University of Alberta

Technology Foresight for Small- to Medium-sized Enterprises

by

Joanne Gladys Phillips

A thesis submitted to the Faculty of Graduate Studies and Research
in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

in

Engineering Management

Department of Mechanical Engineering

ABSTRACT

Businesses, regardless of size, require the best information available to them in order to optimize their technological plans for the future. Currently, however, large, multi-national enterprises (MNEs), along with nations, are availing themselves of a set of tools that are not being used by small- to medium-sized enterprises (SMEs). These tools fall under the general description of "foresight" and the more specific term *technology* foresight.

Technology foresight applies to all purposeful and systematic attempts to anticipate and understand the potential direction, rate, characteristics, and effects of technological change, especially invention, innovation, adoption, and use. Technology foresight is undertaken for the purpose of managing technology as a corporate resource similar to the tools used for financial management or personnel development. Many foresight methods require significant staff and monetary resources. This research, after providing a history of the concept of technology foresight, describes a majority of the foresight methods and techniques currently in use and pares them down with reference to the special resource characteristics of SMEs to identify eight methods that are determined to be sufficiently economic of time and money to be suitable for use by SMEs. These eight methods are: backcasting, bibliometrics, diffusion modeling, long wave analysis, monitoring, technological substitution, trend extrapolation, and vision generation. Two of the eight methods – bibliometrics and long wave analysis – are further explored through application to a hypothetical SME.

Recognizing that eight methods represent a very small sample of the technology foresight methods that are available, a new and original technique for applying the scenarios method for SMEs is introduced and tested. The technique is called Scenario Recycling and involves the use of publicly available scenarios prepared by others for the purpose of providing inspiration and insight to SMEs. It is proposed that recycling may be a valid approach to allow SMEs to access other TFA methods.

It is concluded that SMEs can benefit from technology foresight; both from existing methods and the new technique of Scenario Recycling and a simple plan is presented to illustrate how an SME can develop a foresight program. Areas requiring further research are also identified.

ACKNOWLEDGMENT

This research has been sponsored under an Industrial Postgraduate Scholarship supported by the Natural Sciences and Engineering Research Council of Canada and the Alberta Research Council Inc.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. RESEARCH QUESTION, RELEVANCE AND PROCESS

> *There is a need for development of easily comprehensible, timely, and cheap sources of [technological forecasting] for small companies.*
>
> [Coates et al. 2001, 15]

This chapter will provide the research question to be answered in this thesis, present why the question is important, and describe the process by which the question will be addressed.

1.1 RESEARCH QUESTION

This thesis will answer the basic question "Which technology foresight (TF) or technology futures analysis (TFA) methods can resource-limited SMEs use with ease to assist in their technological decision-making?" In addition, it will present a unique and original idea about how additional TFA methods can be deployed by SMEs using the concept of recycling. Recycling, in this case, refers to the re-purposing of existing futures research conducted by larger, less resource-limited, entities.

1.2 RESEARCH RELEVANCE

Our society is now completely reliant on technology [Coates et al. 2001, 3], and this fact makes technology decisions just as much business decisions as are financial, marketing, and other strategic decisions [Coates et al. 2001, 8]. Setting priorities for research and development (R&D) efforts, understanding and managing the risks of technological innovation, exploiting intellectual property, and enhancing technological competitiveness of products, processes, and service are examples of key technological decisions [TFAMWG 2004, 288]. Technological decisions are important elements of the strategic management of any enterprise.

Businesses, in sum, require the best information available to them in order to optimize their technological plans for the future. This is true regardless of size. Currently, however, large, multi-national enterprises (MNEs), along with nations, are availing themselves of a set of tools that are not being used by small- to medium-sized enterprises (SMEs). These tools fall under the general description of “foresight” and the more specific term *technology* foresight.[1]

Technology forecasting originated in North America[2] in the late 1950s and early 1960s in the military domain in response to a need to predict the characteristics of future weapons systems [Coates et al. 2001, 2]. Military strategists used technology forecasting in conjunction with systems analysis to address the long lead times necessary to develop advanced weaponry and anticipate the countermeasures that may be developed [Coates et al. 2001, 2]. Over time the

[1] It is worth noting that nearly all the methods of technology forecasting are also used for forecasting purposes outside of technology. A couple of examples of methods which may be considered unique to technology are S-curves and patent trend analysis [Millet and Honton 1991, ix].
[2] Technology Forecasting developed somewhat differently in Europe [Cornish 2004, 186].

concept of technology fore*casting* expanded into the realm of technology fore*sight*. Martin [2010] provides an insider's perspective of the origin of the term "foresight" in science and technology. He describes its evolution into a term "to formally signify a new approach to looking systematically into the future of science and technology, an inclusive and wide-ranging process that differed appreciably from that of traditional 'technology forecasting'" [Martin 2010, 1438]. In sharp contrast, some [Coates et al. 2001, 1] consider the two terms essentially interchangeable. For the purpose of this thesis, the latter approach will be taken, except as specifically identified. The term "technology foresight" refers to all purposeful and systematic attempts to anticipate and understand the potential direction, rate, characteristics, and effects of technological change, especially invention, innovation, adoption, and use [Coates et al. 2001, 1].

Industry Canada describes foresight as "...a process of not predicting the future, but to bring stakeholders together to consider what issues and drivers may contribute to the future of a particular industry and/or sector, allowing for a cohesive and coordinated approach and a commitment to action to most effectively deal with future challenges" [Industry Canada 2011].

Comparing Coates et al.'s definition of foresight to that of Industry Canada's, it is important to note the emphasis in Industry Canada's definition on "industry and/or sector" as opposed to individual company (regardless of size). Industry Canada follows its description with a listing of countries or regions and links to their national foresight studies (countries listed are: Finland, Germany, India, Ireland, Japan, Sweden, Thailand, and the United States. Regions listed are: Latin America and the United Kingdom). Industry Canada's failure to identify companies in its definition and the subsequent listing of countries or regions that have undertaken foresight exercises implies that foresight is unsuitable for companies, let alone SMEs.

Industry Canada is not alone in its focus on industry and/or sector and countries. A 1997 review of best-in-kind foresight programs showed the primary practitioners to be the public sector of countries [Skumanich and Silbernagel]. The program of Royal Dutch/Shell in the Netherlands was the only private exception. This may be misleading, however. A 2008 study of how foresight methods are selected created a database of nearly 2,000 foresight exercises from around the world. The study noted a limitation of the created database due to the body of work in a particular sector being underrepresented. The underrepresented sector was identified as "private sector foresight" [Popper 2008, 63]. It is impossible to confirm whether the body of work in private sector foresight is underrepresented because it is not being done or because it is not being published (perhaps for competitive reasons). Dator [2012, 34] indicates that much of the "civilian futures work" being undertaken is "proprietary in nature and entirely hidden from public and even academic view".

The type of SME that this work is aimed at is the type of organization that intends to one day be a large or multi-national enterprise (MNE). Such companies tend to work in technology-driven sectors, such as energy, telecommunications, and information technology. Betz [2000, n.p.] describes a high-tech new venture as “a new company in the emerging industrial value-adding structure, which supplies functionality around a new technology system.” For the purpose of this research, the enterprise does not have to be new, but Betz’s definition otherwise succeeds in describing the type of company being targeted by this work.

The Government of Canada website that provides key small business financing statistics (www.sme-fdi.gc.ca) states “There are many definitions of SMEs, which can be categorized by size according to the number of employees, the value of annual sales, annual revenues or borrowing capacity” [2011]. This inconsistency in definitions is irrelevant to the focus of the work in this thesis. The primary intent of using the phrase small- and medium-sized enterprises (SMEs) is to distinguish the entities focussed on in this thesis from nations or large multi-national enterprises (MNEs).

The reasons for focusing on SMEs in this study are two-fold. First, there is a call within the literature for action to be taken to investigate or develop technological foresight methods for small enterprises [Coates et al. 2001]. Second, recent statistics show that these smaller enterprises – though making significant contributions to the economy – are disappearing from the Canadian corporate landscape at an accelerating rate [Grant, McKenna, and Blackwell 2012].

The bulk of the empirical work on technology foresight in industry is limited to studies on large corporations [Reger 2001, 534] resulting in a dearth of literature describing the application of foresight by SMEs. This lack is emphasized by the 2001 call for work in this area by Coates et al. This is an area worthy of investigation because there is not universal agreement on it. Slaughter [2002] states "Some organisations may be too small to create their own [strategic foresight][3] capability. Schools and small businesses would be good examples". This thesis aims to prove this position incorrect.

Many foresight methods (e.g., Delphi, scenarios, participatory methods) require significant resources (e.g., staff, external consultants, time, etc.) and, as noted previously, it has primarily been countries, industrial sectors or very large entities that have employed these methods [Reeves 2000, n.p.]. This research postulates that some of the methods are sufficiently economic of time and money that SMEs can employ them and, by doing so, potentially gain a competitive advantage over those SMEs that do not. The type of competitive advantage can be expressed by the corporate attributes found in those companies with a capacity for foresight. These attributes are [Slaughter 2002, 11]:

- they are seldom overtaken by change

---

[3] Slaughter defines strategic foresight (SF) as "the ability to create and maintain a high-quality, coherent and functional forward view and to use the insights arising in organizationally useful ways...It represents a fusion of futures methods with those of strategic management" [2002, 1].

- they do not succumb to crisis management
- they find it easy to avoid problems and seize opportunities
- they develop long-term vision and a kind of forward looking prescience.

This thesis proposes that tools – technology foresight (TF) or technology futures analysis (TFA) methods – are available to aid small- to medium-sized enterprises (SMEs) in their technological decision-making.[4]

1.3 PROCESS

This chapter has introduced the problem that SMEs appear to be missing out on the benefit of foresight methods and how this thesis is structured to identify the available tools that may be appropriate for use by SMEs.

Chapter 2 will provide a review of the relevant literature in the form of a history of the development of foresight methods, followed by descriptions of most of the foresight methods referred to in this thesis. The chapter will also examine the numerous attempts that have been made to categorize technology foresight methods. The following chapter – Chapter 3 – will assess the available TFA methods and identify eight which are suitable for use by SMEs based on their

[4] On average, large companies use about 30 percent more tools than smaller firms [Rigby and Bilodeau 2011]. Rigby and Bilodeau's study focused on 25 of the most popular tools. Strategic planning is one of these tools and Scenario and Contingency Planning is another one.

ability to meet the criteria that they require limited financial and manpower resources.

The remaining chapters will primarily present analysis. Chapter 4 will demonstrate the application of two of the eight foresight methods determined suitable for use by SMEs in Chapter 3 – bibliometrics and long wave analysis. These particular methods were selected for demonstration due to their differences. Bibliometrics is a seemingly data-intensive method potentially requiring specialized software. However, the demonstration shows that valuable information can easily be obtained by using the Internet as the primary resource. In the case of long wave analysis, the demonstration shows how the groundwork already exists with respect to predictions about the focus of future waves and the SME must only provide the analysis to determine how the predicted future waves apply to its business.

Recognizing that numerous TFA methods have been deemed unsuitable for SMEs in arriving at the eight that are suitable, Chapter 5 will present a unique and original insight into how the concept of recycling may be used by SMEs to increase the number of TFA methods suitable for their use. The chapter applies the recycling concept to the scenario method and presents a preliminary evaluation of its application to a hypothetical SME. Chapter 6 will offer a discussion of the methods evaluated as suitable for use by SMEs as well as the newly proposed scenario recycling technique.

Chapter 7, the final chapter of this thesis, will provide conclusions and recommendations for future work in this area as well as a simple plan to illustrate how an SME can develop a foresight program.

Technology foresight has existed for less than a century and is actively evolving and developing. This thesis intends to add to the evolution of TF by applying it to a segment of the marketplace which has not historically participated in its use – the SME.

