ENERGY SOURCES AND TECHNOLOGY FOR GLOBAL ELECTRICITY GENERATION

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ABSTRACT

Fossil fuels - coal and gas - dominate the power-generating industry. Events such as global climate change and the introduction of new technologies can alter the fuel mix used by power plants. How the future of electricity generation will develop is of special interest to the suppliers of cooling systems for fossil-fuelled power plants.

For the purpose of scenario planning for cooling-system suppliers, a review was carried out of the literature available on the role played by technological developments in the selection of energy sources for power plants. The information was analysed through the application of a scenario-planning technique. Recommendations were made within the contexts of the scenarios developed.

The main findings were that the current strategy used is not adequately robust across four possible scenarios and that the supplier in question should enter the renewable- or nuclear-energy market in order to improve the long-term viability of its current strategy.

DECLARATION

I, Albert Zapke, declare that this project report is my own, unaided work. It is submitted in partial fulfilment of the requirements for the Degree of Master of Business Administration in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in this or any other university.

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Albert Zapke

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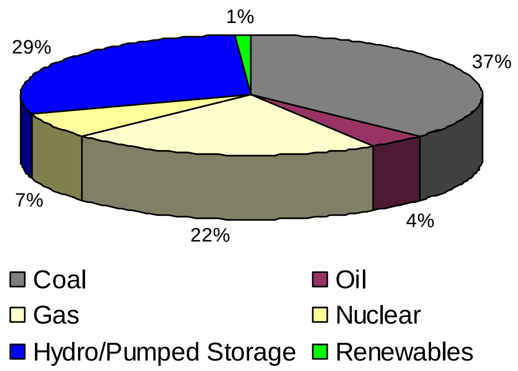
1 INTRODUCTION

1.1 Background to the project

The world has become increasingly dependent on the supply of electricity as the development of technology advances further and further. Electrical energy is a clean form of energy and, at present, one third of the global primary energy is used for the generation of electricity (Hansen, 1998:2). According to Hansen (1998), 4 000 GW of new generating capacity needs to be installed in the period from 1990 to 2020 to meet new demand, as well as to replace power stations which have reached the end of their operating life.

The main energy sources used for the generation of electricity are fossil fuels (coal, gas, oil), hydro electricity from rivers and pump storage schemes, nuclear energy, and renewable energies (mainly wind, solar and biomass). In the mid 1990s, 64% of the annual global energy generation of 13 000 TWh came from fossil fuels, 17% from nuclear power plants, and 19% from hydro plants. More recent statistics on the energy sources used in the generation of electricity have been published by Engineering News (2003) and are illustrated in Figure 1.1.

Figure 1.1: Energy sources used in electricity generation in the world, based on 2001 statistics



Source: Engineering News (2003:72)

According to Gerholm (1998), the so-called mainstream projections published by the International Energy Outlook 1997 fail to successfully forecast future energy demands since they are based on parameters such as economic growth and energy intensity (the energy/GDP ratio). These parameters have large inherent uncertainties, which lead to poor long-term forecasts. Gerholm (1998) further points out that the approach followed by the mainstream projections appears to be a complex solution for a simple problem. Considering the significant inertia of the global energy system, one could conclude intuitively that not very much will change in the next 10 to 20 years, unless some major event or catastrophe causes a structural change in the supply-demand balance or in the fuel mix that acts as a source for power generation.

The contribution by fossil fuel to the generation of electricity will increase in absolute numbers and this reliance on fossil fuel will remain for the first half of this century (Gerholm, 1998 & Matsui, 1998). However, in terms of market share, fossil fuels are already in a decline and are expected to continue to decline in the long term. The question can therefore be asked whether nuclear energy will bridge the gap during the transition to renewable energies such as wind or solar. Should this not be the case, which other energy sources will dominate in the future?

~~1.3~~1.2 The importance of the research

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The aim of the project is to investigate future trends in the power-generating industry, with reference to the type of energy source, the type of power-generating technology, and how such trends could, in particular, affect cooling system suppliers to the power-generating industry.

What follows below is a brief technical overview of the conventional commercialised cooling system technologies that have been designed and constructed over the past decades by the suppliers to the power-generating industry. The purpose of this technical description is to illustrate the “past” to the reader so that he or she might have a better understanding of new technological developments and the effect these could have on “traditional” suppliers of power cooling systems.

In any power-generating cycle, heat has to be discharged to the environment. During the early days of power generation, direct cooling through the use of water from rivers or dams was the norm. Water was channelled from a river through the cooling system of power stations and the heated water was pumped back into the river. This type of cooling method represented the cheapest and most efficient type of cooling but the discharge of hot water had adverse effects on the resident aquatic life.

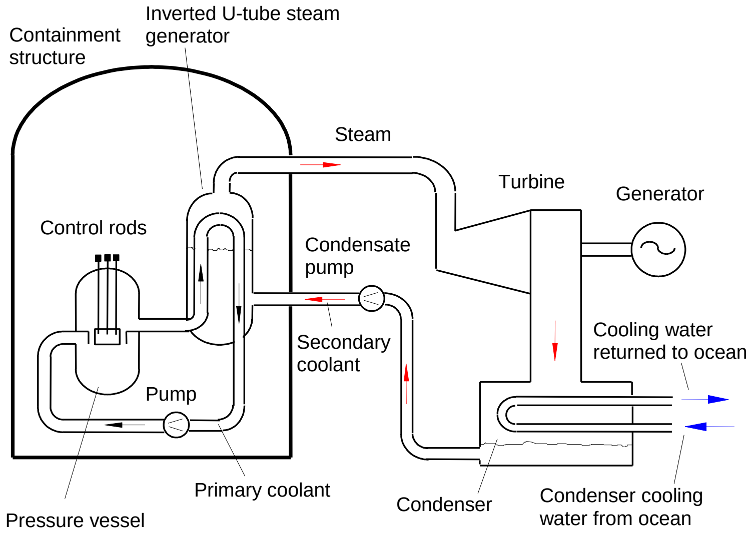
Despite these adverse effects, the once-through direct cooling principle is still used in some applications today. The nuclear power plant close to Cape Town in South Africa makes use of such a system, where cooling water from the Atlantic Ocean is pumped through the turbine condenser before being returned to the ocean. A schematic illustration of such a nuclear power plant is shown in Figure 1.2.

As environmentally related restrictions became more stringent over the years, power stations have increasingly had to rely on so-called closed cycle cooling where water is cycled through the power station in a closed loop. A power-generating cycle cooled by a closed loop wet-cooling system is illustrated in Figure 1.3. Natural draught and mechanical draught wet-cooling systems are shown in Figures 1.4 (a) and (b) respectively.

The heated water returning from a power station is cooled through the process of evaporation in a cooling tower before being pumped back to the steam turbine condenser.

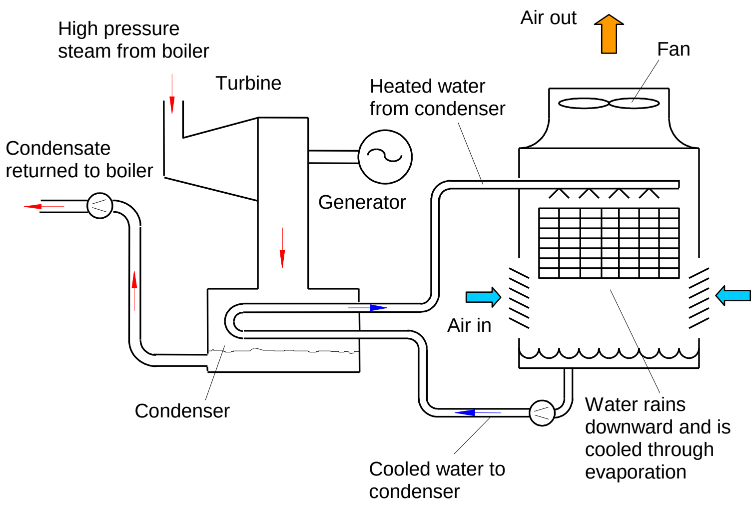
Closed cycle wet-cooling systems lose water to the atmosphere through evaporation. Furthermore, as the water evaporates, dissolved solids build up in the system. As a result, fresh water has to be added on a continuous basis to keep the concentration of solids at predetermined levels. The fresh water replaces a so-called blowdown water stream through which dissolved solids are removed from the cycle.

Figure 1.2: General view of a pressurised water reactor power plant



Source: Zapke (1997:1.6)

Figure 1.3: Schematic of a power generating cycle cooled by a closed loop wet-cooling system



Source: Adapted from Kröger (1998)

Figure 1.4: A natural draught wet-cooling system (a) and a mechanical draught wet-cooling system (b)

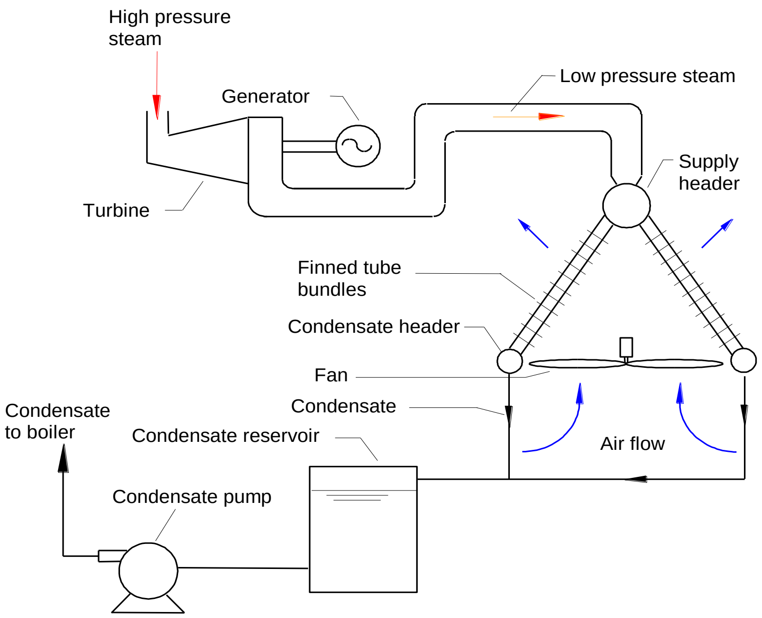
(a) (b)

Source: GEA AG (2003a)

The decrease in water availability in certain parts of world, increasing water costs, and more stringent environmental legislation have pushed up the operating costs of power stations that make use of closed cycle evaporative cooling. As a result, so-called direct dry-cooling systems were introduced in the 1950s. A schematic of a power-generating cycle based on the dry-cooling principle is illustrated in Figure 1.5, while a photograph of such a system is shown in Figure 1.6.

Dry-cooling systems are similar to motor vehicle radiators, which make use of cooling air that is pumped by a fan through a radiator. As the development of direct dry-cooling systems has advanced, the technology has become suitable for large-scale power systems (Schulenberg, 1977).

Figure 1.5: Schematic of a power generating cycle employing a direct air-cooled condenser system



Source: (Zapke, 1997:1.1)

Apart from the advantage of dry-cooling systems to provide an alternative to wet-cooling in areas where the operating costs for wet-cooling are too high, dry-cooling has another major advantage. Since air is freely available almost anywhere, dry-cooling makes the location of a power station independent of water sources, unlike wet-cooling systems. Dry-cooled power stations can therefore be placed close to the fuel source to save in transportation costs in the case of fossil-fuelled power stations.

The Matimba Power Station at Ellisras in South Africa, at present the largest dry-cooled power station in the world, is, for example, located next to large reserves of low-quality coal in an area where water is a very scarce resource. The power station has six steam driven turbines each driving a 665 MWe generator.

The development, design and supply of direct dry-cooling systems for such large power plants are very specialised areas and there are only three organisations in the world that provide this service. In order to stay ahead of the competition, significant financing is required for the purposes of research, development and manufacturing facilities.

Figure 1.6: A direct dry-cooling system

Source: GEA AG (2003b)

The supplier of the turbine technology and power cycle and the type of energy source chosen to heat the power-generating cycle are the main drivers that determine the technical requirements for the cooling systems and the type of cooling system to be employed. The cooling systems described in the preceding paragraphs are not necessarily suitable for every type of turbine technology or energy source. Suppliers of cooling systems, therefore, have to closely follow trends and developments in power-cycle technology to adapt to the demands of their client base, ie the power-plant developers. In addition, it must be kept in mind that such cooling systems are not required for electricity-generating installations that make use of renewable energy. These cooling systems are predominantly employed in nuclear and fossil-fired installations.

The power industry is a global industry and it is characterised by a variety of complexities. Strategy formulation and decision making should be based on marketing research. The importance of this research is the value that it adds to informed decision making and the prediction of future trends. An industry of this nature requires a sophisticated approach when formulating strategies for the future. Organisations that fail to do the necessary preparatory research that will form the basis of their strategy formulation expose themselves to significant business risks and potential financial losses.

~~1.2~~1.3 The research problem

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The main problem is defined as:

to determine the energy sources and power-generating technology that will dominate the power-generating industry in the medium and long term.

A technique similar to existing scenario planning theory will be applied to analyse information related to the topic. The project topic will be addressed on a global basis.

The following sub-problems will be considered as part of answering the main project problem:

~~i)~~i) to identify existing techniques in scenario planning that are suitable for the project under consideration;

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~~ii)~~ii) to collect data related to energy supply and demand and availability of energy sources;

iii) to study existing commercial power-generating technology within the context of potential new developments internal and external to the power-generating industry; and

iv) to develop scenarios that could be faced by suppliers to the power-generating industry.

The outcome of the scenario-building process should expose organisations that are active in the business of power generation to possible future trends that may be ignored at present. The outcome will further be used to generate some strategic options for the future. In particular, the results of the present project report will be geared to the needs of suppliers of cooling-system technology to power-station developers.

At present nuclear energy as a source of power generation does not enjoy the public support that renewable energy enjoys. As a consequence, some industries that could act as possible suppliers of technology and hardware for the construction of nuclear power plants may have made conscious decisions not to get involved in nuclear-related technology. At the same time, however, some organisations may be reluctant to enter the renewable energy market.

Such decisions could result in future opportunities being lost. One purpose of this project is to develop scenarios that can assist management with making informed decisions regarding future business plans, and to expose areas which have potential but which may be avoided at present for a variety of reasons.

The literature review and scenario analysis carried out as part of the project should serve as a basis to suppliers of power-station cooling technology for the development of marketing strategies for the medium term and long term.

1.4 Outline of the report

Chapter 2 of this report provides a brief background to scenario-planning techniques. This chapter presents a literature review on energy sources, power-generating technologies and other factors that may shape the future of the power-generating industry. The scenario-building exercise presented in Chapter 4 is based on this information.

In Chapter 3 the scenario-planning technique chosen for the purpose of this project is described. Deviations from the scenario-planning technique are explained.

The results emerging from the project in the form of future potential scenarios are presented in Chapter 4. Chapter 4 contains all the detailed steps that form part of a scenario-building process.

Chapter 5 sets out the strategic implications of the scenarios on the type of organisation under consideration. It also deals with the robustness of the present strategy within the context of the scenarios developed.

Recommendations to improve the robustness of the current strategy are presented in Chapter 6. Chapter 6 also deals with the shortcomings of the scenarios developed.

In Chapter 7 the opinions from four experts within the power-generating industry are presented, with the emphasis on the relevance and plausibility of the scenarios.

Chapter 8 is a concluding chapter that summarises the highlights of the report, the objectives achieved, the recommendations proposed, and areas for further research.

2 LITERATURE REVIEW

2.1 <u>Scenario planning theory</u>

In the late 1960s and early 1970s Royal Dutch/Shell developed a scenario-planning technique for the petroleum- and energy-business environment (Wack, 1985). The work by Wack (1985) and his business-environment division succeeded in attracting senior management attention in such a way that scenario planning turned out to be a far more useful tool than business forecasting. As a result, the technique of scenario planning made a major contribution to Shell's preparedness for the oil crisis of 1973. Other literature about scenario planning, with particular reference to energy issues that was published after Royal Dutch/Shell developed the scenario technique, includes studies by Brooks (1980), Henry, Harless & Kopelman (1979), Ibrahim (1980) and Kassler (1995).

Wack (1985) pointed out that forecasts predict a future similar to the present and the past and therefore cannot anticipate major shifts in the business environment. In a more recent article, Stauffer (2002) referred to 20 years of enormous opportunities predicted by some scenario planning gurus. Instead, Stauffer (2002) pointed out that events such as the recession, the horrors of 11 September 2001, the Enron scandal and tensions in the Middle East have created major uncertainties in the global environment. These events led Stauffer (2002) to believe that scenario planning is now more important than ever. He listed the following five reasons for considering scenario planning exercises:

- i) to ensure that businesses are not focusing on catastrophe to the exclusion of opportunity;
- ii) to help in the prudent allocation of resources;
- iii) to keep options open;
- iv) to ensure that focus is no longer on the past; and
- v) to give a company the opportunity to rehearse.

Wack (1985) pointed to the importance of scenario planning as part of strategy that serves to create a stable yet flexible foundation. Wright (2000) further elaborated how scenario planning presents a continuous improvement approach to strategy.

Goodwin (1999) also supported scenario planning as an attractive tool for strategic management. It was, however, pointed out by Goodwin (1999), that the evaluation of alternatives across a range of scenarios is an underdeveloped element of scenario planning. A technique called "decision analysis" was proposed to demonstrate how to structure the strategy evaluation process in a way that avoids the problems associated with earlier proposals.

