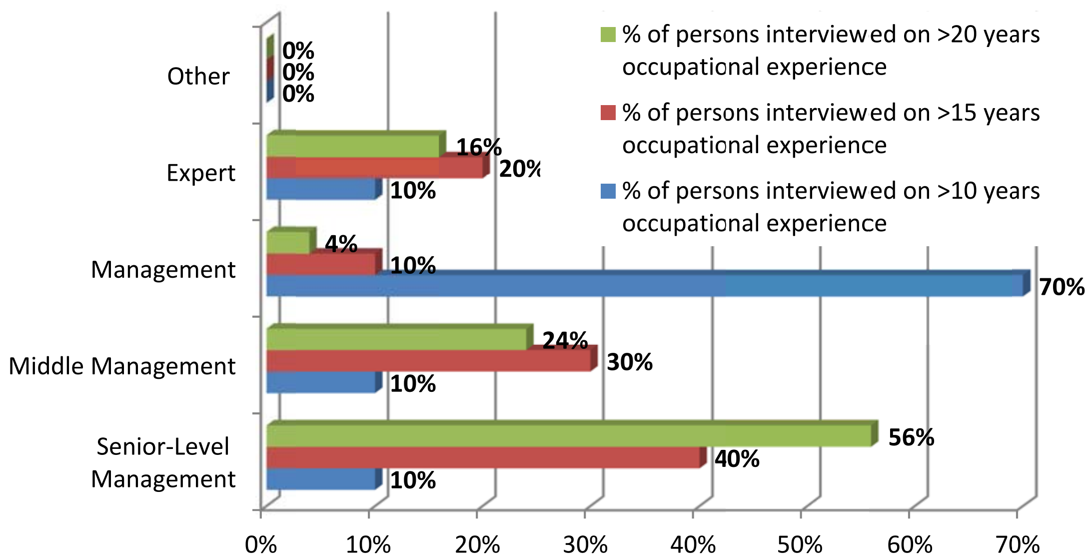

Figure 12-24 : Distribution of the occupational positions over the different degrees of professional experience

	Senior-Level Management	Middle Management	Management	Expert	Other
% of persons interviewed on >10 years occupational experience	2%	2%	16%	2%	0%
% of persons interviewed on >15 years occupational experience	9%	7%	2%	4%	0%
% of persons interviewed on >20 years occupational experience	31%	13%	2%	9%	0%

Figure 12-25 : Distribution matrix of the occupational positions over the different degrees of professional experience

Analysing the results in terms of the respondents' *experience in the process of the determination* of a power plant site reveals no marked or particularly pronounced tendencies (see Figure 12-27). This is especially obvious in the two most represented groups with "2 and more" and no involvement in a process of power plant site determination (cf. Figure 12-12: Distribution of the respondents with experience of power plant approval processes – technology-independent – in section 12.2.1). The tendency that the political criteria received the strongest weighting was again confirmed here, if only with a small accentuation.

Yes 2 and more times	Yes 1 time	No
3,6	3,2	3,4

Figure 12-26 : Overall average weighting over all criteria in terms of experience in processes of power plant site determination

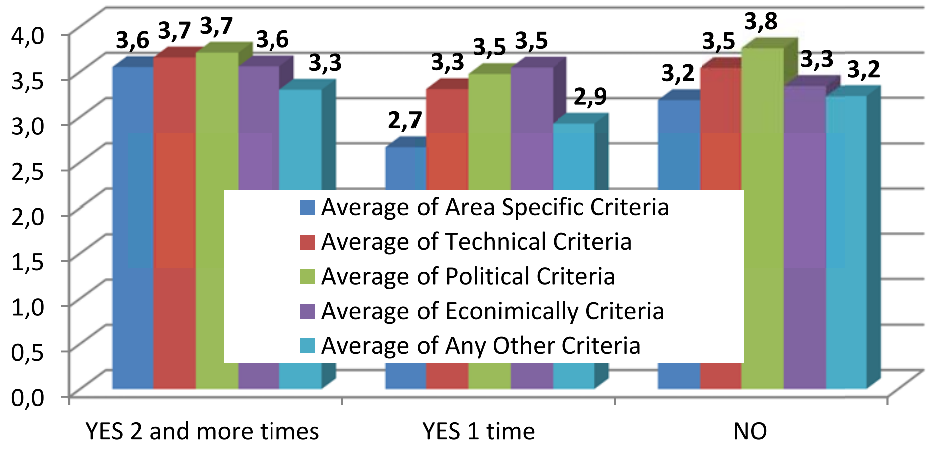

Figure 12-27 : Criteria weighting in terms of different degrees of experience in a power plant site determination process

The most balanced group with regard to the distribution of the number of respondents, the *professional categories* (cf. p 27, section 12.2.1) could be considered to show a certain tendency towards a specific criterion depending on the professional category.

Except for the group “Plant Project Development”, each group has at least one or two criteria which they would weight especially. This suggests that there a clear preferences, depending on the group of people. The group ”Plant Operation”, for example, puts the strongest weight on the technical criteria, whereas the “Commercial Project Management PP” rates the economic criteria as the strongest. These tendencies are most probably due to the experience gained in the respondents’ working environments, which, however, cannot be clearly confirmed by the present survey.

The average weighting per professional category has a range of around one and therefore does not deviate in this point from other groups discussed before (cf. Figure 12-29). From the average weighting per professional category over all criteria it can be seen that there are definitely differences. This means that the professional category has the strongest influence in the weighting of criteria which has the tendency to the higher weighting. In this case, this would be the professional group “PP Engineering” and “Plant Development” (cf. Figure 12-28).

Managing Director	PP Engineering	Plant Project Development	Plant Operation	General Project Management PP	Commercial Project Management PP
2,9	3,9	3,8	3,5	3,6	3,1

Figure 12-28 : Overall average weighting over all criteria in terms of professional categories

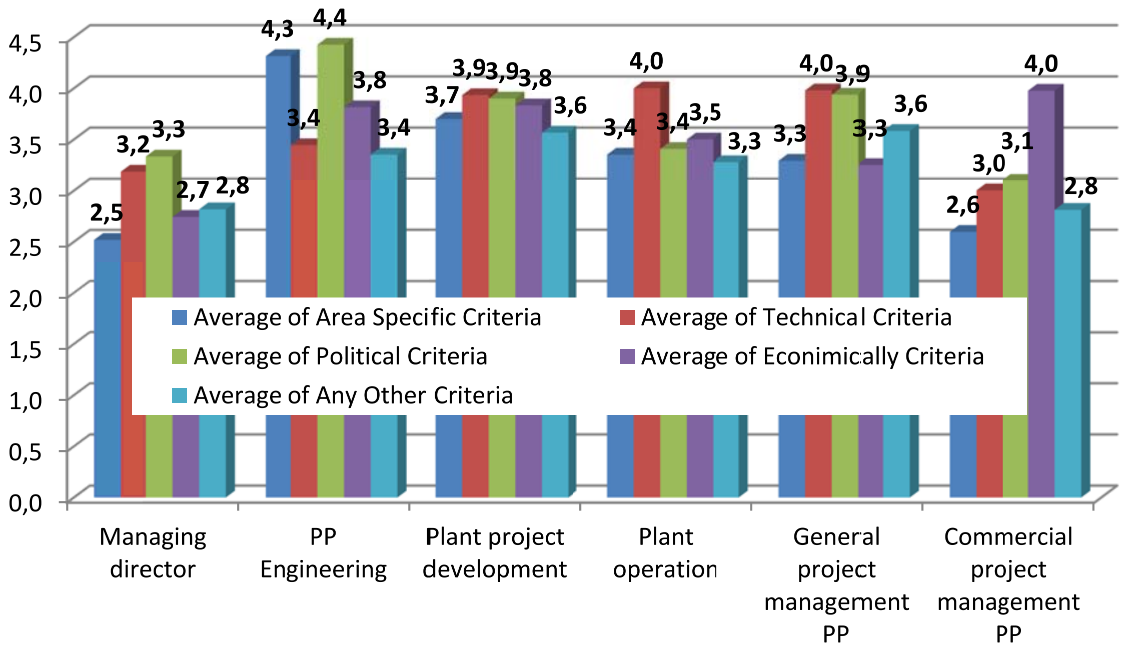

Figure 12-29 : Criteria weighting in terms of different professional categories[1]

The following section illustrates the evaluation of the part "Opinion and Assessment" of the questionnaire (cf. Appendix p. 372, section 16.16 and Figure 12-30). The order of the questions has been changed to allow for a clearer structure for investigation. First, the answers to the three direct questions on gas power stations were studied and analysed. Subsequently, the four general questions relating to energy and environmental policies were analysed.

[1] detailed information about questionnaire responses of the persons interviewed see chapters 16.18, 16.19 and 16.20

The following overview in Figure 12-30 shows the modified order of the questions as described above (cf. Appendix p. 372, section 16.16):

	Relating to gas power plants
1	What is your opinion on the statement: *“Gas and steam power plants are environmentally friendly technologies!“*
2	In what radius from your place of residence would you raise objections to the construction of a gas and steam power plant (capability for permission is taken for granted)?
3	What is your opinion on the statement: „*Gas power plants contribute to* CO_2*- reduction“?*

	Relating to energy and environmental policies
4	In their book “Crossing the Energy Divide – Moving from Fossil Fuel Dependence to a Clean Energy Future”, Robert U. Ayres and Edward H. Ayres argue as follows: “*Energy services are not just a large part of economy; they are a major part of what drives the economy*.”
5	I consider the EU target to achieve a 20% share of energy from renewable sources in the Community’s gross final consumption of energy, set in the Directive “Europe 2020” as: …
6	In his book “Power Hungry - The Mythos of “Green” Energy and the Real Fuels of the Future”, Robert Bryce argues as follows: “*The future of energy supply belongs to natural gas and nuclear power, the only sources that can provide the level of continuous electricity the nation needs, without environmental damage*.”
7	What is your opinion on the political strategy of the EU „Europe 2020“ to reduce greenhouse gas emission by 20%?

Figure 12-30 : Questions in the section „Opinion and Assessment“ of the questionnaire

The first assessment relating to gas power plants asked for an opinion on the statement: *"Gas and steam power plants are environmentally friendly technologies!"* Here, more than half of the respondents chose the answer "I agree partially" (cf. Figure 12-32). On the other hand, the groups that agreed totally and that did not agree at all were represented with an equal percentage of 20%.

The evaluation of the weightings (cf. Figure 12-31 and see Figure 12-33) shows that the graph basically appears to be well proportioned over all groups. A tendency towards rating the political criteria as the most important ones can definitely be deduced, taking account of nuances. On the basis of this special approach "Any Other Criteria" would have to be classified as the least weighted criteria

I agree	I agree partially	I don't agree	I have no idea
3,3	3,4	3,7	

Figure 12-31 : Average weighting over the response groups with regard to: „Gas and steam are environmentally friendly technologies"

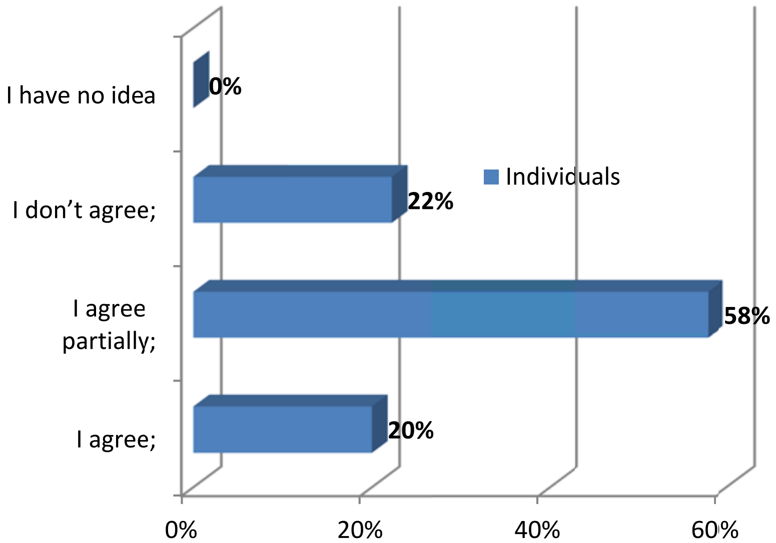

Figure 12-32 : Distribution of opinions on: "Gas and steam are environmentally friendly technologies"

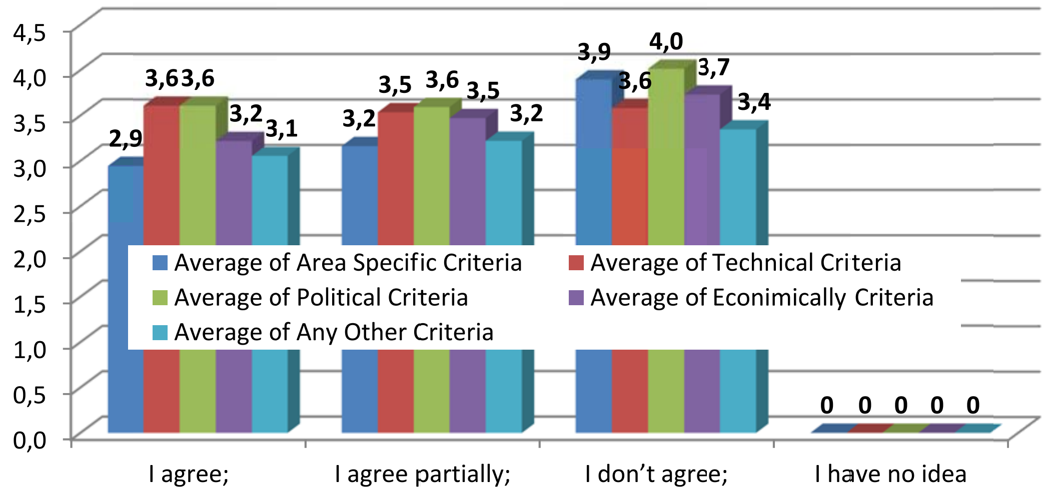

Figure 12-33 : Criteria weighting of the different response groups on: "Gas and steam are environmentally friendly technologies"

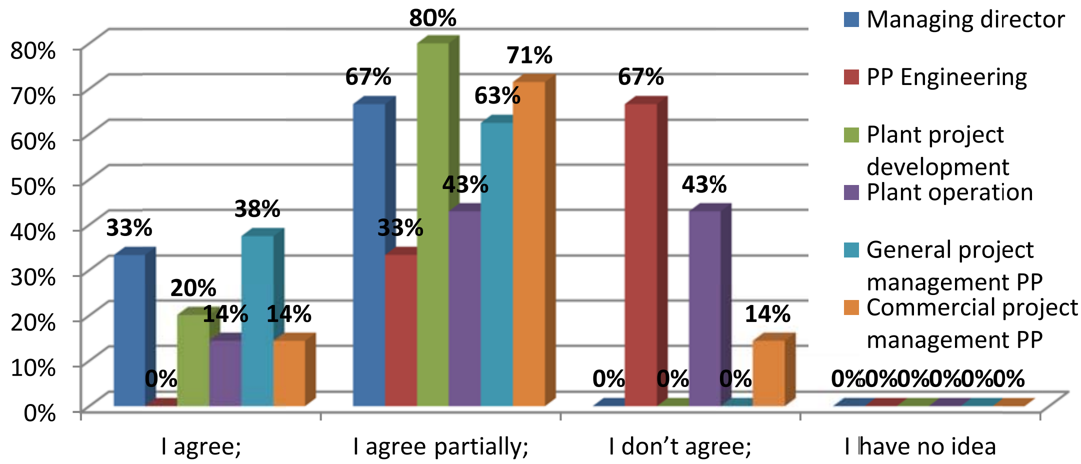

Figure 12-34 : Distribution of the professional categories on the different response groups with regard to the statement: „Gas and steam are environmentally friendly technologies"

	Managing director	PP Engineering	Plant project development	Plant operation	General project management PP	Commercial project management PP
I agree	13%	9%	2%	7%	9%	9%
I agree partially	7%	11%	9%	9%	9%	7%
I don't agree	0%	0%	0%	0%	0%	0%
I have no idea	0%	0%	0%	0%	0%	0%

Figure 12-35 : Distribution matrix of the professional categories on the different response groups with regard to the statement: „Gas and steam are environmentally friendly technologies"

A further question relating to gas power plants refers to the *Acceptance of a possible proximity* to a gas power plant. At 53%, the willingness to accept a power plant in the immediate vicinity is relatively high (cf. Figure 12-37). Following further investigation, an interesting aspect in this context is the fact that there is no managing director among the respondents that accept a power plant in their immediate vicinity (cf. Figure 12-38).
A similar tendency as in the question discussed before appears in the weighting. The political criteria were weighted among the highest and “Any Other Criteria” among the weakest (cf. Figure 12-38). A constant ranking, however, cannot be recognized.
An influence of the professional category on the weighting can be recognized in the response group “< 2 km” (cf. Figure 12-38 and Figure 12-39 + Figure 12-40). In this case it is not the political criteria that are rated the highest, but the economic criteria. This is because the groups “Plant Project Development” and “Plant Operation” were represented with 100% each (cf. Figure 12-39). In the other groups, however, this criteria was clearly deemed to be of less importance.
It is also interesting to note that of the respondents, all managing directors decided in favour of the highest possible distance. Reasons for this cannot be deduced on the basis of the catalogue of questions developed for this survey. The average weighting, however, is definitely influenced by such a high unbalanced proportion. This group has therefore also the lowest weighting factor on average (see Figure 12-36 below).