2. LITERATURE REVIEW

Technology forecasting originated in North America[5] in the late 1950s and early 1960s in the military domain in response to a need to predict the characteristics of future weapons systems [Coates et al. 2001, 2]. Military strategists used technology forecasting in conjunction with systems analysis to address the long lead times necessary to develop advanced weaponry and anticipate the countermeasures that may be developed [Coates et al. 2001, 2]. The systems field, which began in earnest during World War II, has gone by a number of names (including systems thinking, general systems research, cybernetics, management science, operations research, operational research, decision science, and praxiology [Leonard with Beer 2009]) and spawned a number of approaches based on different kinds of models. Each approach relied on the particulars of the problem to be addressed.

The term “technology forecasting” applies to all purposeful and systematic attempts to anticipate and understand the potential direction, rate, characteristics, and effects of technological change, especially invention, innovation, adoption, and use [Coates et al. 2001, 1]. According to Coates et al. [2001, 1], there is no distinction between “technological forecasting”, “technology forecasting”, and “technology foresight”. There is, however, they note, a distinction between

[5] Technology Forecasting developed somewhat differently in Europe [Cornish 2004, 186].

technology forecasting and technology assessment. Technology assessment – also known as social impact analysis – emphasizes the downstream effects of technology's invention, innovation, and evolution. In technology assessment the emphasis is on consequences that are unintended, indirect, or delayed [Rossini and Porter 2000, section II 5.5]. Koivisto et al. [2009, 1163] state that technology assessment has ingredients of both risk assessment and foresight. Since technology forecasting encompasses technology assessment, technology forecasting will refer to both, unless otherwise indicated.

The evolution of technology forecasting (TF) from 1935 to early 1999 has been summarized in Table 1 (2000 to present is discussed in 2.6). Most technology foresight methods have adapted or evolved over time from previous contributions rather than being "invented" from scratch.

YEARS			EVENTS
1935			• Supposed first official account of systemic outlook on the future of science & technology in the form of a U.S. government commission tasked to look into the future of 13 major inventions. • At this early point TF included what would later become TA.
1939 – 1945			World War II – systems field begun in earnest
1947 – 1991			Cold War competition brought forth the need to cope with dramatic developments in technology such as guided missiles, nuclear weapons, and computing. System Analysis became an important tool in designing such complex systems.
	1949 – 1959		• Focus on forecasting the rate of technological change • Normative forecasting introduced during this period along with: relevance trees, mission flow analysis, scenario writing, Delphi • First textbooks on TF
	Late 1960s		Journals, textbooks & conferences on TF extended beyond the U.S. defence establishment
	1970s		Disillusionment with systems analysis spread due to failure to deal with ill-structured systems (i.e., Vietnam, urban systems).
	Late 1970s & 80s		Support for TF within the policy-making arena faltered as it was realized that the uncertainties of technology development defied clear-cut “systems analysis” solutions.
		1975 – early 90s	• TF reduced in practice to a set of tools and methods • forecasts produced during this period were relatively few, generally poorly defined & executed without much attention to formal assumptions, time horizons & limitations
Early 1999			Meetings held to discuss future of TF/TA.

Table 1: Chronology of the development of TF/TA[6]
Developed from [Coates et al. 2001] and [Leonard with Beer 2009]

Sections 2.1 to 2.6 will describe the history of futures investigation and highlight the origins of some of the many available methods for conducting futures research. More detailed descriptions of the methods are provided in the section

[6] TA refers to Technology Assessment. TA is a class of policy studies which examine the effects on society that may occur when a technology is introduced, extended or modified. It emphasizes those consequences that are unintended, indirect or delayed.

following (i.e., 2.7).

2.1 THE BEGINNING: A GOVERNMENT COMMISSION

The roots of technology foresight are found in the American government's response to the Great Depression. Between 1929 and 1932 the income of the average American family was reduced by 40% (from $3,200 to $1,500) and survival was the main focus of the average citizen [Sutton 1999]. According to Sutton [1999], within the decade, the U.S. would evolve from a laissez-faire economy to one heavily regulated by its federal government. This heavy regulation included the establishment of an assortment of commissions set up to regulate Wall Street, the banking industry, and other business enterprises [Sutton 1999]. Coates et al. [2001] propose that the first official account of a systematic outlook on the future of science and technology was the report titled "Technological Trends and National Policy, Including the Social Implications of New Inventions" published in 1937 by the National Resources Committee established in 1935.

2.2 1940S AND 1950S: THE COLD WAR AND SYSTEMS ANALYSIS

Because it brought the right minds together at the right point in time, an important development in technology forecasting was the Douglas Aircraft Company's establishment, in 1946, of Project RAND (the acronym stands for "research and development") to study the "broad subject of inter-continental warfare other than surface" [Cornish 2004, 195]. In 1948 Project RAND split from the aircraft company, changed its name to the RAND Corporation, and changed its goal to "further and promote scientific, educational, and charitable purposes, all for the public welfare and security of the United States."[7] [Cornish 2004, 195]. Original employees of the RAND Corporation are credited with the development of at least two technology forecasting methods. Olaf Helmer and Norman Delkey developed a polling process they called the Delphi method in 1953 [Cornish 2004, 67] and Herman Kahn is credited as the originator of the Scenario method [Strathern 2007, 160].

In the late 1940s Fritz Zwicky, a professor of astrophysics at California Institute of Technology, introduced the concept of the relevance tree, an analytical technique that subdivides a broad topic into increasingly smaller subtopics until the finest level of subdivision is reached [The Futures Group International 2009]. Zwicky proposed that it is only at the finest level of subdivision that individuals are able to innovate and delve deeper into a particular subtopic or, potentially, to combine subtopics in new ways.

It was during this decade that a number of quantitative exploratory methods were developed. However, the methods were quite primitive due to the limited computing power of the day. One example of a quantitative exploratory method is

---

[7] At the same time, the Stanford Research Institute – now SRI International – was formed to address the commercial sector and the civil sector of the U.S. government's interests [Coates with Glenn 2009, 2].

trend extrapolation (described in detail in 2.7.46). At the same time, a need to direct the future to address perceived future needs (normative forecasting, see 2.8.4) was asserting itself and this influence fostered more qualitative approaches such as relevance trees and the afore-mentioned scenarios and Delphi methods.

2.3 1960S: BEYOND THE DEFENCE DOMAIN

The Space Race[8] had a significant influence on technological forecasting in the U.S. in the 1960s since it sparked unprecedented increases in spending on education and pure research in an attempt to achieve at least symbolic technological superiority over the U.S.S.R. [Cornish, 2004, 200]. The increase in spending, in turn, accelerated scientific advancements and the desire to improve the prediction of these advancements.

One of the most basic technology foresight methods [Rossini and Porter 2000, section II 5.5], the objective of which is to find early indications of possible important future developments to gain as much lead-time as possible, was referred to as "environmental scanning" in the 1960s and 1970s. Its name has had to evolve due to the growth of the environmental movement, to avoid the misunderstanding that it refers to systems to monitor changes in the natural environment due to human actions. Therefore, it is also known as: monitoring,

[8] The Space Race effectively began with the Soviet launch of the Sputnik 1 artificial satellite on October 4, 1957, and concluded with the co-operative Soviet-U.S. Apollo-Soyuz Test Project human spaceflight mission in July 1975.

“Futures Scanning Systems”, “Early Warning Systems”, and “Futures Intelligence Systems”. All refer to the process of scanning the horizon (and beyond) of a corporation’s current and planned operating and peripheral environments to identify new developments that can challenge past assumptions or provide new perspectives about future threats or opportunities. Environmental scanning also feeds the processes of issues management and strategic planning [Gordon and Glenn 2009].

The purpose of monitoring is to provide an early alert of any changes that may warrant a revision to current plans. Various scanning techniques exist, but Gordon and Glenn recommend that the following approaches be considered in creating a scanning system:

1. *Expert panels can be created to ‘look out’ for changes on the horizon that could be important to implement or accomplish plans via Delphis, listservs, and various other forms of collaboration software. It is probably worth considering a host of emerging technologies that are similar in terms of promoting potential ‘active’ participation (e.g., Delphi). There are candidates such as facilitated dialogue mapped face-to-face meetings, ‘world cafés’, and even prediction markets...;*
2. *Database literature reviews provide access to a broad range of information useful to policy makers, planners and strategists*
3. *‘Google Alerts’ http://www.googlealert.com allows one to pre-select terms that are searched daily and delivered to your e-mail address. ‘Web crawlers’ can search for sites with new versions that can provide early warning or alert to new information*
4. *Many Websites on the Internet offer press releases available to the public. You should know the best ones for your interests, as these identify issue-related information and emerging trends*
5. *Hard-copy literature reviews of selected periodicals could also be scanned to detect important incipient changes; however, they are increasingly being replaced by electronic versions*
6. *Essays by experts could explore critical long-term issues for recommendations on policy and strategy. These essays could use contemporary software such as issues maps.*
7. *Key person tracking (who knows the most, and how do you keep track of their new*

insights) and monitoring of key conferencing [sic] on your special interests, in person or on-line via streaming or archived video [Gordon and Glenn 2009, 4].

Two shortcomings have been noted with monitoring. These are that it gives little indication of the time frame for any future development and that it does not provide an indication of how different, disparate conditions may affect one another [Skumanich and Silbernagel 1997, 3].

Another method assumed to have its roots in the early 1960s by way of "the father of scientometrics" Derek Price's pioneering work in counting scientific publication activity is "text mining of science and technology information resources for future-oriented technology analyses" [Porter 2009, 2]. The method has parallels with content analysis in the social sciences and is commonly referred to as bibliometrics within the foresight community. A complete description of the method is provided in 2.7.6.

The origin of the awareness of chaotic behaviour of non-linear systems also began in 1961 with the labeling of extreme sensitivity of a system to initial conditions as the "butterfly effect". This knowledge was built on by Robert May in the early 1970s, who discovered, while studying the application of non-linear models to ecology, that his equations exhibited bifurcation and period doubling. In the late 1970s Mitchell Feigenbaum, a staff member of Los Alamos National Laboratory, showed that period doubling was a universal route to chaos. Finally, in 1982, Benoit Mandelbrot, Sterling Professor Emeritus of Mathematical Sciences within the mathematics department at Yale University, identified the fractal property of chaotic behaviour which lead to the definition of fractal dimensions as a means of expressing levels of complexity [Gordon 2009b, 2]. David Ruelle and Floris Takens introduced the concept of strange attractors at about the same time. Since chaotic systems do not behave like non-chaotic systems, it is important for a person studying the future to recognize the chaotic system since conventional forecasting techniques may not be suitable for these systems. However, once recognized as chaotic, means exist for potentially "de-escalating" the situation [Gordon 2009b, 12].

Theodore Gordon and Olaf Helmer (co-developer of the Delphi Method), developed the cross-impact method (see description in 2.7.14) in 1966 to answer the simple question "Can forecasting be based on perceptions about how future events may interact?" [Gordon 2009a, 1]. According to Gordon [2009a, 1], the two developed a game which subsequently appeared in many classrooms in the 1970s as an entertaining way to learn about current social issues (e.g., urban crises).

Another technology foresight method – science and technology roadmapping – has its roots in the planning technique Program Evaluation and Review Technique (PERT) and two studies completed in 1965 and 1967 [Gordon 2009d, 1]. The 1965 study was initiated by the U.S. Department of Defense and found that applied science, rather than basic science, was more useful to the twenty advanced systems studied [Gordon 2009d, 1]. The 1967 study, initiated by the U.S. National Science Foundation, examined five innovations and searched for the research and development events that had to have occurred for the innovation to have been made [Gordon 2009d, 1]. A more in-depth description of the roadmapping method is provided in 2.7.35.

In the late 1960s, Royal Dutch/Shell started to apply the scenario method to the future of oil markets and it has continued to do so. Shell's website states that it develops the scenarios "to cast light on the context in which the Group operates, to identify emerging challenges and to foster adaptability to change. These scenarios are used to help review and assess strategy" [Shell 2012].