Recent trends show that scenario planning is moving away from being a contingency-planning device and is becoming an idea-generation and innovation device (Liss, 2000). According to Schriefer (1999), scenario planning as a strategy tool is on the rise. A new topic that has emerged is "Scenario Lite". This is a concept that focuses on how time and money invested in scenario planning can be reduced without sacrificing the integrity of the process or diminishing the value of the results. In this light, Schriefer (1999) proposed nine steps that could lead to useful scenarios in eight hours or less.

Based on the above general trends and latest specific trends in scenario planning, it can be concluded that scenario planning can play an important role in strategic management. In particular, scenario planning represents a first step and is subsequently used as a foundation for the development of future strategies.

Since Royal Dutch/Shell first developed the scenario-planning technique, several variations of the process have been presented. An illustration of the essential steps as described by Bain & Co. (Stauffer, 2002:4) is shown below:

- Determine the scope and time frame of the scenario being fleshed out.
- Identify the current assumptions and mental models of individuals who influence these decisions.

- Create a manageable number of divergent, yet plausible, scenarios. Spell out the underlying assumptions of how each of these imagined futures might evolve.
- Test the impact of key variables in each scenario.
- Develop action plans based on either: i) the solutions that play most robustly across scenarios; ii) or the most desirable outcome toward which a company can direct its efforts.
- Monitor events as they unfold to test the corporate direction; be prepared to modify as required.

The educational experience that results from this process according to Bain & Co (Stauffer, 2002:4) includes:

- Stretching the mind beyond the groupthink that can slowly and imperceptibly produce a sameness of minds among top team members in any organisation.
- Learning the ways in which seemingly remote potential developments may have repercussions that hit close to home.
- Learning how management and employees might respond under both adverse and favourable circumstances.

In Sections 2.2 to 2.4 which follow below, some basic technical information is presented that will form part of the key input information for the scenario-planning process undertaken for the purpose of this project.

Today one of the leading futurists is Peter Schwartz. In his book titled “The Art of the Long View”, Schwartz (1991) describes a scenario-building process based on his long years of experience as head of the planning department at Shell. The method established by Schwartz (1991) forms the basis of the scenario-planning exercise carried out as part of the project. This method is described in more detail in Chapter 3.

2.2 Current electricity generation technology and energy sources

2.2.1 Electricity generation technology

Hansen (1998) describes technological options for power generation. Current technology can be grouped into three types: i) fossil-fuelled plants, ii) nuclear plants and iii) renewable energies.

Fossil-fuelled power stations represent the oldest technology in this industry. After the conventional coal-fired steam cycle reached maturity, combined-cycle gas and steam turbines became popular. Such combined cycles make use of the gas turbine waste heat to generate steam for a steam cycle. As a result, combined-cycle technology attains better efficiencies than coal-fired or nuclear plants. The following commercial fossil-fuelled power plant technologies are currently employed:

- pulverised coal firing with steam cycle;
- fluidised bed (coal) combustion with steam cycle;
- oil or gas fired boiler with steam cycle;
- oil or gas fired gas turbine;
- combined cycle with gas and steam turbine;
- pressurised fluidised bed combustion with combined cycle (gas and steam); and
- integrated coal gasification with combined cycle (gas and steam).

Nuclear power technologies that are mainly in operation at present are pressurised water reactors and boiling water reactors. Owing to the advanced technology required, nuclear power plants are expensive to operate and can only compete with fossil-fuelled plants if they are built in large units, for example 900 MWe per turbine.

A rapid expansion of nuclear plants took place in the 1970s and 1980s. Since then growth has virtually come to a standstill in North America and Europe. Currently, the South African utility ESKOM is involved in the development of a helium-cooled nuclear reactor, the so-called pebble bed modular reactor (PBMR) project. The advantage of the PBMR is its improved safety features. The PBMR technology is, however, still in a development phase and has not been commercialised as yet.

The following renewable energy technologies are mainly being used and developed further at present:

- hydro power;
- wind power;
- biomass as a fuel for power generation; and
- solar energy.

Other renewable energy sources that play a less significant role are referred to in Section 2.2.2.

Renewable energy sources have the major advantage over fossil fuels and nuclear energy of being non-depletable. Renewable energy is also environmentally friendly and does not produce greenhouse emissions to the extent that fossil-fuelled plants do. According to Lenssen & Flavin (1996) the world energy economy might shift away from fuels such as oil and coal and move towards decentralised and cleaner energy systems. The use of gas turbines, wind and solar energy and hydrogen fuel as the main energy carriers is predicted. A disadvantage of renewable energies is their site dependency.

Hydro power is the most used renewable energy worldwide. It is a mature technology and its employment is mainly dependant on the availability of water sources and suitable sites. Environmental considerations such as the displacement of people are further factors that play a role in the installation of hydro power plants.

2.2.2 Survey of energy resources

The World Energy Council has produced its 19th edition of the Survey of Energy Resources since 1934 (Yokobori, 2001). The 2001 survey provides a review of world energy resources as at the end of 1999. The following energy sources are covered by the survey:

- Coal
- Crude oil
- Oil shale
- Natural bitumen
- Uranium
- Nuclear energy
- Hydro power
- Peat
- Wood
- Biomass
- Solar energy
- Geothermal energy
- Wind energy
- Tidal energy
- Wave energy
- Ocean thermal energy conversion
- Marine current energy

Some of the main findings of the 2001 Survey (Yokobori, 2001) that are relevant to the present study are as follows:

i) Conventional fossil fuels - coal, oil and natural gas - remain in adequate supply. Compared to the 1998 survey, coal and natural gas reserves have increased while oil reserves have declined.

ii) Although the medium-term and long-term supply of coal is assured, its future prospects will largely depend on the impact of deregulation of electricity markets, policies to reduce greenhouse gases and technological advances related to the cleaner use of coal and carbon sequestration.

iii) The current increase in demand for natural gas is assumed to be an indication of a long-term trend.

iv) Conventional fossil fuels are expected to continue their dominance, which makes it seem unlikely that certain non-conventional or renewable energy sources will play an important role in balancing energy demand and supply in the foreseeable future, despite their technical feasibility or plentiful resource base. This relates in particular to oil shale, natural bitumen and extra-heavy oil, peat, tidal energy, wave energy, ocean thermal energy conversion and marine current energy.

v) Uranium will remain in ample supply over the next decade. During the period from 1991 to 1999 over 40% of the total world uranium requirements were met from non-mine supplies, with more than half coming from the Russian Federation's stockpiles.

vi) Construction periods of nuclear power plants have recently been shortened and operating costs have been reduced through the introduction of standardised plants in countries such as France, Japan and the Republic of Korea. Worldwide efforts continue to develop new reactor technologies as well as evolutionary and innovative reactor designs.

vii) 19% of the world electricity supply stems from hydro power. Yet hydro power utilises only one third of its economically exploitable potential.

viii) Wood fuels are estimated to cover nearly 6% of the world energy requirement.

ix) Despite a growing interest in biomass, factors such as low combustion efficiency and health hazards remain major challenges.

x) The Shell Renewables report suggests that the contribution of solar and other renewable resources should rise to 50% of world energy use by the year 2050. This would require sweeping changes in the energy infrastructure, a new approach to the environment and the way that energy is generated and used. A new generation of solar energy pioneers has to be nurtured.

xi) The short- to medium-term future of geothermal energy looks encouraging but its long-term prospects depend on the technological and economic viability of rock heat.

xii) Wind turbine size and output have grown and turbines with capacities up to 3 MW are now available for offshore applications. Global installed wind capacity may reach 150 GW by the year 2010, depending on political support and further improvements in performance and costs.

2.3 World energy consumption and demand

A global power market forecast for the 10 year period from 2000 to 2009 was presented by Poirier (2000). According to this forecast, global power activity decreased significantly in 1998 and 1999, mainly as a result of the economic slowdown in Asia. The market however picked up again with projects involving 145 GWe under development in the United States alone. In the rest of the world it is estimated that 815 GWe of Greenfield generation capacity is underway and comprises almost 2 250 projects.

The article by Poirier (2000) focused mainly on the future total turnover in the global power market, including deregulation activities, divestitures and distribution. It is expected that over the period 2000 to 2009, $175 billion will be invested in new utility plants, representing 280 GWe. Another $270 billion will be invested in new Independent Power Producer Plants, representing 440 GWe capacity.

According to Hansen (1998), 4 000 GWe capacity will have to be installed in the 30-year period from 1990 to 2020 to meet energy demand predictions. This forecast is based on the assumption that the global annual electricity consumption of 11 860 TWh in 1990 would double by the year 2020.

The International Energy Outlook (2002) projections indicate a continued growth in world energy use, including large increases for the developing economies of Asia and South America.

In its 2003 projections, International Energy Outlook (2003) again places emphasis on Asia. An average annual growth rate of three percent is projected for energy use in developing Asia, accounting for nearly 40% of the total projected increment in world energy consumption and 69% of the increment for the developing world alone. World energy consumption is projected to increase by 58% over a 24-year forecast horizon, from 2001 to 2025, with oil being the main source of primary energy. Energy demand growth in the United States was hindered by high world oil prices and several large corporate scandals that shook consumer confidence in recent years.

Other current studies that address future electricity demand and the availability of resources are those by Smil (2002) and Weidenbaum (2002).

In the late 1970s the World Energy Council started with scenario work (World Energy Council, 2003). In 1993 the World Energy Council explored three cases in detail to 2020. Case A described a high-growth world in which economic growth, energy consumption increases and energy efficiency improvements were strong. Case B was a middle-of-the-road evolution to which a modification, B1, was added which reflected stronger growth in energy consumption in developing countries and poorer performance in the improvement of energy efficiency. Case C was ecologically driven, with policy makers and other actors in society succeeding in promoting energy efficiency, technology innovation and transfer, non-fossil fuel development and the reduction of institutional barriers. Case C had the lowest energy consumption and greenhouse gas emissions trajectories of the three cases.

From the three cases defined in 1993, the World Energy Council moved to six variants in its 2003 report. Three variants were scenarios within the A family. Case A1 portrays strong emphasis on oil and natural gas use. Case A2 is coal-intensive (with implications for severe local and regional pollution and high carbon emissions, unless major and costly efforts are taken to tackle these). Case A3 emphasises the roles of natural gas, new renewables and nuclear energy in averting serious problems from emissions. Case B became a single scenario illustrating a middle course. Case C was divided into C1 with its emphasis on energy-efficiency improvements, new renewables (especially solar in the longer run), but with nuclear power phased out by 2100 because of its inability to satisfy its critics; and C2 where nuclear power plays an expanding role. In Scenarios A3, C1 and C2 there is relatively rapid progress along technology learning curves.

2.4 Recent developments in the power-generating industry

This section is devoted to recent developments in the power-generating industry. The purpose of the section is to highlight developments or events that can or will affect the industry in the medium- and long-term. The description of such events should assist the reader in gaining better exposure to information relevant to the scenario-building process.

The events and developments presented below are not intended to be exhaustive. The sections focus on both technological developments and innovations, as well as on business activities such as acquisitions that have occurred recently. The purpose of describing such business activities is to illustrate current movements that may contribute to future structural changes in the industry.

2.4.1 Renewable energy

The European Wind Energy Industry estimates that the continent will have 60 000 MW of total wind capacity by the year 2010, excluding Britain (Refocus Weekly, 2003a). Total capacity could be as high as 90 000 MW if Britain's offshore progress is included.

A financial model developed for a 30 MWe offshore tidal power project at Swansea Bay in Wales, showed that the internal rate of return is just above 30%. Chartered public accountants Chantrey and Vellacott authored the financial model, incorporating United Kingdom accounting and taxation provisions. It is further stated that the proposed Kaplan low-head hydroelectric turbine is mature technology and that its installation in seawater should not prove to be a problem, provided that the proper materials are selected for its construction (Ullman, 2002).

General Electric Power Systems acquired Enron's wind turbine generator division, officially entering the wind power industry (Modern Power Systems, 2002a). The new business will be called GE Wind Energy. General Electric expects this market to grow about 20% a year in Europe, the United States, Japan, China and Latin America. A 3.6 MW wind turbine system is currently being tested by General Electric in Spain. A picture of the 3.6 MW turbine is shown in Figure 2.1.

It has been reported that Siemens is interested in entering the high-growth wind turbine market. It is speculated that the Danish manufacturer Vestas, which has an annual turnover over €1 billion, is a potential target for a takeover (Modern Power Systems, 2002b).

The state of California has approved a law that requires utilities to purchase 20% of their electricity from renewable sources by the year 2017 (Refocus Weekly, 2002a). According to Patterson (2000), the German renewable energy law aims to increase the national contribution made by renewable energy to 30% by 2030. Other

European countries reinforcing their commitments to renewable energy are the United Kingdom, the Netherlands, Denmark, Italy and Belgium.

Figure 2.1: The 3.6 MW wind turbine tested by General Electric in Spain

Source: GE Power Systems (2003)

A super strong material developed at the Brigham Young University may allow the construction of wind turbine towers up to three times the height of those attainable with steel towers. This can increase the generating capacity by three times, possibly up to 5 MW. The new composite derives its strengths from carbon-fibreglass filaments and is reportedly 91% lighter than steel. As a result of the lighter weight, transport and installation costs are reduced with savings of up to 50% compared to steel structures (Modern Power Systems, 2002c). Meanwhile the world's largest offshore wind farm, Horns Rev, is undergoing commissioning in Denmark. It consists of 80 Vestas 2 MW turbines and is located 14 to 20 km from the shore. The distance between the turbines is 560 m and the entire wind farm covers an area of 20 km^2. A photograph of a typical offshore wind farm is shown in Figure 2.2.

Figure 2.2: A typical offshore wind farm

Source: GE Power Systems (2003)

The construction of a so-called solar tower is currently going through the planning and permitting stages in Australia (Sanford, 2002). An artist's impression of the solar tower is shown in Figure 2.3. The plant is to be constructed near Mildura in Victoria and will be the world's tallest structure when it is completed in the year 2005. The plant will consist of a 1 000 m high tower centred on a glass canopy covering an area of 40 km^2. Air is heated under the collector roof mainly by convection associated with heat stored in the ground. The heated air rises in the tower and drives a 200 MWe turbine that is located inside the bottom of the tower. Other configurations considered could make use of multiple small turbines.

Developing nations are considering the increased used of solar power to provide electricity for applications in rural areas, such as telecommunications, medical facilities and other infrastructure needs. This approach would eliminate the costs associated with distribution networks. A United States bank Ex-Im Bank is to fund a solar power project in Peru (Refocus Weekly, 2002b).

Figure 2.3: An artist's impression of the solar tower planned for construction in Australia

Source: EnviroMission Limited (2003)

A Chinese solar power company Shenzen Topway Solar Co Ltd plans to invest $500 000 in a solar unit assembly plant in Uganda. The company already supplies solar products to 15 African countries. It is believed that the assembly of units in Uganda can reduce prices for solar units by between 40% to 50%. It is aimed to bring the costs of solar units within reach of the poorer and middle-class customers (Modern Power Systems, 2002d).

2.4.2 Nuclear energy

The Fourth Report by the Select Committee on Science and Technology in the United Kingdom (The United Kingdom Parliament, 2003a) reports on the UK energy policy. It is noted that public opinion is a major obstacle to new nuclear installations and that this should not preclude the funding of research which addresses public concerns about the waste and safety of existing systems. The committee further points out that the Government should not underestimate the public's pragmatism and should not be afraid of people's ability to balance legitimate concerns with the great dangers posed by climate change. The committee also states that it is hard to imagine that the nuclear legacy will ever be as serious as global climate change. The committee is of the opinion that the next generation of fission reactors is likely to be the last. It should be used to keep the UK's carbon dioxide emissions as low as possible until fusion power and other non-carbon technologies are commercially available.

In its recommendations to the United Kingdom parliament (The United Kingdom Parliament, 2003b), the Select Committee on Science and Technology states that much bolder action is needed to make non-carbon technologies play a significant contribution to the UK's energy mix. The committee recommends the creation of a Renewable Energy Authority which should emulate the function undertaken by the United Kingdom Atomic Energy Authority in driving the nuclear industry after the Second World War. The committee considers carbon dioxide sequestration as a necessary part of the transition to a non-carbon fuel economy but warns that the use of such technologies should not act as a disincentive to the elimination of carbon-based fuels. It further regards offshore technologies (wind, wave and tidal), nuclear fusion and nuclear fission as the United Kingdom's areas of strength and applauds the long-term view British Nuclear Fuel is taking of reactor technologies in an uncertain climate.

A test rig has been completed in South Africa to prove that the three-shaft recuperated Brayton cycle can be sustained and controlled (Modern Power Systems, 2002e). The test rig is a replica of the pebble bed modular reactor (PBMR) currently under development in South Africa. The reactor is heated by silicon-carbide coated particles of enriched uranium oxide encased in graphite, to form a fuel sphere or pebble. Commercial reactors would be sized to produce 165 MWe each. This type of nuclear reactor is considered to be inherently safe and no meltdown can occur in the event of a loss-of-coolant accident scenario, it is reported. Helium is used as a cooling medium. Current partners who are involved in the PBMR project are South Africa's electricity utility ESKOM, British Nuclear Fuel and the Industrial Development Corporation of South Africa. The United States utility Exelon was also an investor but withdrew in 2002, stating that it would in future focus on the fundamentals of generation, power marketing and distribution to ensure a disciplined strategy.