I agree	I agree partially	I don’t agree	I have no idea
3,6	3,7	3,3	

Figure 12-36 : Average weighting over the response groups with regard to acceptance of proximity to a power plant

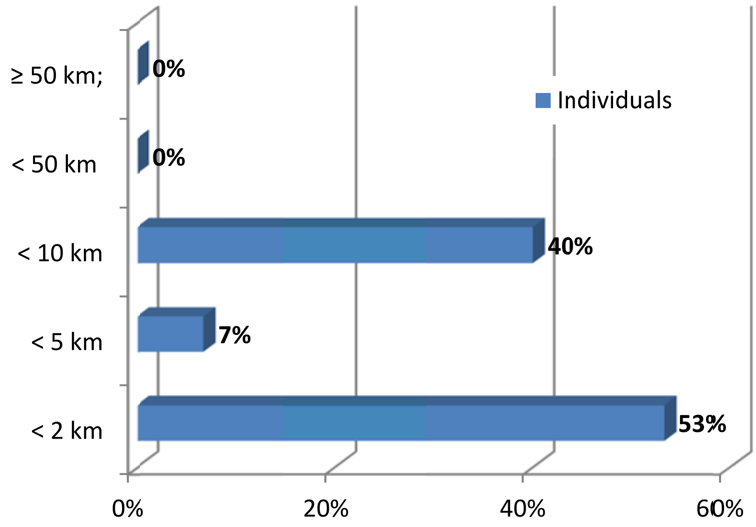

Figure 12-37 : Distribution of acceptance of proximity to a power plant

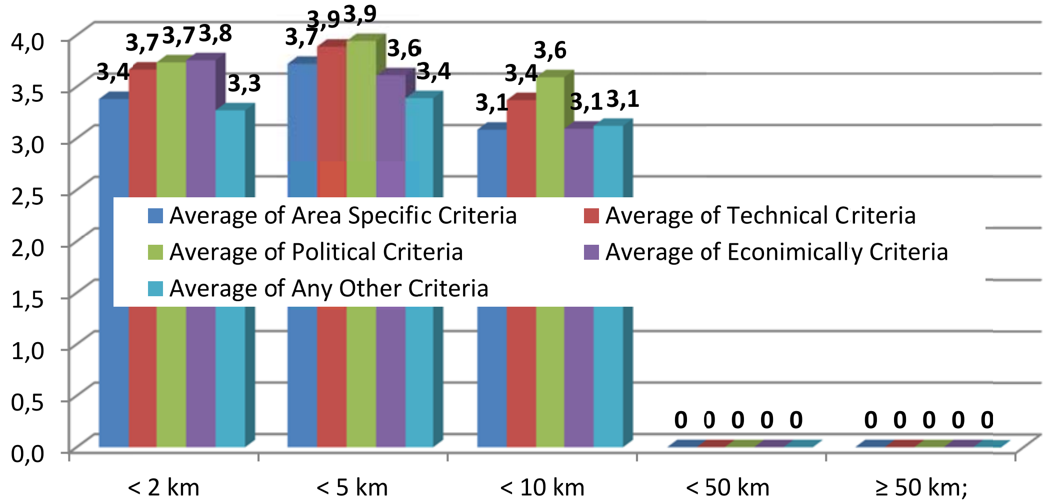

Figure 12-38 : Criteria weighting of the different response groups on proximity to a power plant

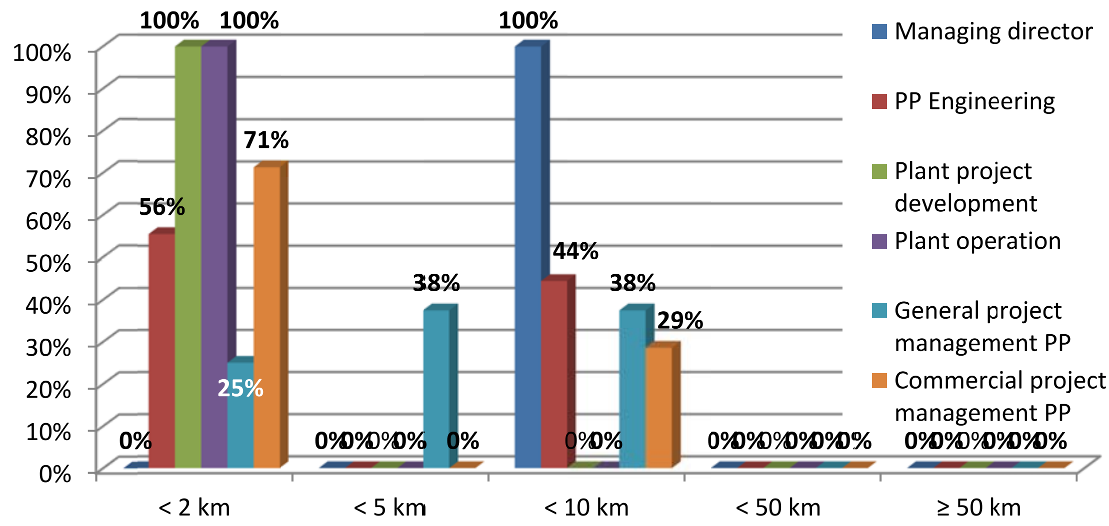

Figure 12-39 : Distribution of professional categories among the different response groups with regard to proximity to a power plant

	Managing director	PP Engineering	Plant project development	Plant operation	General project management PP	Commercial project management PP
< 2 km	0%	11%	11%	16%	4%	11%
< 5 km	0%	0%	0%	0%	7%	0%
< 10 km	20%	9%	0%	0%	7%	4%
< 50 km	0%	0%	0%	0%	0%	0%
≥ 50 km	0%	0%	0%	0%	0%	0%

Figure 12-40 : Distribution matrix of the professional categories on the different response groups with regard to proximity to a power plant

When answering the question if gas power plants contribute to *CO_2 reduction*, around 71% opted for “I partially agree” (cf. Figure 12-42). All professional categories are represented in this group with more than 50% (cf. Figure 12-44). This makes the average weighting in this response group fairly balanced and representative. Here too, the political criteria proved to be the ones with the highest weighting (cf. Figure 12-43). A trend towards a lower weighting in comparison with “Any Other Criteria”, however, cannot be recognized here. In this point, this gas-power-plant-related question and the weighting by the different response groups differ from the two issues discussed before.

The distribution of respondents opting against this statement only splits up into three professional categories (cf. Figure 12-44, Figure 12-45). However, as the number of respondents is similarly small as in the response group that agrees, these results are not regarded as representative and will therefore not be discussed here any further.

I agree	I agree partially	I don't agree	I have no idea
3,2	3,5	3,6	

Figure 12-41 : Average weighting over the response groups with regard to: „Gas power plants contribute to CO2-reduction"

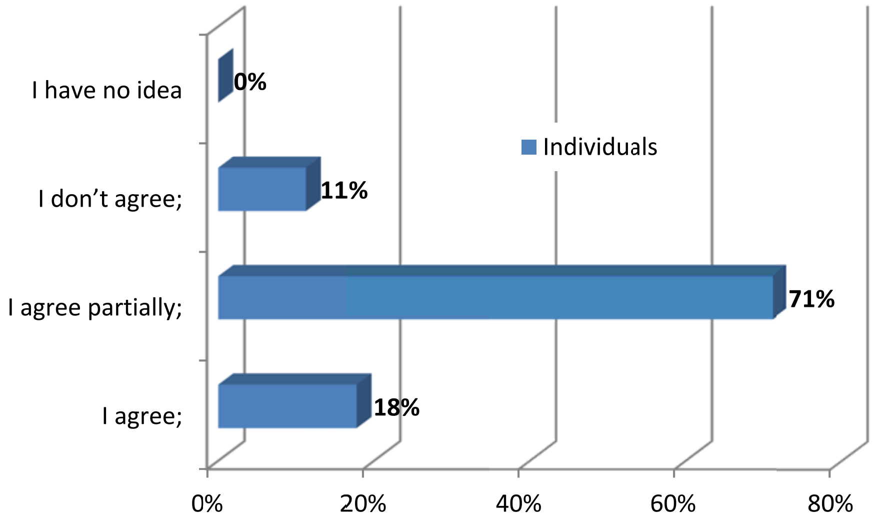

Figure 12-42 : Distribution of opinions on „Gas power plants contribute to CO_2-reduction"

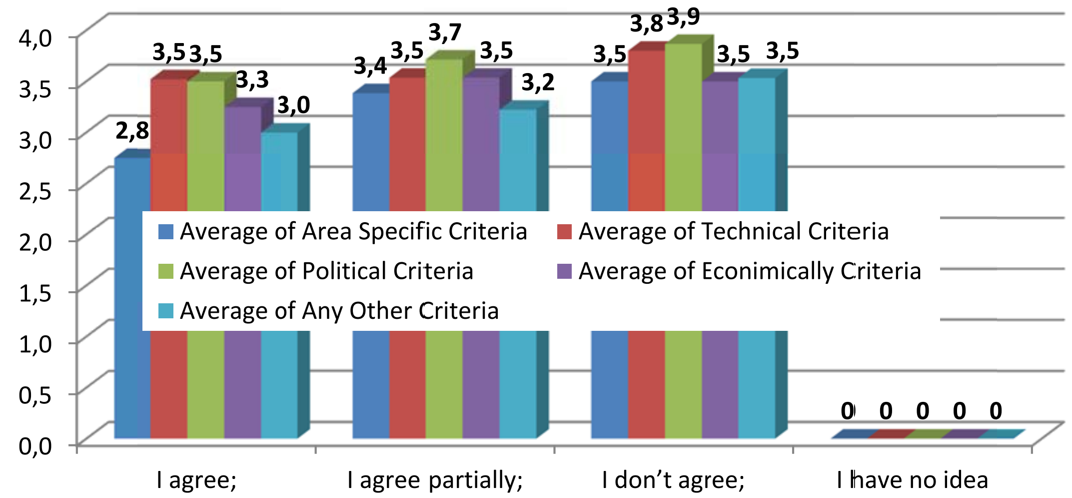

Figure 12-43 : Criteria weighting of the different response groups with regard to: „Gas power plants contribute to CO_2-reduction“

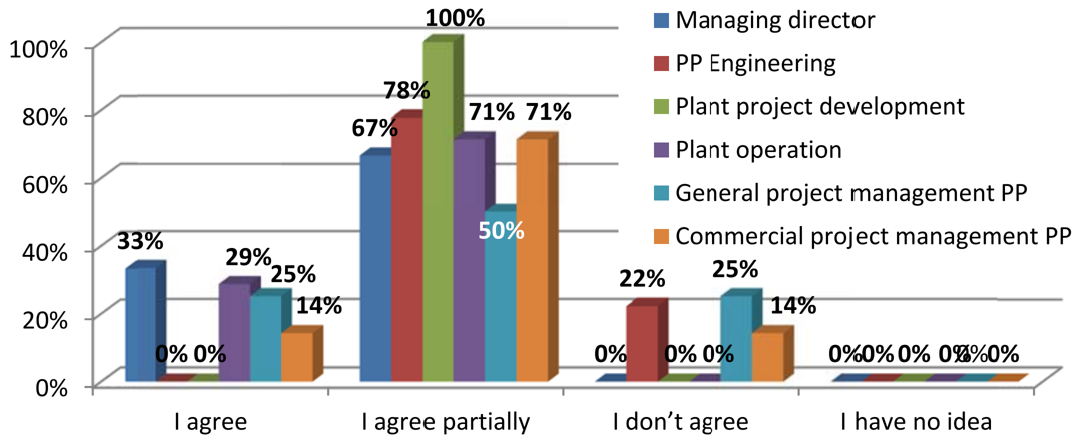

Figure 12-44 : Distribution of professional categories over the different response groups with regard to: „Gas power plants contribute to CO_2-reduction“

	Managing director	PP Engineering	Plant project development	Plant operation	General project management PP	Commercial project management PP
I agree	7%	0%	0%	4%	4%	2%
I agree partially	13%	16%	11%	11%	9%	11%
I don't agree	0%	4%	0%	0%	4%	2%
I have no idea	0%	0%	0%	0%	0%	0%

Figure 12-45 : Distribution matrix of the professional categories over the different response groups relating to: „Gas power plants contribute to CO -reduction“

In the following, the answers to questions relating to energy and environmental policies will be studied and discussed.

The first investigation in this context refers to the quote by Robert U. Ayres and Edward H. Ayres: „*Energy services* are not just a large part of economy; they are a major part of what *drives the economy*."

Here, only two response groups formed with a proportion of 51% and 49%, respectively (cf. Figure 12-50), and hence it can be assumed that all respondents have a positive attitude towards energy generation. As for the criteria weighting, there is also a tendency to weight the political criteria the highest and "Any Other Criteria" the lowest (cf. Figure 12-48). In both response groups, the ranking of the criteria on the basis of the level of weighting is for the first time identical, and the distribution of the professional groups is fairly balanced, with the exception of Plant Project Development. It could be deduced from this that, based on this question, the attitude towards energy generation has no influence on the weighting of site criteria.

I agree	I agree partially	I don't agree	I have no idea
3,4	3,5		

Figure 12-46 : Average weighting over the response groups with regard to: „Energy services are not just a large part of economy; they are a major part of what drives the economy."

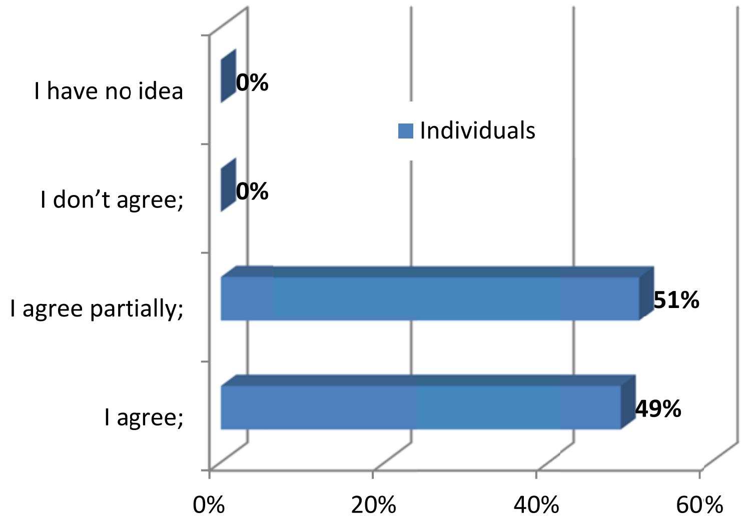

Figure 12-47 : Distribution of opinions with regard to: „Energy services are not just a large part of economy; they are a major part of what drives the economy.“

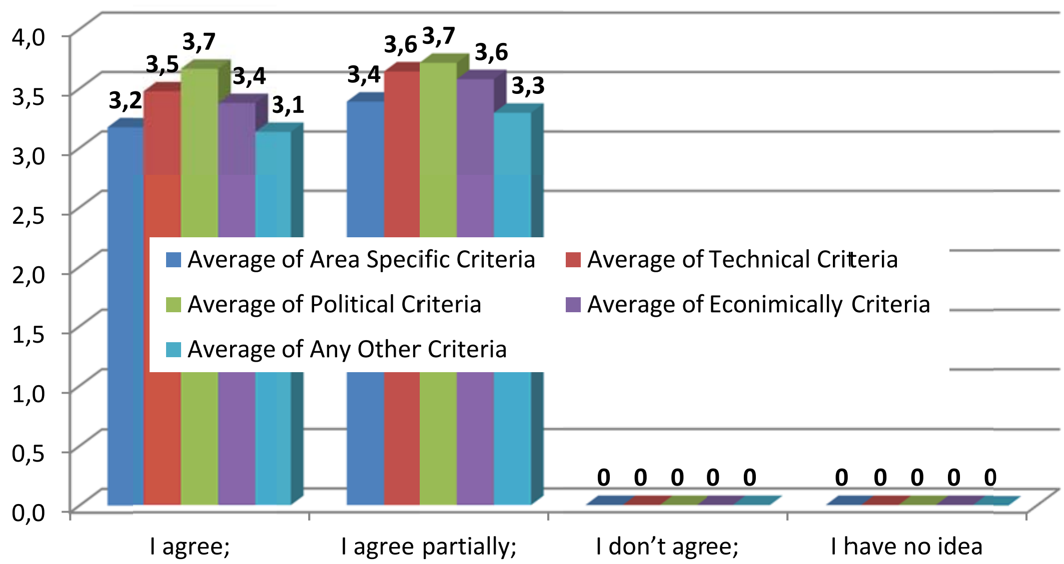

Figure 12-48 : Criteria weighting of the different response groups with regard to: „Energy services are not just a large part of economy; they are a major part of what drives the economy.“

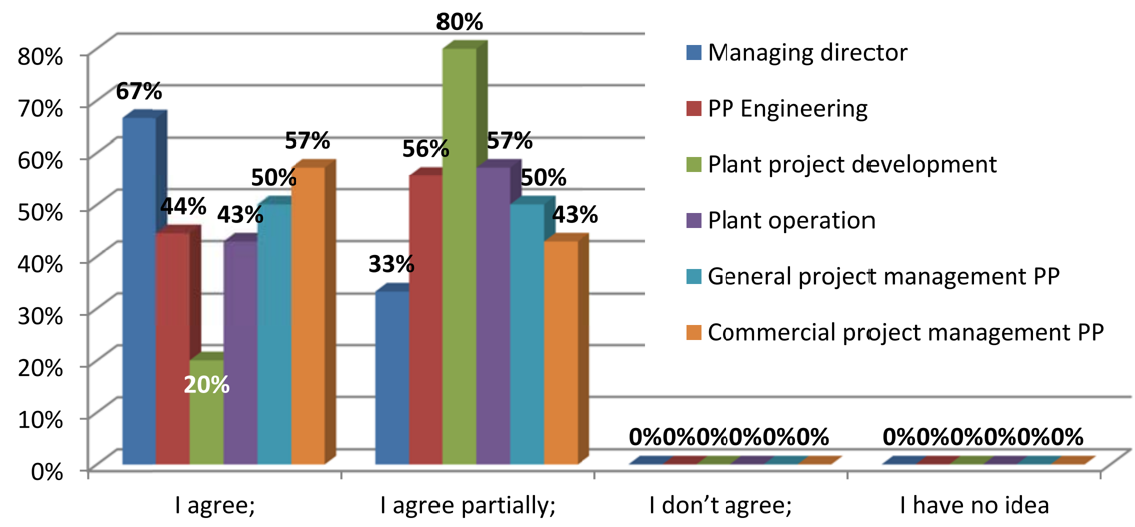

Figure 12-49 : Distribution of the professional categories over the different response groups with regard to: „Energy services are not just a large part of economy; they are a major part of what drives the economy."

	Managing director	PP Engineering	Plant project development	Plant operation	General project management PP	Commercial project management PP
I agree	13%	9%	2%	7%	9%	9%
I agree partially	7%	11%	9%	9%	9%	7%
I don't agree	0%	0%	0%	0%	0%	0%
I have no idea	0%	0%	0%	0%	0%	0%

Figure 12-50 : Distribution of the professional categories over the different response groups with regard to: „Energy services are not just a large part of economy; they are a major part of what drives the economy."

The second investigation relating to energy and environmental policies focused on the question of how the respondents considered the EU target to achieve a *20% share of energy from renewable sources* in the Community's gross final consumption of energy, set in the Directive 'Europe 2020'. The majority of the respondents answered "Sufficient" (47%) and "Expandable" (36%) (cf. Figure 12-52). The average criteria weighting, however, shows slight differences within the response groups. In the "Expandable" group, the highest weighting factor per category was 4.0 and the lowest 3.4., whereas in the "Sufficient" group, the weighting factors were between 3.5 and 3.1 (cf. Figure 12-51 and Figure 12-52).

When looking at the proportions of the professional categories in the different response groups it is recognizable that in the "Expandable" group, the majority of respondents consisted of those belonging to the professional categories PP Engineering and Plant Development (cf. Figure 12-54, Figure 12-55). In section 12.2.2, it was already established that it is these two professional categories that tend to apply higher weightings than all others (see also Figure 12-29 : Criteria weighting in terms of different professional categories on page 279). This is confirmed when looking at the average values (see Figure 12-51). The "Expandable" group exceeds the two other groups by 0.4 weighting points, which is due to the high proportion of the professional categories PP Engineering and Plant Development. This makes a dependence of the weighting on the professional categories unmistakable.

Too high	Sufficient	Expandable	I have no idea
3,3	3,3	3,7	0,0

Figure 12-51 : Average weighting over the response groups with regard to: "I consider the EU target to achieve a 20% share of energy from renewable sources in the Community's gross final consumption of energy, set in the Directive 'Europe 2020'…"

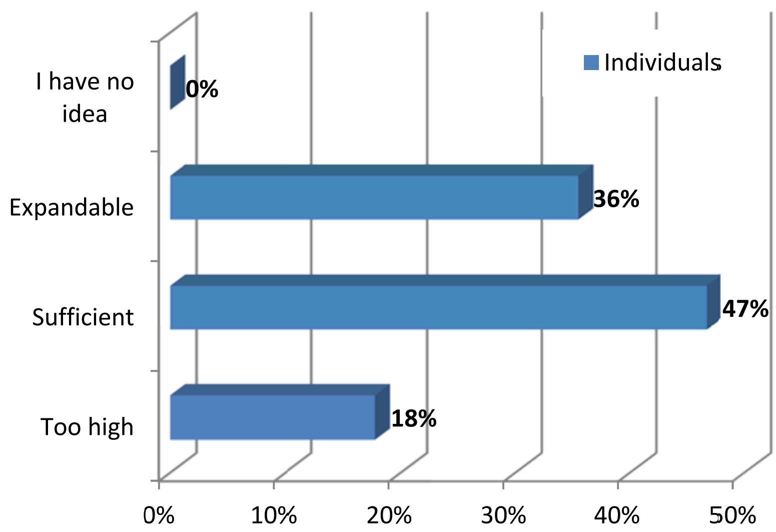

Figure 12-52 : Distribution of opinions on: "I consider the EU target to achieve a 20% share of energy from renewable sources in the Community's gross final consumption of energy, set in the Directive 'Europe 2020'…"

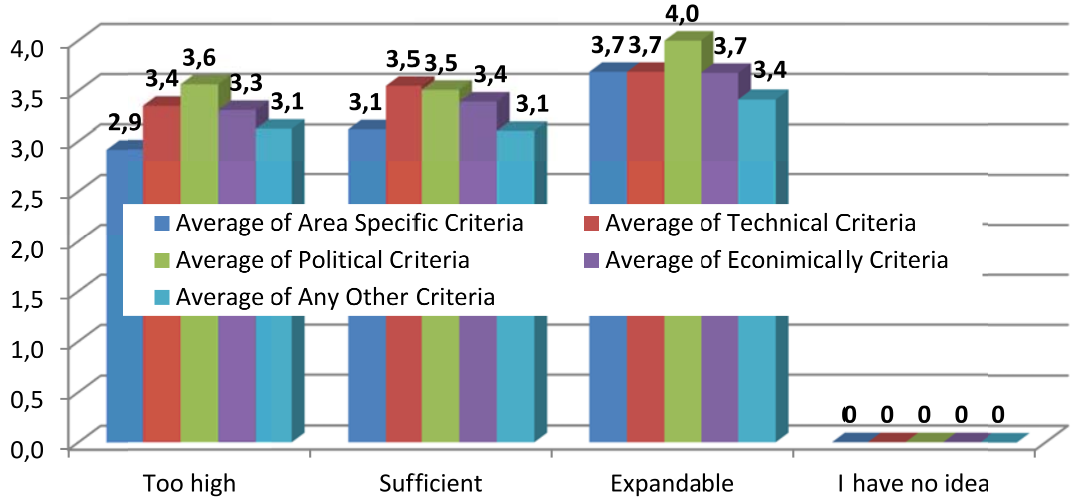

Figure 12-53 : Criteria weighting of the different response groups with regard to: "I consider the EU target to achieve a 20% share of energy from renewable sources in the Community's gross final consumption of energy, set in the Directive 'Europe 2020'…"