During the 1960s several groups devoted to the future formed [Cornish 2004, 201]. In 1964 Robert Jungk initiated a group called Mankind 2000 at the inaugural congress of the International Confederation for Disarmament and Peace[9]. Mankind 2000 is effectively dormant today, but holds positions in active endeavours [Mankind 2000, 2012] and its founder, Robert Jungk, is credited with developing creativity workshops or future workshops (further described in 2.7.13). Per Cornish [2004, 201], in 1966 a group of private citizens in Washington, D.C. formed the World Future Society and shortly after began

[9] Mankind 2000 subsequently formed as an international committee in London and as an educational trust in the Netherlands in 1966. Mankind 2000 was reformed in November 1972 and registered under Belgian law on 5th April 1973 as an independent transnational association of cultural, scientific, and educational character without profit motive [Mankind 2000, 2012].

regular publication of a magazine, *The Futurist*, which remains in publication today. The Club of Rome, an international group of scientists, humanists, planners, and educators interested in looking at the problems of the world from a global standpoint, formed in Italy in 1968 [Cornish 2004, 201]. In 1972 it published *The Limits to Growth: A report for the Club of Rome's project on the predicament of mankind*. The book describes the output from a global model developed by an international project team to examine the five basic factors that it believed determined, and therefore ultimately limited, growth on planet Earth: population, agricultural production, natural resources, industrial production, and pollution. The book questioned the price of progress and suggested that within as few as 70 years "our social and economic system will collapse unless drastic changes are made very soon" [Townsend 1975, back cover]. In 2004, *The Limits to Growth* was updated in *Limits to Growth: The 30-Year Update*. The Club is still warning of "catastrophic overshoot" of the support capacities of the earth.

By the late 1960s journals, textbooks, and conferences on foresight extended far beyond the U.S. defense establishment [Coates et al. 2001, 3]. Concurrently, the financial support afforded to scientific research came under greater scrutiny and the subject of science policy began to get serious attention in the government scientific community. There was growing attention to the unintended side effects of increasingly powerful technology and growing concern about its impacts on "quality of life".

2.4 1970S: DISILLUSIONMENT

The Douglas Aircraft Company's efforts to develop 10-year corporate plans for its four divisions that built various types of military and civil aircraft ultimately led to the development of the field anomaly relaxation method (see description in 2.7.20) in 1970 [Rhyne 1981]. It was initially applied to a wide range of social fields in which business and government policies might have to exist.

The Futures Wheel (see description in 2.7.32.1), a method for identifying and packaging primary, secondary, and tertiary consequences of trends, events, emerging issues, and future possible decisions, was invented in 1971 by Jerome C. Glenn [Glenn 2009c, 1] and subsequent variations have been called the Implementation Wheel, Impact Wheel, Mind Mapping, and Webbing and have been used in a wide variety of situations. Public policy advisors, for example, use the Futures Wheel to help identify potential problems and opportunities, and new markets, products, and services, and to assess alternative tactics and strategies [Snyder 1993].

Although the use of s-shaped curves in demographic and biological applications dates back to the 1920s, another technology forecasting method – known as substitution analysis – came to the forefront in 1971 when economists Fisher and Pry published a simple model to project market adoption of a technologically superior product and the subsequent decline of the product being replaced [Gordon 2009e, 1]. Basically, the s-curve starts out slowly, accelerates for a short time and then levels off. The s-curve was popularized by Malcolm Gladwell in his 2000 bestseller *The Tipping Point: How Little Things Can Make a Big Difference*.

Also in 1971, *Essence of Decision: Explaining the Cuban Missile Crisis* [Allison] was published and Linstone, beginning in 1977, expanded Allison's analysis and modeling for corporate decision making and adapted its application to technology management resulting in the Multiple Perspective Concept (see 2.7.28) for decision making [Linstone 1984]. The concept involves the use of three perspectives when evaluating a decision: the technical, the organizational, and the personal.

In 1972, Julius Kane augmented the original cross-impact method by developing a simulation technique – KSIM – based on the expected interactions among time-series variables rather than events (see 2.7.42). Numerous additional researchers adapted the method for their specific purposes over the decade ([Turoff 1972], [Duval, Fontela, and Gabus 1974], [Duperrin and Godet 1975], [Enzer 1980],). Also in 1972, John Conway built on work done as early as the 1940s to stimulate the field of cellular automata which lead to the agent-based modelling method (further described in 2.7.2).

Also in 1972, the U.S. government formed the Office of Technology Assessment under the Technology Assessment Act. The purpose of the office was to provide Congress with the information needed for the support, management, and regulation of applied technologies. This government focus on foresight activities prompted business firms to apply technology foresight methods to help them identify the probable capabilities of future products and high-technology firms to establish their own, in-house, technological forecasting capabilities [Wiley 2012].

The 1970s were a difficult time in the United States. Many of the "radical" ideas of the 1960s gained wider acceptance in the new decade, and were mainstreamed into American life and culture. Major trends included a growing disillusionment of government, advances in civil rights, increased influence of the women's movement, a heightened concern for the environment, and increased space exploration. The U.S. economy experienced its worst recession in 40 years in 1974 [Gillis 2010]. The Vietnam War came to an end with the fall of Saigon on April 30, 1975 and the U.S. was not considered a winner of the war. The Space Race ended in July 1975 effectively neutralizing an enemy which had been a unifying force for U.S. citizens to combat. The failures in Vietnam and within urban systems in the U.S. created disillusionment with systems analysis from which TF sprang.

Trend impact analysis (further described in 2.7.47) was developed in the late 1970s [Gordon 2009c, 1] to address the primary issue with the trend extrapolation method (see details in 2.7.46). That is, the assumption that the best indicator of future action is past action, without taking into account future events that may change past relationships or, in some other way, alter the trend. Trend impact analysis has widespread applications and can be applied to technological, political, social, economic, and value-oriented events. The general concept of including perceptions about the future in otherwise deterministic forecasting methods has been used in conjunction with systems dynamics to produce a "probabilistic system dynamics" method [Stover 1975].

2.5 1980S AND 1990S: FORESIGHT GOES PUBLIC

In 1985 the concept of "Wild Cards" was developed by Royal Dutch Shell to enhance its application of the scenario method [Wack 1985a, 1985b]. However, no specific methodology was developed [Peterson and Steinmüller 2009, 1]. Events such as the dotcom crisis, the event of September 11, 2001, and the recent meltdown of the financial markets all represent wild cards, or events "with a relatively low probability of occurrence but a likely high impact on the conduct of business" [BIPE Conseil, CIFS and Institute for the Future 1992, v]. A comprehensive wild card methodology was not offered until 1996 when John Peterson first published one in his book *Out of the Blue: How to Anticipate Big Future Surprises* (a second edition was published in 1999).

Later in the 1990s causal layered analysis (CLA) was proposed by Inayatullah [2009, 2] to categorize different views of and concerns about the future and then to assist groups in thinking about the future more effectively than if they were to use a single "layer" as most methods do. Briefly, the four layers of CLA are: litany, social causes, worldview, and metaphor. Per Inayatullah [2009, 8], litany refers to quantitative trends, problems, or issues (e.g., overpopulation). Social causes include economic, cultural, political, and historical factors (e.g., rising birthrates). Worldview goes deeper and is concerned with the deeper social, linguistic and cultural structures that support the trend, problem or issue (e.g., traditional perspectives on family). The last layer, metaphor, provides a gut/emotional level perspective to the worldview (e.g., seeing people as creative resources).

Support for technology foresight faltered within the U.S. policymaking arena during the late 1970s and 80s as complex problems were faced which the available methods had been unable to "solve". Good examples of these problems were the U.S.'s lack of success in the Vietnam War and the 1973 oil crisis (when the members of the Organization of Arab Petroleum Exporting Countries (OAPEC) proclaimed an oil embargo against the U.S. in response to U.S. support of the Israeli military during the Yom Kippur War).

In early 1999, a number of individuals practicing foresight scattered around the globe began to exchange ideas about the future of technology forecasting with the goal of advancing research in the area and at least two papers reflect these efforts: "On the Future of Technological Forecasting" by Vary Coates et al. [2001] and "Technology futures analysis: Toward integration of the field and new methods" by the Technology Futures Analysis Methods Working Group[10] (TFAMWG). The papers share a common theme in their desire to advance the field. Coates et al. state "Promising new tools are anticipated, borrowing variously from fields such as political science, computer science, scientometrics, innovation management, and complexity science" [2001, 1] while the TFAMWG stated the aim of its paper was to advance TFA methods and processes by "sharing perspectives among the several TFA forms and introducing new approaches from other fields…" [2004, 287].

Also in 1999, The Millennium Project[11] began research to determine if progress is being made on 15 global challenges [Gordon 2009f, 1]. This research evolved into the State of the Future Index (SOFI), an annually published report which uses trend impact analysis to analyze the collected data and forecast whether the future will be better or worse. Work continues to determine if new variables should be included in the report and whether or not an increase in some values is good or bad [Gordon 2009f, 23].

The 15 Global Challenges quantified in the Millennium Project's SOFI are

[10] The TFAMWG consists of Alan L. Porter (U.S.), W. Bradford Ashton (U.S.), Guenter Clar (EC & Germany), Joseph F. Coates (U.S.), Kerstin Cuhls (Germany), Scott W. Cunningham (U.S. & The Netherlands), Ken Ducatel (EC, Spain & UK), Patrick van der Duin (The Netherlands), Luke Georghiou (UK), Theodore Gordon (U.S.), Harold Linstone (U.S.), Vincent Marchau (The Netherlands), Gilda Massari (Brazil), Ian Miles (UK), Mary Mogee (U.S.), Ahti Salo (Finland), Fabiana Scapolo (EC, Spain & Italy), Ruud Smits (The Netherlands), and Wil Thissen (The Netherlands).

[11] The Millennium Project is a global participatory futures research think tank of scholars, business planners, and policy makers who work for international organizations, governments, corporations, non-governmental organizations (NGO), and universities.

provided in Table 2.

1. infant mortality rate 2. food availability in low-income countries 3. gross domestic product per capita 4. share of households with access to safe water 5. adult literacy rate	6. life expectancy 7. percent of world population living in countries that are free 8. secondary school enrolment 9. share of the population with access to local health care in the 15 most populated countries 10. carbon emissions	11. share of the population unemployed 12. loss of forestlands 13. ration of global average income of the top 5% to the bottom 5% 14. annual AIDS deaths 15. developing-country debt

Table 2: The 15 global challenges quantified in SOFI

2.6 2000S TO TODAY: RECENT DEVELOPMENTS

Renewed interest in foresight spawned the real-time Delphi method and the future polygon method in 2006. The real-time Delphi method increases the speed of the original Delphi method by employing specially designed software operating at modern computing speeds [Gordon 2009g] while the Futures Polygon method adds the element of evaluating the likelihood of forecasted impacts to the concept of the futures wheel [Pacinelli 2009, 1]. Its name refers to the fact that if the different probabilities of the events/impacts obtained by the futures wheel and their own different years of occurrence are connected with a line, they generate a polygon [Pacinelli 2009, 1]. The Future Polygon method fits within the broader area of impact analysis [Pacinelli 2009, 2].

In 2007 Nassim Nicholas Taleb used a different concept to describe wild cards in his book *The Black Swan: The Impact of the Highly Improbable*, thereby introducing the concept into the public domain. Taleb describes a black swan as “a highly improbable event with three principal characteristics: It is unpredictable; it carries a massive impact; and, after the fact, we concoct an explanation that makes it appear less random, and more predictable, than it was.” Taleb does not present a methodology, but attacks the comfort that prediction provides and warns against not being prepared for all relevant eventualities.