The government of the United Kingdom appears to be working on a plan to revive the country's nuclear industry (Modern Power Systems, 2002f). Part of this process is to overhaul regulations on reactor safety so that new designs can be licensed more quickly and cheaply. Britain intends to follow the United States' lead to end the slump suffered by the West's nuclear power industry since the Chernobyl accident 17 years ago. The government recommends that the nuclear power option be retained should renewable energy sources and increased energy efficiency fail to produce the necessary pollution-free generating capacity and lower demand. At least three types of reactors are under consideration: light water reactors being developed by Westinghouse; the pebble bed modular reactor (PBMR) under development in South Africa; and the Canadian heavy water reactor Candu ACR. The state-owned company British Nuclear Fuel has a stake in all the aforementioned reactors.

Framatome ANP, a company owned 66% by Areva and 34% by Siemens, has acquired Duke Engineering & Services. The acquisition includes the former nuclear business group of Duke Engineering & Services. It is reported that the acquisition is a statement of belief in the United States nuclear market (Modern Power Systems, 2002g). Framatome has also purchased the nuclear fuel handling division of Washington Group International (Modern Power Systems, 2002h).

Recent reports illustrate the go-ahead for construction of new nuclear power plants in various countries; for example, France (Modern Power Systems, 2002i), Finland (Modern Power Systems, 2002j), India (Modern Power Systems, 2002k) and China (Debontride, 2002).

The Economist Global Agenda (2001) reported that the United States of America is about to make a U-turn on nuclear energy. It is reported that the Bush administration will try to revive the nuclear power industry. This would mean renewed construction of nuclear power plants. Counting in favour of nuclear energy are factors such as cost, no production of greenhouse-gas emissions, increased operating efficiencies and attitudes shifting towards nuclear energy. To date, nuclear plants are the only alternative to fossil fuels that could produce enough electricity and make a difference in the level of emissions.

Similar to the United States, The Economist Global Agenda (2001) reported that Russia suffers energy shortages. Russia needs to complete five nuclear reactors that have been under construction for more than a decade by 2005, and also needs to build 25 new reactors over the next 20 years to solve its energy problems.

2.4.3 Carbon capture and sequestration

An interesting trend is predicted by Smith (2002) that oil and gas production around the world and electricity businesses will inevitably be economically interdependent in future. This relates to Enhanced Oil Recovery (EOR) and carbon dioxide sequestration. The amount of oil remaining in deep oil wells after the readily retrievable product is fully exploited is often nearly as much as has been produced. By pumping captured carbon dioxide into natural underground deposits to replace existing resources as they are depleted during tertiary EOR, the carbon dioxide can be safely disposed of. Several billion barrels of oil can reportedly be extracted from wells during EOR, which oil would otherwise be wasted should the wells be sealed as fully depleted without EOR having been carried out.

An aquifer below the North Sea where Statoil of Norway has successfully stored carbon dioxide is said of have a storage capacity of 600 billion tons of carbon dioxide. The entire carbon dioxide emissions from all power stations in Europe could be deposited in this structure for 600 years, it is estimated. If there is investment in infrastructure to transport the carbon dioxide from Europe to the North Sea an extraordinary economic opportunity can be created, and former figures for estimated recoverable resources are now being reclassified as proven recoverable resources that are readily bankable.

A project called CENS (CO_2 – infrastructure for EOR in the North Sea) is being promoted by a joint venture of Kinder Morgan and the Danish utility Elsam. It proposes a common carbon dioxide infrastructure for EOR, connecting key rigs in the North Sea to combined EOR and carbon sequestration functions. Some of the CENS features are an annual reduction in 30 million tons of carbon dioxide, 700 million tons of carbon dioxide supplied over 20 years to the North Sea starting in 2006, two to three billions barrels of additional oil, a $1 billion investment in carbon dioxide pipelines, a $2 billion investment in carbon dioxide capture, and a $4 billion investment in EOR.

Underground coal gasification (UCG) is the conversion of un-worked coal, deep underground, into a combustible gas. This is achieved by injecting oxygen and steam under pressure. The product gas is brought to the surface where it powers a gas turbine. Large-scale schemes were developed in the Soviet Union but interest in them was lost as a result of the introduction of low-cost natural gas and growing environmental concerns about operating UCG at shallow depths. Problems related to the geology of the coal deposition have largely been overcome through major advances in exploration, and surveying and drilling techniques.

Carbon dioxide capture and sequestration can be used in conjunction with UCG, which makes it more environmentally friendly than the direct use of coal in fossil-fuelled power plants. China probably has the most active UCG programme in the world today, where UCG testing is done on abandoned coal mines (Green & Armitage, 2002).

2.4.4 Fossil fuel

A study titled “Power Price Stability: What’s It Worth” conducted by Platts Research & Consulting concludes that generating electricity from renewables could ultimately save consumers $5.20/MWh (Refocus Weekly, 2003b). Although exposure to volatility in the natural gas price can be reduced with futures contracts, the main concern is the price level at which natural gas prices will ultimately settle. Hedging against rising gas prices with financial instruments could then prove to be very expensive. Reference is also made in the same study to non-traditional sources of gas supply, such as Liquefied Natural Gas (LNG) and Arctic reserves that will enter the market between 2006 and 2008. These added sources will also play an important role in determining the future hedge value of gas. It is concluded that renewable energy technologies promote power price stability by avoiding the risks associated with underlying natural gas price escalation, volatility and delivery.

In 2000 the United Kingdom announced a state subsidy of £100 million to assist the coal industry. At that time a gas moratorium was still in place, which was originally introduced in order to assist coal’s competitive position against gas (Wilcox, 2000). The driver behind this issue is technology. Generation by coal-fired plants has an efficiency of approximately 35%, while gas-fired plants have reached efficiency levels of 50% and higher.

2.4.5 Other events of interest

According to Yokobori (2002) the global trend of increased energy-sector competition, promoted by regulatory reforms such as privatisation of public energy services, is becoming an important factor in the selection of the preferred fuel in many countries.

The fuel cell manufacturers, Ballard Power Systems in Canada and Ford Power Products, have developed and produced a generating set that is driven by a hydrogen-fuelled internal combustion engine. It is the first generator set powered this way. The generating set is called Ecostar and will be the cleanest combustion-type generator on the market, according to the makers. Ballard Power Systems plans to build fuel-cell power units for the Japanese residential market (Modern Power Systems, 2002l).

A report prepared for the United States Environmental Protection Agency predicts far reaching changes in geographic conditions, including the disruption of snow-fed water supplies, more heat waves, the permanent loss of some coastal areas as well as some benefits from increased agricultural and forest growth (Modern Power Systems, 2002m). The report concludes that nothing can be done about the environmental consequences of several decades' worth of carbon dioxide and other heat-trapping gases already in the atmosphere. It therefore appears that the United States may follow a strategy that allows for adaptation to such consequences as well as reduction in emissions. This strategy is expected to achieve emission reductions comparable to those described in the Kyoto Protocol without a threat to economic growth.

It has been reported that energy consumption in the European Union is rising, mainly because of transport growth. Energy efficiency is improving slowly and renewable energy usage needs to expand by at least double its current rate if targets for boosting its market share by 2010 are to be reached. European Union emissions of greenhouse gases fell by three-and-a-half percent between 1990 and 2000, but without additional counter-measures the level of emissions is likely to rise to the 1990 figure by the year 2010, because of a projected increase in energy-related emissions. Energy prices in the European Union have fallen since 1985, which discourages energy-saving efforts. Policies are, therefore, required that integrate external costs to the environment and human health into the energy price (Modern Power Systems, 2002n).

A study by the Southwest Energy Efficiency Projects suggests that an investment of $2 billion in Colorado in conservation and energy-efficiency measures over the next

18 years would yield net benefits of $6.4 billion. The state aims to cut energy consumption by 31% through increased efficiency, and reduce water consumption in the process (Modern Power Systems, 2002o).

At the first Group of Eight summit to focus on energy since 1998, ministers heard that energy challenges will become more acute over the next 20 years when increasing demand has to be balanced with environmental protection. It was pointed out that free trade and liberalised policies for private investment were vital to meet the growing demand for energy (Modern Power Systems, 2002p).

Construction of a utility-scale energy-storage system started at Little Bardford in the United Kingdom (Modern Power Systems, 2000). The storage system is based on fuel-cell technology, which appears to have major advantages compared to pumped-storage schemes or compressed air, both of which have geographical limitations. Other technologies such as batteries, flywheels, super-conducting magnetic storage and super-capacitors have capacity limitations inherent in the nature of their design. Fuel-cell technology offers flexibility in its power and energy storage rating. It has a high speed of response and supplies real and reactive power.

~~2.4~~2.5 Research questions

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The literature review presented in Sections 2.1 to 2.4 illustrates that many technologies and other external factors can play a role in the future of power generation. Technologies can be directly or indirectly linked to the power industry. For example, the implementation of enhanced oil recovery in the North Sea evolves around oil production in the first place, but can be linked to the generation of electricity through the carbon dioxide sequestration potential.

It is important that one keeps track of the bigger picture when considering future trends in the power-generating industry, and during the development of strategies that cater for such trends. The following questions will therefore be addressed as part of this project in order to develop a comprehensive basis for strategy formulation in line with the project problem formulated in Chapter 1:

i) What current technologies are employed for power generation on a commercial basis and what other technologies can impact on the current status?

ii) What growth is expected for the future global electricity demand?

iii) What are the typical factors that could shape the power industry in terms of future expansions?

iv) What are the key drivers for the selection of a particular power-generating technology and energy source?

v) What is the current status and consumption of global energy reserves?

vi) What energy sources and power-generating technology will dominate the power-generating industry?

vii) What are the strategic implications for current suppliers of power-station cooling systems in the medium term and long term?

3 RESEARCH METHODOLGY

3.1 Introduction

Scenario planning is an involved exercise undertaken in a large organisation, where it can consume vast resources in the form of research and the number of personnel involved. Such an ambitious approach is beyond the scope of this project. A simplified scenario-planning process is followed instead.

Section 3.2 below outlines the scenario-planning process as propagated by Schwartz (1991). Deviations from that process, as implemented for the purpose of this project, are noted in Section 3.3 that follows.

The research methodology followed can be summarised as follows: Information and data are gathered from the literature. The information then forms the basis of the simplified scenario-planning process. The scenario-planning process is regarded as the tool for data analysis. Finally, the outcomes of the scenario-planning process are used to draw conclusions and make recommendations.

~~3.3~~3.2 Data analysis through scenario planning

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The steps for developing scenarios as given by Schwartz (1991) are summarised as follows:

Step one: Identifying the focal issue or decision

Scenarios at a macro-economy level are similar across industries and organisations. However, at company level scenarios should differ from company to company and be industry specific. Scenario planners must ensure that the differences that distinguish their particular scenarios should make a difference to a specific company's business.

For this reason the scenario-developing process should begin "from the inside out" where a specific decision or issue is identified. The focal issue then forms the basis of the process.

Step two: Key forces in the local environment

During the second step the emphasis is placed on the "outside". Key factors influencing the success or failure of the decision or issue are listed; ie, facts about customers, suppliers, competitors, etc.

This step can be summarised by the following questions: What may key-decision makers want to know when taking that decision? What will be seen as successes or failures? What are the considerations that will shape those outcomes?

Step three: Driving forces

Following the identification of key factors as described above, driving forces in the macro-environment that influence the key factors are listed. The compiling of this list involves the use of a typical checklist of social, economic, political, environmental, and technological forces.

Here it is important to establish which of these forces are predetermined (eg, demographics) and which are highly uncertain (eg, public opinion).

Step three is the most research-intensive step in the process. Research typically covers markets, new technology, political forces, economic forces and environmental issues. The underlying point here is to search for and find the major trends and the trend breaks.

Step four: Ranking by importance and uncertainty

Key factors and driving forces are now ranked on the basis of two criteria: firstly, the degree of importance for the success of the focal issue or decision identified in step one; and secondly, the degree of uncertainty surrounding those factors and trends.

In the process the two or three factors or trends that are the most important and the most uncertain are identified.

Step five: Selecting scenario logics

The outcome of the ranking exercise provides the scenario planner with a number of key drivers. The key drivers form the axes along which the eventual scenarios will differ. Selecting and defining the axes form the most important part of the scenario-planning process.

Although the axes are the basis for the scenario logics, the core of the logics lies more in the themes and plots of a scenario story than in the position of the scenario on the axes. Plots that are developed for each scenario encompass subtleties that best capture the dynamics of the situation and communicate the point effectively.

Step six: Fleshing out the scenarios

Driving forces determine the logics that distinguish the scenarios, but once identified, a return to the key factors and trends is required to complete the process of scenario building. Each key factor and trend must be given some attention in each of the scenarios.

The purpose of step six is the development of a more complete picture that can show “how the world would get from here to there” or find events that may be necessary to make the end point of the scenario plausible.

Step seven: Implications of scenarios for the organisational strategy

Once the building of scenarios is complete it is necessary to return to the focal issue or decision identified in step one. Here the future is rehearsed by placing the decision into the context of each scenario.

An attempt is made to establish the robustness of the decision or strategy across all the scenarios. A decision or strategy that looks good in only one of the possible scenarios is considered a high-risk strategy. Should this be the case and if the particular scenario that is desired shows signs of not happening, the strategy should be adapted to make it more robust.

Step eight: Selecting leading indicators and signposts

Following steps six and seven, it is necessary to identify a few indicators that have to be monitored in an ongoing way. Such carefully selected indicators can represent the edge that a company can gain over its competitors.

Schwartz (1991) recommends practical guidelines for scenario building. These guidelines are set out below.

- One should avoid ending up with three scenarios, as people would be tempted to consider one of the three as the ‘middle’ or ‘most likely’ scenario. As a result the other two scenarios would receive less attention. At the same time care should be taken not to end up with too many scenarios.
- Scenarios should not be assigned probabilities.

- It is important to name scenarios. Names form part of the story line and assist with effectively communicating scenarios to an audience.
- The selection of a scenario-building team should be guided by the support and participation of the highest level within organisations. A broad range of functions and divisions should be represented and, lastly, the members should be imaginative and have an open mind.
- Good scenarios are usually plausible and surprising. Such scenarios should break stereotypes and their makers should assume ownership and put them to work.

3.3 Deviations from the formal scenario-building process

The formation of a comprehensive scenario building-team is beyond the scope of this project. Instead, the project looks at a one-person team where the scenario builder acts as an expert at the same time. Therefore, the selection of a scenario-building team is not carried out.

The information that needs to be gathered as part of steps one and two is drawn from strategy information that is communicated to management inside the organisation, rather than through the typical use of interviews.

After the scenario-building process has been completed, the scenarios are communicated to some experts in the field. The role of the experts is to comment on the relevance and plausibility of the scenarios developed. These experts are not involved during the scenario-building process.

~~3.2~~3.4 Information and data collection

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Information and data were collected through a literature survey and are presented in Chapter 2.

Chapter 2 both covers the background of scenario planning as well as information related to the subject of power generation.

In the context of this project report scenario planning is considered as a complete and available tool that can be applied to the project topic. An extensive literature review about scenario planning per se is therefore not considered necessary. The fact that Peter Schwartz (1991) worked closely together with the leading experts who originally developed scenario-planning techniques is considered sufficient evidence that his method of scenario planning is acceptable for application in this project report.

The information and data presented in the second part of Chapter 2 form the input for the scenario-building process. Step three of the scenario-building process in particular relies on the information gathered as part of the literature review.

Opinions and views given by experts in the field form the last part of the information-gathering process. Owing to the qualitative and exploratory nature of this project, no questionnaire was used for the purpose of collecting information and data or for obtaining the input from the experts. The completed project report was handed to the experts and they were requested to comment on the relevance and plausibility of the scenarios generated. The experts were further asked to comment on the robustness of the current organisational strategy as well as the adapted strategy proposed in Chapter 6.

Finally, the experts added their views about the shortcomings of the scenario-building process as listed in Section 6.2. They further presented their recommendations with regards to improving the scenarios and activities that would have to be carried out prior to implementing the adapted strategy at operational level in the organisation.

4 PRESENTATION OF RESULTS

4.1 Scenario building

As discussed previously, the first step of the scenario-building process takes a look inside the organisation. The typical strategies pursued by the industry under consideration and the associated focal issues are discussed as part of step one in the context of marketing theory. What follows is a brief description of the marketing context that forms the basis of the discussion in step one.

Goals represent what a company or business unit wants to achieve, while strategy is the plan for reaching the goals. As described by Kottler (2000), a business must tailor its strategy, which consists of a marketing strategy, a compatible technology strategy and a sourcing strategy, to achieve its goals. Many types of marketing strategies are available. Porter (1980) has condensed these strategies into three generic types; namely, overall cost leadership, differentiation, and focus.

In the case of overall cost leadership, a business aims at achieving the lowest production cost so that it can price its products lower than its competitor does. A differentiation strategy concentrates on achieving superior performance in an important customer-benefit area valued by a large part of the market. Lastly, a business focuses on one or more narrow market segments when it follows a focus strategy.

4.1.1 Step one: Identifying the focal issue or decision

Current organisational goals evolve around increasing annual sales as well as the return on sales.