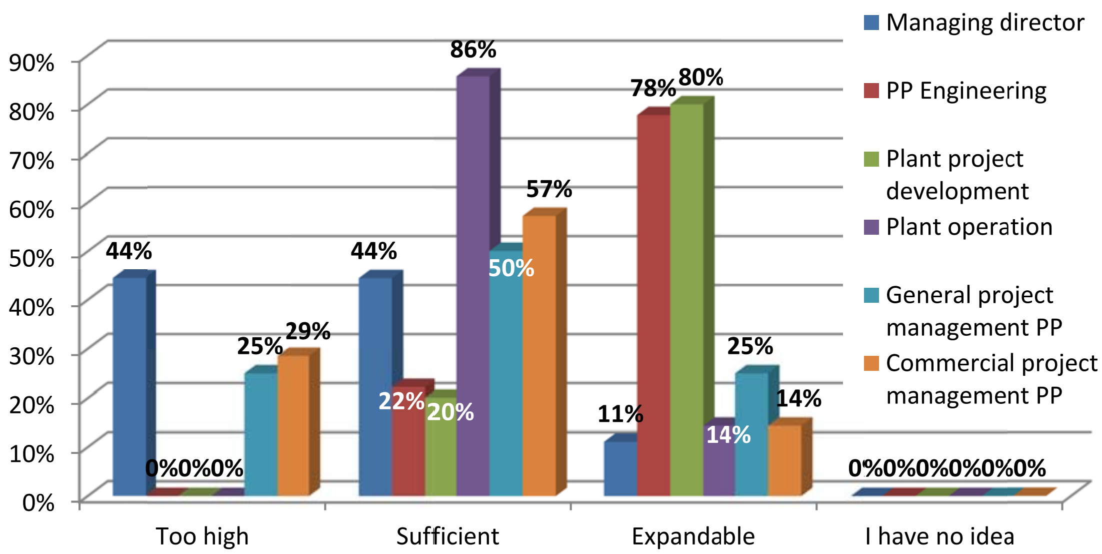

Figure 12-54 : Distribution of the professional categories over the different response groups with regard to: "I consider the EU target to achieve a 20% share of energy from renewable sources in the Community's gross final consumption of energy, set in the Directive 'Europe 2020'…"

	Managing director	PP Engineering	Plant project development	Plant operation	General project management PP	Commercial project management PP
Too high	9%	0%	0%	0%	4%	4%
Sufficient	9%	4%	2%	13%	9%	9%
Expandable	2%	16%	9%	2%	4%	2%
I have no idea	0%	0%	0%	0%	0%	0%

Figure 12-55 : Distribution matrix of the professional categories over the different response groups with regard to: "I consider the EU target to achieve a 20% share of energy from renewable sources in the Community's gross final consumption of energy, set in the Directive 'Europe 2020'…"

The third investigation relating to energy and environmental politics focused on the respondents' opinion on the quotation by Robert Bryce: "*The future of energy supply belongs to natural gas and nuclear power*, the only sources that can provide the level of continuous electricity the nation needs, without environmental damage." As indicated in the questionnaire in the Appendix, the second answer "agree partially -> in combination with:" offers an option for the specification of an energy mix for electricity generation with five more energy resources (nuclear power, natural gas, coal, renewable sources, e.g. biomass, wind, solar energy, etc.) As not all respondents decided for one of these combinations, but opted for "I don't agree" (see Figure 12-57), it seems reasonable to conclude that the combination of gas and nuclear power plus other energy resources is not regarded as the only sustainable energy source. It is worthwhile noting in this context that it was not necessarily the professional category with the highest number of power plant engineers, the PP Engineering decided for this option, but predominantly the categories Plant Project Development, Plant Operation and General Project Management[1]. Consequently, the average weightings of the site criteria do not show significant differences. This is largely attributable to the fact that the two professional categories Plant Project Development and PP Engineering were distributed among the only two resulting response groups (cf. Figure 12-58).

[1] The reasons why particularly the engineers chose this option is not subject of this study and will therefore not be investigated any further.

The influence of different professional categories becomes also obvious by the fact that it was the technical criteria that were weighted the highest in the response group "I don't agree", and not the political criteria, as was usually the case. In the investigation of the weighting of the site criteria by the different professional categories in section 12.2.2, there are exactly three categories which weighted the technical, rather than the political criteria the highest (cf. Figure 12-29 : Criteria weighting in terms of different professional categories: on p. 279). It is these three professional categories that are also most strongly represented in this response group, PP Development, Plant Operation and General Management (cf. Figure 12-59, Figure 12-60). An influence among differently composed professional categories is therefore directly visible and measurable.

I fully agree	I agree partially -> in combination with:	I don't agree	I have no idea
0,0	3,3	3,6	0,0

Figure 12-56 : Average weighting over the response groups with regard to: „…The future of energy supply belongs to natural gas and nuclear power, …"

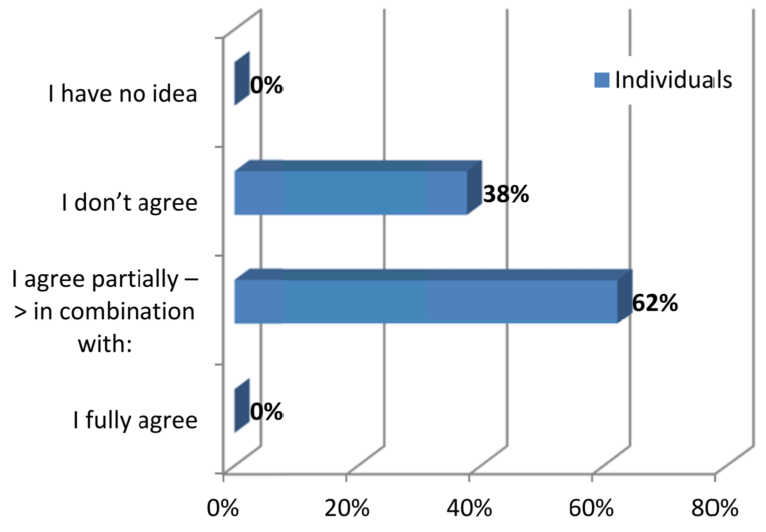

Figure 12-57 : Distribution of opinions on: "The future of energy supply belongs to natural gas and nuclear power, the only sources that can provide the level of continuous electricity the nation needs, without environmental damage."

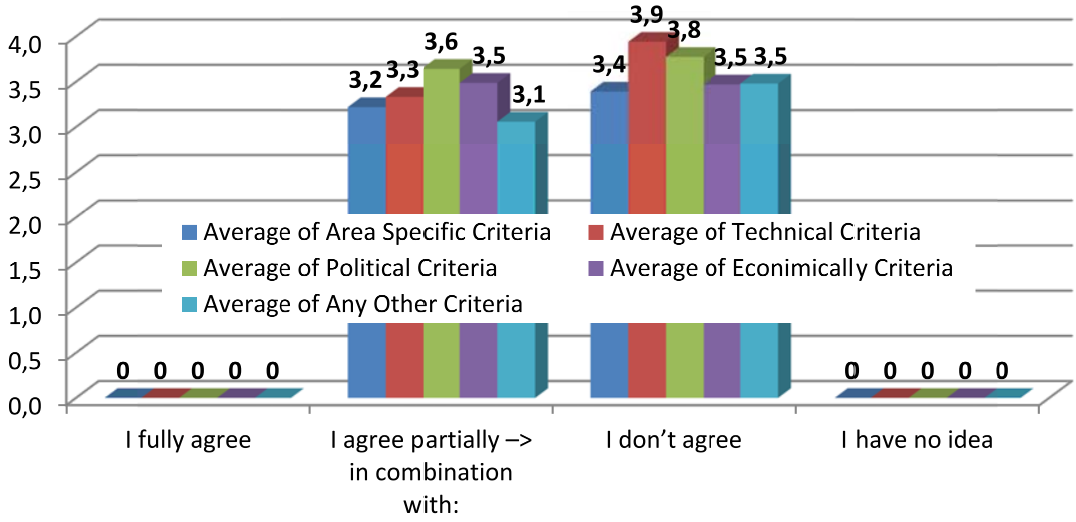

Figure 12-58 : Criteria weighting of the different response groups on: "The future of energy supply belongs to natural gas and nuclear power, the only sources that can provide the level of continuous electricity the nation needs, without environmental damage."

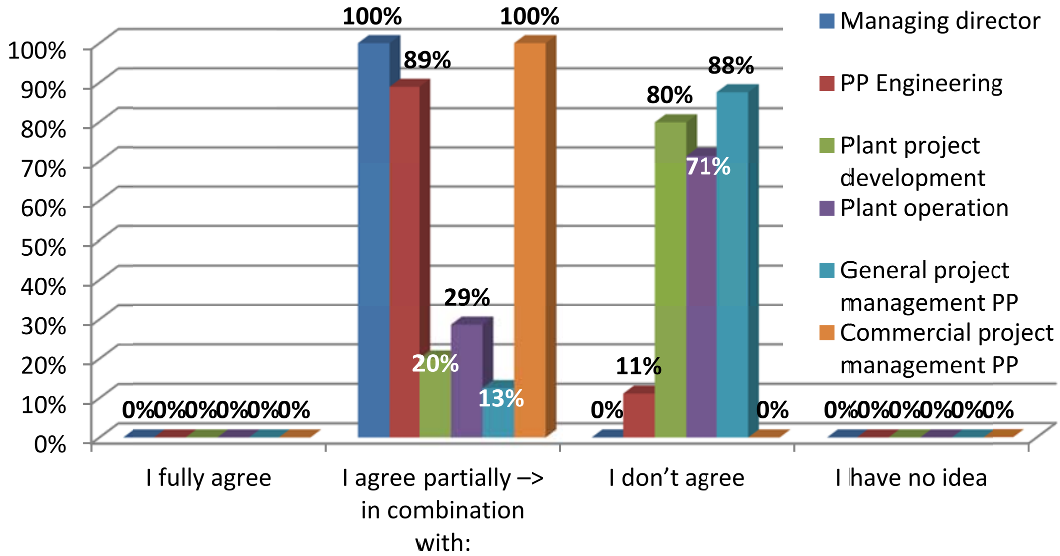

Figure 12-59 : Distribution of the professional categories over the different response groups on : "The future of energy supply belongs to natural gas and nuclear power, the only sources that can provide the level of continuous electricity the nation needs, without environmental damage."

	Managing director	PP Engineering	Plant project development	Plant operation	General project management PP	Commercial project management PP
I fully agree	0%	0%	0%	0%	0%	0%
I agree partially –> in combination with:	20%	18%	2%	4%	2%	16%
I don't agree	0%	2%	9%	11%	16%	0%
I have no idea	0%	0%	0%	0%	0%	0%

Figure 12-60 : Distribution matrix of the professional categories on: "The future of energy supply belongs to natural gas and nuclear power, the only sources that can provide the level of continuous electricity the nation needs, without environmental damage."

The fourth investigation relating to energy and environmental politics dealt with the respondents' opinion on the political strategy *Europe 2020 on the greenhouse gas emission reduction by 20%*. Basically, there are two response groups here. One of them agrees with the strategy and the other one agrees only partially. There is also a small percentage of 4% of those who reject greenhouse gas emission (cf. Figure 12-62). As the number of those persons is very small, the weighting of the different criteria and any derivable information are not necessarily to be regarded as representative, therefore, as not very significant.

The average criteria weighting over the response groups is generally fairly balanced (cf. Figure 12-61 and Figure Figure 12-63). This seems to be because decisive professional categories are distributed accordingly, as e.g. 78% of PP Engineering answered "I agree" and 80% of Plant Project Development "I agree partially" (cf. Figure 12-64, Figure 12-65).

The ranking in the two response groups also looks very similar, except for insignificant deviations. Here, too, the political criteria were the ones with the highest weighting, followed by the technical criteria. Any Other Criteria were given the lowest weighting.

I fully agree	I agree partially -> in combi-nation with:	I don't agree	I have no idea
3,6	3,4	3,5	0,0

Figure 12-61 : Average weighting over the response groups relating to: „The political strategy Europe 2020 on the greenhouse gas emission reduction by 20%"

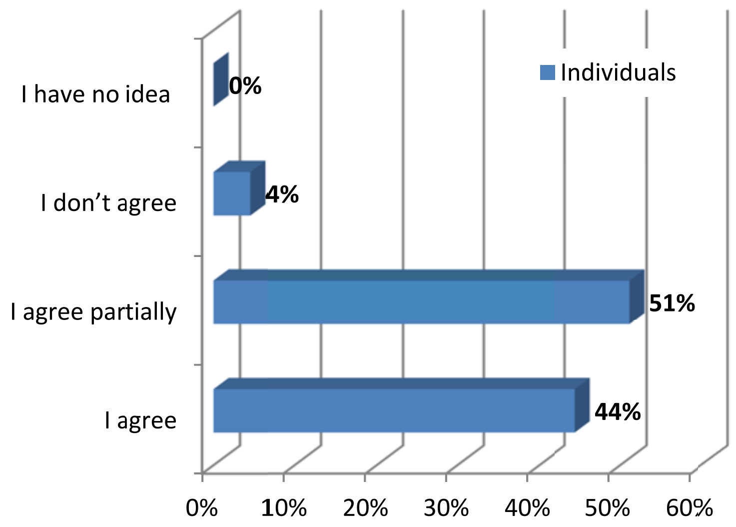

Figure 12-62 : Distribution of opinions on:" The political strategy Europe 2020 on the greenhouse gas emission reduction by 20%"

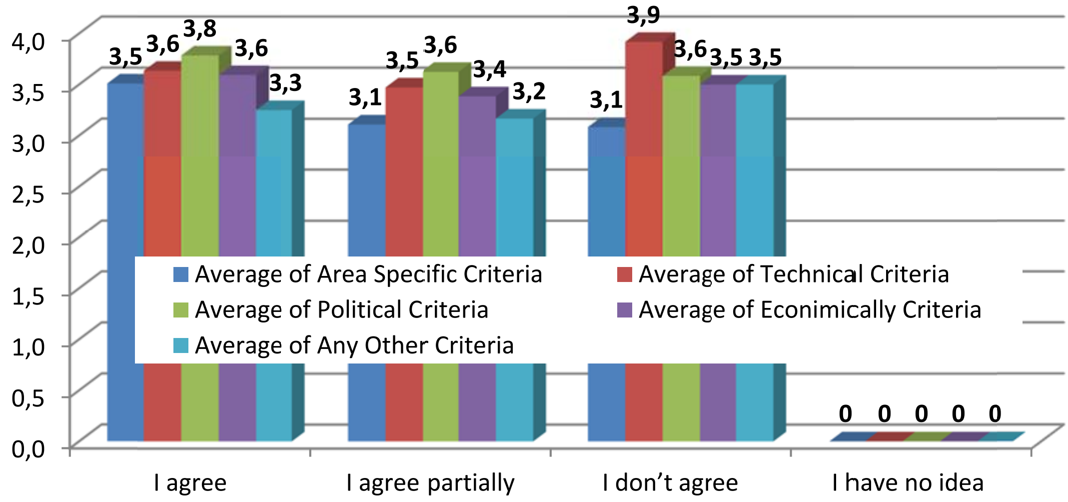

Figure 12-63 : Criteria weighting of the different response groups on: "The political strategy Europe 2020 on the greenhouse gas emission reduction by 20%"

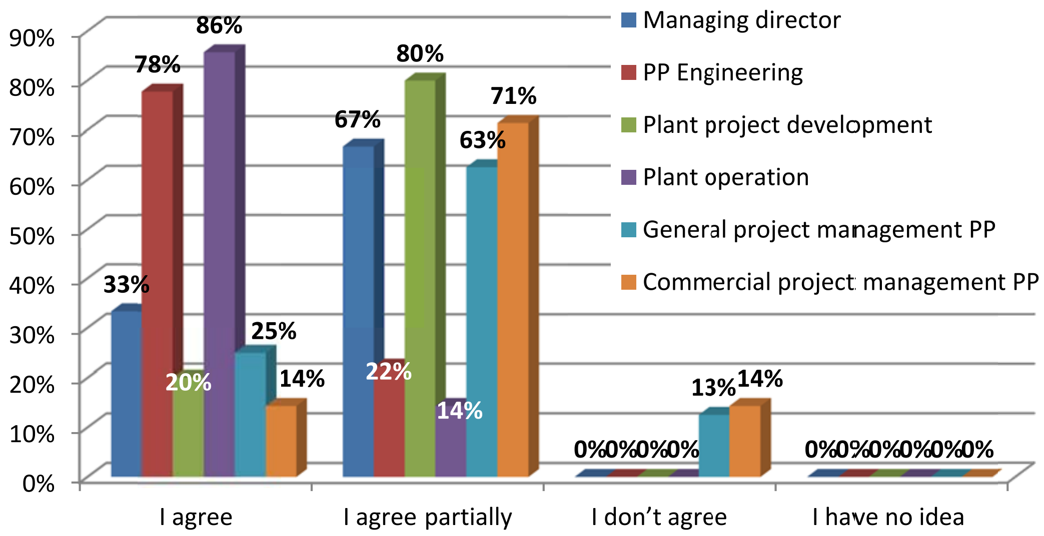

Figure 12-64 : Distribution of the professional categories over the different response groups with regard to: "The political strategy Europe 2020 on the greenhouse gas emission reduction by 20%"

	Managing director	PP Engineering	Plant project development	Plant operation	General project management PP	Commercial project management PP
I agree	7%	16%	2%	13%	4%	2%
I agree partially	13%	4%	9%	2%	11%	11%
I don't agree	0%	0%	0%	0%	2%	2%
I have no idea	0%	0%	0%	0%	0%	0%

Figure 12-65 : Distribution matrix of the professional categories over the different response groups with regard to: "The political strategy Europe 2020 on the greenhouse gas emission reduction by 20%"

12.3 Summary of the empirical study

At the beginning of the empirical study, the following hypothesis or theory, respectively, was proposed:"….A site evaluation of the site criteria summarized in subject groups deviates if this evaluation is carried out by different people…"[1]. It can be noted that this is true. The results of the investigation show a clear trend towards different weightings by different groups of respondents. This is also and especially true of results with ambiguity features.
The survey method used in the questionnaire has proven successful in the present study. More than half of the people questioned returned the questionnaire fully completed. The collected data were processed and investigated in accordance with their statements in three different ways, 1) the general information on the group of respondents, 2) an overall analysis, in which no differentiation according to certain groups of respondents was made, and 3) a specific analysis, in which criteria weightings were measured against the different groups of respondents and their opinions and attitudes (ambiguity feature analysis).

> To 1) After the evaluation of the questionnaires and first investigations it was found that it is worthwhile to define a further additional investigation on a group of respondents to be redefined beyond different professional categories. The advantage of these categories is that finally there was a fairly balanced distribution of the respondents among them. In the other groups there were high concentrations and/or shifts in several cases, which significantly reduces the representativeness when forming ambiguity features. Especially in the question on the professional position it became apparent that the respondents tended towards a higher status in their personal interpretation.
>
> To 2) The evaluation in the overall analysis resulted in an average overall weighting of all criteria summarized in subject groups with the factor 3.4.

[1] cf. section 12 Empirical study on the criteria weighting on p. 222

The overall variation of the average values of the subject groups ranged between 3.2 and 3.7, thus revealing nominal differences that are not particularly strong, but that rather represent a tendency. Further investigations demonstrated that there is a general tendency to weight negatively formulated criteria descriptions higher than positive (or optimistic) formulations. It has to be ensured that criteria are either formulated positively or negatively throughout the whole questionnaire. The political criteria turned out to be the criteria with the highest weighting.

To 3) The specific analysis revealed that only very few groups of respondents differ from the average maximum and minimum weightings, but a concentration of this group of respondents on a specific feature leads directly to a definite influence on the weighting. On the other hand, however, a relative consistency in the ranking of the subject groups according to the weighting can be noted, apart from a few exceptions. The subject groups with the highest weightings were mainly the Political Criteria and Technical Criteria, irrespective of the group of respondents. This implies that a consideration and weighting of the ranking would definitely be worthwhile when establishing a catalogue of site criteria.