This research was also aided by a very early draft of a foresight encyclopaedia provided by Elizabeth Florescu, then Director of Research for the American Council for the United Nations University. The encyclopaedia – not yet available to the public – provided an excellent resource for confirming the definitions obtained for the various foresight methods. In addition, it provided a general overview of foresight outside of the technology niche.

2.7 TFA METHOD DESCRIPTIONS

This section presents definitions for almost all of the TFA methods mentioned in this thesis in alphabetical order. In cases where there is a specific technique for performing a method, the technique is identified in square brackets following the method name and its definition is presented as a sub-heading under the primary method name. In some cases there is no definitive definition of the method and this fact is also indicated.

2.7.1 Action analysis

Porter et al. (the Technology Futures Analysis Methods Working Group) in their paper "Technology futures analysis: Toward integration of the field and new methods" did not provide a reference for action [options] analysis. However, according to Strategic Decisions Group, a strategy consulting firm which applies "leading-edge decision theory to uncover opportunities for creating shareholder value" [SDG 2007a]:

> *There are similarities between acquiring options in the world of finance and making strategic business decisions: both deal with dynamic risk and both attempt to respond to anticipated changes in the future. This has led to the application of many key concepts and methods from financial options theory to 'real,' non-financial assets. Real options analysis focuses on the temporal aspects of risk, attempting to accurately capture the potential for future value in investments and decisions made today* [SDG 2007b].

The British Council for Science and Technology in a letter to the The Rt Hon Alan Johnson MP, Secretary of State for Trade and Industry, Department of Trade and Industry in Britain on May 18, 2005 described the methodology as follows:

> *Real Options Analysis (ROA) is a useful tool for stimulating thinking about a range of possible options and helping to make decisions on what to invest in. In particular, ROA helps to keep investment options open, and enable riskier approaches to be explored, without making long-term commitments to them. It enables analysis of the range of options available both now and in the future, while identifying investment cut-off points.*
>
> *The main thrust of ROA is that it enables a number of investments to be made in parallel, until an identified time in the future, and assumes that some will fail and some succeed. This flexibility means that, at various points in the future, decisions can be taken on which of the options are worth continuing with and which should be dropped.*
>
> *Venture capitalists, economists and other communities have found ROA to be a helpful tool in decision-making. While ROA has mainly been applied to scenarios where inputs and outcomes are based on market values and wealth generation, the approach has the potential to be extended more broadly, and in the area of public policy* [King and Peters 2005].

2.7.2 Agent-based modeling method

Agent modeling is a relatively new method that has grown out of the medical industry. John Conway, a mathematician at Cambridge, is generally credited with stimulating the field of cellular automata and bringing it to the attention of others in 1972 by inventing the game of Life. The rules were simple: a matrix board contains cells that are either alive or dead. In sequential “plays” every cell that is alive scans its neighbours. If it is in a location with less than two neighbours or more than three, the cell will die. In a place with two neighbours, the cell will remain as it was (alive, or dead). In a place with three neighbours, a live cell will be there even if it was not before [Gordon 2009j, 1].

Gordon [2009j] describes his attempts to develop an agent model designed in a way that would allow its users to change the simple rules governing the behaviours of the agents that comprise it and thus make it “complete enough to permit its use in forecasting”. However, at the time of writing of his paper Gordon was able to provide only a simple model as an example. The simple model involves a grid of 100 by 100 to create 10,000 sites for the agents. The user specifies the number of sites populated by agents (that is, the population density), the number of initially infected agents, and the maximum number of cells over which an infection can jump (the “reach” of the infectious vector). The model employs multiple runs, each simulating a period of time. The spatial distribution of agents is randomly determined. Once an agent is infected, it stays infected and becomes, in turn, infectious [Gordon 2003].

2.7.3 Analogies

> *The use of analogies in forecasting...involves a systematic comparison of the technology to be forecast with some earlier technology that is believed to have been similar in all or most important respects* [Martino 1983, 39].

Martino, in *Technological Forecasting for Decision Making* (2nd edition), directs one to compare the two situations based on the areas identified in Table 3. These areas have been developed through investigation of the factors that affect technological change through invention, adoption, and diffusion.

1. Technological	4. Political	7. Intellectual
2. Economic	5. Social	8. Religious – Ethical
3. Managerial	6. Cultural	9. Ecological

Table 3: Dimensions of comparison

Martino is also quick to point out the shortcomings of analogies in forecasting:

> *Analogies are based on the assumption that there is a 'normal' way for people to behave and that given similar situations, they will act in similar ways. However, there is no guarantee that people today will act as people did in the model situation. Hence the forecast is at most probable, never certain* [Martino 1983, 40].

2.7.4 Analytical hierarchy process (AHP)

The Analytic Hierarchy Process (AHP), developed by Thomas Saaty, is used when making complex decisions involving multiple criteria. The AHP allows the decision-maker to include intangibles along with tangible numerical data from many sources to make a decision. The AHP has a history of use in areas such as finance and land-use planning.

> *A typical application of AHP in the context of land-use planning would involve the classification of land zones according to land cover, agricultural exploitation, construction types, accessibility by road and so forth. These criteria might then be organized in one or several layers so as to define a suitable hierarchy for determining the corresponding preferences* [Dubois 2002].

The AHP is performed by a team in three basic steps. The first step involves creating a hierarchy of criteria and sub-criteria, relevant to the decision at hand. Relative weightings are developed in the second step by making comparisons between pairs of criteria and sub-criteria. In the final step the relative weights are used to populate a matrix which, when solved using eigenvalues, checks the evaluations made for consistency while yielding a composite score for each choice at every tier, as well as an overall score.

2.7.5 Backcasting

Edward Cornish in *Futuring: The Exploration of the Future* defines backcasting as:

> *A method of forecasting or planning in which an event is posited as having occurred in the future. The question then becomes, How did this event come to be? For example, one might posit that, in the year 2050, the cost of a year's worth of electricity for either a car or a home will be less than $10. The task then is to develop a scenario to explain how the posited future might actually come about. Backcasting offers a way to get a group to envision a desirable future and then determine what must happen in order for that goal to be reached* [Cornish 2004, Glossary].

An excellent example of backcasting is the Australian Army's use of the method as part of its continuous modernization program. An aspirational, notional "Army-after-next" (AAN), set 30 years into the future, is backcast to identify the capabilities necessary for the Objective Force (OF), set in the 15-20 year timeframe [Dortmans 2005, 277].

2.7.6 Bibliometrics

Bibliometrics, the counting of publications or other bibliographic items, includes such activities as research profiling, patent analysis, and text mining. The most elementary example of the bibliometric method is the traditional literature review [Porter 2009, 1]. Whereas the traditional literature review focuses on a discrete number of publications and summarizes them, modern bibliometrics allows one to analyze the *body* of all pertinent literature. Such analysis can result in the identification of useful patterns.

To understand a subject area it is helpful to know the basic aspects of it. The three basic laws of bibliometrics are ([Tarapanoff et al. 2001, 8], [Nicolaisen and Hjørland 2007, 359]):

- Bradford's Law (also known as the Law of Dispersion),
- Lotka's Law, and
- Zipf's Law (also called the fundamental quantitative law of human activity).

Bradford's Law asserts that documents on a given subject are distributed according to a mathematical function (see next paragraph) so that a certain growth in papers on a subject requires a certain growth in the number of journals. In 1934 when Samuel C. Bradford described this relationship he provided both a graphical and a descriptive version of his law. However, these have since been found not to be mathematically equivalent. As a result, the exact mathematical function remains the subject of ongoing research [Nicolaisen and Hjørland 2007, 359].

One formulation of Bradford's Law states that if journals in a field are sorted by number of articles into three groups, each with about one-third of all *articles*, then the number of *journals* in each group will be proportional to $1:n:n^2$ [Black 2004]. That is to say, the number of journals in the first group will be equivalent to an unknown number of journals in the second group, n, and the third group will contain n^2 articles. Bradford's Law has been used over the years to assist library staff with selecting the most salient journals to subscribe to with a limited library budget. For example, if the library can only afford to subscribe to a single journal, Bradford's Law posits that the library can offer to its clientele approximately one-third of the available articles on a subject area (if it selects the appropriate journal).

Lotka's Law states that the number of authors making n contributions is approximately $1/n^a$ of those making one contribution, where "a" is often approximately two. What this means for 100 authors, who on average each write one article over a specific period of time, is that one author in the group will actually write 10 papers, five authors in the group will each write four papers, and 25 authors in the group who will each write two papers. In other words, Lotka's Law offers that a small number of researchers make a large contribution in the form of publications, a larger number make fewer contributions, and many more make a small number of contributions, or only one.

Zipf's Law states that given a comprehensive collection of writings on a specific subject, the frequency of any word in the collection is inversely proportional to its rank in the frequency table where the frequency table refers to a two-column table containing the rank in one column and the words in the comprehensive collection of writings in the other column (see Table 4 for an example).

RANK	**WORD**
1	the
2	of
3	and
. . .	aaa bbb ccc
n	xxx

Table 4: Example of a frequency table

Referring to Table 4, Zipf's Law estimates that the second most common word, "of", will occur 1/2 as often as the most common word, "the". The third most common word, "and", will occur 1/3 as often as the word "the". The n^{th} most common word (whatever it may be) will occur 1/n as often as the word "the".

For it to be useful, bibliographic data must be turned into bibliometric indicators, also known as bibliometric elements and units. Due to its standardization, the scientific paper published in refereed scientific journals has become the basic unit of bibliometric research [Glänzel 2003, 12]. Author or co-authors, article or paper titles, year of publication, journal titles, references, and citations are all examples of bibliometric elements. Virtually any publication can be examined bibliometrically [Hérubel 1999, 380].

There is evidence ([Porter 2009], [Porter and Cunningham 2004]) that bibliometrics can provide insight into the near future. An interesting example of this was provided in an article in the Calgary Herald on March 13, 2009. The article indicated that researchers from the University of Ottawa and Harvard Medical School found peak searching for the term "listeriosis" spiked in mid to late July 2008, almost a month before the public was officially told that a listeriosis outbreak had killed someone on August 20, 2008. The value in this information is that, as futures analysis tools become more generally accepted and advance in their application, there may become a way to avert situations such as the listeriosis crisis that ultimately arose and, in this case, to save lives. The application of bibliometrics to avert crisis situations is not currently happening. At present, researchers cannot even identify who was searching for the information about listeriosis, nor why [Kirkey 2008].

Although none of the three basic laws of bibliometrics are specifically helpful with respect to TFA, they are relevant to understanding the value of the information that can be obtained from a regimented search of bibliometric measures and are indicative of the roots of more sophisticated bibliometric approaches. Bibliometric measures were initially gathered and analyzed manually. However, with the availability of large bibliographic databases in machine-readable form and the evolution of computer technology, bibliometric programs have become available and continue to advance.

2.7.6.1 Research Profiling, Patent Analysis and Text Mining

The bibliometric method encompasses a variety of techniques – research profiling, tech mining, text mining, data mining, and patent analysis – all with a common goal of eliciting useful intelligence from sizable amounts of raw data. Research profiling refers to monitoring research development and ranking research performance. Tech mining is a newer term coined as a short form for "text mining of science [and] technology information resources" [Porter 2009, 1]. Text mining is distinguished from data mining in that the former is the mining of textual sources while the latter has commonly come to refer to the mining of numeric sources. Patent analysis refers to the specific dataset under investigation – patents – as opposed to a publication abstract database, etc.

Rodrigues [2001, 183] proposes an example of the hidden intelligence that can be obtained from reviewing the sizable amounts of raw information that form the life cycle of technological products. He asserts that the infancy of technological products is often marked by a peak in patents and technical reports, its commercial emergence by a peak in conference papers, and its maturity by a peak in journal articles, all measurable in many commercial databases.