Increase in sales should be achieved through an increase in current market share as well as through entering new markets.

In order to increase market share, various action plans exist for reducing costs so that an overall cost leadership can be obtained in established markets. Such a cost-leadership position will then turn into a competitive advantage. Cost leadership can also contribute to increasing the return on sales.

On the other hand, past activities that focused on the Far East have recently paid off when the Chinese market was entered. Dry-cooling systems that derive from the existing product range will be exported to China where the construction of new power plants is underway.

New products are furthermore developed for introduction into existing markets. Here the emphasis is on the creation of service divisions. In the past the business focus has been on engineering and manufacturing. A newly created service division will look after existing customers who have been supplied with cooling systems in the past. Apart from adding to annual sales, the provision of services should assist with increasing profitability since higher margins are expected in this type of market.

The above strategies can be classified as internal or organic growth strategies. Growth through the acquisition of direct competitors in the field of manufacturing was considered but has been put on hold for the time being.

The introduction of new products into the current product mix through acquisitions was also investigated but is not being pursued further at present. Traditionally, suppliers of cooling systems to the power-generation industry have focused mainly on fossil-fuelled power plants. The renewable energy sector has so far not been considered. Other energy sectors such as nuclear energy have practically been avoided.

According to Peter & Donnely (2000), the available strategic choices that a business can consider can be presented in the form of a two-by-two matrix based on products and markets, as shown in Figure 4.1.

The entries in Figure 4.1 represent the strategies that are currently being implemented by the organisation. As can be seen in Figure 4.1, the marketing strategies envisaged to increase sales and profitability fall inside three of the possible four strategic areas.

Key questions or focal issues that arise from the current strategic considerations can be summarised as follows:

- Various types of areas in the power-generating industry could be targeted through acquisitions. Where should the focus be? Options for acquisitions are as follows: i) direct competitors, ie suppliers of traditional cooling systems to the fossil-fuelled power-generating industry, ii) established businesses in the renewable energy industry, iii) component suppliers within the traditional power-generating market other than the suppliers of cooling systems, or iv) businesses in the nuclear energy sector.
- Capacity issues: Should the current manufacturing capacity that serves the air-cooled heat exchanger market be expanded further? If capacity should be expanded, what would be the right timing and how much capacity should be added? Should capacity be added through the acquisition of direct competitors?
- Research and development (R & D): Where should the focus of R & D be? Should R & D focus on production and operations to contribute to the overall cost leadership position? Alternatively, should the focus be on innovation and the introduction of new products into the market?
- Service division: How should service activities be positioned in the current divisional structure? What types of services should be targeted? What are the resource requirements for a dedicated service arm of the organisation?

Figure 4.1: Illustration of current organisational strategies

Products / Markets	Present products	New products
Present customers	**Market penetration:** 1) Cost leadership through innovation and R & D	**Product development:** 1) Service division 2) Innovation
New customers	**Market development:** 1) Expand activities in the Asian market	**Diversification:**

Source: Adapted from Peter & Donnely (2000)

4.1.2 Step two: Key forces in the local environment

Before listing key forces in the local environment, this environment has to be defined within the context of the type of organisation under consideration. The organisation has a network of businesses in various countries on all continents to service the power industry on a global basis. Many countries in the world are either already being served or can be served in future. The major markets are, however, concentrated in the United States of America, Europe and the Far East. In this context, key forces in the local environment refer to country-orientated forces; in other words, forces that would play a role in a particular geographic market.

The following key forces can be identified:

- environmental policy and legislation;
- energy policy;
- supply and demand of electricity;

- entry by competitors or other organisations into the renewables market;
- ageing of existing power plants and replacement and maintenance policies;
- new technological developments by competitors for the traditional cooling system products; and
- capacity expansion plans by competitors for traditional cooling system products.

4.1.3 Step three: Driving forces

Step three consists of two stages. Macro-environmental forces that influence the key factors identified in step two are listed during the first stage. During the second stage, the driving forces are grouped into two categories; namely, predetermined forces and highly uncertain forces.

Predetermined forces can typically be slow-changing phenomena, constrained situations, factors considered in the pipeline today or inevitable collisions. On the other hand, critical uncertainties are sought out by scenario planners so that they can be planned for. Step four explains more about the importance of the difference between predetermined elements and critical uncertainties.

Familiar categories for macro-environmental forces are society, technology, economics, politics and the environment. The macro-environmental forces relevant to the current research problem are given in Table 4.1 and are ordered according to the aforementioned categories.

Table 4.1: Macro-environmental forces

Society	i) Popular opinion about nuclear energy. ii) Popular opinion about global warming. iii) Global demographics and consumer patterns (growing use of electronic equipment by younger generations).
Technology	i) Advances in power-generating technology from renewable energies. ii) Increased operating efficiency of nuclear power plants. iii) Extended life of various nuclear power plants. iv) Improvement in the thermodynamic cycle efficiency of gas and steam turbines. v) Development of carbon dioxide capture and sequestration. vi) Development of energy storage technology.
Economics	i) Potential increase in costs to mine coal at deeper levels. ii) Potential increase in natural gas supply costs due to increase in depth of exploration. iii) Solar power becoming viable in remote rural areas. No electricity distribution costs are incurred. iv) Global economic growth (decreasing or stagnant at present). v) Deregulation of electricity markets and the introduction of independent power producers.
Politics	i) Use of nuclear energy outside regions such as the United States and Europe in defiance of demands by the United States, such as in North Korea for example. ii) Present subsidies granted for the installation of renewable energy systems.

Table 4.1: Continued from previous page

Environment	i) Evidence of global warming and resultant changes in weather patterns. ii) Potential problems associated with the disposal of nuclear waste. iii) Offshore installation of so-called wind farms to avoid noise and environmental pollution caused by inland installations. iv) Water becoming a scarcer resource.

Tables 4.2 and 4.3 below illustrate how the above macro-environmental forces are grouped into predetermined elements and critical uncertainties. The tables further show the reasoning for the selection of each force as a predetermined element or a critical uncertainty respectively.

Table 4.2: Predetermined elements

Predetermined element	**Reason for being a predetermined element**
i) Global demographics and consumer patterns (growing use of electronic equipment by younger generations).	Global population growth is a driver for electricity demand, independent of the type of energy source that is used for generation of power.
ii) Advances in power-generating technology from renewable energies.	Renewable energy sources are regarded as an integral part of a future that is focused on sustainable development. Current and future research in the field of renewable energy technology can therefore be expected to continue. It can be considered as a driver that is in the pipeline today.
iii) Increased operating efficiency of nuclear power plants.	Nuclear plants have now been in operation for some decades. The resultant experience as well as future experience contributes to improved operation of such plants.
iv) Extended life of various nuclear power plants.	Recent applications of licences to extend the operating life of nuclear power plants in the United States is a trend that can be expected to spread to other parts of the world.

Table 4.2: Continued from previous page

v) Improvement in the thermodynamic cycle efficiency of gas and steam turbines.	In a quest to be leaders in the supply of turbines, and to maintain or create a competitive advantage, suppliers of turbine technology will continue to carry out research and development to improve the cycle efficiency of their equipment.
vi) Potential increase in costs to mine coal at deeper levels.	It is a natural trend to mine coal in areas where the operation is the most economical. As such areas become depleted, continued demand will force mining activities to areas that are potentially more costly to mine.
vii) Potential increase in natural gas supply costs due to increase in depth of exploration.	A similar reasoning applies as in the case of coal mining. As natural gas may tend to be sourced from more remote areas, the costs associated with transporting the gas via pipelines are expected to increase (eg gas from Alaska for the US).
viii) Solar power becoming viable in remote rural areas of developing countries. No electricity distribution costs are incurred.	The electricity demand in rural areas is relatively low and does not justify the costly distribution networks required to bring electricity to rural areas. This creates an ideal market for solar power installations as solar power technology becomes more affordable.

Table 4.2: Continued from previous page

ix) Global economic growth (decreasing or stagnant at present).	Global economic growth, regardless of the rate of growth, is considered a predetermined element because it will feature the same across each of the potential scenarios. Global economic growth is a driver of electricity demand, regardless of the type of energy source used to generate power. Should economic growth continue to slow down, as is presently the case, economic conditions will become tougher. In such a case the cost of power generation will become one of the main criteria for the selection of the type of energy source and the power-generating cycle.
x) Deregulation of electricity markets and the introduction of independent power producers.	This existing trend can be expected to continue as various countries are forced to deregulate the power industry so that normal market forces govern the industry, with the expected reduction in the cost of supply.
xi) Offshore installation of so-called wind farms to avoid noise and environmental pollution caused by inland installations.	Windmills are tall structures and large areas are required for the installation of wind farms. The associated noise pollution is significant. These factors require the installations to be located offshore, as is currently the trend. The trend will continue to maintain the viability of wind farms.

Table 4.2: Continued from previous page

xii) Water is becoming a scarcer resource.	Water as a resource is a constraint within the context of a planet as a closed system. As the population growth continues, water consumption tends to increase in the absence of water-saving measures.

Table 4.3: Critical uncertainties

Critical uncertainty	**Reason for being a critical uncertainty**
i) Popular opinion about nuclear energy.	Popular opinion about nuclear energy can play a key role in the future use of nuclear energy. Popular opinion can be gauged for the present, but remains uncertain for the future. Furthermore, popular opinion is not static. While the feeling towards nuclear energy was mainly negative in the past, it could turn positive in future.
ii) Popular opinion about global warming.	As long as there is no clear evidence of dramatic consequences of global warming, day-to-day reaction towards global warming will be limited. This situation can, however, change overnight.

Table 4.3: Continued from previous page

iii) Development of carbon dioxide capture and sequestration.	Should the development for carbon dioxide capture and sequestration prove to be successful and commercially viable, the perception about the use of fossil fuels in the context of global warming will change. Until such time, it remains uncertain.
iv) Development of energy storage technology.	The significant advantages of electricity storage are clear. At present, electricity-generation capacity is planned around peak loads and, as a result, overcapacity exists during off-peak periods. Energy storage can reduce the installed capacity required substantially. However, large-scale storage facilities do not yet exist on a commercial basis.
v) Use of nuclear energy outside regions such as the United States and Europe in defiance of demands by the United States, such as in North Korea for example.	To date, the United States of America and international bodies have exerted their influence on the use of nuclear energy by developing nations. Following September 11 and the subsequent disagreement amongst the United States and European nations about the war in Iraq, the current world order can change. As a result, the use of nuclear energy by developing nations remains an uncertainty.

Table 4.3: Continued from previous page

vi) Present subsidies granted for the installation of renewable energy systems.	In order to accelerate the development of renewable energy technology, and to meet renewable energy targets, various governments subsidise the capacity expansion of renewable energy installations. Should the use of renewable energy be unable to compete with fossil fuel and nuclear energy on a commercial basis, prolonged subsidies could be doubtful.
vii) Evidence of global warming and resultant changes in weather patterns.	Although the rise in atmospheric temperature has been recorded and natural catastrophes such as floods have occurred, the effect of global warming has so far not produced dramatic events to such an extent that would force immediate reductions in the use of fossil fuel. The occurrence of dramatic events in the immediate future, therefore, remains a critical uncertainty.
viii) Potential problems associated with the disposal of nuclear waste.	The long-term storage of nuclear waste and potential adverse consequences to the environment remain uncertain, since sufficient evidence will only emerge once storage technology and practices have been tested over several decades.

4.1.4 Step four: Ranking by importance and uncertainty

The driving forces listed in Section 4.1.2 (key forces in the local environment) as well as the macro-environmental forces that are defined as critical uncertainties (see Table 4.3) are presented in Figure 4.2 in a ranked format.

The predetermined elements shown in Table 4.2 do not form part of this ranking since they do not contain the uncertainty factor. This does not imply that the predetermined forces are not important. Their role will be discussed under step six when each scenario is described in more detail.

Two key factors or trends that are the most important and the most uncertain as determined by the ranking exercise are:

- the future level of nuclear energy use as part of the overall fuel mix; and
- the effect of heat-trapping gases on global warming and climate change.

The most important and uncertain drivers eventually form the axes along which the scenarios will differ, when the scenario logics are selected as part of step five of the scenario-building process. These key drivers must therefore be independent. In other words, a change in trend along one of these axes may not necessarily force a change along the other axis.

It could be argued that the above two key factors are not independent in the sense that an increased use in nuclear energy will reduce the emission of carbon dioxide and other heat-trapping gases and, as a result, the effect on global warming will be reduced. However, the increased use of nuclear energy is not the only alternative to achieve the reduction in emissions. Furthermore, the selection of nuclear energy for the purpose of capacity expansion can be driven by economic reasons and the lack of other energy sources in the region and does not have to be linked to global warming. It can, therefore, be concluded that the above key factors are independent of each other to a large degree.

4.1.5 Step five: Selecting scenario logics

The two key drivers are presented in a graphical form in Figure 4.3. Four possible scenarios emerge from Figure 4.3 and are named as follows:

- Nuclear to the Rescue (scenario 1);
- Wind, Water & Sun (scenario 2);
- No Winds of Change (scenario 3); and
- A Future without Alternatives (scenario 4).

"Nuclear to the Rescue" is a scenario where adverse global climate changes force a reduction in the use of fossil fuels while, at the same time, alternative or renewable energy capacity is insufficient to satisfy electricity demand. Nuclear energy then comes to the rescue. No heat-trapping gases are emitted and the supply-and-demand balance is restored.

In the case of "Wind, Water & Sun" a significant reduction in the emission of heat-trapping gases is required due to dramatic climate change consequences similar to those in scenario 1. However, here renewable energy sources and technology can supply the shortfall in electricity supply that arises when no more fossil-fuelled power plants may be constructed.

"No Winds of Change" is a scenario that resembles the current energy-mix scenario to a large extent. Renewable energy sources continue to play a secondary role as climate changes and their consequences are very limited. Gas and coal remain the primary energy sources with further contributions by nuclear energy and hydro electricity.

The fourth scenario depicts a situation where power generation from alternative energy sources is commercially unsuccessful. In other words, it cannot compete against the costs associated with mature fossil-fuelled technology. In "A Future without Alternatives” fossil fuel and nuclear energy dominate the power-generation industry, public opinion about nuclear energy is neutral and global warming effects are minimal, such that gas and coal remain significant contributors.

Figure 4.2: Ranking of key factors and driving forces on the basis of importance and degree of uncertainty