Considering all results it can be noted that a weighting of subject groups would definitely make sense in order to ensure an order of priority. To guarantee equal weighting, the individual criteria have to be consistently formulated positively or negatively. The amount of the factor for subject groups should take a group of respondents as the reference, preferably the decision makers. Assigning the ranking to the decision makers can definitely enhance the final acceptance of the analysis of the site evaluation, irrespective of the result. The direct evaluation of the criteria, however, should be carried out by different groups of people (professional category / professional position/…) in order to be able to define possible weak points of a site from various perspectives.

13 Conclusion

The present thesis deals with the foundations for solving the decision problem of site selection for a feasibility study of gas-fired power plants. It was the author's aim to make realistic and practical statements. The analysis of different theories and the investigation of site-relevant decision criteria has illustrated the broad range of site-specific factors and criteria that are to be taken into account. Neither one-dimensional investment procedures, nor the approaches of the traditional site theory, nor the behaviour of the players involved in the site decision are, considered individually, capable of explaining all aspects of a site decision for a gas power plant.

On the basis of existing projects, in which site theories were analysed for various industries, the present research project thus lays a new foundation for an extended specific approach in the area of electricity generation in gas-fired power plants.

It was not the author's intention to claim completeness by providing a detailed analysis of all methods and possibilities available in an evaluation and decision process, but rather to critically examine the characteristic and fundamental theories as well as their practicability.

The basis for an extended site evaluation theory and an optimized selection process of a gas power plant site is the discussion and critical consideration of the existing fundamental site theories as well as the representation and criticism of existing investment calculations and the evaluation of non-quantifiable site criteria associated with this.

Based on the criticism of prerequisites for and conclusions drawn from available investment calculations and siting theories, new findings were established using an investment calculation model for the site decision of a gas power plant that satisfied theoretical and practical requirements.

The extension of the quantitative investment calculation by a refined qualitative evaluation and decision process and the introduction of a modified utility analysis rightly seem to claim their place in such a paradigm.

On the basis of empirical material, a detailed characterization of the weighting of site criteria was performed. As a result of this it was found that the criteria weighting for a site decision is a multipersonal process, in which the behaviour of the subjective or restricted rationality of the players involved does not allow for a definite conclusion, but only provides a conclusion on tendencies. However, it could be proved that the subjective component is moderated by a multipersonal process[1] and thus, by forming collective judgements instead of individual judgements.

Based on the problem area described in the introduction of this thesis, the author addresses a further problem. Over time, restrictions change, new energy concepts and technologies are developed, decision criteria and parameters vary. This induces permanent adaptation and further optimization of the present approach. It remains to be discussed if the application of approaches derived from game theory or dynamic algorithms with a more complex model world would have been more useful.

[1] = the involvement of several people in the evaluation process

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16 Appendix

16.1 Overview „Area-specific criteria“

Size of the area

• Is the area sufficiently large for the planned project?
  o How large is the potential area?
  o What shape does the potential area have, and does this shape allow a sensible and practicable arrangement of the power plant components?
• Are there any possibilities for expansion (what are the adjacent areas like)?

Properties of the area

• Does the building ground meet the standards of a power plant project?
  o Kind of ground (soil composition)?
  o Is the surface plane?
  o Is there suspicion of soil contamination, mining subsidence etc.?
• Are the climatic characteristics of the area suitable for a power plant project?
  o Height above sea level?
  o Annual minimum and maximum air temperature (efficiency in cooling mode)?
  o What is the prevailing wind direction? (influence on the pollution level for environment)

Ownership status

• Is the purchase of land possible without any difficulty on the basis of the present ownership?
  o How many owners does the potential area belong to??
  o Who are the owners of the potential area?
  o Is the area in private or public ownership?
  o What is the earliest possible disposability of the area?

Environmental situation

• Can, under the existing local environmental conditions, a power plant be erected on the potential ground without major environment-related impairments?
  o Are there any trees or shrubs on the area (potential biotopes)?
  o Are there any habitats of protected species (Red List) on the area?
  o Are there any standing or flowing bodies of water on the area (potential biotopes)?
  o Are there specially protected sites (FFH habitats, bird sanctuaries)?
  o Are there water protection areas in the immediate vicinity?
  o Is the area in a retention area?
  o Is there an initial level of pollution due to previous use or use of neighbouring land plots?
• Are there any environmental risks that oppose the suitability of the site for the construction of a power plant?
  o Can floods be expected on the potential area?
  Have there been floods in the region in the last 100 years?
  o Can earthquakes be expected on the potential area?
  Have there been earthquakes in the region in the last 100 years?

Conflicts relating to past use
• Is there suspicion of ground contamination due to previous use? • Is there the possibility of mining subsidence damages? • Can absence of explosive ordinance be guaranteed? • Are there possible archaeological sites? • Are there any environmental procedures pending?

16.2 Overview „Technical criteria“

Cooling water situation
• Is a cooling water source available, such as a sea, river, lake or canal which can satisfy the demand for cooling water for the power plant project throughout the year without restrictions? o In what distance is the cooling water source situated? o What are the average annual temperatures of the cooling water source? What is the maximum cooling water temperature in the summer? o Is the cooling water source already being used for other cooling purposes? o Are there any existing restrictions of use or are any future restrictions of use to be expected? o Does the water quality meet the requirements and are special contaminations by the water to be expected, such as shells and algae growth or chemical contamination caused by agriculture, etc., which could affect the operation of the power plant?
Network access
• Is network access possible under the given conditions (geographical, technical and regulatory)? o Is a network connection point in the ultra-high voltage network available in the vicinity of the potential area? In what distance? o What voltage level does the potential network connection point have? o Where is the nearest transformer substation? o What regulations for network connection apply? Is an increase in the expenditure of time to be expected due to the network connection regulations?

- Who is responsible for the implementation of the network connection procedure? - Would a necessary network connection line to the potential network connection point pass through critical areas, such as housing estates or nature conservation areas? • Is a spare network connection available?
Network capacity
• Is the capacity available at the network connection point sufficient for the connection of the planned project? - Are the any investigations concerning the network expansion in the region? How can the situation relating to the transition network be assessed? Is it sufficient for the connection of the planned project? - Are there any plans for network expansion measures in the country/the region, and if so, what kind of plans? - Is competing use to be expected that can lead to network congestion? - Is there a regulation for network congestion management in the country/the region? - Is the static stability of the network sufficient? - Is the dynamic stability of the network sufficient?
Fuel transport capacity and infrastructure
• Is there a gas pipeline in the vicinity of the potential area, which can be used to operate a power plant throughout the year? - In what distance is the gas pipeline or a connection point? - Is it necessary to build a connecting line or a new gas pipeline? Does this pipeline pass through critical areas, such as nature conservation areas or housing estates? Is this pipeline eligible for approval? If so, under what conditions/prerequisites? - Who is the owner of the gas pipeline?

- Who is the operator of the gas pipeline? Are there any objections to a long-term cooperation?
- What transport capacity does the gas pipeline have?
- What consumers are supplied by this gas pipeline?
- Is competing use of the gas pipeline to be expected, which could lead to supply bottlenecks?
- Is there a regulation for the management of a gas supply bottleneck in the country/the region?

- Is the potential site in the vicinity of a sea or inland port through which the power plant could be supplied with fuel via an LNG terminal?
  If so …
  - In what distance is the LNG terminal?
  - What capacity does the LNG terminal have?
  - Who is the owner or operator of the LNG terminal?
  - What consumers are already being supplied by this terminal?
  - Is competing use to be expected which could possibly lead to supply bottlenecks? Is there a potential for expansion?
  - Are there restrictions of navigability and consequently, of a stable gas supply due to seasonal events (such as low water levels or floods, freezing, etc.) or other local conditions (such as tidal range, bridges, locks, etc.)?

16.3 Overview "Political and regulatory criteria"

Political situation (national, regional and municipal)

• Is support or opposition of the political sector to be expected with regard to the planned project?
  o Which party forms the government, which the opposition? What are the majority ratios?
• Are politically motivated changes in the requirements regarding power plant projects to be expected in the foreseeable future?
  o When will the next elections be held?
  o Are there any statements on energy supply in the election programs of the parties? If so, what statements?

Situation with regard to planning law (national, regional and municipal)

• Do the federal planning requirements allow a power plant project?
  o What planning law requirements exist on national level?
  o Is the potential area defined as power plant area in the federal planning?
  o Are there conflicts between the federal planning law requirements and a power plant project?
  o Is there the possibility to adjust and alter the federal planning law requirements in favour of the power plant project?
• Do the regional planning requirements allow a power plant project?
  o What planning law requirements exist on regional level?
  o Is the potential area defined as power plant area in the regional planning?
  o Are there conflicts between the regional planning law requirements and a power plant project?
  o Is there the possibility to adjust and alter the regional planning law requirements in favour of the power plant project?
• Do the municipal planning requirements allow a power plant project?
  o What planning law requirements exist on municipal level?

- Is the potential area defined as power plant area in the municipal land use planning?
  - Are there conflicts between the municipal land use planning requirements and a power plant project?
  - Is there the possibility to alter the land use plan?
  - Is there the possibility to alter an existing development plan?

Competing land use

- Are there residential areas in the immediate vicinity of the potential area?
- Are there recreational areas in the immediate vicinity of the potential area?
- Is there an airport in the vicinity of the potential area?
- Is there a military area in the vicinity of the potential area?

Environmental conditions

- Are there any NATURA 2000 areas (FFH-habitats and bird sanctuaries) in the immediate vicinity of the potential area?
- Is there an initial level of pollution in the surrounding environment?
- Are compensation areas (for incursions on the environment) available in the vicinity of the potential area?

Situation regarding regulatory approval

- Are particular requirements to be expected from the regulatory point of view?
  - Is a licence application necessary for the construction or operation of the power plant?
  - What emission limit values apply for the project?
  - Is an environmental impact assessment/strategic environmental assessment necessary?
  - What approvals are necessary for the construction and operation of the power plant?
  - What application procedure is necessary for the construction permit and operating licence?

- Which is the authority in charge?
- Have any licences for the construction and operation of comparable projects been granted recently by this authority?
- Is a permission for the construction of a high-voltage power line necessary?
- Which is the authority in charge?
- Is a permission for infrastructure interventions (pipelines, streets, etc.) necessary? Which is the authority in charge?
- Is the potential area near a national border and if so, is a cross-border environmental impact assessment necessary? Which are the authorities in charge?

16.4 Overview “Economic criteria“

Construction costs

- Will there be additional costs that exceed the costs involved in the erection of a power plant at all sites?
    - costs for the purchase of land
    - costs for remediation of contaminated sites
    - costs for the purchase of compensation areas
    - costs for necessary infrastructure development, such as gas pipeline, cooling water supply, road construction, etc.
    - costs of network expansion for grid connection and, if necessary, reinforcement in the downstream network

Operating costs

- Are the recurrent operating costs involved in the operation of a power plant above average?
    - What are the charges for using the gas network?
    - What are the charges for cooling water abstraction?
    - What are the general disposal costs?
    - What are the sewage charges?
    - What are the grid usage fees?
    - What are the costs for the CO^2-certificates?
    - What are the labour costs involved in the operation?
    - What are the costs involved in other requirements for the operation of the power plant, such as eligibility for oil operation?

Redispatch

- Are restrictions of the operation of the power plant on the potential area due to privileged generation to be expected?
    - Are there any existing privileged power generation plants in the vicinity (wind, solar, geothermal, biomass, etc.)?

- Are there plans for further expansion of privileged power generation plants?
- If so, of what nature are the planned power generation plants and how much line capacity is the planned plant supposed to provide?

Marketing opportunities

- Is there the possibility to supply neighbouring industries with process steam?
    - What industries are there in the catchment area of the potential site?
    - What demand for process steam (pressure level specific) is estimated as marketable?
- Is there the possibility to supply adjacent residential areas or industrial areas with district heat?
    - Are there political efforts to establish or expand district heating supply? If so, what kind of efforts?
    - Are there any regulations or requirements concerning the obligation for housing estates to be connected to the district heating grid?
    - What is the envisaged potential of the district heating supply?

Energy market prospects

- What demand for electricity is to be expected in the future?
- How are the other energy market participants currently positioned?
- What plans for capacity expansion are there already?

Potential synergies

- Are there possibilities to obtain staff synergies by merging operational tasks?
- Can synergies in operational processes be achieved by the joint use of existing plants?

• Can saving effects be achieved by a possible increase in fuel requirements? • Can synergies be achieved in administration?
NPV (Net Present Value)
• What is the minimum rate of return expected from the project on the site? • What is the assumed minimum and maximum term? • Is it possible to meet the economic expectations towards the NPV (Net present Value) with the total investment in the site?
Tax system
• Is there the possibility to receive tax exemptions on the site? If so, under what circumstances and conditions? • Are additional taxes to be expected on the site? • Are there any tax-related particularities on the site? • If the site is in a foreign country, which is the optimum legal tax form from the point of view of the company as a whole?

16.5 Overview „Other criteria“

Local contacts
• Are contacts or experiences available with local maintenance and repair companies in the vicinity of the potential site? • Are contacts or experiences available with local manufacturing companies in the vicinity of the potential site? • Are contacts or experiences available with local consulting firms?
Stakeholder analysis
• Are objections to and rejection of the project to be expected by the residents? How is the project evaluated by the residents? • Are objections to and rejection of the project to be expected by the political sector? • Are objections to and rejection of the project to be expected by non-governmental organizations (NGO)? What is their position towards the project?
Structure of the region and the country
• What is the population density of the region or the country? • How well is the general infrastructure developed in the region or the country? • What is the general standard of living and the level of education in the country or the region?
Corporate strategy
• Is the potential site in line with the general corporate strategy? • Are there already business activities of other sectors in the region or the country of the potential site?

Workforce
• Is workforce available on site? • Is the local workforce suitably qualified? • Are there maintenance and repair companies on site?

16.6 Example AA - Alternative evaluation of area specific criteria

PROJECTEXAMPLE "AA" = Brownfield

Special conditions: South of Europe; direct cooling water access (Mediterranean Sea); direct gas pipeline access; direct grid connection

ENGLISH (Spain)

Criteria description	criteria evaluation description	Total evaluation Value (SG_{ij}, K_{ij} and U_{ij})	Weighting factor (g_i)	Total utility value N_j	Information source description	Information factor (IF)	Criteria information result (KI_{ij})
Total Information Amount NI_j		**18,1**		**62,4**			**22,6**
AREA SPECIFIC CRITERIA		3,8	3,3	12,4		1,3	5,1
Size of the area		3,3	3,3	10,7		1,5	4,9
• Is the area sufficiently large for the planned project?		4,5	3,3	14,8		1,5	6,8
o How large is the potential area?	more than sufficient	5,0	3,3	16,4	site plan available	1,5	7,5
o What shape does the potential area have, and does this shape allow a sensible and practicable arrangement of the power plant components?	after decommissioning, yes	4,0	3,3	13,1	site plan available	1,5	6,0
• Are there any possibilities for expansion (what are the adjacent areas like)?	only quite limited, because it is in an inductrial area	2,0	3,3	6,6	site plan available	1,5	3,0
Properties of the area		3,3	3,3	11,0		1,3	4,6
• Does the building ground meet the standards of a power plant project?		3,3	3,3	11,0		1,2	4,2
o Kind of ground (soil composition)?	close to the beach with a lot of sand, low ground water level	3,0	3,3	9,9	from former plant	1	3,0
o Is the surface plane?	yes	5,0	3,3	16,4	contruction plans of old PP	1,5	7,5
o Is there suspicion of soil contamination, mining subsidence etc.?	yes from the old firing system	2,0	3,3	6,6	own expectation	1	2,0
• Are the climatic characteristics of the area suitable for a power plant project?		3,3	3,3	11,0		1,5	5,0
o Height above sea level?	very low; <5m	4,0	3,3	13,1	measurements	1,5	6,0
o Annual minimum and maximum air temperature (efficiency in cooling mode)?	very high temperatures in summer time; mild winter temperatures	3,0	3,3	9,9	statistics	1,5	4,5
o What is the prevailing wind direction? (influence on the pollution level for environment)	away from the living area to the industrie area	3,0	3,3	9,9	statistics	1,5	4,5
Ownership status		5,0	3,3	16,4		1,5	7,5
• Is the purchase of land possible without any difficulty on the basis of the present ownership?		5,0	3,3	16,4		1,5	7,5
o How many owners does the potential area belong to??	Oone owner	5,0	3,3	16,4	given information	1,5	7,5
o Who are the owners of the potential area?	own ownerhsip	5,0	3,3	16,4	given information	1,5	7,5
o Is the area in private or public ownership?	own ownership	5,0	3,3	16,4	given information	1,5	7,5
o What is the earliest possible disposability of the area?	immediately	5,0	3,3	16,4	given information	1,5	7,5
Environmental situation		3,5	3,3	11,4		1,2	4,4
• Can, under the existing local environmental conditions, a power plant be erected on the potential ground without major environment-related impairments?		4,4	3,3	14,5		1,3	5,9
o Are there any trees or shrubs on the area (potential biotopes)?	not in the form of an biotop	4,0	3,3	13,1	given information	1,5	6,0
o Are there any habitats of protected species (Red List) on the area?	no	5,0	3,3	16,4	given information	1,5	7,5
o Are there any standing or flowing bodies of water on the area (potential biotopes)?	no	5,0	3,3	16,4	given information	1,5	7,5
o Are there specially protected sites (FFH habitats, bird sanctuaries)?	no	5,0	3,3	16,4	given information	1,5	7,5
o Are there water protection areas in the immediate vicinity?	yes; there exist regulations for the usage of the sea	4,0	3,3	13,1	given information	1,5	6,0
o Is the area in a retention area?	no	5,0	3,3	16,4	site visit	1	5,0
o Is there an initial level of pollution due to previous use or use of neighbouring land plots?	due to vicinity of harbor/ ports, possible	3,0	3,3	9,9	own expectation	0,5	1,5
• Are there any environmental risks that oppose the suitability of the site for the construction of a power plant?		2,5	3,3	8,2		1,1	2,9
o Can floods be expected on the potential area?	very unlikely, but not strictly to exclude	3,0	3,3	9,9	statistical datas	1,5	4,5
Have there been floods in the region in the last 100 years?	yes	3,0	3,3	9,9	interview	1	3,0
o Can earthquakes be expected on the potential area?	according to authorities, yes	2,0	3,3	6,6	interview	1	2,0
Have there been earthquakes in the region in the last 100 years?	yes	2,0	3,3	6,6	interview	1	2,0
Conflicts relating to past use		3,8	3,3	12,5		1,0	4,1
• Is there suspicion of ground contamination due to previous use?	yes	2,0	3,3	6,6	own expectation	0,5	1,0
• Is there the possibility of mining subsidence damages?	no	5,0	3,3	16,4	site visit	1	5,0
• Can absence of explosive ordinance be guaranteed?	still existing old bunkers are very close, but due to existing plant low probility	3,0	3,3	9,9	own expectation + interview	1	3,0
• Are there possible archaeological sites?	because of existing plant, no	4,0	3,3	13,1	interview	1	4,0
• Are there any environmental procedures pending?	no	5,0	3,3	16,4	given information	1,5	7,5

16.7 Example AA - Alternative evaluation of Technical Criteria

PROJECTEXAMPLE "AA" = Brownfield

Special conditions: South of Europe; direct cooling water access (Mediterranean Sea); direct gas pipeline access; direct grid connection

ENGLISH (Spain)