2.7.6.2 Bibliometric software

Bibliometric software allows the user to move beyond the limitations of traditional manual, paper-based bibliometric research. The next sections describe five examples of bibliometric software which are available:

1. The Bibliometrics Toolbox [Glänzel 2003, 98];
2. Dataview [Glänzel 2003, 98] now Matheo Analyzer [Rostaing 2010];
3. Bibexcel [Glänzel 2003, 98];
4. BibTechMon^{TM} [Glänzel 2003, 98]
5. *TechOASIS*.

2.7.6.2.1 The Bibliometrics Toolbox

The Bibliometrics Toolbox is freeware created by Terrence A. Brookes. It consists of a set of computer programs written in Turbo Prolog under DOS 2.0 in the 1980s. The software measures the bibliometric aspects of “a literature”. A literature, according to the Bibliometrics Toolbox reference manual, is “a set of related documents usually about one topic.” An example of a literature would be a listing of all journals relevant to power systems engineering.

2.7.6.2.2 Dataview now Matheo Analyzer

Dataview was commercial software developed by the Centre de Recherche Rétrospective de Marseille (CRRM) of the Aix-Marseille III University, St. Jérome Centre, Marseilles, in France [Tarapanoff et al. 2001]. Per Glänzel, Dataview was designed as a software tool for experts of scientific and technological information processing [Glänzel 2003, 98]). Dou et al. [2005, 211] identify Dataview as bibliometric software which analyses patents according to the various patent fields available in a formatted patent database. When pricing information was sought for Dataview, the CRRM responded that Dataview has been redeveloped by Matheo Software; a company created by former CRRM PhD students. The software is marketed under the name Matheo Analyzer. Matheo Analyzer is a license subscription-based software program and a single-user license costs €3450 (approximately $4,850 at the exchange rate in existence on March 6, 2010).

2.7.6.2.3 Bibexcel

Bibexcel is freeware for academic non-profit use developed by Olle Persson, Inforsk, Umeå Univ (Sweden), and available at http://www8.umu.se/inforsk/Bibexcel/. Bibexcel was made public in 2000. The idea behind Bibexcel is to generate data files (multi-column tables of data) that can be imported to Microsoft Excel, or any program that takes tabbed data records, for further processing.

2.7.6.2.4 BibTechMon™

BibTechMon™ is a commercial product developed by the Austrian Research Centres Seibersdorf. Although numerous references were found referring to the use of the software for knowledge management[12] purposes ([Noll and Frölich 2002], [Kopcsa 1999], [Hörlesberger and Schiebel 2004], [Kasztler and Leitner 2002]), none were found referring to its use for TFA purposes. BibTechMon™ costs €14,900 (approximately $20,680 at the exchange rate in existence on March 17, 2010).

2.7.6.2.5 TechOASIS

TechOASIS is the software that Alan L. Porter and Scott W. Cunningham used for the examples in their book *Tech Mining: Exploiting New Technologies for Competitive Advantage* [Porter and Cunningham 2004, 39]. It is software that the two describe as the "twin" version of *VantagePoint* software. A single seat/user license for VantagePoint costs US$7,500 [VantagePoint 2009]. The product is described on its website (www.thevantagepoint.com) as having capabilities that can be broadly classified into five categories: importing (getting the raw data into the software and mining the raw data to get more data from it), cleaning (transforming the data into a consistent set, combining the relevant data into a

---

[12] Knowledge management (KM) is the design, implementation, and maintenance of a strategy for maximizing the value of knowledge capital where knowledge capital is what people know and can do that is expected to produce value. Knowledge capital has two components: information capital (IC) and human capital (HC) [Nasseri 2004].

group, and merging and normalizing the data from diverse sources), analyzing, reporting, and automating ("encoding the entire process to make it consistently and easily repeatable").

TechOASIS is a specially branded version of VantagePoint, exclusively available to agencies of the United States government. According to Dou et al. [2005, 212]: "VantagePoint provides Competitive Technical Intelligence professionals and Technology Managers with new, powerful, and unique capabilities to help extract knowledge from text databases". Note the focus on competitive technical intelligence as opposed to TFA. Competitive technical intelligence implies an investigation targeted at specific competitors as opposed to an open investigation of the future of a technology or technologies.

2.7.7 Brainstorming [brainwriting; nominal group process (NGP)]

Brainstorming is a fairly common concept, usually performed in a group, whereby as many solutions as possible are presented as quickly as possible for a particular problem. The solutions generated should ideally be as broad as possible and include solutions which may be considered radical or odd if one were given the time to analyze them (ideas should only be evaluated once the brainstorming session has been completed). Brainstorming is designed to open up possibilities and to break down wrong assumptions about the limits of the problem.

2.7.7.1 Brainwriting

Brainwriting is the silent, written generation of ideas in a group. According to Arthur B. VanGundy, there are two basic types:

1. *nominal ideas in a group that are not shared with other group members while generating ideas and,*
2. *interacting ideas that are shared for additional stimulation* [VanGundy 2005].

Although multiple variations exist, one example of nominal brainwriting would be for a group of people to write down ideas on index cards. At the end of a set period of time, such as 10 – 15 minutes, the cards are collected, organized into groups, and evaluated. One example of interacting brainwriting would be if the participants in the session, after writing an idea on an index card, passed that card to the person next to them. The person receiving the card has three options as to what to do with the idea written on the card. He may use the other's idea as a stimulus for a new idea, use the other's idea to think of a modification, or simply pass the card on to the next person.

2.7.7.2 Nominal Group Process

The nominal group process (NGP) is a formalized 4-step process that group members must agree to follow. It is designed to ensure that all group members have the opportunity to contribute ideas and that discussions are not dominated by a few individuals. The process involves a facilitator who guides the group through the following steps:

1. *Each team member, in turn, makes a suggestion for one of the items of interest (e.g., a barrier to implementation or a possible metric to monitor).*

The facilitator gives all members a chance to offer suggestions before discussion on any of the proposed items.

2. *Then rank the items in order of priority. To do this, the facilitator asks each team member to identify the 3 to 5 items that he/she thinks are most important. Tally the counts of votes as each member reports their candidates.*
3. *After the ranking is completed, the team members identify items where they disagree and discuss the merits of each item. NOTE: An alternative approach is to reverse the order of steps 2 and 3, so that the group discusses the items briefly before ranking them, discarding any that the team agrees are not appropriate. This discussion should be limited in length, serving to identify issues that team members should consider as they do their rankings.*
4. *The team reviews the priority list to assess how acceptable it is to the group and to identify any break-off points where a "cluster" of items clearly are rated more highly than the remaining items. If these results are not acceptable to the team, repeat the ranking process (steps 2 and 3)* [RAND 2005].

2.7.8 Causal models

Causal models are the answer to the rational and explicit technology forecasting methods such as analogies, trend extrapolation, and correlation analysis which are unable to warn the forecaster that there has already been a significant change in the conditions that produced past behaviour and that therefore this behaviour will not continue. Causal models take causal factors into account and relate technological change to the specific factors that produce it. Unfortunately, existing theories of technological change are not adequate to allow development of elaborate and precise models. Three types of models that are currently in use are:

1. Technology-only models which attempt to forecast technological change on the basis of factors internal to the system that produces technological change;

2. Technoeconomic models that assume the technology is driven by economic factors;
3. Simulation models that include relevant portions of the social and economic system in which the technologies are being developed.

2.7.9 Checklists for impact identification

No reference was supplied by the TFAMWG in their paper “Technology futures analysis: Toward integration of the field and new methods” for “checklists for impact identification”. However, it is likely that the two sets of checklists provided in Table 5 are good examples of “checklists for impact identification”. They are examples of the content of the checklists used by the United Kingdom’s Department for International Development[13] in the process of environmental appraisal.

[13] The Department for International Development (DFID) is the part of the UK Government that manages Britain's aid to poor countries and works to get rid of extreme poverty.

Screening Checklists
□ ***Environmental Features***
Areas containing rare or endangered species
National parks, nature reserves, Etc.
Habitats providing important resources for vulnerable groups
Moist or dry tropical and sub-tropical forest
□ ***Development Features***
Important policy changes likely to affect the environment
Major changes in land tenure or use
Substantial changes in water use
Large infrastructure projects
□ ***Potential adverse and beneficial effects***
Livelihoods
Culture
Land management
Water quality and quantity
Local air quality
Global impacts
Conservation
□ ***Impact characterisation***
Is the impact beneficial, benign or harmful?
What is the scale and intensity of impact?
Are effects irreversible?
Are the effects due to construction and/or operations?
Are the effects likely to be politically or socially controversial?
Will there be different effects on different members of society?
What are the timescales of impact?
Checklists for Policy Approvers and Decision-makers
□ ***Project setting***
Have underlying causes of environmental damage been considered?
Would these underlying causes be better addressed by other means?
□ ***Impact identification***
Is there any effect on environmentally sensitive or important areas?
Have the environmental and social risks been evaluated?
Have indirect effects been addressed?
□ ***Mitigation measures***
What mitigation measures are proposed?
What measures will be taken to enhance environmental benefits?
What consultation was there with concerned stakeholders?
□ ***Procedures***
Have appropriate guidelines been followed?
Have the beneficial and adverse environmental effects been integrated into the economic analysis?
Have the appropriate authorities been consulted?
□ ***Implementation***
Do local institutions need strengthening in order to effect the environmental measures?
Who will monitor the environmental impact?
Have environmental measures been costed, and funds allocated?

Table 5: Example Checklists for Impact Identification

"The process of impact identification is based upon an appreciation of how the proposed project might interact with its receiving environment" [Fouracre 2008, 4] and the checklists "seek to determine the nature of the proposed development, the sensitivity/importance of the local environment, and the likely environmental effects and their scale" [Fouracre 2008, 4].

2.7.10 Complex adaptive system (CAS) modeling

> *A complex adaptive system is a large set of objects that interact with each other and with an external environment to produce overall patterns that are significantly more complex than the behaviors of the individual objects of the system. The objects of such a system are usually called agents. Thus, a complex adaptive system is one in which many independent agents interact with each other in many ways. The richness and volume of these interactions allows a complex system as a whole to undergo spontaneous self-organization* [Koppl 2005].

Figure 1 shows a complex adaptive system. It should be noted that, although pattern and feedback are shown above the regularities – and could be mistaken for being outside the system – in reality, they are all intrinsic parts of the system.

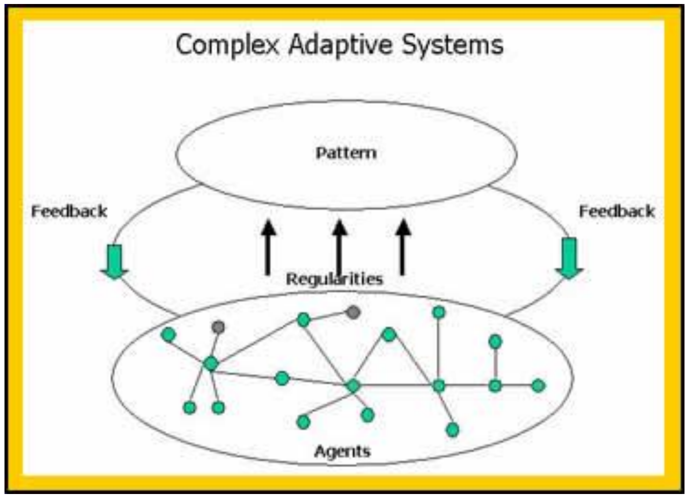


Figure 1: Complex Adaptive Systems
[Fryer 2005]

2.7.11 Correlation analysis

Sometimes it is easier to forecast something that correlates with something you would like to forecast than it is to forecast the something you would like to forecast itself. This is the theory behind correlation analysis. For example, Martino, in *Technological Forecasting for Decision Making*, reports that there is a constant relationship between total industry capacity and the size of the largest single installation in many industries (e.g., in 1983 when Martino published his book, there was a correlation between the total installed steam turbine capacity in the United States and the maximum size of a single steam turbine electric generator). This would allow one to forecast the largest size of a steam turbine electric generator based on the forecast total industry capacity.