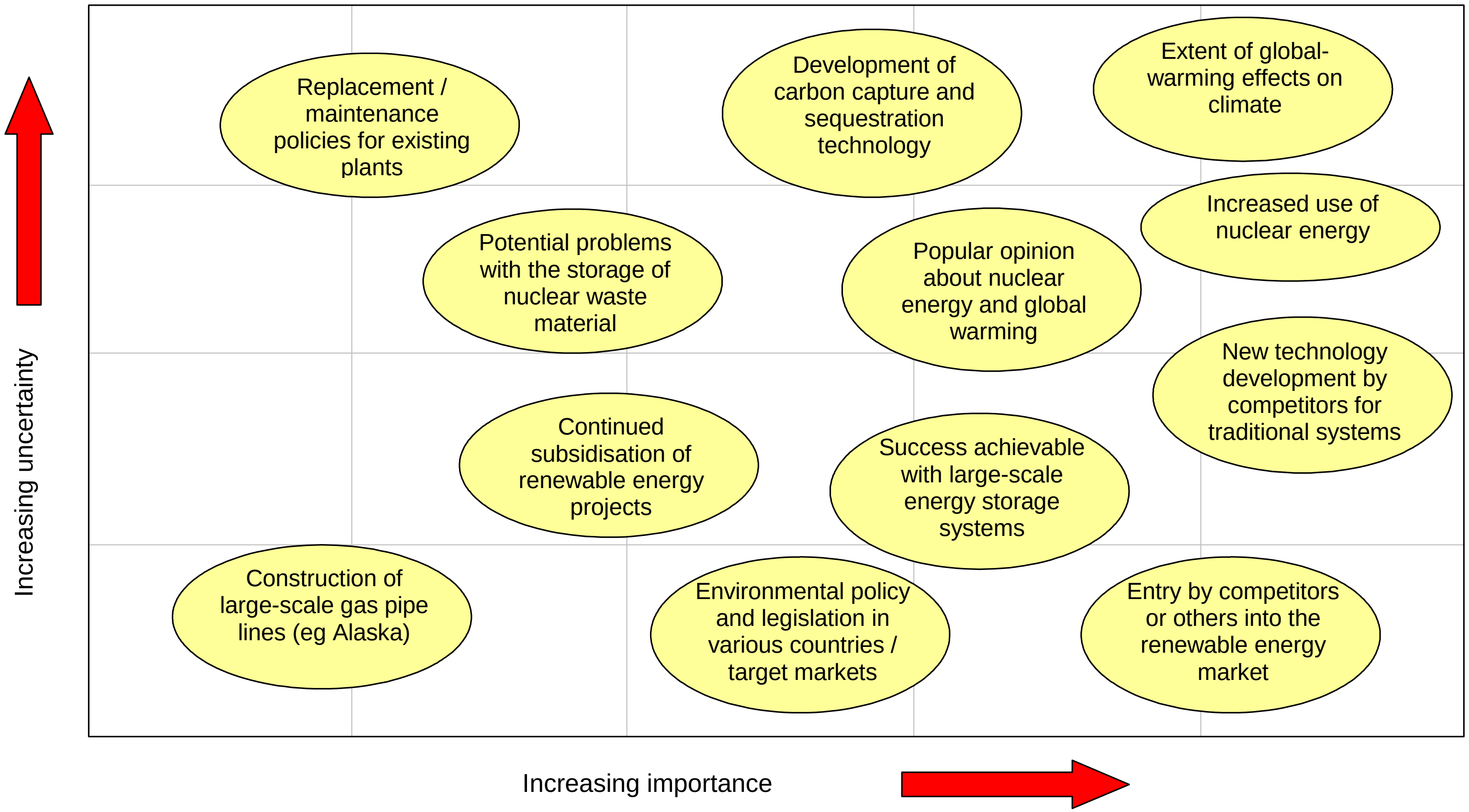
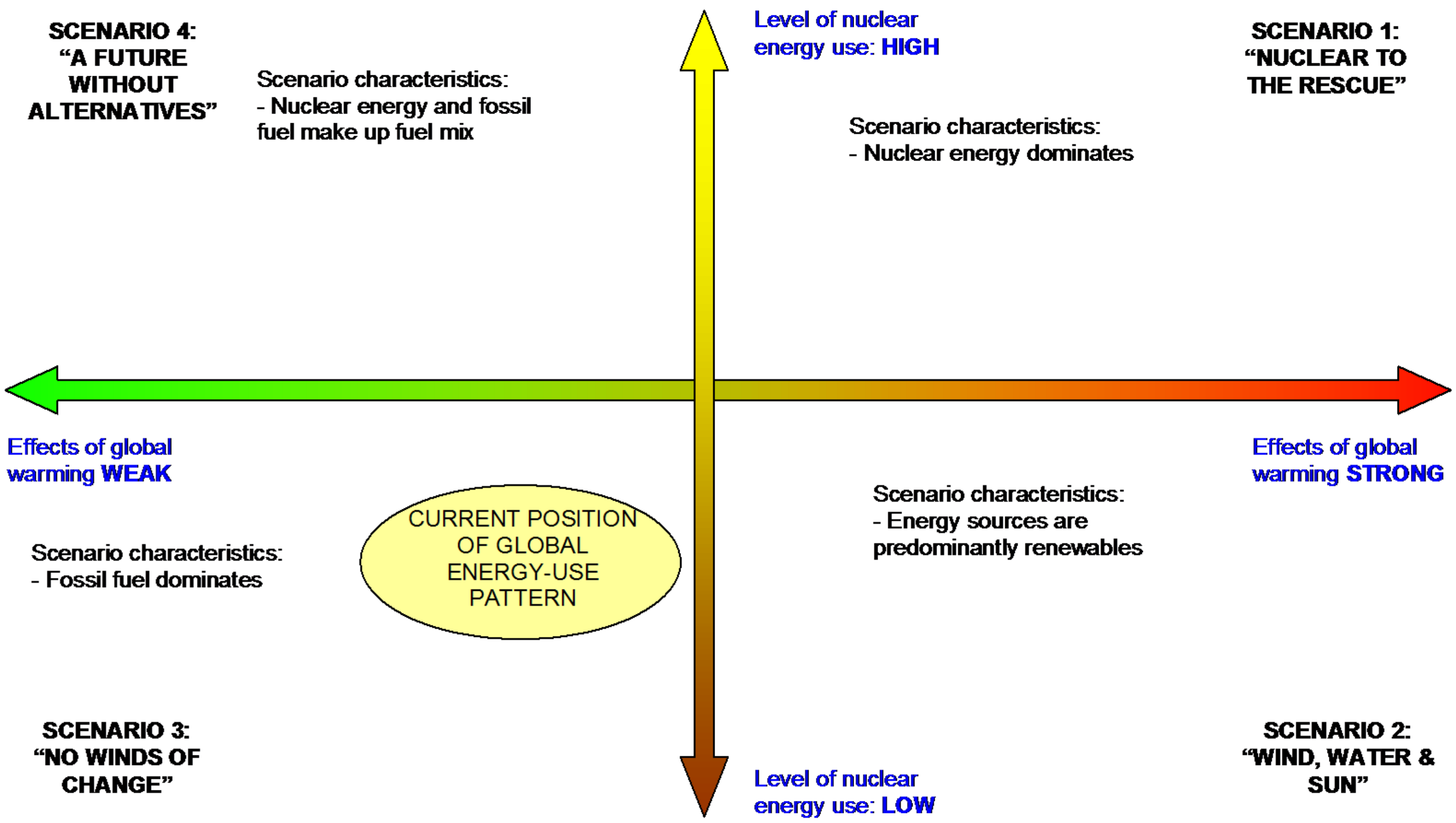


Figure 4.3: Presentation of scenario logics



4.1.6 Step six: Fleshing out the scenarios

The purpose of this step is to compose narratives for each scenario on the basis of a certain plot (Schwartz, 1991). While the scenarios use the same sort of logics to describe how the driving forces might behave in future, it is the type of plot that distinguishes the different ways in which the driving forces will behave. In other words, the same set of driving forces may behave differently according to different possible plots.

Before turning to the detail of each scenario, it is useful to present a brief description of the different types of generic plots that can typically be found, as discussed by Schwartz (1991).

“Winners and Losers” is a plot based on the perception that world resources are scarce and limited and that if one side gets richer, the other side must get poorer. This type of plot can often be found in politics and in very mature industries. For example, only one country can dominate the economy, therefore other countries must be subservient. Or, in computers there can only be one IBM.

Another type of plot is “Challenge and Response”. The term “challenge and response” comes from script writing where it refers to adventure stories in which an individual faces one unexpected test after the other. It is important to overcome the tests. The tested person emerges different from the way he was before, each time he passes a test. America’s history had been a continual succession of challenge and response stories. Another example of challenge and response can be found in environmentalism. In the past, the perceived relationship between economics and environment was a zero-sum game based on a winner-and-loser logic. Growth and environmental safety could not coexist. If you wanted a cleaner environment, a business had to waste money on catalytic converters or coal-plant scrubbers. These days the idea of sustainable development has emerged, which suggests that both economic growth and environmental quality are possible. People have to tackle the challenge of satisfying both criteria, which means developing technologies that cut waste and save energy.

The third type of plot is “Evolution”. Evolution involves small changes in one direction, usually a growth or a decline. The most common evolutionary plot is technology where new innovations grow in a biological fashion. Furthermore, any scenario for technology must include an understanding of the political and social systems around it. The regulatory framework for telecommunications, for example, hindered the advance of fibre telecommunications in the United States of America. On the other hand, Europe and Japan are moving more aggressively, having different regulatory frameworks.

Sometimes, a sudden dramatic change, usually unpredictable in nature, occurs. This is the characteristic of a so-called “Revolution” plot. Examples are an earthquake, a volcanic eruption or a political revolution. Such discontinuities can also include human-made natural disasters such as a pollution-precipitated sudden climate change, or surprising changes in public attitude. Revolutions are usually important for their aftermath.

“Cycles” represent another type of plot. Many cities go through cycles of decline and rejuvenation. Economic matters often occur in cycles. When a reserve bank increases the money supply for example, it can be expected that interest rates will decline. As a result borrowing and spending increase which, in turn, raises inflation. Ultimately, the money supply is reduced to previous lower levels. The timing of cycles is important, but cycles are often unpredictable. For this reason, awareness of clues is of utmost importance.

The sixth type of plot is called “Infinite Possibility”. Under an infinite possibility scenario, the starting point is a public perception that the world will expand and improve infinitely. This may be a seductive story, but it is not always seduction with a bad result. The computer industry in 1975 was driven by infinite possibility. Although many businesses related to computers and software development failed over time, the computer industry as a whole had an unequivocal economic boom. Infinite possibility is a powerful plot where the pursuit of infinite possibility can make change possible.

A further type of plot is called “The Lone Ranger” plot. Margaret Thatcher found herself in a lone ranger plot when she followed the strategy of dismantling the existing political system. The lone ranger plot is mainly a social logic driven by street sensibility. David facing Goliath is a lone ranger hero, which reminds one of the situation when Apple Computer had to face organisations such as IBM. It must be noted that a lone ranger has a romantic image but when two lone rangers face each other, a virulent winner-and-loser conflict is set loose.

Lastly there is the “My Generation” plot. This plot evolves around culture and the influence culture has on people’s values and, in particular, the culture of large generations of people. The youth generation of the post-war era for example was large in numbers and grew up in an environment of affluence, peace and freedom. As a result their need for food, shelter and companionship was satisfied and they were given the freedom to think about self-expression, status and the meaning of life. This led to the subsequent youth rebellion and social experimentation. Furthermore, the youth generation and women had enough freedom to increase their affluence and, as a result, they began to question their traditional roles.

Following the description of the types of plots above, attention is now shifted towards describing the plot of each of the four scenarios defined in step five. Figure 4.3 illustrates how the plots can shift the world from its current position towards each of the possible scenarios.

Scenario 1: “Nuclear to the Rescue”

The world is forced into a “Winners and Losers” situation through an element of “Revolution”. Sudden natural disasters are extremely severe and can be traced back directly to global warming. The people of the world wake up to an ultimatum where the choice lies between nuclear energy and the consequences of global warming.

The development of renewable-energy technology has advanced, but existing capacity is insufficient to replace fossil-fuelled power plants and meet global electricity demand. Existing nuclear technology is economically viable and reliable, construction lead times of new plants have been reduced significantly and, as a result, there is little choice but to stop any further developments of fossil-fuelled power plants and to limit expansion to nuclear plants.

Society has come to accept nuclear energy as they view the devastation brought about by greenhouse gases on global television networks from the armchairs of their homes. The environment emerges as a winner where no further increases in the emission of greenhouse gases are permitted.

Improvement in thermodynamic cycle efficiency of fossil-fuelled plants is too limited to cater for new power demands. Energy-storage technology is still in its early stages of development and has not yet had the dampening effect on the demand of new power plants as was expected initially. The development of carbon capture and sequestration technology has not delivered the desired results. All these factors have contributed to the drastic decision that fossil fuel may not, at present, be considered for future power-generating plants.

Authorities have seized on the idea of supporting the further development of renewable-energy technology, realising that progress in the near future will be limited. A lot of funds now have to be diverted to disaster relief operations following the severe natural disasters, putting further strain on government finances. Nuclear energy dominates the research and development arena, and emphasis is now placed on solving some of the remaining challenges related to the safe disposal of nuclear waste and the commercialisation of the first generation of fusion reactors.

Water is increasingly becoming a scarcer resource as the global population grows and nuclear power plants are predominantly located in coastal areas where seawater is used for cooling purposes. As a result, the new emphasis on nuclear power plants does not add a further burden to freshwater sources. The environmentalist lobby groups welcome this new trend, in fact.

No more organisations enter the renewable energy sector and those that have invested significant amounts of capital in this industry cannot make the desired returns anymore.

Production capacity for the supply of traditional cooling systems to the fossil-fuelled power industry exceeds market demand and suppliers abandon all existing capacity expansion programmes. Research in this area virtually comes to a standstill and the development of new or improved technology is halted.

Governments across the world agree on the maintenance and replacement policies of existing fossil-fuelled power stations. Maintenance is limited to plant safety requirements and no extra effort is made to extend the life of plants. Once such plants reach the end of their lifetime, they have to be replaced with nuclear reactors.

Scenario 2: “Wind, Water & Sun”

A “Challenge and Response” plot drives this scenario in which the world recognises that renewable energy is the only basis for a sustainable energy supply in the longer term. Public perception and opinion have turned against the use of nuclear energy in a world order that has made it increasingly difficult to control the use of nuclear technology and proliferation.

Fossil-fuelled power plants still contribute significantly to electricity generation but the focus is on renewable energy when adding new power-generating capacity. As exploration, mining and extraction costs increase because fossil fuels have to be reached at deeper levels underground or offshore, renewable energy technology becomes very cost competitive.

Global warming remains a problem and stricter emission control is required for fossil-fuelled power plants. This further adds to the cost of generating electricity from fossil fuels. More knowledge is gained about the effect of carbon dioxide and other greenhouse gases on climate change. The situation is serious but enough time is available to shift from a fossil-fuel-dominated industry to a completely new power industry that draws its resources mainly from renewable energy.

Eventually wind, solar power, hydro power and tidal and wave energy dominate the power-generating industry. Solar power is mainly used in remote areas where significant savings can be realised through the elimination of costs traditionally related to distribution infrastructure. Wind and hydro power have the main share of the fuel mix. Fossil-fuelled power stations provide the minimum steady generating capacity or base load of approximately 20% of total demand, which is required to ensure grid stability.

Some suppliers of large-scale cooling systems that have traditionally served the power industry shift their focus to renewable energy technology. Some businesses do not make the shift in time and face going out of business or restructuring for the purpose of downsizing.

A further complication is that the faces of past competition have changed. In the past a well-defined structure existed within the industry that supplied large-scale cooling systems. Businesses were specialised in the field of cooling and the industry was regarded as stable apart from the usual rivalries that evolved around fighting for market share. The move to renewable energy introduces new competitors never thought of before. For example, large oil companies invest heavily in solar power systems while traditional steam turbine manufactures enter the market for the supply of wind turbines. Organisations such as oil companies or steam turbine manufactures, which were never considered as competitors to the suppliers of large-scale cooling systems in the past, suddenly become competitors. However, following the move to renewable energy, significant structural changes emerge in the power-generating industry.

Scenario 3: "No Winds of Change"

"No Winds of Change" presents a scenario that is characterised by more of the same. Essentially the fuel mix remains as is currently the situation, but this does not imply that there is no technological advance.

This scenario follows a route of evolution. Global climate changes have not materialised to the extent that drastic action has been required. Some natural disasters such as flooding have occurred, but the world has learned how to deal with such isolated incidences. Through step-by-step technological improvements the gas- and coal-fired power stations remain the most cost-effective systems.

The main problems associated with renewable-energy technology are the inability to achieve the advantages of economies of scale and to provide the capacity that large-scale fossil-fuelled systems can provide. The share of renewable energy therefore does not go beyond 20% and its existence relies on continuous subsidisation.

As the world becomes more energy efficient, the future expansion of electricity-generating capacity is moderate. Improved technologies assist with containing the rate at which greenhouse gases are emitted into the atmosphere. These factors convince various regions of the world that gas and coal can be regarded as sustainable while these resources can still be found in abundant quantities.

Nuclear energy is losing market share in the process. It is too expensive because of stringent safety requirements and waste disposal turns out to be problematic. Some further accidents have led society to believe that nuclear energy is not an option anymore. It is decided that existing plants may be operated until the end of their life, after which decommissioning will take place. No new nuclear plants will be constructed. This also assists with the control of nuclear technology in a world order where it has become increasingly difficult to maintain a balance of power because of the use of nuclear technology in the armament strategies of various countries.

As existing gas- and coal-fired power stations reach the end of their operating life they are replaced with similar but improved plants. This places huge demands on the suppliers of cooling systems, who have to cater for replacement plants as well as new capacity expansion projects. Production capacities are insufficient and strategies have to be devised to overcome these challenges. The shortage in production capacities initially favours the profit margins but the improved profit margins attract new entrants to the market.

Water as a resource is at its limit and wet-cooling systems become too costly to operate. Dry-cooling is the favoured alternative in an environment where the emphasis is on saving water resources.

Scenario 4: "A Future without Alternatives"

Through an evolutionary process fossil-fuel technology and nuclear energy come out on top. Both have their advantages and disadvantages but, generally speaking, match each other in terms of cost competitiveness. In the process, renewable or so-called "alternative energy" loses market share because it cannot compete in terms of economics. Governments therefore decide not to subsidise the development of renewable energy any further. Hydro power is still used in some parts of the world, but fossil-fuelled power stations and nuclear energy are the main contributors to the generation of electricity.