Criteria description	criteria evaluation description	Total evaluation Value (SG_{ij}, K_{ij} and U_{ij})	Weighting factor (g_i)	Total utility value N_j	Information source description	Information factor (IF)	Criteria information result (KI_{ij})
Total Information Amount NI_j		**18,1**		**62,4**			**22,6**
TECHNICAL CRITERIA		4,4	3,6	15,7		1,4	6,1
Cooling water situation		3,8	3,6	13,7		1,5	5,8
• Is a cooling water source available, such as a sea, river, lake or canal which can satisfy the demand for cooling water for the power plant project throughout the year without restrictions?		3,8	3,6	13,7		1,5	5,8
o In what distance is the cooling water source situated?	directly at the sea	5,0	3,6	17,8	given information	1,5	7,5
o What are the average annual temperatures of the cooling water source?	very high	3,0	3,6	10,7	statistical informations	1,5	4,5
What is the maximum cooling water temperature in the summer?	unknown, can be influance the efficiancy and authority requirements	2,0	3,6	7,1	statistical informations	1,5	3,0
o Is the cooling water source already being used for other cooling purposes?	partially yes	3,0	3,6	10,7	given information	1,5	4,5
o Are there any existing restrictions of use or are any future restrictions of use to be expected?	by comlying with legislations, no	5,0	3,6	17,8	given information	1,5	7,5
o Does the water quality meet the requirements and are special contaminations by the water to be expected, such as shells and algae growth or chemical contamination caused by agriculture, etc., which could affect the operation of the power plant?	sufficient for plant operation	5,0	3,6	17,8	given information	1,5	7,5
Network access		4,9	3,6	17,3		1,5	7,3
• Is network access possible under the given conditions (geographical, technical and regulatory)?		4,7	3,6	16,8		1,5	7,1
o Is a network connection point in the ultra-high voltage network available in the vicinity of the potential area? In what distance?	yes, directly on the plant area	5,0	3,6	17,8	given information	1,5	7,5
o What voltage level does the potential network connection point have?	110 kV	5,0	3,6	17,8	given information	1,5	7,5
o Where is the nearest transformer substation?	directly beside the plant area	5,0	3,6	17,8	given information	1,5	7,5
o What regulations for network connection apply? Is an increase in the expenditure of time to be expected due to the network connection regulations?	generally relevant	4,0	3,6	14,3	given information	1,5	6,0
	no	5,0	3,6	17,8	given information	1,5	7,5
o Who is responsible for the implementation of the network connection procedure?	operator	4,0	3,6	14,3	given information	1,5	6,0
o Would a necessary network connection line to the potential network connection point pass through critical areas, such as housing estates or nature conservation areas?	no	5,0	3,6	17,8	given information	1,5	7,5
• Is a spare network connection available?	yes	5,0	3,6	17,8	given information	1,5	7,5
Network capacity		4,6	3,6	16,3		1,1	5,2
• Is the capacity available at the network connection point sufficient for the connection of the planned project?		4,6	3,6	16,3		1,1	5,2
o Are the any investigations concerning the network expansion in the region?	yes	5,0	3,6	17,8	given information	1,5	7,5
How can the situation relating to the transition network be assessed? Is it sufficient for the connection of the planned project?	yes	5,0	3,6	17,8	given information	1,5	7,5
o Are there any plans for network expansion measures in the country/the region, and if so, what kind of plans?	no	3,0	3,6	10,7	interview	1	3,0
o Is competing use to be expected that can lead to network congestion?	no	5,0	3,6	17,8	own expectation	0,5	2,5
o Is there a regulation for network congestion management in the country/the region?	yes	4,0	3,6	14,3	given information	1,5	6,0
o Is the static stability of the network sufficient?	yes	5,0	3,6	17,8	interview	1	5,0
o Is the dynamic stability of the network sufficient?	yes	5,0	3,6	17,8	interview	1	5,0
Fuel transport capacity and infrastructure		4,4	3,6	15,6		1,4	6,1
• Is there a gas pipeline in the vicinity of the potential area, which can be used to operate a power plant throughout the year?		4,4	3,6	15,6		1,4	6,1
o In what distance is the gas pipeline or a connection point?	on the plant area	5,0	3,6	17,8	given information	1,5	7,5
o Is it necessary to build a connecting line or a new gas pipeline? Does this pipeline pass through critical areas, such as nature conservation areas or housing estates? Is this pipeline eligible for approval? If so, under what conditions/prerequisites?	no	5,0	3,6	17,8	given information	1,5	7,5
o Who is the owner of the gas pipeline?	operator the gas pipeline	4,0	3,6	14,3	given information	1,5	6,0
o Who is the operator of the gas pipeline? Are there any objections to a long-term cooperation?	no objections	5,0	3,6	17,8	given information	1,5	7,5
o What transport capacity does the gas pipeline have?	ausreihend, mit Reserve	5,0	3,6	17,8	given information	1,5	7,5
o What consumers are supplied by this gas pipeline?	rafenerie system	3,0	3,6	10,7	interview	1	3,0
o Is competing use of the gas pipeline to be expected, which could lead to supply bottlenecks?	use of the gas pipeline yes; supply bottlenecks no	4,0	3,6	14,3	interview	1	4,0
o Is there a regulation for the management of a gas supply bottleneck in the country/the region?	yes	4,0	3,6	14,3	given information	1,5	6,0
• Is the potential site in the vicinity of a sea or inland port through which the power plant could be supplied with fuel via an LNG terminal?	no	0,0	3,6	0,0		0,0	0,0
If so …			3,6	0,0			0,0
o In what distance is the LNG terminal?			3,6	0,0			0,0
o What capacity does the LNG terminal have?			3,6	0,0			0,0
o Who is the owner or operator of the LNG terminal?			3,6	0,0			0,0
o What consumers are already being supplied by this terminal?			3,6	0,0			0,0
o Is competing use to be expected which could possibly lead to supply bottlenecks? Is there a potential for expansion?			3,6	0,0			0,0
o Are there restrictions of navigability and consequently, of a stable gas supply due to seasonal events (such as low water levels or floods, freezing, etc.) or other local conditions (such as tidal range, bridges, locks, etc.)?			3,6	0,0			0,0

16.8 Example AA - Alternative evaluation of political and regulatory criteria

PROJECTEXAMPLE "AA" = Brownfield

Special conditions: South of Europe; direct cooling water access (Mediterranean Sea); direct gas pipeline access; direct grid connection

ENGLISH (Spain)

Criteria description	criteria evaluation description	Total evaluation Value (SG_{ij}, K_{ij} and U_{ij})	Weighting factor (g_i)	Total utility value N_j	Information source description	Information factor (IF)	Criteria information result (KI_{ij})
Total Information Amount NI_j		**18,1**		**62,4**			**22,6**
POLITICAL and REGULATORY CRITERIA		3,1	3,7	11,4		1,1	3,5
Political situation (national, regional and municipal)		1,8	3,7	6,5		0,6	1,1
• Is support or opposition of the political sector to be expected with regard to the planned project?		2,0	3,7	7,4		0,5	1,0
o Which party forms the government, which the opposition? What are the majority ratios?	XXX	2,0	3,7	7,4	own expectation	0,5	1,0
• Are politically motivated changes in the requirements regarding power plant projects to be expected in the foreseeable future?		1,5	3,7	5,5		0,8	1,3
o When will the next elections be held?	in 3 yers	2,0	3,7	7,4	interview	1	2,0
o Are there any statements on energy supply in the election programmes of the parties? If so, what statements?	yes	1,0	3,7	3,7	own expertise	0,5	0,5
Situation with regard to planning law (national, regional and municipal)		4,0	3,7	14,7		1,0	3,9
• Do the federal planning requirements allow a power plant project?		4,0	3,7	14,8		1,1	4,6
o What planning law requirements exist on national level?	usal requirements	4,0	3,7	14,8	interview	1	4,0
o Is the potential area defined as power plant area in the federal planning?	yes	5,0	3,7	18,5	given information	1,5	7,5
o Are there conflicts between the federal planning law requirements and a power plant project?	no, not direct	4,0	3,7	14,8	interview	1	4,0
o Is there the possibility to adjust and alter the federal planning law requirements in favour of the power plant project?	yes	3,0	3,7	11,1	interview	1	3,0
• Do the regional planning requirements allow a power plant project?		3,8	3,7	13,8		1,0	3,8
o What planning law requirements exist on regional level?	normal requirements	4,0	3,7	14,8	interview	1	4,0
o Is the potential area defined as power plant area in the regional planning?	yes	4,0	3,7	14,8	interview	1	4,0
o Are there conflicts between the regional planning law requirements and a power plant project?	no	4,0	3,7	14,8	interview	1	4,0
o Is there the possibility to adjust and alter the regional planning law requirements in favour of the power plant project?	yes	3,0	3,7	11,1	interview	1	3,0
• Do the municipal planning requirements allow a power plant project?		4,2	3,7	15,5		0,8	3,4
o What planning law requirements exist on municipal level?	normal requirements	4,0	3,7	14,8	interview	1	4,0
o Is the potential area defined as power plant area in the municipal land use planning?	yes	5,0	3,7	18,5	interview	1	5,0
o Are there conflicts between the municipal land use planning requirements and a power plant project?	in principal no	4,0	3,7	14,8	interview		0,0
o Is there the possibility to alter the land use plan?	yes	4,0	3,7	14,8	interview	1	4,0
o Is there the possibility to alter an existing development plan?	yes	4,0	3,7	14,8	interview	1	4,0
Competing land use		2,5	3,7	9,2		1,5	3,8
• Are there residential areas in the immediate vicinity of the potential area?	yes	2,0	3,7	7,4	site visit	1,5	3,0
• Are there recreational areas in the immediate vicinity of the potential area?	yes	2,0	3,7	7,4	given information	1,5	3,0
• Is there an airport in the vicinity of the potential area?	yes	3,0	3,7	11,1	given information	1,5	4,5
• Is there a military area in the vicinity of the potential area?	yes	3,0	3,7	11,1	given information	1,5	4,5
Environmental conditions		3,3	3,7	12,3		1,3	4,7
• Are there any NATURA 2000 areas (FFH-habitats and bird sanctuaries) in the immediate vicinity of the potential area?	no	4,0	3,7	14,8	given information	1,5	6,0
• Is there an initial level of pollution in the surrounding environment?	yes	2,0	3,7	7,4	interview	1	2,0
• Are compensation areas (for incursions on the environment) available in the vicinity of the potential area?	yes	4,0	3,7	14,8	given information	1,5	6,0
Situation regarding regulatory approval		3,8	3,7	14,1		1,0	3,8
• Are particular requirements to be expected from the regulatory point of view?		3,8	3,7			1,0	3,8
o Is a licence application necessary for the construction or operation of the power plant?	yes	3,0	3,7		interview	1	3,0
o What emission limit values apply for the project?	in normal limits	4,0	3,7		interview	1	4,0
o Is an environmental impact assessment/strategic environmental assessment necessary?	yes	4,0	3,7		interview	1	4,0
o What approvals are necessary for the construction and operation of the power plant?	overview list avaliable	3,0	3,7		interview	1	3,0
o What application procedure is necessary for the construction permit and operating licence?	procedure is known	4,0	3,7		interview	1	4,0
o Which is the authority in charge?	authority is known	5,0	3,7		interview	1	5,0
o Have any licences for the construction and operation of comparable projects been granted recently by this authority?	yes	3,0	3,7		interview	1	3,0
o Is a permission for the construction of a high-voltage power line necessary?	ne, because already existing	4,0	3,7		interview	1	4,0
o Which is the authority in charge?	known	5,0	3,7		interview	1	5,0
o Is a permission for infrastructure interventions (pipelines, streets, etc.) necessary? Which is the authority in charge?	permission necessary, authorities known	4,0	3,7		interview	1	4,0
o Is the potential area near a national border and if so, is a cross-border environmental impact assessment necessary? Which are the authorities in charge?	yes, is near to national border	3,0	3,7		interview	1	3,0

16.9 Example AA - Alternative evaluation of economic criteria

PROJECTEXAMPLE "AA" = Brownfield

Special conditions: South of Europe; direct cooling water access (Mediterranean Sea); direct gas pipeline access; direct grid connection

ENGLISH (Spain)

Criteria description	criteria evaluation description	Total evaluation Value (SG_{ij}, K_{ij} and U_{ij})	Weighting factor (g_i)	Total utility value N_j	Information source description	Information factor (IF)	Criteria information result (KI_{ij})
Total Information Amount NI_j		18,1		62,4			22,6
ECONOMIC CRITERIA		3,1	3,5	10,7		1,0	3,2
Construction costs		3,8	3,5	13,2		1,0	4,0
• Will there be additional costs that exceed the costs involved in the erection of a power plant at all sites?		3,8	3,5	13,2		1,0	4,0
o costs for the purchase of land	no costs	5,0	3,5	17,4	given information	1,5	7,5
o costs for remediation of contaminated sites	quite high	1,0	3,5	3,5	indication from subsupplier	1	1,0
o costs for the purchase of compensation areas	low, because already available	5,0	3,5	17,4	given information	1,5	7,5
o costs for necessary infrastructure development, such as gas pipeline, cooling water supply, road construction, etc.	low	4,0	3,5	13,9	own calculation	0,5	2,0
o costs of network expansion for grid connection and, if necessary, reinforcement in the downstream network	low	4,0	3,5	13,9	own calculation	0,5	2,0
Operating costs		3,6	3,5	12,6		1,3	4,8
• Are the recurrent operating costs involved in the operation of a power plant above average?		3,6	3,5	12,6		1,3	4,8
o What are the charges for using the gas network?	normal charges	4,0	3,5	13,9	given information	1,5	6,0
o What are the charges for cooling water abstraction?	expected increase	3,0	3,5	10,4	interview	1	3,0
o What are the general disposal costs?	expected increase	3,0	3,5	10,4	given information	1,5	4,5
o What are the sewage charges?	normal level	4,0	3,5	13,9	given information	1,5	6,0
o What are the grid usage fees?	contract	4,0	3,5	13,9	given information	1,5	6,0
o What are the costs for the CO^2-certificates?	low	4,0	3,5	13,9	interview	1	4,0
o What are the labour costs involved in the operation?	at normal level	3,0	3,5	10,4	given information	1,5	4,5
o What are the costs involved in other requirements for the operation of the power plant, such as eligibility for oil operation?	no special requirements	4,0	3,5	13,9	interview	1	4,0
Redispatch		2,3	3,5	8,1		0,7	1,5
• Are restrictions of the operation of the power plant on the potential area due to privileged generation to be expected?		2,3	3,5	8,1		0,7	1,5
o Are there any existing privileged power generation plants in the vicinity (wind, solar, geothermal, biomass, etc.)?	yes	2,0	3,5	7,0	interview	1	2,0
o Are there plans for further expansion of privileged power generation plants?	yes, but on a low level expected	3,0	3,5	10,4	own expertise	0,5	1,5
o If so, of what nature are the planned power generation plants and how much line capacity is the planned plant supposed to provide?	uncertain	2,0	3,5	7,0	own expertise	0,5	1,0
Marketing opportunities		1,8	3,5	6,4		1,3	2,3
• Is there the possibility to supply neighbouring industries with process steam?		2,0	3,5	7,0		1,0	2,0
o What industries are there in the catchment area of the potential site?	rafenerie system	3,0	3,5	10,4	interview	1	3,0
o What demand for process steam (pressure level specific) is estimated as marketable?	very low, up to 0	1,0	3,5	3,5	interview	1	1,0
• Is there the possibility to supply adjacent residential areas or industrial areas with district heat?		1,7	3,5	5,8		1,5	2,5
o Are there political efforts to establish or expand district heating supply? If so, what kind of efforts?	no	1,0	3,5	3,5	given information	1,5	1,5
o Are there any regulations or requirements concerning the obligation for housing estates to be connected to the district heating grid?		2,0	3,5	7,0	given information	1,5	3,0
o What is the envisaged potential of the district heating supply?		2,0	3,5	7,0	given information	1,5	3,0
Energy market prospects		3,0	3,5	10,4		0,5	1,5
• What demand for electricity is to be expected in the future?	increasing	3,0	3,5	10,4	own expectation	0,5	1,5
• How are the other energy market participants currently positioned?	marcet participants partially known	3,0	3,5	10,4	own expertise	0,5	1,5
• What plans for capacity expansion are there already?	activities known	3,0	3,5	10,4	own expertise	0,5	1,5
Potential synergies		2,3	3,5	7,8		1,3	2,5
• Are there possibilities to obtain staff synergies by merging operational tasks?	yes, with a coal plant	3,0	3,5	10,4	interview	1	3,0
• Can synergies in operational processes be achieved by the joint use of existing plants?	no	1,0	3,5	3,5	given information	1,5	1,5
• Can saving effects be achieved by a possible increase in fuel requirements?	no	1,0	3,5	3,5	given information	1,5	1,5
• Can synergies be achieved in administration?	yes, with a coal plant	4,0	3,5	13,9	interview	1	4,0
NPV (Net Present Value)		4,0	3,5	13,9		1,2	4,7
• What is the minimum rate of return expected from the project on the site?	10%	4,0	3,5	13,9	given information	1,5	6,0
• What is the assumed minimum and maximum term?	25 years	4,0	3,5	13,9	given information	1,5	6,0
• Is it possible to meet the economic expectations towards the NPV (Net present Value) with the total investment in the site?	yes	4,0	3,5	13,9	own calculation	0,5	2,0
Tax system		3,8	3,5	13,1		1,3	4,6
• Is there the possibility to receive tax exemptions on the site? If so, under what circumstances and conditions?	no	2,0	3,5		given information	1,5	3,0
• Are additional taxes to be expected on the site?	no	4,0	3,5		interview	1	4,0
• Are there any tax-related particularities on the site?	no particularities	4,0	3,5		interview	1	4,0
• If the site is in a foreign country, which is the optimum legal tax form from the point of view of the company as a whole?	clarified	5,0	3,5		given information	1,5	7,5

16.10Example AA - Alternative evaluation of other criteria

PROJECTEXAMPLE "AA" = Brownfield

Special conditions: South of Europe; direct cooling water access (Mediterranean Sea); direct gas pipeline access; direct grid connection

ENGLISH (Spain)

Criteria description	criteria evaluation description	Total evaluation Value (SG_{ij}, K_{ij} and U_{ij})	Weighting factor (g_i)	Total utility value N_j	Information source description	Information factor (IF)	Criteria information result (KI_{ij})
Total Information Amount NI_j		**18,1**		**62,4**			**22,6**
OTHER CRITERIA		3,8	3,2	12,2		1,2	4,7
Local contacts		4,3	3,2	13,9		1,5	6,5
• Are contacts or experiences available with local maintenance and repair companies in the vicinity of the potential site?	yes	5,0	3,2	16,1	given information	1,5	7,5
• Are contacts or experiences available with local manufacturing companies in the vicinity of the potential site?	yes	4,0	3,2	12,9	given information	1,5	6,0
• Are contacts or experiences available with local consulting firms?	yes	4,0	3,2	12,9	given information	1,5	6,0
Stakeholder analysis		2,0	3,2	6,4		0,5	1,0
• Are objections to and rejection of the project to be expected by the residents? How is the project evaluated by the residents?	yes, with rejection has to be expected	2,0	3,2	6,4	own expertise	0,5	1,0
• Are objections to and rejection of the project to be expected by the political sector?	yes, with rejection has to be expected	1,0	3,2	3,2	own expertise	0,5	0,5
• Are objections to and rejection of the project to be expected by non-governmental organisations (NGO)? What is their position towards the project?	yes, with rejection has to be expected	3,0	3,2	9,7	own expertise	0,5	1,5
Structure of the region and the country		3,7	3,2	11,8		1,0	3,7
• What is the population density of the region or the country?	on a normal level	3,0	3,2	9,7	interview	1	3,0
• How well is the general infrastructure developed in the region or the country?	quite good	4,0	3,2	12,9	interview	1	4,0
• What is the general standard of living and the level of education in the country or the region?	sufficient	4,0	3,2	12,9	interview	1	4,0
Corporate strategy		4,0	3,2	12,9		1,3	5,0
• Is the potential site in line with the general corporate strategy?	yes	4,0	3,2	12,9	given information	1,5	6,0
• Are there already business activities of other sectors in the region or the country of the potential site?	yes	4,0	3,2	12,9	interview	1	4,0
Workforce		5,0	3,2	16,1		1,5	7,5
• Is workforce available on site?	yes	5,0	3,2		given information	1,5	7,5
• Is the local workforce suitably qualified?	yes	5,0	3,2		given information	1,5	7,5
• Are there maintenance and repair companies on site?	yes	5,0	3,2		given information	1,5	7,5

16.11 Criteria result matrix project phase „Preliminary study in the site decision process“

Location		Criteria weighting	Location AA	Location BB	Location CC
Other criterias	Workforce				
	Corporate strategy				
	Structure of the region and the country				
	Stakeholder analysis				
	Local contacts				
Economic criterias	Tax system				
	NPV (Net Present Value)				
	Potential synergies				
	Energy market prospects				
	Marketing opportunities				
	Redispatch				
	Operating costs				
	Construction costs				
Political and regulatory criteria	Situation regarding regulatory approval				
	Environmental conditions				
	Competing land use				
	Situation with regard to planning law				
	Political situation				
Tecnical criterias	Fuel transport capacity and infrastructure				
	Network capacity				
	Network access				
	Cooling water situation				
Area specific criterias	Conflicts relating to past use				
	Environmental situation				
	Ownership status				
	Properties of the area				
	Size of the area				
Total Information Amount NIj					