2.7.12 Cost-benefit analysis

The features of cost-benefit analysis (CBA) include: "…a systematic cataloging of impacts as benefits (pros) and costs (cons), valuing in dollars (assigning weights), and determining the net benefits of the proposal relative to the status quo (net benefits equal benefits minus costs)" [Boardman et al. 2001, 1]. Since cost-benefit analysis tries to consider all of the costs and benefits to society as a whole, it is also frequently called *social* cost-benefit analysis. "The broad purpose of CBA is to help social decision making. More specifically, the objective is to facilitate more efficient allocation of society's resources" [Boardman et al. 2001, 1]. CBA applies to policies, programs, projects, regulations, demonstrations, and other government interventions.

2.7.13 Creativity workshops or future workshops

Future workshops were developed by a social inventor named Robert Jungk in 1962 and are popular in Europe. "The Future Workshop helps small groups of people to dream up and implement creative ideas and projects for a saner society" [The Global Ideas Bank 2005]. This method is best suited to addressing *social* change using those participants interested in participating in the social change.

2.7.14 Cross-impact method

> *The cross-impact method is an analytical approach to the probabilities of an item in a forecasted set…An event without a predecessor that made it more or less likely or that influenced its form is hard to imagine – or to imagine an event that, after occurring, left no mark. This interrelationship between events and developments is called 'cross-impact'* [Gordon 2009a, 4].

The first step in the cross-impact method is to compile an initial set of events by conducting a literature search and interviewing key experts in the relevant field. The second step is to estimate the initial probability of each event.

2.7.15 Decision analysis

> *The purpose of decision analysis is to help a decision maker think systematically about complex problems and to improve the quality of the resulting decisions* [Clemen 1996, 10].

Figure 2 shows a flowchart for the decision-analysis process. Decision analysis is typically an iterative process. As the arrows depict, as one investigates the alternatives and models the problem, insights are gained which may make it necessary to adjust previous assessments.

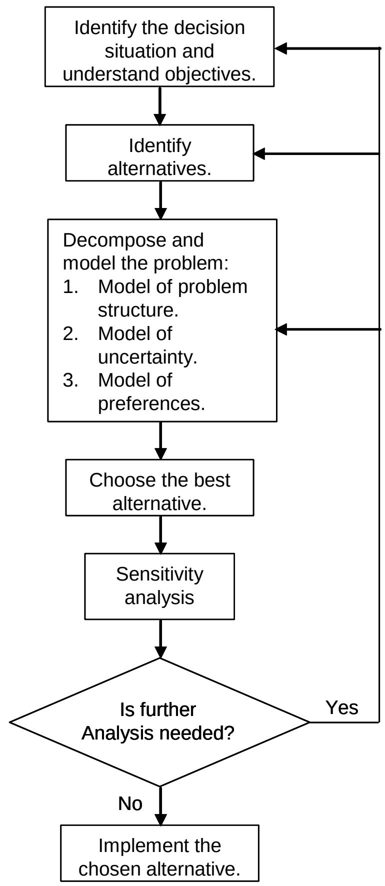


Figure 2: A decision-analysis process flowchart
[Clemen 1996, 6]

2.7.16 Delphi method

The Delphi method is characterized by two irreducible elements: anonymity and feedback [Gordon 2009i, 1]. To conduct a Delphi, experts from the required disciplines are identified and asked to participate in a series of questionnaires. The first questionnaire will ask the experts the specific question that the researchers are seeking an answer for and the experts will be asked to respond. Based on the experts' responses, a range of answers will be determined. In the second questionnaire this range is presented to the experts and those experts holding extreme views (those on the upper end and those on the lower end of the range) are asked to reassess their opinion in view of the group's range and to provide reasons for their positions. Since anonymity is assured, no expert needs to feel self conscious about adjusting his opinion. The third questionnaire will contain the reasons along with the new range. Each expert is asked to adjust his or her opinion based on the new range and the reasons or to provide contradictory evidence to any or all of the reasons. In a fourth and final round the contradictory evidence is presented along with the revised range and a reassessment requested.

A Delphi allows for the exploration of issues that require judgment in an objective way, independent of personalities. However, because the number of respondents is small, Delphis do not (and are not intended to) produce statistically significant results [Gordon 2009i, 4]. Delphis are also difficult to perform (since the questions must be prepared very carefully to avoid ambiguity) and they are time intensive (a single round may take three weeks and a three-round Delphi is likely to take three to four months) [Gordon 2009i, 10, 11]. A recent critique of the method is that the results may be negatively influenced due to the pressure brought upon participants who hold extreme opinions [Gordon 2009i, 10, 11]. Additionally, since those with extreme opinions are required to defend their opinions, they must work harder to participate in the Delphi and may be tempted to take the easier route of simply shifting views to match the majority [Gordon 2009i, 10, 11]. Since its inception a further critique of the method is whether or not the foresight of experts and, especially, of self-rated experts, is superior to that of others [Tichy 2004, 341].

2.7.17 Demographics

The TFAMWG [2004, 290] identify demographics as a TFA method, but provide no reference "that can serve as a starting point for obtaining more details", as they do for the other methods they identify. Demographics is not identified as a foresight method in other literature. Specifically, demographics is not among the over thirty methods described in The Millennium Project's *Futures Research Methodology 3.0*[14] compact disk. As a result, the following definition is only supposition of what Porter et al. intended.

Formal demography is the study of population structure and change [Hinde 1998, 1]. The broader field of *population studies* expands on the demographer's domain to include the study of population dynamics and a wide range of economic, social, cultural, and biological characteristics [Hinde 1998, 1]. For demographics to be of use for technology foresight, it is assumed that Porter et al. intended the broader field of population studies. The Population Reference Bureau[15], for example, uses data it obtains to link population, health, and environmental issues. It believes that

[14] According to the Millennium Project, *Futures Research Methodology 3.0* "is the largest internationally peer-reviewed collection of methods to explore the future ever assembled in one resource" [Glenn, Gordon and Florescu 2011].

[15] Founded in 1929, the Population Reference Bureau provides information on U.S. and international population trends and their implications. It is located in Washington, D.C. and is funded through government contracts, foundation grants, individual and corporate contributions, and the sale of publications.

consumption patterns, development choices, wealth and land distribution, government policies, and technology can mediate or exacerbate the effects of demographics on the environment [Nash and De Souza 2002, 1].

Demographics have been in the popular culture for some time. Canadian demographics expert, David K. Foote, wrote the Canadian best-seller *Boom, Bust and Echo* published in 1996. It has since been updated to *Boom, Bust and Echo: Profiting from the Demographic Shift in the 21st Century*.

2.7.18 Diffusion modeling

Diffusion is the process by which innovations are disseminated among members of a market [Armstrong and Yokum 2001, 94]. Aiding in the development of models to reflect how innovations are disseminated are the seven characteristics identified by Rogers [1995, 15] that he attributes to the adoption of innovations. These are presented in Table 6.

1.	Relative advantage	- whether the proposed technology is superior to the current technology;
2.	Compatibility	- whether the technology fits in with the prior experiences and existing behaviour of the potential adopters;
3.	Divisibility	- the degree to which the adopter can experiment with the technology;
4.	Communicability	- the ease with which the technology can be described to potential users;
5.	Complexity	- the extent to which the technology is difficult to understand or use;
6.	Product risks	- relates to the use of the product (e.g., whether the technology may break down in critical situations); and
7.	Psychological risks	- the reactions (real or perceived) of peer groups.

Table 6: The 7 characteristics affecting innovation adoption
[developed from Armstrong and Yokum 2001, 94]

Edwin Mansfield in his 1961 paper, “Technical change and the rate of imitation”, introduced a model that was built around the hypothesis that “…the probability that a firm will introduce a new technique is an increasing function of the proportion of firms already using it and the profitability of doing so, but a decreasing function of the size of the investment required” [Mansfield 1961, 763]. One of the weaknesses of the model is that it was tested on only twelve innovations and how rapidly they spread from enterprise to enterprise in only four industries.

In 1969, Frank Bass proposed a model for forecasting the diffusion of new consumer products. “The Bass Model”, as it is known, assumes that potential adopters of an innovation are influenced by two types of communication channels: (1) mass media and (2) interpersonal channels. It predicts “…how many adoptions of a new product will occur at future time periods, or on the basis of pilot launches of a new product, or from managerial judgments made on the basis of the diffusion history of analogous products.” [Rogers 1995, 209]

> *One of the most serious shortcomings of diffusion research is its pro-innovation bias…The pro-innovation bias is the implication in diffusion research that an innovation should be diffused and adopted by all members of a social system, that it should be diffused more rapidly, and that the innovation should be neither re-invented nor rejected* [Rogers 1995, 106].

The risk arising from this bias is that diffusion researchers may underemphasize the rejection or discontinuance of innovations.

Three other shortcomings of diffusion research exist. The first is that memories can be faulty with respect to the recall of respondents regarding their date of adoption of an innovation, which may lead to inaccuracies in the model. The second is that there is a tendency to hold an individual responsible for his or her problems, rather than the system of which the individual is a part (the *individual-blame bias*). For example, late adopters or laggards can be labeled “traditionally resistant to change” and/or irrational, but “a more careful analysis might show that the innovation is not as appropriate for these later adopters, perhaps because of their smaller-sized operations and more limited resources. In fact, for them, *not* adopting may be extremely rational” [Rogers 1995, 121]. Finally, the consideration that socioeconomic gaps among the members of a social system are often widened as a result of the spread of new ideas is often omitted.

2.7.19 Economic base modeling [input-output analysis]

Economic base is a theory for understanding a local economy that breaks that economy into a “basic” and a “non-basic” sector. A basic sector is composed of firms and parts of firms whose economic activity is dependent on factors external to the local economy. A non-basic sector is that part of the local economy that consists of firms and parts of firms whose economic activity is dependent on local economic conditions.

2.7.19.1 Input-output analysis

Input-output is based on a fundamental identity which equates supply and demand. Supply or sectoral output X, must equal Y (final demand) + Z (intermediate demand). On the production side, the output X is produced by combining intermediate inputs Z and primary inputs W. If we assume a very simple production function then X is produced using fixed proportions of intermediate inputs, that is $X_i = \frac{z_{ij}}{a_{ij}}$ *. On the one hand the above implies the identity X=AX+Y. On the other hand it implies the identity X=AX+W* [Johnson n.d.].

Input-output analysis is:

a technique used in economics for tracing resources and products within an economy. The system of producers and consumers is divided into different branches, which are defined in terms of the resources they require as inputs and what they produce as outputs. The quantities of input and output for a given time period, usually expressed in monetary terms, are entered into an input-output matrix within which one can analyse what happens within and across various sectors of an economy where growth and decline takes place and what effects various subsidies may have [Krippendorff 1986].

2.7.20 Field Anomaly Relaxation method (FAR)

The FAR method was developed in 1970 by Rhyne.

The starting point of Field Anomaly Relaxation (FAR) is Lewin's social field theory to the effect that we all live within 'fields' of interactions with other people and events. For example, someone's personal 'field' might include such as [sic] factors as interest rates on the mortgage, a change of government which might affect taxes, a choice between going on holiday to one place or another, an interest in genealogy and so on for myriad aspects such as the fact that Aunt Mabel's cat had kittens last week but one died. The field is infinitely fine-grained, even down to the detail of why the kitten died [Coyle 2009, 2].

FAR is a four-step process as outlined in Figure 3:

Step 1 requires a team of those charged with answering the strategic question to develop some kind of imaginative views of the future into which the decision must unfold.

Step 2 requires the team to identify the critical uncertainties and their ranges of possibility, expressed in a matrix.

Step 3 eliminates the anomalies.

Step 4 strings the surviving configurations together to form time lines.