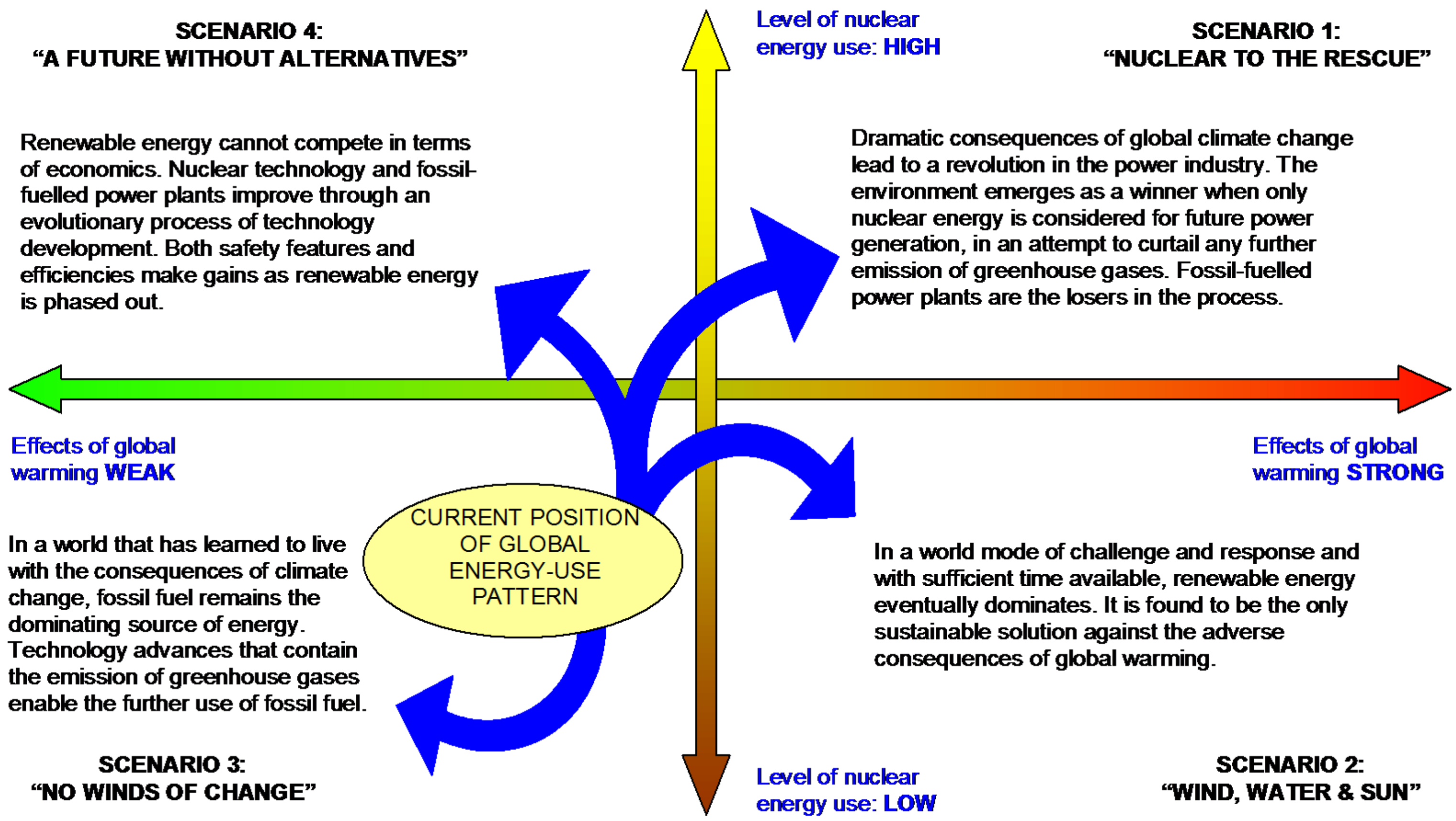
Contributions by fossil fuel and nuclear energy are approximately equal. Regions which tend to have less fossil fuel resources install nuclear power plants. On the other hand, where fossil fuel is abundant and cost effective to mine or extract, nuclear energy plays a lesser role.

Similar to the “No Winds of Change” scenario, climate change is not significant and the world can live with a certain degree of greenhouse gas emission. The difference between “A Future without Alternatives” and “No Winds of Change” lies in the level of the use of nuclear energy. The popular notion of the past against nuclear energy is forgotten in a world where significant advances in the safety aspects of nuclear plants have been achieved. Nuclear energy is now regarded as one of the favourite energy sources because it is less harmful to the environment and, at the same time, it represents a provider of low-cost energy. A new generation of smaller nuclear power plants emerges. The small size and ease of construction make it possible to install these small units close to areas where there is a concentrated power demand. As a result, extensive distribution networks are not required any longer, which further reduces the cost of electricity.

As subsidisation of renewable energy technology is phased out, the focus shifts towards nuclear technology where areas such as fusion reactors and nuclear waste disposal receive attention. Other technologies related to carbon containment in the atmosphere also gain from restructured global research and development spending.

Suppliers of cooling systems for fossil-fuelled power plants find themselves in a more difficult situation than ever before. The market for such cooling systems is not growing at the same rate as the economy as a whole because nuclear energy is increasing its share of the fuel mix at the expense of fossil fuel. The market for large-scale cooling systems for fossil-fuelled power plants remains sizable enough to pursue, but margins come under pressure because of the reduced growth in demand for such cooling systems. Traditional suppliers now focus heavily on research and development efforts to find ways of making cooling systems more efficient while reducing the cost of supply.

Figure 4.4: Presentation of scenario characteristics and plots



4.2 Comments about the predetermined elements

When the different scenarios were described in Section 4.1, the emphasis was placed on the critical uncertainties, as they distinguish the scenarios from each other. On the other hand, predetermined elements can be expected to be the same across all scenarios. The purpose of this section is to discuss the predetermined elements listed in Table 4.3 within the context of the four scenarios.

Population growth and global economic growth are drivers of electricity demand. In the long term it can be expected that demand for electricity will rise as the population grows. As the world becomes more energy efficient, it may offset the increase in demand to some degree. Nonetheless, an important point is what would happen in the short term. A sudden strong rise in demand for electricity will require immediate power-generating expansion, which in turn will favour the mature technologies. In such a case the focus would be on coal- or gas-fired plants when adding capacity and we may find ourselves in the “No Winds of Change” scenario. It may be too early for next-generation nuclear plants or renewable-energy installations and the further commercialisation of such technologies may simply be postponed. A sudden drop in power demand, on the other hand, will delay the further addition of capacity and leave more time and opportunity for newer technologies to be implemented on a commercial scale. Such circumstances could guide the fuel mix towards “Wind, Water and Sun”.

Man’s quest for technological advance will ensure that technology related to renewable energy will advance further and further. The underlying issue here is the fact that at present there simply seems to be a role for renewable energy in future. Operating costs are limited to maintenance and once the capital outlay has been reduced to a level that makes such installations viable, there could be a market regardless of the degree of global warming and climate change. We may therefore see a contribution of renewable energy in any of the four scenarios in the long term.

Any technological development is evolutionary in nature. Although nuclear plants may have suffered poor availabilities in the early days and risks related to accidents and safety may have been high, this type of power plant has proven itself. What matters most probably these days is public opinion. In other words, nuclear technology can be considered competitive and decision making regarding future expansion revolves around political issues rather than technological issues.

Exploration of resources such as coal or gas usually takes place in areas which prove to be the most economical, and one could expect the supply cost of such resources to increase with time, unless technological advances reduce the cost of extraction or mining. Renewable energy does not rely on a continuous supply of such resources, which may become more expensive over time. Although renewable energy suffers a cost disadvantage at present, fossil fuel technology faces the long-term challenge of how to become more cost effective or even how to maintain costs at present levels.

Deregulation of electricity markets and the introduction of independent power producers are underway and can be expected to continue. The implication is that decisions will increasingly be based on economic factors. Regardless of the type of scenario that governs, costs will emerge as one of the most important drivers. Governments will, however, be able to interfere with the economic forces through subsidisation and legislation, which can swing the situation in favour of renewable energy.

Offshore wind farms are now a reality and may become more attractive as the turbine size increases. At present, there seams to be a problem with grid stability as the contribution by wind energy approaches 20%. If technological development allows such barriers to be overcome, the future potential for wind energy could be significant.

5 INTERPRETATION OF RESULTS

Chapter 5 deals with the last two steps of the scenario-building process, namely looking at the implications of the selected scenarios within the context of the current company strategy, and identifying leading indicators that are required to be monitored on an ongoing basis.

5.1 Step seven: Implications of scenarios

5.1.1 Scenario 1: "Nuclear to the Rescue"

If the future lies in "Nuclear to the Rescue" the organisation will find itself unprepared to a degree, since its involvement in the nuclear energy industry is limited. In such an environment the organisation is not excluded as such, since various nuclear power plants make use of evaporative cooling systems, a product that forms part of the core expertise of the organisation.

The market for dry-cooling systems will, however, be negatively affected. The location of nuclear power plants is not determined by the energy source, as is the case with many fossil-fuelled power stations and nuclear power plants can, therefore, be located in areas where there is a sufficient water supply. Since the market growth for dry-cooling systems will decline, the fight for market share will increasingly be driven by cost factors. The organisation's current strategy to achieve cost leadership will be of great benefit in the medium term during the transition from a fossil-fuel dominated industry to a nuclear-energy dominated industry.

The newly established service division may not reach its desired sales target in the longer term, as the fossil-fuelled power plants are phased out. Service activities may then be limited to maintaining wet-cooling systems where they are applied for the cooling of nuclear power plants.

The decision not to enter the renewable energy market turns out to be correct. Since renewable energy plays no significant role in “Nuclear to the Rescue”, investments in renewable energy technology would have implied wasted financial resources. During a transition to “Nuclear to the Rescue”, financial resources will play a very important role, as they will carry the organisation while it finds a new role in the new business environment.

The decision not to proceed with the acquisition of one of the current major competitors also proves to be a major advantage, as it would have led to overcapacity of production facilities for dry-cooling systems at a time when this market is negatively affected.

It can be concluded that the current strategy avoids expending valuable financial resources on technologies and production capacity that have no significant role to play in the future. However, the current product offerings for the “Nuclear to the Rescue” scenario are limited and sales could be negatively affected in the medium term.

5.1.2 Scenario 2: “Wind, Water & Sun”

The decision not to enter the field of renewable energy technology turns out to be a mistake. “Wind, Water & Sun”, however, follows an evolutionary plot and in the interim the cost leadership strategy keeps the company competitive in the traditional fossil-fuel dominated industry. It is not too late to enter the renewable-energy market, as time is available in this evolutionary plot where valuable sales are still derived from current product offerings.

The service division becomes a profitable business operation as power station operators aim to prolong the life of fossil-fuelled power stations until they are eventually phased out. The long-term focus of the service division needs to be revisited so that it can be adapted as the electricity generation industry becomes dominated by renewable energy sources.

The capacity expansion of dry-cooling systems through an acquisition that was put on hold saves financial resources, a decision that benefits the organisation. The limited involvement in nuclear energy technology is of a further advantage in a world where the use of nuclear energy is slowly being phased out.

Through its current strategy, the organisation can position itself as a leading competitor during the transition phase towards a renewable-energy-dominated industry. It will, however, have to start planning and developing a strategy that will accommodate the upcoming transition.

5.1.3 Scenario 3: "No Winds of Change"

"No Winds of Change" implies that the current product offerings will continue to be in strong demand. The degree of demand depends on general world economic conditions, of course.

The service division is well positioned and future market potential is significant. The service division expands its product offerings and does not limit itself to providing a maintenance service and supplying components for cooling systems. Emphasis is also placed on emissions control and the service and technology required for effective emissions control at fossil-fuelled power stations.

Current production capacity for dry-cooling systems is, however, too limited for the organisation to dominate the market and customers heavily depend on the competitors' production capacity as well. A danger exists where new entries to the market occur because of the attractive margins that are enjoyed.

The decision not to get involved in nuclear-energy technology is of benefit since nuclear energy is relegated to a secondary role in the power-generating industry.

The organisation is further not involved in the renewable energy market in an environment where the contribution by renewable energy is marginal. The organisation does not expose itself to financial resources that are committed to technologies that show very limited returns.

The current strategy fits the “No Winds of Change” scenario, but this scenario is not without its challenges. Profit margins come under pressure as past competitors remain strong contenders and new entrants to the market cannot be excluded.

5.1.4 Scenario 4: “A Future without Alternatives”

“A Future without Alternatives” sees fossil fuel competing with nuclear energy almost exclusively on a cost basis. It turns out to be quite a difficult scenario for the organisation to deal with. Market growth for the traditional cooling-system product offerings is dampened by the increasing contribution of nuclear power plants, which predominantly make use of seawater cooling. In this light, the decision not to add further production capacity for dry-cooling systems makes sense.

The cost-leadership strategy pursued to improve returns for current product offerings is of vital importance for the organisation to remain a strong contender in “A Future without Alternatives”.

It is beneficial to the organisation to stay out of the renewable-energy market but the limited exposure to the nuclear-energy market makes it difficult to increase sales substantially.

There is room for a dedicated service division in this scenario as it helps to sell the organisation to clients. The professional aftermarket service is attractive to clients and complements the cost-leadership strategy.

It can be concluded that the current strategy positions the organisation fairly well to face “A Future without Alternatives”, but the scenario is not without its challenges. Challenges will become more pronounced should nuclear-energy technology gain the upper hand on a cost basis.

5.1.5 Robustness of current strategy

The current organisational strategy looks good across two of the four scenarios. The organisation is basically positioned to do well should scenarios “No Winds of Change” or “A Future without Alternatives” materialise.

Since no immediate inroads are envisaged into the field of renewable-energy technology, the current strategy does not cater for any scenarios that would be characterised by power that is mainly generated from renewable-energy sources. Furthermore, the organisation’s limited involvement in the field of nuclear energy implies that a scenario that is dominated by nuclear power will challenge the organisation’s current strategy.

Taking cognisance of the current organisational strategy, the scenario “No Winds of Change” can be regarded as the organisation’s desired future. In actual fact, the organisation has been active in this type of environment for several decades and is regarded as a leading expert in the field of dry- and wet-cooling technology in the power-generating industry.

Considering the relatively small contribution by renewable energy to the current mix of energy sources as well as the negative attitude towards nuclear energy in some parts of the world, the organisation may tend to regard “No Winds of Change” as its official future.

5.2 Step eight: Selection of leading indicators

The purpose of a scenario-planning exercise and the subsequent strategy implementation is to have the organisation prepare itself for all scenarios and to train its members how to look for small details in their daily environment that will assist them in recognising the full play before it happens. These small details are the so-called warning signs or leading indicators. Warning signs can be subtle in nature and may not have anything directly to do with the business.

The change in global weather patterns is one of the most important leading indicators within the context of the scenarios as portrayed in Figure 4.3. Increases or decreases in environmental temperatures and extreme weather conditions such as floods or severe droughts all represent leading indicators about the effect produced by greenhouse gas emissions. These leading indicators could ultimately signal a move away from the past that was dominated by fossil fuels.

On the other hand, any successes observed within the development of carbon capture and sequestration technology can serve as a signal that fossil fuels will not lose their dominating role in the short term to medium term.

A development that further requires ongoing monitoring is the cost structure of nuclear power plants. As such plants become more standardised and construction times are reduced, it could signal the onset of an industry where nuclear energy will dominate. Other leading indicators related to nuclear issues are public or government representatives or leaders. Should a government decide to change policies in favour of nuclear energy, government or political party representatives will initially test public opinion. It is also useful to monitor developments in neighbouring countries in this regard. If a neighbour takes the lead it is bound to eventually happen in one's own country as well.

In the United States some nuclear power plants are being considered for the granting of licences to have their operating life extended. This in itself is a leading indicator. The distribution of national research and development spending can generally be regarded as a predictor of long-term trends.

Turbine suppliers usually play a central role in the development and construction of new power plants. Their research and development activities can serve as a useful leading indicator.

Events that illustrate that renewable-energy technology are benefiting from economies of scale must be closely monitored. The recent construction of offshore wind farms is an example. Such large wind farms would be difficult to construct onshore because of space requirements as well as noise pollution. The movement offshore overcomes these challenges and signals the beginning of a commercial phase for wind power.

Should renewable energy fail to make a significant contribution and should it leave fossil fuel to compete with nuclear energy, the cost trend of mining/extracting fossil fuel could serve as a leading indicator for which of the two technologies may eventually win on the basis of cost. Trends in steam turbine performance and efficiencies should not play a role since steam turbines are used for both nuclear and fossil fuel applications. Trends in gas turbine performance and efficiencies can, however, be regarded as leading indicators since improvements in efficiencies of gas turbines will favour the use of natural gas.

It is important to monitor cost structures and trends for all types of power-generating technologies. Since electricity is increasingly generated by independent power producers these days, the technology with the lowest cost is likely to dominate should environmental and political factors play a lesser role.

A future dominated by nuclear energy as portrayed in “Nuclear to the Rescue” may seem strange or unlikely. It must, however, be kept in mind that however strange a scenario appears, if it is plausible it adds value to the scenario-building process. One may ask what type of event could trigger “Nuclear to the Rescue”. A recent article describes clathrates, an ice-like substance containing gas such as methane and water (Economist, 2003). Conditions at the bottom of the sea are often ideal for the formation of clathrates. Under the right conditions, clathrates can release methane gas and this can soon find its way to the atmosphere where it would add to the greenhouse effect and cause temperatures to rise. Under such conditions, drastic measures may be required to curb further emissions of greenhouse gases. The topic of clathrates is, however, still under debate in academic circles and the release of gas from clathrates is not a foregone conclusion.

6 RECOMMENDATIONS

6.1 Recommendations to adapt the current strategy

Recommendations to improve the current strategy essentially evolve around making the strategy robust across all four scenarios.

6.1.1 Entering the field of renewable energy technology

Previous discussions have illustrated that the organisation is well positioned for “No Winds of Change” and “A Future without Alternatives”. For the organisation to become part of a future where renewable energy will be the main contributor to the power-generating industry implies that it should enter this market through the acquisition of businesses that are already involved in the field of renewable-energy technology. Acquisitions represent the only means for a quick entry into this market because the current range of systems or products offered by the organisation does not include renewable-energy technology and developing such products from scratch would take too long.

6.1.2 Backward integration as part of the current cooling system range

As part of increasing future sales, the acquisition of businesses that act as suppliers to the organisation at present is considered. This is a form of backward integration and is aimed at components such as rotary equipment (eg, pumps, fans, transmission systems, valves etc). Although such a strategy will contribute to the goal of increasing sales, it does not make the strategy robust across all scenarios.