16.12Questionnaire result matrix of „Site evaluation example“

Location	Total evaluation Value (SGij, Kij and Uij)	Area specific criterias: Size of the area	Properties of the area	Ownership status	Environmental situation	Conflicts relating to past use
Criteria weighting						
Location AA	**18,1**	3,3	3,3	5,0	3,5	3,8
Location BB	**16,2**	5,0	2,0	2,5	2,9	3,8
Location CC	**16,8**	2,0	3,3	3,3	4,4	4,2

Location	Tecnical criterias: Cooling water situation	Network access	Network capacity	Fuel transport capacity and infrastructure
Criteria weighting				
Location AA	3,8	4,9	4,6	4,4
Location BB	4,2	2,7	4,3	2,9
Location CC	2,0	2,8	4,0	4,6

Location	Political and regulatory criteria: Political situation	Situation with regard to planning law	Competing land use	Environmental conditions	Situation regarding regulatory approval
Criteria weighting					
Location AA	1,8	4,0	2,5	3,3	3,8
Location BB	2,5	3,7	3,0	3,3	3,3
Location CC	2,5	3,8	4,5	4,0	3,4

Location	Economic criterias: Construction costs	Operating costs	Redispatch	Marketing opportunities	Energy market prospects	Potential synergies	NPV (Net Present Value)	Tax system
Criteria weighting								
Location AA	3,8	3,6	2,3	1,8	3,0	2,3	4,0	3,8
Location BB	2,0	3,1	3,3	1,8	3,0	1,5	3,7	3,0
Location CC	2,2	3,6	3,3	2,3	3,0	1,3	3,7	3,8

Location	Other criterias: Local contacts	Stakeholder analysis	Structure of the region and the country	Corporate strategy	Workforce
Criteria weighting					
Location AA	4,3	2,0	3,7	4,0	5,0
Location BB	3,7	3,0	3,7	4,5	3,3
Location CC	2,7	3,0	4,0	4,0	3,7

18,1	100,0%	5	3,7	ist Vorteilhaft für das Projekt
16,2	89,4%	3,6	2,3	ist bedingt vorteilhaft für das Projekt
16,8	92,5%	2,2	1,0	wirkt dem Projekt entgegen

16.13 Questionnaire result matrix of „Site evaluation example“ with weighting factor

Location	Total utility value Nj	Size of the area	Properties of the area	Ownership status	Environmental situation	Conflicts relating to past use	Cooling water situation	Network access	Network capacity	Fuel transport capacity and infrastructure	Political situation	Situation with regard to planning law	Competing land use	Environmental conditions	Situation regarding regulatory approval	Construction costs	Operating costs	Redispatch	Marketing opportunities	Energy market prospects	Potential synergies	NPV (Net Present Value)	Tax system	Local contacts	Stakeholder analysis	Structure of the region and the country	Corporate strategy	Workforce
		Area specific criterias					Tecnical criterias				Political and regulatory criteria					Economic criterias								Other criterias				
Criteria weighting		3,3					3,6				3,7					3,5								3,2				
Location AA	62,4	10,7	11,0	16,4	11,4	12,5	13,7	17,3	16,3	15,6	6,5	14,7	9,2	12,3	14,1	13,2	12,6	8,1	6,4	10,4	7,8	13,9	13,1	13,9	6,4	11,8	12,9	16,1
Location BB	55,8	16,4	6,6	8,2	9,4	12,5	14,8	9,7	15,3	10,2	9,2	13,5	11,1	12,3	12,1	7,0	10,9	11,6	6,4	10,4	5,2	12,8	10,4	11,8	9,7	11,8	14,5	10,7
Location CC	57,9	6,6	11,0	10,7	14,4	13,8	7,1	9,9	14,3	16,5	9,2	14,2	16,6	14,8	12,4	7,7	12,6	11,6	7,8	10,4	4,4	12,8	13,1	8,6	9,7	12,9	12,9	11,8

62,4	100,0%	1	8,0	unvotreilhaft, aber nicht so wichtig
55,8	89,5%	8,1	16,0	bedingt vorteilhaft + mittlere Wichtigkeit
57,9	92,7%	16,1	25,0	vorteilhaft und relevant

16.14 Questionnaire result matrix of „Site evaluation example“ with information factor (result of alternative evaluation)

Criteria group	Criterion	Location AA	Location BB	Location CC			
Other criterias	Workforce	7,5	3,3	2,5			
	Corporate strategy	5,0	6,8	6,0			
	Structure of the region and the country	3,7	5,5	6,0			
	Stakeholder analysis	1,0	2,7	2,7			
	Local contacts	6,5	4,3	2,0			
Economic criterias	Tax system	4,6	2,0	2,4			
	NPV (Net Present Value)	4,7	4,2	4,8			
	Potential synergies	2,5	1,1	1,8			
	Energy market prospects	1,5	1,5	2,0			
	Marketing opportunities	2,3	1,5	2,8			
	Redispatch	1,5	2,3	2,3			
	Operating costs	4,8	2,4	2,5			
	Construction costs	4,0	1,0	1,7			
Political and regulatory criteria	Situation regarding regulatory approval	3,8	1,6	4,0			
	Environmental conditions	4,7	2,3	6,0			
	Competing land use	3,8	2,1	6,8			
	Situation with regard to planning law	3,9	1,9	4,9			
	Political situation	1,1	1,3	2,9			
Tecnical criterias	Fuel transport capacity and infrastructure	6,1	2,0	6,9			
	Network capacity	5,2	2,5	3,7			
	Network access	7,3	1,5	2,3			
	Cooling water situation	5,8	4,6	1,5			
Area specific criterias	Conflicts relating to past use	4,1	2,9	4,8			
	Environmental situation	4,4	2,5	5,9			
	Ownership status	7,5	1,8	4,6			
	Properties of the area	4,6	2,0	4,0			
	Size of the area	4,9	6,3	2,6			
Total Information Amount NIj		**22,6**	**14,1**	**19,3**	100,0%	62,4%	85,2%
Location		Location AA	Location BB	Location CC	22,6	14,1	19,3

16.15 Questionnaire result of „Site evaluation example“ Criteria Weighting & Information Factor Matrix

Location	Total evaluation Value (SGij, Kij and Uij)	Area specific criterias	Tecnical criterias	Political and regulatory criteria	Economic criterias	Other criterias
		Size of the area Properties of the area Ownership status Environmental situation Conflicts relating to past use	Cooling water situation Network access Network capacity Fuel transport capacity and infrastructure	Political situation Situation with regard to planning law Competing land use Environmental conditions Situation regarding regulatory approval	Construction costs Operating costs Redispatch Marketing opportunities Energy market prospects Potential synergies NPV (Net Present Value) Tax system	Local contacts Stakeholder analysis Structure of the region and the country Corporate strategy Workforce
Criteria weighting		3,3	3,6	3,7	3,5	3,2
Location AA	2,8	2,3	2,2	3,4	3,3	2,7
Location BB	4,1	3,5	4,6	5,2	4,4	2,6
Location CC	3,1	2,4	3,6	2,6	3,8	3,1

2,8	100,0%	0,5	2,4
4,1	145,9%	2,5	4,8
3,1	110,8%	4,9	7,5

16.16 Questionnaire for the empirical investigation of the criteria weighting

UNIVERSITAT POLITÈCNICA DE CATALUNYA

Questionnaire – Dissertation Jan Krüger

Topic and introduction

In my **doctoral thesis** I deal with the question of a possible adaptation and extension of the existing classical site theories to the new construction of power plants, in particular to gas and steam power plants. To collect empirical data required for this purpose, I have provided the attached questionnaire.

The **situation** that will be looked at more closely is the following:
The construction of a gas and steam power plant is planned, for which different potential sites have been identified.
To find out the "best" site, these will have to be compared. A possible approach would be to determine and identify different site factors, which will serve as a basis for ascertaining their suitability and, finally, for taking a decision. For this, the factors will have to be examined and assessed.
Not every site has the same influence on and the same significance for the decision in favour of a power plant site.

This leads to the question of how important the specific factors are for the individual person when it comes to a decision.

This **questionnaire** is structured as follows:
First, there will be several questions of general nature.
These will be followed by the main part with questions about the so-called site factors.
Finally, you will be asked for your opinion on related issues and on a number of quotations.
Thank you in advance for your cooperation!

Notes on **completing** the questionnaire:
(!) Please tick the statement which comes closest to your position.
(!) If you feel uncertain about your own assessment, let yourself be guided by a German saying: "The first thought is often the best one."

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Questionnaire – Dissertation Jan Krüger

Profile

My data must be remain anonymous: ☐ YES
My name may be mentioned in the doctoral thesis: ☐ YES

In which area of business do you work (multiple choice is possible)?

- ☐ Power plant operation
- ☐ Power plant construction
- ☐ Energy sector, general
- ☐ University
- ☐ Authority
- ☐ Politics
- ☐ Other

How would you describe your occupational position:

- ☐ Senior-level management
- ☐ Middle management
- ☐ Management
- ☐ Expert
- ☐ Other

How many years of professional experience do you have:

- ☐ > 5 years
- ☐ > 10 years
- ☐ > 15 years
- ☐ > 20 years

Of these, how many years in the energy business:

- ☐ 1 to 5 years
- ☐ 6 to 10 years
- ☐ 11 to 15 years
- ☐ > 15 years

Have you ever been, either directly or indirectly, involved in a power plant site determination process (independent of technology)?

- ☐ YES 2 and more times
- ☐ YES 1 time
- ☐ NO

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Questionnaire – Dissertation Jan Krüger

Power plant site factors

In the following, different site factors will be listed in the form of statements, which have to be taken into account in the site decision process of a gas and steam power plant.
The statements are deliberately not schematically classified or structured. Some of them are rather general, others are formulated in more concrete terms.
Summarising all existing or possible aspects in a survey would go beyond the scope of this questionnaire. This is why it is restricted to some selected aspects and issues.

You will now be asked to give your opinion concerning the **significance** of the individual statements.
The scale ranges from 1 = weak significance over 3 = normal significance to 5 = very high significance.

Criteria weighting	**Assessment factor (AF)**
Very high significance; Big to very big influence on the site potential.	5
High significance; Moderate to big influence on the site potential.	4
Normal significance; Average significance on the site potential.	3
Minor significance; Below-average to small influence on the site potential.	2
Weak significance; Very weak to negligible influence on the site potential.	1

To avoid delays in completing the questionnaire due to possible uncertainties relating to the contents, please accept your first thought as the right one and tick the respective answer on the basis of this approach!

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Significance / influence on the site potential:
1 = weak; **2** = minor; **3** = normal; **4** = high; **5** =very high

No.	Statement	1	2	3	4	5
1.	The majority of the area is in private ownership!	☐	☐	☐	☐	☐
2.	A few individual resistance from the local policy is to be expected!	☐	☐	☐	☐	☐
3.	A few restrictions of use of the cooling water source are to be expected!	☐	☐	☐	☐	☐
4.	The residents may individually disapprove of or object to the project!	☐	☐	☐	☐	☐
5.	There are a few additional costs, which exceed the normal costs involved in the construction of a power plant on all other sites!	☐	☐	☐	☐	☐
6.	Geological or tectonic peculiarities are to be expected!	☐	☐	☐	☐	☐
7.	It is possible to fulfil the expectations with regard to the NPV (Net Present Value) with the total investment at the site!	☐	☐	☐	☐	☐
8.	There are no particularities concerning the application for a licence (e.g. at the Ministry of Economics or the Ministry of Energy) for the construction and / or operation of a power plant!	☐	☐	☐	☐	☐
9.	The building ground meets the requirements of a gas power plant project!	☐	☐	☐	☐	☐
10	Archaeological finds are to be expected!	☐	☐	☐	☐	☐
11	There are possibilities to adapt / change requirements with regard to land-use planning and regional or municipal regulations in favour of the power plant project!	☐	☐	☐	☐	☐
12	Future congestion of networks could be expected due to competing sectors (e.g. wind)!	☐	☐	☐	☐	☐
13	There will be no additional overheads which exceed the costs involved at all sites!	☐	☐	☐	☐	☐
14	There are no protected areas (FFH-areas, bird sanctuaries) on the ground!	☐	☐	☐	☐	☐
15	No extreme climatic conditions are to be expected!	☐	☐	☐	☐	☐

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Significance / influence on the site potential:
1 = weak; **2** = minor; **3** = normal; **4** = high; **5** =very high

No.	Statement	1 2 3 4 5
16	There will be sufficient transmission network capacity!	☐☐☐☐☐
17	The area / site is in line with the current general company strategy!	☐☐☐☐☐
18	The majority of the area is in public ownership!	☐☐☐☐☐
19	There are no possibilities of supplying adjacent residential or industrial areas with district heating!	☐☐☐☐☐
20	There are residential and recreational areas in the immediate vicinity!	☐☐☐☐☐
21	Under certain circumstances investments in energy generation are tax funded by the government!	☐☐☐☐☐
22	There are potential biotopes, e.g. due to bodies of standing or flowing water on the ground!	☐☐☐☐☐
23	The region of the planed power plant is generally seen as socially and economical stable!	☐☐☐☐☐
24	In the foreseeable future, politically motivated changes in the requirements to the power plant project could be possible!	☐☐☐☐☐
25	Accessibility of the site is guaranteed during the construction phase and reserve space is available!	☐☐☐☐☐
26	Polluted areas (soil contamination) are suspected!	☐☐☐☐☐
27	The economic criteria for the power plant at the respective site can only be met with optimistic predictions for the energy market!	☐☐☐☐☐
28	A gas pipeline or an LNG terminal is available in the vicinity of the potential site only in the radius of more than 15 km!	☐☐☐☐☐
29	Support by the state policy can be expected!	☐☐☐☐☐
30	There is a very low population density in the vicinity of the power plant with a limited availability of specialised labour!	☐☐☐☐☐

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Questionnaire – Dissertation Jan Krüger

Opinion and assessment

In their book "Crossing the Energy Divide – Moving from Fossil Fuel Dependence to a Clean Energy Future", Robert U. Ayres and Edward H. Ayres argue as follows:

"Energy services are not just a large part of economy; they are a major part of what drives the economy."

- ☐ I agree;
- ☐ I agree partially;
- ☐ I don't agree;
- ☐ I have no idea

What is your opinion on the statement: *"Gas and steam power plants are environmentally friendly technologies":*

- ☐ I agree;
- ☐ I agree partially;
- ☐ I don't agree;
- ☐ I have no idea

I consider the EU target to achieve a 20% share of energy from renewable sources in the Community's gross final consumption of energy, set in the Directive "Europe 2020" as

- ☐ too high
- ☐ sufficient
- ☐ expandable
- ☐ I have no idea

In what radius from your place of residence would you raise objections to the construction of a gas and steam power plant (capability for permission is taken for granted)?

- ☐ < 2 km
- ☐ < 5 km
- ☐ < 10 km
- ☐ < 50 km
- ☐ ≥ 50 km;

Questionnaire – Dissertation Jan Krüger

In his book "Power Hungry - The Mythos of "Green" Energy and the Real Fuels of the Future", Robert Bryce argues as follows:

"The future of energy supply belongs to natural gas and nuclear power, the only sources that can provide the level of continuous electricity the nation needs, without environmental damage."

- ☐ I fully agree;
- ☐ I agree partially –> in combination with:
  - ☐ nuclear power
  - ☐ natural gas
  - ☐ coal
  - ☐ renewable sources (e.g. biomass, win, solar …)
  - ☐ others
- ☐ I don't agree;
- ☐ I have no idea

What is your opinion on the political strategy of the EU „Europe 2020" to reduce greenhouse gas emission by 20%?

- ☐ I agree;
- ☐ I agree partially;
- ☐ I don't agree;
- ☐ I have no idea

What is your opinion on the statement: *„Gas power plants contribute to CO_2- reduction"*?

- ☐ I agree;
- ☐ I agree partially;
- ☐ I don't agree;
- ☐ I have no idea

THANK YOU VERY MUCH FOR YOUR EFFORTS AND YOUR SUPPORT IN BRINGING THIS DOCTORAL THESIS TO A MORE ADVANCED STAGE.

JAN KRÜGER

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16.17 Survey system for the five subject groups of site criteria

Significance / influence on the site potential: min. **1** = weak; **2** = minor; **3** = normal; **4** = high; max. **5** = very high

1.	The majority of the area is in private ownership!	Area -specific		+
2.	A few individual resistance from the local policy is to be expected!	political		-
3.	A few restrictions of use of the cooling water source are to be expected!	technical		-
4.	The residents may individually disapprove of or object to the project!	any other		-
5.	There are a few additional costs, which exceed the normal costs involved in the construction of a power plant on all other sites!	economically		-
6.	Geological or tectonic peculiarities are to be expected!	any other		-
7.	It is possible to fulfil the expectations with regard to the NPV (Net Present Value) with the total investment at the site!	economically		+
8.	There are no particularities concerning the application for a licence (e.g. at the Ministry of Economics or the Ministry of Energy) for the construction and / or operation of a power plant!	political		+
9.	The building ground meets the requirements of a gas power plant project!	technical		+
10.	Archaeological finds are to be expected!	Area -specific		-
11.	There are possibilities to adapt / change requirements with regard to land-use planning and regional or municipal regulations in favour of the power plant project!	political		+
12.	Future congestion of networks could be expected due to competing sectors (e.g. wind)!	technical		-
13.	There will be no additional overheads which exceed the costs involved at all sites!	economically		+
14.	There are no protected areas (FFH-areas, bird sanctuaries) on the ground!	Area -specific		+
15.	No extreme climatic conditions are to be expected!	any other		+
16.	There will be sufficient transmission network capacity!	technical		+
17.	The area / site is in line with the current general company strategy!	any other		+
18.	The majority of the area is in public ownership!	Area -specific		+
19.	There are no possibilities of supplying adjacent residential or industrial areas with district heating!	economically		-
20.	There are residential and recreational areas in the immediate vicinity!	political		-
21.	Under certain circumstances investments in energy generation are tax funded by the government!	economically		+
22.	There are potential biotopes, e.g. due to bodies of standing or flowing water on the ground!	Area -specific		-
23.	The region of the planed power plant is generally seen as socially and economical stable!	any other		+
24.	In the foreseeable future, politically motivated changes in the requirements to the power plant project could be possible!	political		-
25.	Accessibility of the site is guaranteed during the construction phase and reserve space is available!	technical		+
26.	Polluted areas (soil contamination) are suspected!	Area -specific		-
27.	The economic criteria for the power plant at the respective site can only be met with optimistic predictions for the energy market!	economically		-
28.	A gas pipeline or an LNG terminal is available in the vicinity of the potential site only in the radius of more than 15 km!	technical		-
29.	Support by the state policy can be expected!	political		+
30.	There is a very low population density in the vicinity of the power plant with a limited availability of specialised labour!	any other		-

	15 x	(red)	negativ
	15 x	(green)	positiv

political	-	3 x
	+	3 x
technical	-	3 x
	+	3 x
economically	-	3 x
	+	3 x
Area-specific	-	3 x
	+	3 x
any other	-	3 x
	+	3 x