The "relaxation" part of the method involves completing the four-step process a second time, using the knowledge gained from Step 4 of the previous cycle of the steps. The output of this method is a collection of short stories: typically four but may range up to ten.

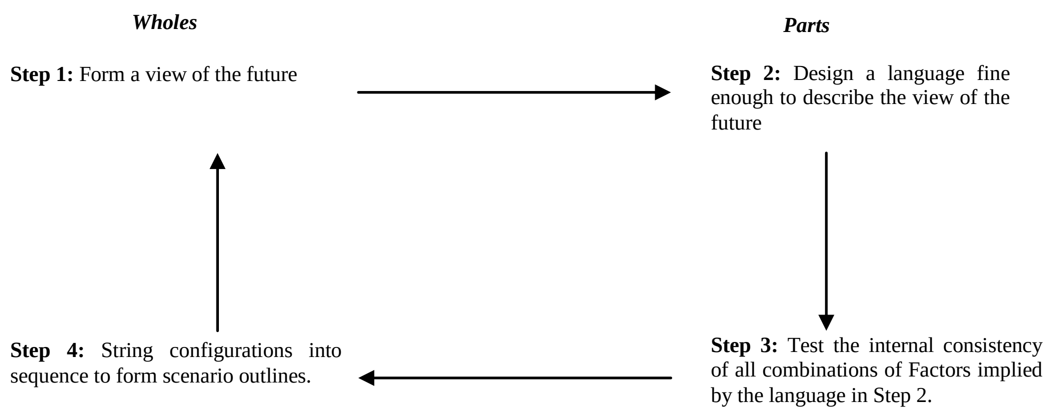


Figure 3: The FAR cycle (after Rhyne)
[Coyle 2009, 3]

Another way to describe the "short stories" that result from the FAR method is to call them "scenarios". Another method by which one arrives at scenarios, is (not surprisingly), using the scenarios method (see 2.7.37).

2.7.21 Innovation system modeling

"The conceptual foundation upon which technological forecasting rests is a degree of orderliness in the innovation process" [Watts and Porter 1997, 25]. Innovation system modeling refers to the process of creating a model to describe how innovation occurs. There are two major approaches:

> *the first one is based on the analysis of innovation processes and attempts to understand better the dynamics of sociotechnological innovation processes. The second approach focuses on the analysis of systems and is used to search for ways of deepening the level of understanding of the genesis of new organizations (institutions, structures, systems)* [Smits 2002, 875].

2.7.22 Institutional analysis

In the context of institutional analysis, an institution is a group of individuals (i.e., organizations) whose collective activities have a bearing on the technological delivery system (e.g., governmental agencies, special interest groups, cultural organizations). The first step in institutional analysis is to identify the formal organizations involved and their characteristics (their statutory authority with respect to the technology of interest, their mode of operation, how they interact with other institutions, where they get their funding, etc.). The second step is to do the same for informal organizations involved. The third step is to analyze the effectiveness of the various institutions, both on an individual basis and as part of a system; with respect to the implementation of the technology of interest. In the fourth step, new institutional options are generated that are deemed to be more conducive to the implementation of the technology of interest and the political realities associated with these options are explored. The final step is to evaluate "the combinations of technological and institutional options: include the baseline institutional case and the no-action technological option. Identify the sequence of institutional actions and the time needed for implementation of the technological options" [Porter et al. 1980, 342 - 343].

> *Institutional impacts are troublesome to document and also highly sensitive because institutions act to protect their interests* [Porter et al. 1980, 344].

2.7.23 Interviews

Popper [2008, 88] starts his description of the interview method by stating that interviews are a fundamental tool of social research, but that in this field they are often described as "structured conversations". He goes on to indicate that "in foresight they are often used as formal consultation instruments, intended to gather knowledge that is distributed across the range of interviewees."

2.7.24 Long wave analysis

Long wave analysis is based on Kondratieff waves or K-waves, for short. These are defined as a pattern of alternation between periods of high sectoral growth and periods of low sectoral growth in the economy (i.e., the cycle of economic prosperity-recession-depression-recovery). They are approximately 50 to 60 years in length and it is believed that the study of the pattern they create aids in political and economic predictions [Modelski 2005]. Nikolai Kondratieff was a Russian economist who was executed by the Stalin government in 1938 because it disapproved of evidence that there might be forces beyond its control. According to the paper, “Corporate planning, forecasting, and the long wave”, a long wave pattern has existed over the last 200 years [Linstone 2002, 317].

Figure 4 represents the work of many authors and there are, therefore, minor date variations and the years given at the top of the figure should be considered approximate. The pattern consists of an upswing or growth phase in which innovations created in the preceding downswing are exploited and mainly incremental improvements occur; followed by a down-swing in which creative destruction occurs and innovative knowledge accumulates.

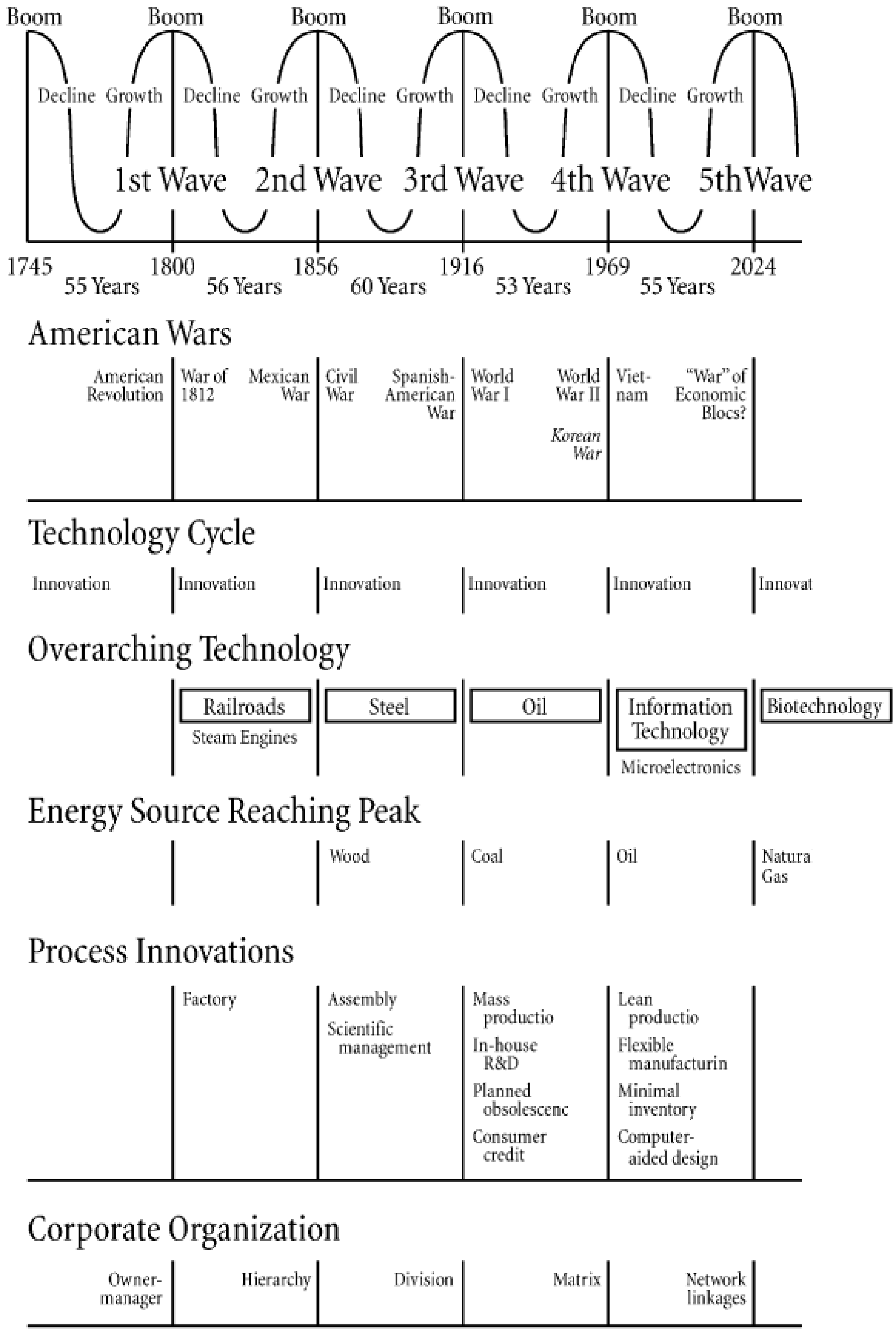


Figure 4: Long wave cycles
[Linstone 2002, 318] Used with permission

2.7.25 Mitigation analysis

No definition of this method was found.

2.7.26 Morphological analysis

> *The purpose of morphology is to organize information in a relevant and useful way in order to help solve a problem or stimulate new ways of thinking* [The Futures Group International 2003, 6].

Morphological analysis involves mapping options to obtain an overall perspective of possible solutions.

> *Morphological analysis is a foresighting method that creates a list of all of the possible combinations of the characteristics or 'shapes' of a given object (e.g., a new material) in order to determine different categories of application or effect…For example, even though cardboard was developed as a material for packaging, a morphological analysis would evaluate that given its strength, density, and other properties it could also be used for sound insulation, heat insulation, and other applications (Wissema, 1982)* [Skumanich and Silbernagel 1997, 3].

> *The limitation of morphological analysis is that while it examines the possible applications and developments of an object, it cannot address the likelihood of these futures based on current realities, such as funding resources or markets* [Skumanich and Silbernagel 1997, 3].

2.7.27 Multicriteria decision analyses

> *In multicriteria analysis the emphasis is on the comparison of alternatives which are viewed as options for further actions. This is in contrast to Delphi studies, for instance where the topics do not correspond to alternatives in the same sense but, rather, descriptions about potential future developments* [Salo, Gustafsson, and Ramanathan 2003, 238].

Although there are a number of different types of multicriteria decision analysis, all types follow a similar process as illustrated in Figure 5 [Salo, Gustafsson, and Ramanathan 2003].

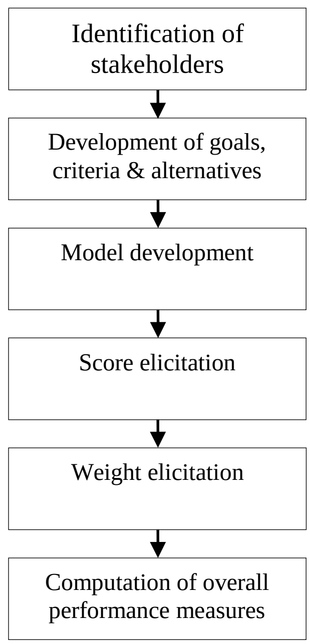


Figure 5: Phases in Multicriteria Analysis

The first phase of the process involves the identification of representatives from relevant stakeholder groups. Relevant stakeholder groups typically include policy makers, research and technology development managers, and science and technology experts. Depending on the decision, stakeholders may also include representatives from non-governmental organizations or members of the general public.

In the second phase of the process the stakeholders identified from the first phase are consulted to define: (1) the goal, (2) the criteria through which the attainment of the goal is measured (ideally the criteria are mutually exclusive and collectively exhaustive), and (3) the alternatives among which choices are made. The goal refers to the fundamental problem objective such as to identify technologies that are expected to contribute to long-term industrial competitiveness.

In the third phase a model is created by identifying the goal as the topmost element and working down from there in a hierarchical fashion through criteria and sub-criteria. In most techniques a measurement scale is defined for each lowest-level criterion.

Having developed a measurement system, the fourth phase involves scoring the various alternatives based on the lowest-level criteria. Phase five, weight elicitation, is where multicriteria techniques differ the most from each other. This phase involves determining the relative importance of the criteria to each other and can be assessed by an individual, by a group whose members act independently, or by a group whose members work together. The criteria weights are typically normalized so that they add up to one.