Such components would form part of the current dry- and wet-cooling systems that feature strongly in “No Winds of Change” and “A Future without Alternatives”. Should the power industry move towards “Nuclear to the Rescue” or “Wind, Water and Sun”, the demand for the aforementioned components may drop in tandem with the decrease in demand for the cooling systems, which may force the organisation into selling off the newly acquired component manufacturers.

Apart from adding rotary equipment suppliers to the current organisation, other components such as secondary heat exchangers that usually fall outside the scope of supply of the main cooling system can be added to the current product range. As for the rotary equipment, it will add to annual sales but will not improve the robustness of the strategy.

Since financial resources for acquisitions can be a constraint, capital investment into backward integration is not recommended. Financial resources should rather be channelled towards acquisitions that make the current strategy more robust.

6.1.3 Entering the field of nuclear energy

In the case of “Nuclear to the Rescue” the challenge is to find a way that will enable the organisation to be involved should nuclear energy dominate in the future. This essentially involves investigating and analysing typical nuclear power plant systems and identifying components that could be offered, either by adapting current production facilities or through acquisitions of existing component suppliers that would fit the organisation and which show potential for synergies with the current organisational structure.

Involvement in the nuclear industry can be in the form of services, engineering or component supply. Further consideration is required to establish what combination of the aforementioned activities would suit the organisation the most.

6.1.4 Presentation of the adapted strategy

The adapted strategy is illustrated in Figure 6.1. The cost-leadership strategy through innovation and research and development has been retained from the current organisational strategy. The cost-leadership strategy is of great importance across at least three scenarios; ie, “Wind, Water & Sun” (during the transition phase), “No Winds of Change” and “A Future without Alternatives”. Similarly, the establishment of a service division is retained. In the medium term such services will be in demand across all four scenarios even though they mainly target fossil-fuelled power plants. Even if such power plants are eventually phased out, such a process will not happen overnight and business is secure at least in the short term and medium term.

Expanding activities in the Asian markets is also retained. This is self-explanatory since the current cooling systems are in demand in countries such as China and, as a result, there are substantial short-term and medium-term business opportunities. Furthermore, global economic growth prospects are limited in other parts of the world, such as the United States of America and Europe, and as a result the world depends on China in this regard.

The acquisition strategies for entering both the renewable-technology market and the nuclear-energy sector are presented as an “and/or” approach in the bottom-right corner in Figure 6.1. In other words, the organisation may be of the opinion that it should choose only one of the acquisition strategies since implementing both acquisition strategies can be classified as too risky. It would expose the organisation simultaneously to two new fields of technology, perhaps without a sufficient degree of knowledge and experience of these fields.

What does such a decision imply in terms of the robustness of the strategy?

It can be argued that it makes the strategy less robust. On the other hand, such a conscious decision still defines guidance for the future and the organisation is informed that there is an undesired scenario that could potentially materialise. The situation will have to be dealt with accordingly when the undesired scenario arises.

Figure 6.1: Illustration of the adapted strategy

Products / Markets	Present products	New products
Present customers	**Market penetration:** 1) Cost leadership through innovation and R & D	**Product development:** 1) Service division
New customers	**Market development:** 1) Expand activities in the Asian market	**Diversification:** 1) Acquisitions to enter the renewable technology market, and/or 2) acquisitions to enter the nuclear energy market

Source: Adapted from Peter & Donnely (2000)

6.2 Shortcomings of scenarios and suggestions for improvements

The scenario-planning process is mainly qualitative in nature and so are the discussions that revolve around its implications and recommendations. Before implementation can take place at operational level within the organisation, some further quantitative analysis is required, as explained below.

The planned construction of new power plants making use of dry- or wet-cooling needs to be recorded as well as the power-generating capacity that is added by new renewable-energy installations. This will enable the organisation to determine the “lost business” either because the demand for main cooling systems for fossil-fuelled power plants is reduced or because the organisation does not take part in the construction of renewable energy installations. A similar study has to be carried out with respect to nuclear power plants. If the outcome of such an analysis shows that significant business opportunities remain untapped within the current strategic outlay of the organisation, an action plan can be developed accordingly.

Businesses targeted for potential acquisition in the renewable-energy market must be identified and valued to estimate the return on investment achievable from such acquisitions. This exercise must also assist with the decision of which type of renewable energy technology should form part of the organisation’s future product offerings. A similar exercise should be conducted for nuclear-plant-equipment suppliers, should nuclear energy be integrated into the organisational strategy.

Calculations for the required manufacturing capacity for dry-cooling systems have to be carried out for each of the scenarios, based on current market information and forecast demand for such cooling systems. Such calculations require that assumptions about future demand have to be made for each scenario. A detailed capacity evaluation of this nature will assist with decisions regarding future manufacturing-capacity requirements and the timing of capacity expansion, should it be required.

Gas and coal generally have been treated together as fossil fuel. In the case of “No Winds of Change” and a “Future without Alternatives” both gas and coal feature as the dominating energy sources. In order to refine both these scenarios further, additional research is required that differentiates between coal and gas. This will shed more light on the individual contributions made by coal and gas within the given scenarios.

7 REVIEW OF SCENARIOS BY EXPERTS IN THE FIELD

(Note: For editorial and style purposes the transcripts of the feedback reports have been altered very slightly in places.)

7.1 Expert 1: Chief executive officer at divisional level within the organisation

The topic of future energy sources and technologies for electricity generation is definitely one of the most discussed issues in today's business environment. At the same time, population growth and general climate warming are of concern to the basic requirements of our nature and economy.

The detailed study provided by Mr Albert Zapke gives a thorough overview about the dominant opportunities and risks in the field of electricity generation.

The availability of electricity will continue to dictate our future growth potential and thus needs constant updates on needs of electricity on one side and technology trends on the other side. The political support for some selected technologies is also very important to take into consideration.

In the case of a company providing all types of advanced cooling technologies for the power-generation industry, the question has always been how to prepare the product and service portfolio for the future demands. Cooling technology, however, is just one example and could serve as a platform for other industry scenarios.

As outlined in this study, I fully agree that one cannot expect a major or radical change in the power-generation industry over the next five to ten years.

The existing fuel types, mainly fossil fuels and nuclear will certainly continue to play an important role in the future. Only partly will the renewable fuels such as wind and solar power substitute the traditional fuels. Water can be seen as a traditional and, at the same time, renewable electricity source. However, it is limited to certain areas of the globe and can probably not increase its current market share of 19%.

The driving force for all economies has always been the availability of cheap electricity.

This is not only a matter of generation but also of distribution. Some areas in China and India for example have a huge generating capacity but a relatively weak distribution network.

The present study outlines the new role of Independent Power Producers (IPPs). Those special-purpose companies have only one driving factor in common: financing and return on investment. This would be an additional aspect for the scenario-planning procedure.

Together with IPPs and the deregulation and liberalisation of the generation markets comes a certain level of government control. This may sound like a clear contradiction but there must be a body to guarantee payments from the end users.

Another political influence would be the support of certain technologies through government subsidies. Wind energy is a perfect example: without the direct or indirect subsidies the technology would never have reached the level of single 5 MW generating units. This may not be the end of the ongoing R&D projects.

Germany is probably one of the leading “Wind-Countries” in the world, mainly because of the direct subsidies. On the other hand, as mentioned above, the driving force for economic growth is the availability of cheap electricity. Subsidies can only offer temporary support – at the end of the day, the stand-alone generating technology has to be competitive without any subsidies.

The public perception of nuclear power plants plays a major role in future scenario planning. This perception has basically nothing to do with the technical and environmental merits; safety is the key concern.

Two extreme examples are the neighbour countries France and Germany: France having about 70% of its electricity generated in nuclear plants, Germany having about 40% as of today, with the clear political decision to abandon this technology over the next 20 years.

Besides the availability of fossil fuels such as crude oil and natural gas, we also have to consider the limitation of the "unlimited" availability of clean water. Water is essential to the people in an ever growing population and cannot be used for cooling purposes in the power-generation industry only.

The use of sweat water for cooling can be limited through means of dry or dry-wet cooling, together with enhanced performance and efficiency of the water-steam cycle.

Besides the basic technological improvements, "service" is another aspect in improving the reliability and performance of power plants. "Service" is meant to cover the life cycle of a power plant: The costs for so-called "operation and maintenance" activities in most cases exceed the initial capital costs of the plant.

To summarise, the current study gives a very good overview on the technological and environmental issues of future power generation. The availability of fuels and at the same time the political constraints are well analysed.

The recommendation to follow the "No winds of change" scenario is fully supported. The reasoning that we will not face any drastic changes in the near future is well elaborated.

However, before implementing this scenario in an operation of the cooling industry (or any operation of the power generation industry), the following topics should be further analysed:

- besides the literature studies, review meetings should be arranged with key players and political bodies;
- the importance of government subsidies for certain technologies must be analysed region by region;
- before entering the field of renewable energies, the environmental and cost issues (without subsidies) must be clear, as technology never works for itself; and
- a service strategy should be developed in order to really support the life-cycle aspects.

Above all, financing of technologies and projects remains the major concern. Further studies in this field are recommended.

The study submitted by Mr Albert Zapke is a solid basis for a strategy-planning process.

Georg Silbermann
CEO, GEA Energy Technology Division
Bochum, May 20th, 2003

7.2 Expert 2: Managing director of a manufacturing facility within the organisation

"Global Electricity Generation" is a topic that has enjoyed a substantial amount of focus and evaluation over the past couple of years. The "unforeseen" impact on the path forward has however been drastically changed with the events of 9/11, SARS, the war in Iraq etc.

To further implicate matters, these factors only speeded up the process on an already weakening USA economy. With the emergence of issues like “Enron”, the visions/strategies that were in place will probably have to be revisited by all the major players in the industry. Finding the correct balance between applicable technological solutions and economical kick-back will be of utmost importance. Furthermore, the environmental impact on the selected solution will be crucial.

It is interesting to note that the USA is the only so-called “Super Power” remaining that has refrained from signing the Kyoto Agreement. The assumption that one can make from this is that until the American “worldwide Oil and Gas Industry” has resolved its pollution problem, namely flaring off of gas, nothing will change. At the same time this also creates an opportunity to establish technology to use this wasted resource for power generation.

The study performed by Dr Zapke has provided a thorough overview of the technological developments currently at play in the solution of energy sources for constructing power plants. The opportunities and risks were well defined and evaluated with respect to the company selecting the correct portfolio of technology, R&D, product and services.

During the scenario-planning phase one has almost to take the approach of splitting the market evaluation process between established markets (USA, Europe, Japan etc) and emerging markets (Africa, South America, China etc). Projections indicate that the world’s annual energy consumption may double by 2025. It is expected that by 2030 about 50% of the world’s electricity production will occur in developing, emerging, new industrialised countries. A crossroad has almost been reached in terms of what the future strategy will be in terms of technologies that will be developed for power generation. It therefore makes it very difficult for a company to decide in which field to remain or into which field diversification should take place to ensure maximum market share.

Fossil fuels will certainly continue to play a major role in future energy generation. However, “renewables” is a market that one cannot ignore in the future. One almost has to promote opportunity and encourage innovation so that “renewables” become cost effective and competitive with the traditional energy sources. The question that comes to mind in terms of “renewables” is: “Are they getting a free ride?” Has this involvement in fact distorted the market? For example, wind energy has reached advanced levels of technology (5 MW units) purely due to government subsidies. Many of the other newly developed “renewable” markets have also been receiving concessions from governmental institutions, which could lead to an unfair advantage in terms of economic cost comparison. Therefore, a fair picture needs to be formed on the issues and opportunities with regard to energy supply and demand facing mankind over the next 30 to 40 years, keeping in mind that the main driving force for economic growth is the availability of cheap electricity.

Available energy makes a vital contribution to the lives of everyone and without access to sufficient energy the whole fabric of current and future societies would be undermined. Issues relating to energy must be evaluated appropriately by industry and society if it is not to lead to a future energy crisis, where an escalation in the prices of traditional fossil fuels coupled with a loss in the diversity and security of energy supply, leading to an unpredictable and volatile energy market.

All economic activities require the use of energy. An industrial society in its present form would not be possible without an abundant and concentrated form of energy such as that provided by fossil fuels. Industrialisation remains the principal social and economic aspiration of those countries that have not yet industrialised. These countries also contain the great majority of the world’s human population, which is expected to double over the next century. Achieving these countries’ aspirations would seem to require an enormous increase in the consumption of fossil fuels.

As expressed in the evaluation phase by Dr Zapke, one cannot expect radical changes in the power industry over the next ten years; therefore, fossil fuels and nuclear power will continue to dominate the field. However, measures need to be taken to complement, extend and eventually displace fossil-fuel-based energy supply systems with alternative low-emission sources of energy. Climate change and dwindling fossil fuel reserves are important drivers for change and are compelling governments and societies to appreciate the relevant issues and to recognise the need to invest in R&D on low-emission energy technologies. This, however, is easier said than done and it is predicted, as noted above, that fossil fuels will continue to be the main fuel source for the next ten years at least, forcing society, industries and governments to have increased investments into developments in the fossil-fuel arena, including combustion research coupled with improvements in efficiency in energy use.

There is little doubt that carbon emissions could be substantially reduced through public policy and at promoting the efficiency of energy use and the accelerated development of “renewables”. Whether the political will to implement such a policy is forthcoming largely depends both on the perceived urgencies of the climate change issues and on perceptions of the economic costs that are likely to be involved.

Renewable energy is still one of the great business imponderables of the future. Not since the early days of the development of nuclear power has an energy source been so advocated in advance of its real commercial viability.

If nuclear power is to have a significant part in a future energy mix then progress needs to be made on the issue of “safe” disposal of nuclear waste. The development of reactor designs with greater intrinsic safety properties needs to be encouraged. Nuclear power needs increasingly to be perceived by policy makers and the public as an economic and sustainable form of energy. Hydrogen does not exist in nature in its elemental form, so it must be extracted from a compound such as water or a hydrocarbon fuel cell combining hydrogen and oxygen to produce electricity and water. Nuclear power is considered as a promising energy source for producing hydrogen since it is a secure long-term energy supply and because it is greenhouse free. The next generation of reactors to generate heat and electricity for hydrogen production is most definitely a feasible option.

Therefore, the long-term goal is a global energy policy where fossil fuels, nuclear power and “renewables” are part of a mixed-energy economy. For such a policy, the diversity of energy resources will be important for reasons of strategy and security.

Besides the availability of energy-generating technologies, the scarce resources like water must be considered. As water is a basic essential for the growing population, using water for cooling purposes will become an important issue for the selection of “wet” or “dry” systems in the future.

The aspect of “service” is another important issue to evaluate. To enhance the “life cycle” of plants, service implementation has to be identified in the strategy.

As part of the ability to turn adversity into an opportunity, one’s flexibility is a pre-requisite to manoeuvre out of difficult situations. When the future branches off in an unexpected and undesirable direction, the success of a world-class company is due to excellence in implementation and delivery under a variety of conditions. Handling uncertainty in a systematic and realistic manner provides a real competitive advantage to companies that want to be imaginative. It paves the way for a strategic conversion about the future. Scenarios offer a glimpse of the possible events in the future. They act as a catalyst to achieve the amount of understanding necessary for movement. It is only by studying all scenarios simultaneously and looking at what you want to achieve as well as what you want to avoid that you get a feel for all options. The error of concentrating only on the desired future creeps in. There is logic to identifying the key uncertainties that would have the greatest impact on the business. These uncertainties need to be translated into scenarios that present a vision of options; in other words, the bridging mechanism to get an organisation from the key uncertainties to the options available.

Dr Zapke performed this type of scenario-planning exercise in this thesis. He has also analysed the driving forces and leading indicators in great detail and the resultant study gives an excellent overview of the technological and environmental issues of potential future power development. The four scenarios are well orchestrated and evaluated, and explore the majority of impacts possible. The recommendation on “No Winds of Change” and “A Future without Alternatives” is supported. However, it is of utmost importance that the tools developed are further refined and used by the company on a continuous basis to ensure that the path selected is still in line with the overall strategy and external market forces. Other issues that may require further analysis and evaluation are:

- detailed economic cost evaluation and comparison between the various technologies, ie current (fossil and nuclear) and “renewables” (wind, solar fuel cells etc), including the impact of government subsidies;
- the current and future role of independent power producers – what impact this will have on pricing and availability;
- distribution network systems in the world related to generation;
- detailed inter-action with the governmental bodies, IPPs and environmentalists to confirm certain issues and statements; and
- the expected growth requirements in the different fields in question, as well as the “financing” options available to support the future plans.

To conclude, the document prepared by Dr Zapke is well thought, thorough, and the majority of the important strategic influences are taken into account. With some further refinements and additional evaluations as stated above, it will be an excellent basis for any company in this field to use for future scenario planning.

Lambert Petersen
Managing Director, GEA Aircooled Systems (Pty) Ltd
Johannesburg, June 04, 2003

7.3 Expert 3: Managing director of an engineering business within the organisation

After a century of evolution and stability, the energy industry has experienced nothing short of a revolution. Privatisation, IPPs (Independent Power Producers), PPAs (Power Purchase Agreements), deregulation, merchant power are all terms which meant nothing to the industry just 25 years ago. Through these recent years it has become apparent that the industry suppliers adapt quite well to the changing environment but have done a horrible job of forecasting these changes. We seem to be a step behind. In this regard, Dr Zapke's topic is extremely relevant for an industry that produces a commodity that has become as essential as food and shelter to the world economy.