16.18 Questionnaire response matrix of professional categories managing director and PP Engineering

		criteria	+-0	a	a	a	a	a	a	a	a	a	b	b	b	b	b	b	b	b	b
1.	The majority of the area is in private ownership!	Area -specific	+	3	2	5	3	3	4	3	3	3	5	1	5	5	5	5	3	5	5
2.	A few individual resistance from the local policy is to be expected!	political	-	4	5	5	4	4	3	3	4	4	4	3	4	4	3	4	5	4	4
3.	A few restrictions of use of the cooling water source are to be expected!	technical	-	3	3	4	3	3	3	4	3	3	5	5	5	5	5	5	5	5	5
4.	The residents may individually disapprove of or object to the project!	any other	-	3	2	2	3	3	3	4	3	3	4	3	3	4	4	4	5	4	4
5.	There are a few additional costs, which exceed the normal costs involved in the construction of a power plant on all other sites!	economically	-	4	5	4	2	1	4	2	4	5	3	2	3	5	3	2	4	3	3
6.	Geological or tectonic peculiarities are to be expected!	any other	-	2	5	3	2	1	2	2	3	2	4	4	5	4	2	4	3	4	4
7.	It is possible to fulfil the expectations with regard to the NPV (Net Present Value) with the total investment at the site!	economically	+	2	2	1	5	2	2	3	2	2	5	5	5	3	5	2	5	5	5
8.	There are no particularities concerning the application for a licence (e.g. at the Ministry of Economics or the Ministry of Energy) for the construction and / or operation of a power plant!	political	+	2	2	1	2	2	2	1	5	2	5	2	5	4	3	5	5	5	5
9.	The building ground meets the requirements of a gas power plant project!	technical	+	3	3	1	3	3	4	2	3	3	3	4	3	5	5	3	3	2	3
10.	Archaeological finds are to be expected!	Area -specific	-	3	3	4	3	3	4	3	2	3	4	4	4	5	4	5	4	3	4
11.	There are possibilities to adapt / change requirements with regard to land-use planning and regional or municipal regulations in favour of the power plant project!	political	+	3	3	2	3	3	2	3	2	3	5	4	5	5	5	4	4	5	5
12.	Future congestion of networks could be expected due to competing sectors (e.g. wind)!	technical	-	4	4	5	4	3	4	4	5	4	2	2	1	2	1	2	3	2	2
13.	There will be no additional overheads which exceed the costs involved at all sites!	economically	+	1	2	1	1	2	1	3	1	2	4	2	4	4	5	4	3	3	4
14.	There are no protected areas (FFH-areas, bird sanctuaries) on the ground!	Area -specific	+	2	1	1	2	2	2	1	2	4	5	5	5	4	5	4	5	5	2
15.	No extreme climatic conditions are to be expected!	any other	+	2	2	1	2	1	2	2	2	3	2	2	2	5	2	1	2	1	2
16.	There will be sufficient transmission network capacity!	technical	+	4	3	4	3	4	2	4	4	4	5	4	5	4	5	3	5	5	5
17.	The area / site is in line with the current general company strategy!	any other	+	4	4	3	3	4	4	4	2	4	4	4	4	5	4	2	2	4	4
18.	The majority of the area is in public ownership!	Area -specific	+	2	1	1	2	2	2	4	2	2	5	5	4	5	5	5	4	1	5
19.	There are no possibilities of supplying adjacent residential or industrial areas with district heating!	economically	-	2	2	3	2	2	2	1	2	5	4	4	3	4	4	1	4	4	5
20.	There are residential and recreational areas in the immediate vicinity!	political	-	3	4	3	5	3	3	3	3	1	5	5	4	5	2	5	5	5	5
21.	Under certain circumstances investments in energy generation are tax funded by the government!	economically	+	2	1	2	2	4	2	2	1	2	4	4	2	3	4	4	4	5	4
22.	There are potential biotopes, e.g. due to bodies of standing or flowing water on the ground!	Area -specific	-	2	3	2	2	5	2	2	1	2	5	4	5	5	5	5	4	5	4
23.	The region of the planed power plant is generally seen as socially and economical stable!	any other	+	4	4	3	2	4	2	4	2	4	3	3	1	3	5	3	3	2	3
24.	In the foreseeable future, politically motivated changes in the requirements to the power plant project could be possible!	political	-	5	5	4	5	5	5	5	4	5	5	5	5	3	5	5	5	5	5
25.	Accessibility of the site is guaranteed during the construction phase and reserve space is available!	technical	+	3	3	2	3	3	4	3	2	3	3	3	2	3	4	3	2	3	2
26.	Polluted areas (soil contamination) are suspected!	Area -specific	-	2	2	2	2	5	2	4	2	2	4	3	4	3	5	5	4	4	4
27.	The economic criteria for the power plant at the respective site can only be met with optimistic predictions for the energy market!	economically	-	5	5	5	4	5	5	4	5	5	5	5	3	3	5	5	5	5	2
28.	A gas pipeline or an LNG terminal is available in the vicinity of the potential site only in the radius of more than 15 km!	technical	-	3	3	3	2	3	3	3	1	2	3	4	3	2	2	4	3	3	3
29.	Support by the state policy can be expected!	political	+	4	4	2	2	4	4	3	4	3	5	5	4	3	5	5	4	5	3
30.	There is a very low population density in the vicinity of the power plant with a limited availability of specialised labour!	any other	-	3	3	3	1	3	5	3	3	2	4	4	3	2	4	4	4	5	4
	In which area of business do you work (multiple choice is possible)?	area of business	0	1	2	2	3	2	3	3	1	1	2	2	2	2	2	2	2	2	2
	How would you describe your occupational position:	occupational position	0	1	1	1	1	1	1	1	1	1	2	4	4	4	4	4	2	4	2
	How many years of professional experience do you have:	years of experiance	0	3	4	4	3	4	4	4	3	3	4	4	4	4	2	4	4	3	3
	Of these, how many years in the energy business:	*years of energy business*	0	3	4	4	2	4	4	4	3	3	4	4	4	4	2	4	4	3	3
	Have you ever been, either directly or indirectly, involved in a power plant site determination process (independent of technology)?	site determination	0	3	3	1	2	1	3	1	3	1	3	3	1	1	3	3	1	3	1
	In their book "Crossing the Energy Divide – Moving from Fossil Fuel Dependence to a Clean Energy Future", Robert U. Ayres and Edward H. Ayres argue as follows: "Energy services are not just a large part of economy; they are a major part of what drives the economy."	economy driver	0	2	1	1	1	1	2	1	1	2	2	1	2	2	1	1	2	1	2
	What is your opinion on the statement: "Gas and steam power plants are environmentally friendly technologies":	friendly technology	0	2	2	2	1	2	1	2	1	2	3	3	2	3	2	3	3	2	3
	I consider the EU target to achieve a 20% share of energy from renewable sources in the Community's gross final consumption of energy, set in the Directive "Europe 2020" as	20% share in EU	0	2	2	2	2	1	3	1	1	1	3	3	2	3	3	3	2	3	3
	In what radius from your place of residence would you raise objections to the construction of a gas and steam power plant (capability for permission is taken for granted)?	residence redius	0	3	3	3	3	3	3	3	3	3	1	1	3	3	3	3	1	1	1
	In his book "Power Hungry - The Mythos of "Green" Energy and the Real Fuels of the Future", Robert Bryce argues as follows: "The future of energy supply belongs to natural gas and nuclear power, the only sources that can provide the level of continuous electricity the nation needs, without environmental damage."	Mythos of Green Energy	0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2
	nuclear power plant	*nuclear power plant*	0	1			1	1	1	1	1	1	1	1	1	1	1	1		1	1
	natural gas	*natural gas*	0			1							1	1	1	1	1	1		1	1
	coal	*coal*	0													1		1			
	renewable sources (e.g. biomass, win, solar …)	*renewable sources (e.g. biomass, win, solar …)*	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1
	others	*others*	0												1					1	
	What is your opinion on the political strategy of the EU „Europe 2020" to reduce greenhouse gas emission by 20%?	20% emission reduce	0	2	2	1	2	1	2	2	2	1	1	1	1	2	1	2	1	1	1
	What is your opinion on the statement: „Gas power plants contribute to CO2-reduction"?	Gas PP = CO2 reduction	0	2	1	1	2	2	2	2	1	2	2	3	2	3	2	2	2	2	2

a		b	
2,9		3,9	
2,5	Average of Area Specific Criteria	4,3	Average of Area Specific Criteria
3,2	Average of Technical Criteria	3,4	Average of Technical Criteria
3,3	Average of Political Criteria	4,4	Average of Political Criteria
2,7	Average of Econimically Criteria	3,8	Average of Econimically Criteria
2,8	Average of Any Other Criteria	3,4	Average of Any Other Criteria

			a	a	a	a	a	a	a	a	a	b	b	b	b	b	b	b	b	b
Number of Answers	45																			
Number of criterias / number of questions per area	6																			
Average of Area Specific Criteria	3,3		2,3	2,0	2,5	2,3	3,3	2,7	2,8	2,0	2,7	4,7	3,7	4,5	4,5	4,8	4,8	4,0	3,8	4,0
Average of Technical Criteria	3,6		3,3	3,2	3,2	3,0	3,2	3,3	3,0	3,0	3,2	3,5	3,7	3,2	3,5	3,7	3,3	3,5	3,3	3,3
Average of Political Criteria	3,7		3,5	3,8	2,8	3,5	3,5	3,2	3,0	3,7	3,0	4,8	4,0	4,5	4,0	3,8	4,7	4,7	4,8	4,5
Average of Econimically Criteria	3,5		2,7	2,8	2,7	2,7	2,7	2,7	2,5	2,5	3,5	4,2	3,7	3,3	3,7	4,3	3,0	4,2	4,2	3,8
Average of Any Other Criteria	3,2		3,0	3,3	2,5	2,2	2,7	3,0	3,2	2,5	3,0	3,5	3,3	3,0	3,8	3,5	3,0	3,2	3,3	3,5
	3,4																			

POSITIVE QUESTIONS

a		b	
2,6		3,9	
2,4	Average of Area Specific Criteria	4,4	Average of Area Specific Criteria
3,1	Average of Technical Criteria	3,6	Average of Technical Criteria
2,7	Average of Political Criteria	4,4	Average of Political Criteria
2,0	Average of Econimically Criteria	4,0	Average of Econimically Criteria
2,9	Average of Any Other Criteria	2,9	Average of Any Other Criteria

			a	a	a	a	a	a	a	a	a	b	b	b	b	b	b	b	b	b
Number of criterias / number of questions per area	3																			
Average of Area Specific Criteria	3,2	0,1	2,3	1,3	2,3	2,3	2,3	2,7	2,7	2,3	3,0	5,0	3,7	4,7	4,7	5,0	4,7	4,0	3,7	4,0
Average of Technical Criteria	3,5	0,1	3,3	3,0	2,3	3,0	3,3	3,3	3,0	3,0	3,3	3,7	3,7	3,3	4,0	4,7	3,0	3,3	3,3	3,3
Average of Political Criteria	3,6	0,1	3,0	3,0	1,7	2,3	3,0	2,7	2,3	3,7	2,7	5,0	3,7	4,7	4,0	4,3	4,7	4,3	5,0	4,3
Average of Econimically Criteria	3,4	0,1	1,7	1,7	1,3	2,7	2,7	1,7	2,7	1,3	2,0	4,3	3,7	3,7	3,3	4,7	3,3	4,0	4,3	4,3
Average of Any Other Criteria	3,1	0,1	3,3	3,3	2,3	2,3	3,0	2,7	3,3	2,0	3,7	3,0	3,0	2,3	4,3	3,7	2,0	2,3	2,3	3,0
	3,3																			

NEGATIVE QUESTIONS

a		b	
3,2		3,9	
2,7	Average of Area Specific Criteria	4,3	Average of Area Specific Criteria
3,3	Average of Technical Criteria	3,3	Average of Technical Criteria
4,0	Average of Political Criteria	4,4	Average of Political Criteria
3,5	Average of Econimically Criteria	3,7	Average of Econimically Criteria
2,7	Average of Any Other Criteria	3,8	Average of Any Other Criteria

			a	a	a	a	a	a	a	a	a	b	b	b	b	b	b	b	b	b
Number of criterias / number of questions per area	3																			
Average of Area Specific Criteria	3,4	-0,1	2,3	2,7	2,7	2,3	4,3	2,7	3,0	1,7	2,3	4,3	3,7	4,3	4,3	4,7	5,0	4,0	4,0	4,0
Average of Technical Criteria	3,6	-0,1	3,3	3,3	4,0	3,0	3,0	3,3	3,7	3,0	3,0	3,3	3,7	3,0	3,0	2,7	3,7	3,7	3,3	3,3
Average of Political Criteria	3,8	-0,1	4,0	4,7	4,0	4,7	4,0	3,7	3,7	3,7	3,3	4,7	4,3	4,3	4,0	3,3	4,7	5,0	4,7	4,7
Average of Econimically Criteria	3,6	-0,1	3,7	4,0	4,0	2,7	2,7	3,7	2,3	3,7	5,0	4,0	3,7	3,0	4,0	4,0	2,7	4,3	4,0	3,3
Average of Any Other Criteria	3,4	-0,1	2,7	3,3	2,7	2,0	2,3	3,3	3,0	3,0	2,3	4,0	3,7	3,7	3,3	3,3	4,0	4,0	4,3	4,0
	3,6																			

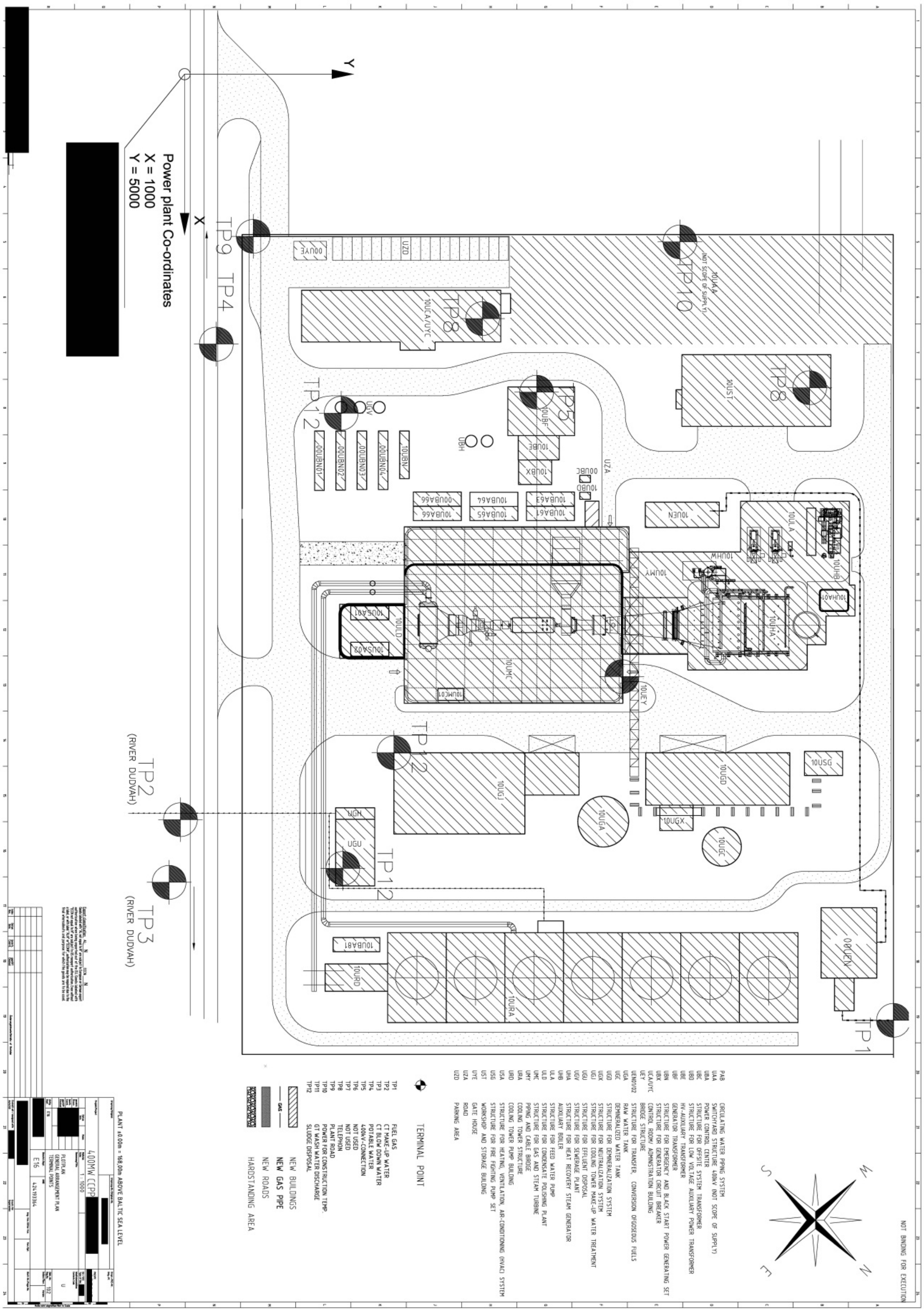
16.19 Questionnaire response matrix of professional categories Plant Project Development and Plant Operation

		criteria	+-0	c	c	c	c	c	e	e	e	e	e	e	e
1.	The majority of the area is in private ownership!	Area -specific	+	5	1	5	1	5	2	2	2	1	2	1	3
2.	A few individual resistance from the local policy is to be expected!	political	-	4	3	4	4	3	3	3	3	5	3	3	4
3.	A few restrictions of use of the cooling water source are to be expected!	technical	-	4	3	4	2	4	3	3	4	3	4	3	5
4.	The residents may individually disapprove of or object to the project!	any other	-	3	5	3	2	3	3	3	3	3	5	3	4
5.	There are a few additional costs, which exceed the normal costs involved in the construction of a power plant on all other sites!	economically	-	4	4	5	3	4	4	4	5	5	4	3	2
6.	Geological or tectonic peculiarities are to be expected!	any other	-	4	4	5	2	4	4	4	3	4	4	4	4
7.	It is possible to fulfil the expectations with regard to the NPV (Net Present Value) with the total investment at the site!	economically	+	5	5	5	2	4	5	5	3	4	5	5	4
8.	There are no particularities concerning the application for a licence (e.g. at the Ministry of Economics or the Ministry of Energy) for the construction and / or operation of a power plant!	political	+	4	5	4	3	4	4	2	1	3	3	4	4
9.	The building ground meets the requirements of a gas power plant project!	technical	+	4	5	4	4	3	4	4	4	5	4	4	3
10.	Archaeological finds are to be expected!	Area -specific	-	3	4	5	3	3	4	4	3	4	4	5	3
11.	There are possibilities to adapt / change requirements with regard to land-use planning and regional or municipal regulations in favour of the power plant project!	political	+	4	3	4	3	2	4	5	2	3	4	4	4
12.	Future congestion of networks could be expected due to competing sectors (e.g. wind)!	technical	-	5	4	5	5	5	5	5	5	4	5	5	5
13.	There will be no additional overheads which exceed the costs involved at all sites!	economically	+	4	2	4	2	3	3	2	3	2	3	4	3
14.	There are no protected areas (FFH-areas, bird sanctuaries) on the ground!	Area -specific	+	5	4	5	5	5	4	4	4	5	5	4	3
15.	No extreme climatic conditions are to be expected!	any other	+	5	2	5	1	5	3	2	5	2	4	3	3
16.	There will be sufficient transmission network capacity!	technical	+	4	5	4	3	4	5	5	5	5	3	5	5
17.	The area / site is in line with the current general company strategy!	any other	+	4	5	4	3	4	4	4	4	5	4	4	2
18.	The majority of the area is in public ownership!	Area -specific	+	4	1	4	2	4	4	4	4	1	4	4	3
19.	There are no possibilities of supplying adjacent residential or industrial areas with district heating!	economically	-	3	3	1	5	3	3	3	1	3	5	3	1
20.	There are residential and recreational areas in the immediate vicinity!	political	-	5	4	5	2	5	3	3	3	4	3	2	4
21.	Under certain circumstances investments in energy generation are tax funded by the government!	economically	+	5	4	5	5	3	3	1	3	4	3	3	5
22.	There are potential biotopes, e.g. due to bodies of standing or flowing water on the ground!	Area -specific	-	3	4	4	3	2	4	4	2	4	3	4	3
23.	The region of the planed power plant is generally seen as socially and economical stable!	any other	+	4	2	4	5	2	4	4	3	4	2	4	2
24.	In the foreseeable future, politically motivated changes in the requirements to the power plant project could be possible!	political	-	5	5	3	5	4	4	4	2	5	4	4	3
25.	Accessibility of the site is guaranteed during the construction phase and reserve space is available!	technical	+	4	4	4	4	2	4	4	3	4	3	4	2
26.	Polluted areas (soil contamination) are suspected!	Area -specific	-	5	3	5	5	3	4	3	3	3	3	4	3
27.	The economic criteria for the power plant at the respective site can only be met with optimistic predictions for the energy market!	economically	-	5	4	5	5	3	4	4	4	4	3	5	5
28.	A gas pipeline or an LNG terminal is available in the vicinity of the potential site only in the radius of more than 15 km!	technical	-	4	4	4	4	3	4	4	3	5	4	2	3
29.	Support by the state policy can be expected!	political	+	4	5	4	4	3	4	4	3	5	2	4	1
30.	There is a very low population density in the vicinity of the power plant with a limited availability of specialised labour!	any other	-	3	3	3	5	3	2	1	2	3	4	2	2
	In which area of business do you work (multiple choice is possible)?	area of business	0	3	2	3	3	2	3	2	1	3	3	1	1
	How would you describe your occupational position:	occupational position	0	1	1	2	2	2	1	1	3	3	1	1	1
	How many years of professional experience do you have:	years of experiance	0	4	2	3	4	3	4	4	3	4	4	4	4
	Of these, how many years in the energy business:	*years of energy business*	0	4	3	2	4	2	4	3	3	4	4	4	4
	Have you ever been, either directly or indirectly, involved in a power plant site determination process (independent of technology)?	site determination	0	1	1	1	3	1	1	1	3	3	1	1	3
	In their book "Crossing the Energy Divide – Moving from Fossil Fuel Dependence to a Clean Energy Future", Robert U. Ayres and Edward H. Ayres argue as follows: "Energy services are not just a large part of economy; they are a major part of what drives the economy."	economy driver	0	2	2	2	1	2	1	1	2	2	1	2	2
	What is your opinion on the statement: "Gas and steam power plants are environmentally friendly technologies":	friendly technology	0	2	2	2	1	2	3	3	2	1	3	2	2
	I consider the EU target to achieve a 20% share of energy from renewable sources in the Community's gross final consumption of energy, set in the Directive "Europe 2020" as	20% share in EU	0	3	3	3	3	2	2	2	2	3	2	2	2
	In what radius from your place of residence would you raise objections to the construction of a gas and steam power plant (capability for permission is taken for granted)?	residence redius	0	1	1	1	1	1	1	1	1	1	1	1	1
	In his book "Power Hungry - The Mythos of "Green" Energy and the Real Fuels of the Future", Robert Bryce argues as follows: "The future of energy supply belongs to natural gas and nuclear power, the only sources that can provide the level of continuous electricity the nation needs, without environmental damage."	Mythos of Green Energy	0	3	3	2	3	3	3	3	3	2	3	3	2
	nuclear power plant	*nuclear power plant*	0									1			
	natural gas	*natural gas*	0			1						1			
	coal	*coal*	0									1			
	renewable sources (e.g. biomass, win, solar …)	*renewable sources (e.g. biomass, win, solar …)*	0			1						1			1
	others	*others*	0			1									
	What is your opinion on the political strategy of the EU „Europe 2020" to reduce greenhouse gas emission by 20%?	20% emission reduce	0	2	1	2	2	2	1	1	1	2	1	1	1
	What is your opinion on the statement: „Gas power plants contribute to CO2-reduction"?	Gas PP = CO2 reduction	0	2	2	2	2	2	2	2	2	1	2	2	1
				3,8					**3,5**						
				3,7		Average of Area S			3,4		Average of Area Specific Criter				
				3,9		Average of Techn			4,0		Average of Technical Criteria				
	Number of Answers	**45**		3,9		Average of Politic			3,4		Average of Political Criteria				
				3,8		Average of Econi			3,5		Average of Econimically Criteri				
	Number of criterias / number of questions per area	6		3,6		Average of Any C			3,3		Average of Any Other Criteria				
	Average of Area Specific Criteria	3,3		4,2	2,8	4,7	3,2	3,7	3,7	3,5	3,0	3,0	3,5	3,7	3,0
	Average of Technical Criteria	3,6		4,2	4,2	4,2	3,7	3,5	4,2	4,2	4,0	4,3	3,8	3,8	3,8
	Average of Political Criteria	3,7		4,3	4,2	4,0	3,5	3,5	3,7	3,5	2,3	4,2	3,2	3,5	3,3
	Average of Econimically Criteria	3,5		4,3	3,7	4,2	3,7	3,3	3,7	3,2	3,2	3,7	3,8	3,8	3,3
	Average of Any Other Criteria	3,2		3,8	3,5	4,0	3,0	3,5	3,3	3,0	3,3	3,5	3,8	3,3	2,8
		3,4													
				3,8					**3,5**						
				3,7		Average of Area S			3,1		Average of Area Specific Criter				
				3,9		Average of Techn			4,0		Average of Technical Criteria				
				3,7		Average of Politic			3,4		Average of Political Criteria				
	POSITIVE QUESTIONS			3,9		Average of Econi			3,5		Average of Econimically Criteri				
	Number of criterias / number of questions per area	3		3,7		Average of Any C			3,3		Average of Any Other Criteria				
	Average of Area Specific Criteria	3,2	0,1	4,7	2,0	4,7	2,7	4,7	3,3	3,3	3,3	2,3	3,7	3,0	3,0
	Average of Technical Criteria	3,5	0,1	4,0	4,7	4,0	3,7	3,0	4,3	4,3	4,0	4,7	3,3	4,3	3,3
	Average of Political Criteria	3,6	0,1	4,0	4,3	4,0	3,3	3,0	4,0	3,7	2,0	3,7	3,0	4,0	3,0
	Average of Econimically Criteria	3,4	0,1	4,7	3,7	4,7	3,0	3,3	3,7	2,7	3,0	3,3	3,7	4,0	4,0
	Average of Any Other Criteria	3,1	0,1	4,3	3,0	4,3	3,0	3,7	3,7	3,3	4,0	3,7	3,3	3,7	2,3
		3,3													
				3,8					**3,5**						
				3,7		Average of Area S			3,6		Average of Area Specific Criter				
				4,0		Average of Techn			4,0		Average of Technical Criteria				
				4,1		Average of Politic			3,4		Average of Political Criteria				
	NEGATIVE QUESTIONS			3,8		Average of Econi			3,5		Average of Econimically Criteri				
	Number of criterias / number of questions per area	3		3,5		Average of Any C			3,2		Average of Any Other Criteria				
	Average of Area Specific Criteria	3,4	-0,1	3,7	3,7	4,7	3,7	2,7	4,0	3,7	2,7	3,7	3,3	4,3	3,0
	Average of Technical Criteria	3,6	-0,1	4,3	3,7	4,3	3,7	4,0	4,0	4,0	4,0	4,0	4,3	3,3	4,3
	Average of Political Criteria	3,8	-0,1	4,7	4,0	4,0	3,7	4,0	3,3	3,3	2,7	4,7	3,3	3,0	3,7
	Average of Econimically Criteria	3,6	-0,1	4,0	3,7	3,7	4,3	3,3	3,7	3,7	3,3	4,0	4,0	3,7	2,7
	Average of Any Other Criteria	3,4	-0,1	3,3	4,0	3,7	3,0	3,3	3,0	2,7	2,7	3,3	4,3	3,0	3,3
		3,6													

16.20 Questionnaire response matrix of professional categories General Project Management and Commercial Project Management

		criteria	+-0	f	f	f	f	f	f	f	f	jk	jk	jk	jk	jk	jk	jk
1.	The majority of the area is in private ownership!	Area -specific	+	3	2	2	4	2	1	2	4	3	3	4	4	3	2	3
2.	A few individual resistance from the local policy is to be expected!	political	-	4	3	5	4	5	5	5	5	3	5	5	5	5	3	5
3.	A few restrictions of use of the cooling water source are to be expected!	technical	-	5	3	5	4	5	5	5	3	4	3	4	3	4	3	4
4.	The residents may individually disapprove of or object to the project!	any other	-	4	3	4	4	5	3	4	5	2	3	3	3	5	3	3
5.	There are a few additional costs, which exceed the normal costs involved in the construction of a power plant on all other sites!	economically	-	2	4	2	2	1	4	2	3	4	4	4	3	4	4	5
6.	Geological or tectonic peculiarities are to be expected!	any other	-	5	4	5	5	5	4	5	4	2	2	4	2	2	3	2
7.	It is possible to fulfil the expectations with regard to the NPV (Net Present Value) with the total investment at the site!	economically	+	4	5	5	3	5	3	5	5	5	5	5	5	5	5	5
8.	There are no particularities concerning the application for a licence (e.g. at the Ministry of Economics or the Ministry of Energy) for the construction and / or operation of a power plant!	political	+	4	4	5	3	5	4	5	5	4	3	4	2	2	4	4
9.	The building ground meets the requirements of a gas power plant project!	technical	+	3	4	5	5	5	5	5	3	3	3	3	3	2	4	3
10.	Archaeological finds are to be expected!	Area -specific	-	3	4	3	3	2	3	3	5	2	3	2	2	1	2	2
11.	There are possibilities to adapt / change requirements with regard to land-use planning and regional or municipal regulations in favour of the power plant project!	political	+	4	4	5	5	4	5	5	5	3	3	2	3	2	4	3
12.	Future congestion of networks could be expected due to competing sectors (e.g. wind)!	technical	-	5	4	5	5	5	5	5	5	5	5	5	3	3	5	5
13.	There will be no additional overheads which exceed the costs involved at all sites!	economically	+	3	3	4	3	4	3	4	3	4	4	3	4	2	2	4
14.	There are no protected areas (FFH-areas, bird sanctuaries) on the ground!	Area -specific	+	3	4	4	4	5	4	2	4	3	2	3	3	2	3	3
15.	No extreme climatic conditions are to be expected!	any other	+	3	3	4	4	5	4	2	3	2	2	2	1	1	2	2
16.	There will be sufficient transmission network capacity!	technical	+	5	3	5	4	5	4	5	5	3	3	2	3	2	3	3
17.	The area / site is in line with the current general company strategy!	any other	+	2	4	3	3	3	2	3	4	4	4	2	4	5	4	4
18.	The majority of the area is in public ownership!	Area -specific	+	3	4	3	3	1	3	3	4	2	2	2	1	1	1	2
19.	There are no possibilities of supplying adjacent residential or industrial areas with district heating!	economically	-	1	3	2	2	1	2	2	3	3	3	3	1	3	5	3
20.	There are residential and recreational areas in the immediate vicinity!	political	-	4	3	2	2	1	2	2	4	2	2	3	1	2	2	2
21.	Under certain circumstances investments in energy generation are tax funded by the government!	economically	+	3	3	2	2	1	2	2	5	4	4	2	2	4	5	4
22.	There are potential biotopes, e.g. due to bodies of standing or flowing water on the ground!	Area -specific	-	3	4	4	4	3	4	4	5	3	3	3	1	3	4	3
23.	The region of the planed power plant is generally seen as socially and economical stable!	any other	+	2	4	3	3	2	3	3	3	3	3	1	2	3	3	3
24.	In the foreseeable future, politically motivated changes in the requirements to the power plant project could be possible!	political	-	3	4	4	4	4	5	4	5	3	3	3	2	3	4	3
25.	Accessibility of the site is guaranteed during the construction phase and reserve space is available!	technical	+	3	5	3	4	2	4	2	3	2	2	1	1	2	4	2
26.	Polluted areas (soil contamination) are suspected!	Area -specific	-	3	5	3	3	2	4	3	4	4	3	2	3	4	4	3
27.	The economic criteria for the power plant at the respective site can only be met with optimistic predictions for the energy market!	economically	-	5	5	5	4	4	5	5	5	5	5	5	5	5	5	5
28.	A gas pipeline or an LNG terminal is available in the vicinity of the potential site only in the radius of more than 15 km!	technical	-	3	4	2	2	2	1	2	4	3	1	2	2	2	4	2
29.	Support by the state policy can be expected!	political	+	1	4	4	4	2	4	4	5	3	3	2	3	3	4	3
30.	There is a very low population density in the vicinity of the power plant with a limited availability of specialised labour!	any other	-	2	2	4	4	3	5	4	4	3	4	2	3	3	4	3
	In which area of business do you work (multiple choice is possible)?	area of business	0	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2
	How would you describe your occupational position:	occupational position	0	1	2	2	2	4	2	1	1	3	3	3	3	3	3	3
	How many years of professional experience do you have:	years of experiance	0	4	4	4	4	3	2	4	4	2	2	2	2	2	2	2
	Of these, how many years in the energy business:	*years of energy business*	0	4	4	4	4	2	2	4	4	2	2	2	2	2	2	2
	Have you ever been, either directly or indirectly, involved in a power plant site determination process (independent of technology)?	site determination	0	1	1	2	1	3	3	2	1	1	2	2	2	3	2	1
	In their book "Crossing the Energy Divide – Moving from Fossil Fuel Dependence to a Clean Energy Future", Robert U. Ayres and Edward H. Ayres argue as follows: "Energy services are not just a large part of economy; they are a major part of what drives the economy."	economy driver	0	2	2	2	1	2	1	1	1	2	2	2	1	1	1	1
	What is your opinion on the statement: "Gas and steam power plants are environmentally friendly technologies":	friendly technology	0	2	1	2	1	2	1	2	2	1	3	2	2	2	2	2
	I consider the EU target to achieve a 20% share of energy from renewable sources in the Community's gross final consumption of energy, set in the Directive "Europe 2020" as	20% share in EU	0	3	2	2	2	3	1	2	1	2	3	2	2	1	1	2
	In what radius from your place of residence would you raise objections to the construction of a gas and steam power plant (capability for permission is taken for granted)?	residence redius	0	2	2	1	3	3	3	1	2	1	1	1	1	3	3	1
	In his book "Power Hungry - The Mythos of "Green" Energy and the Real Fuels of the Future", Robert Bryce argues as follows: "The future of energy supply belongs to natural gas and nuclear power, the only sources that can provide the level of continuous electricity the nation needs, without environmental damage."	Mythos of Green Energy	0	3	2	3	3	3	3	3	3	2	2	2	2	2	2	2
	nuclear power plant	*nuclear power plant*	0									1	1	1	1	1	1	1
	natural gas	*natural gas*	0		1							1	1	1	1	1	1	1
	coal	*coal*	0												1	1	1	
	renewable sources (e.g. biomass, win, solar …)	*renewable sources (e.g. biomass, win, solar …)*	0		1							1	1	1	1	1	1	1
	others	*others*	0									1	1	1				1
	What is your opinion on the political strategy of the EU „Europe 2020" to reduce greenhouse gas emission by 20%?	20% emission reduce	0	2	2	1	3	2	1	2	2	2	1	2	2	2	3	2
	What is your opinion on the statement: „Gas power plants contribute to CO2-reduction"?	Gas PP = CO2 reduction	0	1	1	2	3	2	3	2	2	2	1	2	2	2	3	2
				3,6								3,1						
				3,3		Average of Area Specific Criteria						2,6		Average of Area Specific Criteri				
				4,0		Average of Technical Criteria						3,0		Average of Technical Criteria				
	Number of Answers	45		3,9		Average of Political Criteria						3,1		Average of Political Criteria				
				3,3		Average of Econimically Criteria						4,0		Average of Econimically Criteria				
	Number of criterias / number of questions per area	6		3,6		Average of Any Other Criteria						2,8		Average of Any Other Criteria				
	Average of Area Specific Criteria	3,3		3,0	3,8	3,2	3,5	2,5	3,2	2,8	4,3	2,8	2,7	2,7	2,3	2,3	2,7	2,7
	Average of Technical Criteria	3,6		4,0	3,8	4,2	4,0	4,0	4,0	4,0	3,8	3,3	2,8	2,8	2,5	2,5	3,8	3,2
	Average of Political Criteria	3,7		3,3	3,7	4,2	3,7	3,5	4,2	4,2	4,8	3,0	3,2	3,2	2,7	2,8	3,5	3,3
	Average of Econimically Criteria	3,5		3,0	3,8	3,3	2,7	2,7	3,2	3,3	4,0	4,2	4,2	3,7	3,3	3,8	4,3	4,3
	Average of Any Other Criteria	3,2		3,0	3,3	3,8	3,8	3,8	3,5	3,5	3,8	2,7	3,0	2,3	2,5	3,2	3,2	2,8
		3,4																
				3,6								3,0						
				3,1		Average of Area Specific Criteria						2,5		Average of Area Specific Criteri				
				4,0		Average of Technical Criteria						2,6		Average of Technical Criteria				
				4,2		Average of Political Criteria						3,0		Average of Political Criteria				
	POSITIVE QUESTIONS			3,4		Average of Econimically Criteria						4,0		Average of Econimically Criteria				
	Number of criterias / number of questions per area	3		3,1		Average of Any Other Criteria						2,7		Average of Any Other Criteria				
	Average of Area Specific Criteria	3,2	0,1	3,0	3,3	3,0	3,7	2,7	2,7	2,3	4,0	2,7	2,3	3,0	2,7	2,0	2,0	2,7
	Average of Technical Criteria	3,5	0,1	3,7	4,0	4,3	4,3	4,0	4,3	4,0	3,7	2,7	2,7	2,0	2,3	2,0	3,7	2,7
	Average of Political Criteria	3,6	0,1	3,0	4,0	4,7	4,0	3,7	4,3	4,7	5,0	3,3	3,0	2,7	2,7	2,3	4,0	3,3
	Average of Econimically Criteria	3,4	0,1	3,3	3,7	3,7	2,7	3,3	2,7	3,7	4,3	4,3	4,3	3,3	3,7	3,7	4,0	4,3
	Average of Any Other Criteria	3,1	0,1	2,3	3,7	3,3	3,3	3,3	3,0	2,7	3,3	3,0	3,0	1,7	2,3	3,0	3,0	3,0
		3,3																
				3,7								3,2						
				3,5		Average of Area Specific Criteria						2,7		Average of Area Specific Criteri				
				3,9		Average of Technical Criteria						3,4		Average of Technical Criteria				
				3,7		Average of Political Criteria						3,1		Average of Political Criteria				
	NEGATIVE QUESTIONS			3,1		Average of Econimically Criteria						4,0		Average of Econimically Criteria				
	Number of criterias / number of questions per area	3		4,0		Average of Any Other Criteria						2,9		Average of Any Other Criteria				
	Average of Area Specific Criteria	3,4	-0,1	3,0	4,3	3,3	3,3	2,3	3,7	3,3	4,7	3,0	3,0	2,3	2,0	2,7	3,3	2,7
	Average of Technical Criteria	3,6	-0,1	4,3	3,7	4,0	3,7	4,0	3,7	4,0	4,0	4,0	3,0	3,7	2,7	3,0	4,0	3,7
	Average of Political Criteria	3,8	-0,1	3,7	3,3	3,7	3,3	3,3	4,0	3,7	4,7	2,7	3,3	3,7	2,7	3,3	3,0	3,3
	Average of Econimically Criteria	3,6	-0,1	2,7	4,0	3,0	2,7	2,0	3,7	3,0	3,7	4,0	4,0	4,0	3,0	4,0	4,7	4,3
	Average of Any Other Criteria	3,4	-0,1	3,7	3,0	4,3	4,3	4,3	4,0	4,3	4,3	2,3	3,0	3,0	2,7	3,3	3,3	2,7
		3,6																

16.21 Example arrangement drawing of a gas fired power plant with closed-circuit cooling


Power plant Co-ordinates
X = 1000
Y = 5000
TP2 (RIVER DUDVAH)
TP3 (RIVER DUDVAH)
TERMINAL POINT
NOT BINDING FOR EXECUTION

16.22 Rules-of-thumb and hints on the formulation of questions and / or statements for questionnaires[1]

Introductory question
The introductory questions are of special importance. They are decisive to the commitment of the respondent in completing the whole questionnaire. Therefore, they should be an interesting lead-in to the subject and should be easy to answer in order to minimize any possible fears of the respondent relating to the complexity of a questioning.
Number of questions
More than one questions should be asked on one subject area.
Position oft he question
Questions that, relating to their contents, belong to the same question complex, can be asked at different places of the questionnaire in order to obtain control over the „truthful“ answering (control questions). But beware: an excessively high variation of the question complexes could lead to a confusion of the respondent rather than yielding the desirable effect.
Transition between the question complexes
New question complexes should be introduced by „transition questions“..
Differentiation between questions and answers
Differentiating between questions and answers should be made as easy as possible for the interviewer. As a general rule for solving this problem, the use of different typefaces has proven successful.
Filter
Generally, efforts should be made to ensure that the time required for filling in the questionnaires is as short as possible.
Scope of the questionnaire
Generally, the time designed to fill in the questionnaire should be as short as possible.

[1] cf. Schnell et. al. (2008) p. 336 ff, p. 354

Pre-test
As there is no theory of questioning from which all details of the design of the questionnaire can be derived, every questionnaire has to be empirically tested in a pre-test prior to the actual data acquisition. [1]

[1] Pre-tests mainly serve to check a) the sufficient variation of the answers; b) the comprehension of the questions by the respondent; c) the degree of difficulty of the questions for the respondent; d) the interest in and attention of the respondent towards the questions; e)the continuity of the course of the interview („flow"); f) the effects of the sequence of questions; g) the quality of the filtering; h) the context effects; i) the duration of the questioning; j) the interest of the respondent in the complete questioning; k) the burden placed on the respondents by the questioning
cf. Schnell et al. (2008) p. 347