Each scenario is relevant in support of the main topic. Although each is plausible, I believe each, as written, is unlikely to actually occur as within each scenario at least one or two issues appear to be too dramatic to be realistic (eg continuous natural disasters). The likely scenario, in my opinion, will be a combination of each. The question then becomes what combination? The recommendations to adapt the current strategy are very good. However, should not the revision of existing products to a new application be investigated? Why dismiss dry-cooling for the nuclear industry? Certainly redundancy and design codes can be addressed in an appropriate nuclear design. Are there other issues?

Regarding the "driving forces" and "leading indicators", the listing is very complete. The one factor that I would concentrate on a bit more is public opinion. In a democratic representative government such as the USA, it has a tremendous impact on the course of the nation. It brought the nuclear industry to a virtual standstill for almost 25 years after the Three Mile Island accident. It has also driven the Air Cooled Condenser business in the US. Most of our early installations were in New England where water supply is certainly adequate. However, the environment is important to people in this part of the US and dry-cooled power plants have become the system of choice on many plants in New England.

Looking at the key factors and driving forces in Figure 4.2, the public's perception and resultant opinion will directly influence half of the listed factors and forces. I believe this is probably true for Europe and the developed nations of Asia in addition to the US. It is certainly less of a factor in developing nations where the next meal is far more important to the populace than the type of energy produced or its effect on the environment. Nevertheless, the US, Europe, and Asia represent approximately 80% of our market and this is where public opinion is strongest.

A problem which may deserve more attention is the looming disposal problem of nuclear waste. This can easily become a public relations and political nightmare, at least in the USA. It has gotten press recently and the media's influence on public opinion can be tremendous. National Geographic recently featured the disposal problem in their magazine and even the most pro-nuclear advocate would have second thoughts after reading this article. What do you do with the waste? Fusion is a long way off.

The influence from Enron's collapse and the resultant effect on the financial health of other, primarily US, energy companies has had a huge impact on the industry. In addition to numerous bankruptcy filings, it has brought a halt to new plant construction. Although this could be viewed as a positive development in the longer term (industry consolidation, reduction of overcapacity), it has started political discussions which are of concern for our industry. California, the seventh largest economy in the world, found itself in an incredible energy crisis a few years ago. There is now legislation being proposed which would re-regulate the energy industry in California. Yet the state may find itself in the same situation as before if, in fact, new generating capacity is not added. With the inability of the energy companies to raise capital and the mere thought of regulation, meaningful plant construction is not likely to occur anytime soon.

Regarding recommendations, the national energy policy proposed by the present US administration has nuclear energy as a very key component. As stated above, a lot will depend on the public's perception of nuclear power. This needs to be monitored closely. If this perception begins to change, we should seriously lay out plans to support this industry with either existing technology (see above) or newly acquired products. With the largest installed generating capacity in the world aging rapidly, this will present the well-positioned companies with a significant market, which does not exist today.

Albert, thanks for inviting me to take part in your project and congratulations on an excellent presentation.

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7.4 Expert 4: Professor in mechanical engineering and leading academic in the field of heat transfer

In view of the world's increasing needs for power and pressures on the environment this topic is of great relevance as are the individual scenarios. The scenarios listed in the report are all plausible.

The main categories of macro-environmental forces are listed, and each category is subdivided in Table 4.1. The subdivisions can be expanded, eg:

Society:	(a)	Popular opinion and perceptions concerning "renewable" or "green" energy
Technology:	(a)	Coal gasification
	(b)	Fluidised bed combustion (coal shale etc)

Important business decisions are often made based on “leading indicators”. The number of indicators of essentially equal significance are increasing and subsequent developments are often more rapid or dramatic than in the past where developments tended to be more evolutionary. Many examples exist where companies made the wrong decisions “too early” (eg wind power in California) and shortly thereafter went out of business, while some years later the same decision would have resulted in a very successful business. In retrospect, it would thus appear that usually more than one “indicator” would be preferred before a decision is made to invest in a new venture.

From Sections 5.1 and 6.1 concerning the nuclear option one is left with the impression that this could be problematic for the organisation, ie “the organisation will find itself unprepared to a degree …..” (Section 5.1.1) and “should the power industry move towards “Nuclear to the Rescue” …. (Section 6.1.2). I do not believe that this is necessarily so.

In the case of the “Nuclear to the Rescue” option there will be a trend to site such plants near coastal water for their cooling need. However, environmental pressures in many of these potential coastal areas (eg the coast of California) are such that any thermal pollution of the ocean waters is unacceptable (even existing nuclear power plants are already under pressure to reduce the heat rejected). Nuclear power plants located near the coast will thus be under great pressure to minimise heat rejection. By installing “helper” cooling towers to cool “once-through” seawater before it is returned to the ocean, potential opportunities already exist today and would increase in future with the nuclear options. In certain areas “once through” cooling systems might be considered if a parallel development of the changing ocean environment occurs, as is the case along parts of the Japanese coast.

For various reasons (transmission, strategy, economic, seismic activity, etc) future large base load nuclear plants may also be constructed far from the coastal waters. In such cases wet-cooling towers (limited), indirect dry-cooling towers or combinations of wet- and dry- or hybrid cooling towers would be considered.

Cooling systems designed specifically for the PBMR concept should receive attention. The intention is to locate these smaller nuclear plants in areas of the country where power is most needed (because of their inherently “safe” operational characteristics they may be located close to relatively densely populated areas). All types of cooling systems should thus be considered; ie, wet (waste-water or any other acceptable source), dry, wet/dry, dry/wet hybrid.

I believe that the organisation could be in a potentially relatively good position if the scenario “Nuclear to the Rescue” should materialise if the necessary preparatory research and development is done.

A future of “Wind, Water & Sun” can also present opportunities. The organisation can invest more or less in acquiring technology in the “renewable” or “green” energy sector. In the short term an investment can be made by “buying up” a company in the wind-power-generating field and simply becoming one of the players in a particular part of the relatively fast developing renewable area. In addition to the development of ever larger wind-power generators, niches exist for the development and marketing of smaller wind generators. I, however, see more in such a potential investment.

The organisation presently buys its large fans for its cooling plants. Many of the fans are for dry-cooling or hybrid plants, the demand for which will increase in the medium term, independent of the scenarios presently under investigation. Such fans or improved (the most advanced and appropriate aerodynamic and materials expertise is presently found in the wind-generator industry) fans could be developed and manufactured by the new acquisition. Such a company could also become involved in the solar power business by developing turbines for solar tower plants as shown in Figure 2.3.

I believe that suppliers of cooling systems for power plants have the potential for expanding their business independent of which of the listed scenarios ultimately materialises.

To be successful some new acquisitions may be required. It is, however, most important that the existing organisation has an ongoing research programme (in-house and in collaboration with universities or other research organisations) in which existing cooling systems are improved and new products are developed. Without such a research and development programme (economic and technical), it is only a matter of time before the company will experience problems.

Among other suggestions wet-cooling towers could be further developed to improve performance (more effective fills, less sensitivity to winds, etc) and to reduce life cycle costs. The performance of air-cooled condensers could be improved (more effective finned tubes; better performance during windy conditions (+100 % is theoretically possible); better performance during periods of high ambient temperatures etc).

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7.5 Summary of comments by the experts

Expert 1 agreed with the opinion expressed in the introduction that no radical change can be expected in the power-generating industry over the next decade. In this context Expert 1 supported the “No Winds of Change” scenario as elaborated in

Section 5.1.5. Expert 1 made specific reference to Independent Power Producers (IPPs) and the importance of financing and return on investment in the power-generating industry as a result of the introduction of IPPs. Another driving force highlighted is the support by government for certain technologies through subsidisation. It was further emphasised that public perception of nuclear power plants is all about safety and not about technology or the environment. Expert 1 discussed specific issues that would require further investigation prior to the implementation of a strategy that supports the “No Winds of Change” scenario.

Climate change and dwindling fossil fuel reserves are important drivers of change according to Expert 2. Other key factors pointed out are fossil fuel price escalations and the scarcity of water as a resource. Expert 2 recommended that the power market should be segmented according to developed industries and emerging regions. New developments would take place mainly in emerging regions which aspire to reach the levels of developed nations. Such aspirations could, however, imply the consumption of vast quantities of fossil fuel, should other energy sources fail to make a significant contribution. Expert 2 further stated that the development of nuclear reactor designs with greater intrinsic safety properties needs to be encouraged. Such reactors could also be used for the production of hydrogen, should the world eventually embrace hydrogen as a clean form of energy. Expert 2 supported the “No Winds of Change” and “A Future without Alternatives” scenarios as the likely future of the organisation. Finally some areas for further investigation were recommended prior to the implementation of the strategies based on the aforementioned scenarios.

Expert 3 explained that in the past suppliers were able to adapt to changes in the power industry, but have not done well at forecasting these changes. Expert 3 found the four scenarios to be plausible but stated that the likely scenario would be a combination of each. Some events characterising each of the individual scenarios appear too dramatic according to Expert 3. Public opinion as an important driving force was highlighted, especially in a country such as the United States of America. Another factor that was emphasised is the looming problem associated with the disposal of nuclear waste, which could weigh heavily against the future of nuclear power. Expert 3 also made reference to state legislation and regulation and how these factors could have a significant effect on the power-generating industry. Reference was made to the power crisis that was experienced in California some years ago and how the inability of energy companies to raise capital delays meaningful power plant construction. Expert 3 concluded by recommending that the perception towards nuclear energy should be closely monitored. If it changes, plans should be generated to support the nuclear-energy sector. These plans should include the revision of existing products such as dry-cooled systems to meet the needs of applications, such as nuclear power plants.

Expert 4 emphasised that more than one leading indicator would be preferred prior to a business decision being made. Reference was made to a company where business decisions were made “too early” and, as a result, the company went out of business. This was the case with wind power in California. Expert 4 disagreed with the author that the organisation could, to some degree, be unprepared for “Nuclear to the Rescue”. In fact, Expert 4 is of the opinion that the organisation could be in a relatively good position if the scenario “Nuclear to the Rescue” materialises, if the necessary preparatory work and research and development are carried out. Suggestions were further made as to how the organisation could become involved in the field of renewable energy. It was also recommended that the cooling systems designed specifically for the Pebble Bed Modular Reactor project should receive attention. Expert 4 concluded by highlighting the importance of an ongoing research programme through which existing cooling systems could be improved and new products developed.

8 CONCLUSION

8.1 Highlights of the report

Fossil fuels such as coal and gas make up approximately two thirds of the energy sources used for the generation of electricity. The remainder of the energy sources is provided by nuclear energy and hydroelectricity. The contribution by renewable energies such as wind and solar is still limited to a few percent.

The type of energy source and turbine technology determines the nature of the cooling system required for the purpose of removing heat from the power-generating cycle. Traditional cooling systems typically comprise wet (evaporative cooling) or dry systems (air-cooled), or a combination thereof.

The main research problem was to determine the energy sources and power-generating technology that will dominate the power industry in the medium term and long term. In this report, a technique similar to existing scenario-planning theory was applied to analyse information and data related to the topic. The outcome of the scenario-planning exercise was presented in the form of four scenarios.

The present strategy of a traditional supplier of large-scale cooling systems to the power industry was evaluated within the context of the four scenarios. The cooling system business unit of the organisation mainly targets fossil-fuelled power station developments. An adapted strategy was proposed that would make it robust across all four scenarios.

The scenario-planning methodology proposed by leading futurist Peter Schwartz was employed for the purpose of this project. The method introduced by Schwartz (1991) contains seven steps. These are: the identification of the focal issue of the organisation under consideration; the identification of the key forces in the local environment; listing of the driving forces in the macro-environment; ranking of the driving forces by importance and uncertainty; selection of the scenario logics;

fleshing out the scenarios; and, lastly, determining the implications for the organisation.

Following the ranking of the key driving forces, the following two driving forces were found to be the most important and uncertain, ie:

- the future level of nuclear energy use as part of the overall fuel mix; and
- the effect of heat-trapping gases on global warming and climate change.

The four scenarios that emerged from the scenario logics as determined by the above two driving forces are:

- Nuclear to the Rescue (scenario 1);
- Wind, Water & Sun (scenario 2);
- No Winds of Change (scenario 3); and
- A Future without Alternatives (scenario 4).

"Nuclear to the Rescue" refers to a situation where adverse global climate changes force a reduction in the use of fossil fuels while, at the same time, alternative or renewable energy capacity is insufficient to satisfy electricity demand. Nuclear energy then comes to the rescue. This is a "Winners and Losers" type scenario where the environment emerges as a winner while fossil fuel becomes the loser.

In the case of "Wind, Water & Sun" a significant reduction in the emission of heat-trapping gases is required because of dramatic climate-change consequences similar to those in scenario 1. However, here renewable energy sources and technology can supply the shortfall in electricity supply that arises when no more fossil-fuelled power plants may be constructed. A "Challenge and Response" plot drives this scenario. There is sufficient time to adapt to the new energy mix, when it is recognised that renewable energy is the only basis for sustainable energy supply.

“No Winds of Change” is a scenario that resembles the current energy mix to a large extent. Renewable energy sources continue to play a secondary role as climate changes and their negative consequences are very limited. Gas and coal remain the primary energy sources, with further contributions by nuclear energy and hydroelectricity. Evolution characterises this scenario, where fossil-fuel technology improves over time to limit the rate at which greenhouse gases are emitted into the atmosphere.

The fourth scenario depicts a situation where power generation from alternative energy sources is commercially unsuccessful. In “A Future without Alternatives” fossil fuel and nuclear energy dominate the power-generation industry. These technologies develop through evolutionary changes and renewable energy cannot compete on a commercial basis. The difference between “A Future without Alternatives” and “No Winds of Change” lies in the level of the use of nuclear energy.

The goal of the company is to increase both sales and profitability.

The current organisational strategy focuses on improving the present product range through innovation and research and development. In order to sell the present products to new customers, activities in Asia are expanded. A service division is furthermore created. This essentially represents a new product that is offered to existing clients.

The above strategy was found to be robust across two of the four scenarios, namely “No Winds of Change” and “A Future without Alternatives”. In order to improve the robustness of the strategy, it was proposed that the organisation should either enter the field of renewable energies and/or nuclear power plants. Such strategies would cater for scenarios “Wind, Water & Sun” and “Nuclear to the Rescue” respectively.

The organisation can regard “No Winds of Change” as its official future if one considers the negative attitude that exists in some parts of the world towards nuclear energy, as well as the small contribution by renewable energy to the current mix of energy sources. The present organisational strategy is directed towards “No Winds of Change”. In fact, the organisation has been active in this type of business environment for several decades and is regarded as a leading expert in the field of dry- and wet-cooling technology in the power-generating industry.

8.2 Achievement of objectives

The main objective to generate scenarios that depict the future potential fuel mix in the field of power generation was achieved through gathering the relevant information and data from the available literature and the popular press and applying the scenario-planning methodology proposed by Schwartz (1991). The implication for the company in the context of its current strategy was described in detail and recommendations on how to adapt the current strategy were presented.

No experts, internally or externally to the organisation, were involved during the development of the scenarios. The author acted both as the “facilitator” and the “expert”. In order to obtain input from other parties, the completed analysis was handed to four individuals who are active in the field of power generation. The comments by the four experts are presented at the end of the report. By studying the report and the comments provided by the experts, the reader should be presented with a more objective picture of potential scenarios that could face suppliers of cooling systems.

8.3 Summary of recommendations

As referred to in Section 8.1 above, it was recommended that the organisation enter the field of renewable energy and/or nuclear energy. This could be mainly achieved through acquisitions. The recommendation is presented as “and/or” since the organisation may regard it as a high risk to enter two new areas of technology simultaneously.

For the purpose of increasing sales, the organisation also considered backward integration through the acquisition of rotary equipment manufacturers. Rotary equipment such as fans and pumps forms an integral part of the current range of cooling systems offered by the organisation. Apart from considering rotary equipment, the organisation also showed interest in supplying auxiliary cooling equipment in addition to the main cooling systems currently offered. It was pointed out that both these options do not improve the robustness of the current strategy, as they still focus on the basic product offering of traditional cooling systems that feature mainly in two of the four scenarios.

According to the input from the experts as presented in Chapter 7, the organisation can prepare itself for scenarios such as “Nuclear to the Rescue” or “A Future without Alternatives” through the further development and adaptation of existing products. In other words, participation in the nuclear-energy sector does not necessarily require an acquisition strategy, but could be achieved through adaptation and internal growth or a change in focus.

8.4 Areas for further research

The scenario-planning process was mainly qualitative in nature. The value of the scenarios could be improved through quantitative analysis. Such an analysis should address aspects such as total market size and potential market share, production-capacity calculations, forecasting of future power demand etc. Prior to embarking on acquisitions, valuations of the targeted businesses would have to be carried out.

This investigation treated gas and coal together as fossil fuel. There is potential to refine the current scenarios by treating gas and coal separately.

The cost trends or level of costs for different power-generating technologies can be analysed in more detail. This could act as a leading indicator to determine which of the scenarios is/are most likely to materialise.

The current research and development plan of the organisation could be reviewed within the context of the scenarios and company goals and refined accordingly. This should assist with improving the robustness of the current strategy and/or the adapted strategy. Such an exercise would have to take cognisance of the contribution and recommendations of the experts, as presented in Chapter 7.

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