Finally, the results from score and weight elicitation are combined to derive an aggregate performance measure (or value) for each alternative.

2.7.28 Multiple Perspectives Assessment

Multiple perspectives assessment, as its name implies, examines a specific problem from three classes of perspectives: the technical (T), the organizational (O), and the personal (P).

Table 7 provides a comparison of the perspectives to each other.

	Technical (T)	Organizational (O)	Personal (P)
World view	Science-technology	Unique group or institutional view	Individual, the self
Objective	Problem solving, product	Action, process, stability	Power, influence, prestige
System focus	Artificial construct	Social	Genetic, psychological
Mode of inquiry	Observation, analysis, data and models	Consensual, adversary, bargaining and compromise	Intuition, learning, experience
Ethical basis	Logic, rationality	Justice, fairness	Morality
Planning horizon	Far (low discounting)	Intermediate (moderate discounting)	Short for most (high discounting for most)
Other descriptors	Cause and effect	Agenda (problem of the moment)	Challenges and response, leaders and followers
	Optimization, cost-benefit analysis	Satisfying	Ability to cope with only a few alternatives
	Quantification, trade-offs	Incremental change	Fear of change
	Use of probabilities, averages, statistical, analysis, expected value	Reliance on experts, internal training of practitioners	Need for beliefs, illusions, misperception of probabilities
	Problem simplified, idealized	Problem delegated and issues and crisis management factored	Hierarchy of individual needs (survival to self-fulfillment)
	Need for validation replicability	Need for standard operating procedures, routinization	Need to filter out inconsistent images
	Conceptualization, theories	Reasonableness	Creativity and vision by the few, improvisation
	Uncertainties noted	Uncertainty used for organizational self-preservation	Need for certainty
Criteria for "acceptable risk"	Logical soundness, openness to evaluation	Institutional compatibility, political acceptability, practicality	Conduciveness to learning, time-space distance to event
Scenario types	Probable	Preferable	Possible
Criterion	analytic (reproducible)	value	image
Orientation	exploratory (extrapolative)	Normative (prescriptive)	Visionary
Mode	structural	participatory	perceptual
Creator	think-tank teams	stakeholders	Individuals
Communications	Technical reporting, briefing	Insider language	Personality, charisma desirable

Table 7: Characteristics of multiple perspectives
[Linstone 2009, 8]

There is much flexibility in applying the multiple perspectives concept, but five key guidelines should be observed:

1. *T, O, and P together form a superior basis for decision making than T alone…*
2. *The choice of perspectives requires judgment; it is usually not possible to consider all perspectives. A good balance among the three types is always desirable, but there exists no 'correct' weighting formula…*
3. *O and P are case-specific. Obtaining input for O and P uses different processes than it does for T…*

4. *Perspectives are dynamic and change over time. A decision process may involve different actors and different issues as it proceeds. This makes it advantageous to undertake development of the various perspectives in parallel and consider subsequent iterations.*
5. *T usually dominates in the planning phase, O and P dominate in the decision and implementation phases…* [Linstone 2009, 10].

The process by which input for the O and P perspectives is obtained can vary, but it is frequently done in personal interviews and it is most desirable to obtain input from individuals who have distinctly different backgrounds. Multiple perspectives assessment was initially developed to assist with decisions in technology management, and the application of the concept results in the collector of the three perspectives presenting the perspectives to the decision maker, such as a CEO, and allowing her to do the integration.

2.7.29 Organizational analysis

Organizational analysis has traditionally been concerned with three distinct areas: organization theory, organization behavior and strategic management. The former examines the design and structure of organizations; the complementary processes of differentiation (the division of labor and the grouping of functions) and integration (the distribution of authority); the relationship between organizations and their social, political, institutional, and economic environments; and the nature and role of politics, power, and conflict that may result from inherent tensions in coordinating a range of disparate functions and interests. The focus of organizational behavior is human behavior in a variety of settings within work organizations, the extent to which management is able to influence this, how this might be achieved and with what effects. Strategic management has as its focus an analysis of the organization in its environment, examining the processes by which organizations position themselves and seek to marshal resources and capabilities to support and implement strategies. It is concerned with how organizations match, or fail to match, organizational capabilities and strengths with external opportunities and constraints [U of A 2005].

2.7.30 Participatory method

…the purpose of participatory processes is to improve decision making [Glenn 2009b, 5].

As the name suggests, a participatory method is one in which a group (large or small) meets face-to-face in one location or uses communications technology to connect from a variety of places to take part in the development of either a possible or a desirable future.

There are a variety of participatory techniques: focus groups and opinion polling, charrette, Syncon, public Delphi, and groupware [Glenn 2009b] which will be described in the following sections.

2.7.30.1 Focus groups and opinion polling

Focus groups are usually conducted by a facilitator who guides the conversation amongst a small group of respondents (typically 8 to 12 people) covering a wide spectrum of people. The discussion topic or topics are pre-selected based on what the focus group host wishes to learn and the discussions are typically an hour and a half in length. Respondents are encouraged to provide their uncensored opinions on the topic or topics and additional topics can be added spontaneously by the facilitator based on the context of the discussion. The facilitator has the opportunity to seek additional details regarding the respondents' feedback when deemed necessary.

The pros of a participatory technique such as focus groups are that in-depth views are received from a specific sample of people and as well as finding out what people want, they also elicit how and why they want it. "This is an excellent technique to explore what futures are more desirable and why, what are the key impediments to achieving that future and how" [Glenn 2009b, 24].

A con of the focus group technique is that if integrity is not maintained and the process is manipulated to force a previously decided conclusion or a conclusion specific to a special interest group, not only will the participants feel used and betrayed, but the output of the process is of no value. Because of the requirement for a qualified facilitator, focus groups can be expensive on a per person involved basis. Other issues with this technique include: how to involve a shy participant, how to counteract the impact of cliques, and how to make participants comfortable enough to express private thoughts in public.

Opinion polling differs from focus groups in that "Focus groups are usually conducted by a researcher or trained group leader who guides the conversation among a small group of respondents" [Glenn 2009b, 5] whereas "an opinion poll or survey asks specific questions of a random sample or a specific quota of the public" [Glenn 2009b, 5].

2.7.30.2 Charrette

"Charrette is an intensive face-to-face process carefully designed to bring people from various segments of society into consensus within a short period of time" [Glenn 2009b, 5]. Prior to the meeting, the main issue is broken into its component parts. Each part is given to a group of people who are expected to report back to the whole. Feedback from the whole is used as input to the next round of group discussion. “This sequence is repeated until consensus is reached at the final deadline for a report of the whole to whomever - the news media, government officials, or the larger public drawn to the final event through media coverage of the process. Charrettes vary in size, from 50 to over 1,000 people, and in time, from one day to two weeks [Glenn 2009b, 5].

2.7.30.3 Syncon

Syncon, which is a contraction of Synergetic Convergence, “is the most future-oriented and holistic of the participatory processes” [Glenn 2009b, 6]. The Syncon process is based on the Syncon Wheel (see Figure 6).

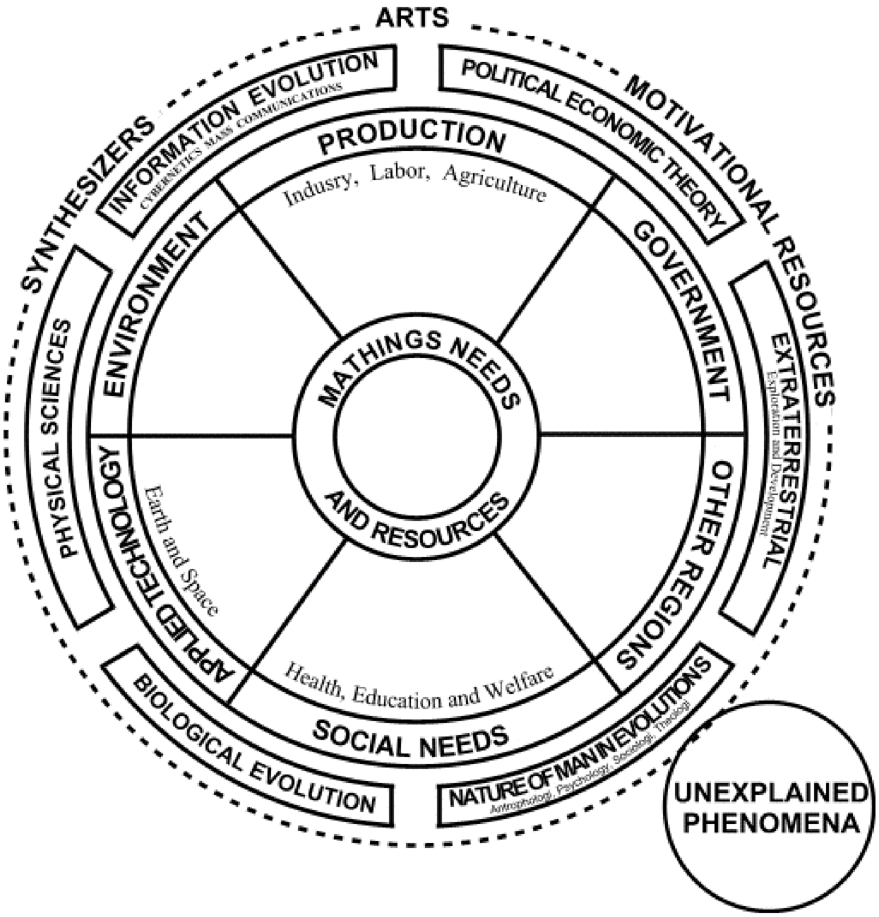


Figure 6: The SYNCON Wheel
[Glenn 2009b, 7] Used with permission

> *The process begins with small groups, merges to larger composite groups, and finally becomes one total group. This sequence occurs inside a huge pre-designed wheel-like environment highlighting our present fragmented society. Removable walls between groups are spokes of the wheel. The inner sections of the wheel - social needs, technology, environment, government, production, and other regions - represent functional areas of any culture, nation, or community. The outer sections represent the 'growing edge' of future potentials in biology, physics, information, extraterrestrial, political/economic theory, human nature, the arts, and unexplained phenomena. This three-and-one-half-day process is usually on live television with computer communications to link those unable to be present at the Syncon location* [Glenn 2009b, 7].

2.7.30.4 Public Delphi

Although a Delphi is usually conducted among a preselected and carefully screened panel of experts (see 2.7.16), it can also be conducted using the general public and contact made through the Internet, newspapers, or radio [Glenn 2009b, 9].

2.7.30.5 Groupware

Groupware is computer software that connects groups of people to collaborate on the same project [Glenn 2009b, 10]. When groupware is used specifically as a participatory decision system, it is referred to as a "group decision support system (GDSS)" [Glenn 2009b, 10].

2.7.31 Precursor analysis

> *Precursor analysis, the evaluation of 'near misses,' has been an activity of the Nuclear Regulatory Commission for almost twenty years* [Borgonovo et al. 2005].

The theory behind precursor analysis is that there are precursor events which make it possible to predict the eventual breakthrough of new technologies, or – in the case of a nuclear reactor – an accident. Forecasting a technological breakthrough (or accident), therefore, requires that precursor events be identified. Signs of precursor events are to be gleaned from as wide a range of sources as possible since breakthrough signals often occur in areas remote from the final application.

2.7.32 Relevance trees [futures wheel]

Relevance trees can be used to identify problems and solutions and to deduce the performance requirements of specific technologies. They can also be used to determine the relative importance of efforts to increase technological performance.

> *The methodology of relevance trees requires that the planner determine the most appropriate path of the tree by arranging, in a hierarchical order, the objectives, subobjectives, and tasks in order to ensure that all possible ways of achieving the objectives have been found. The relevance of individual tasks and subobjectives to the overall objective is then evaluated* [Wiley W.A.V.E. 2005].

Figure 7 provides an example of a relevance tree created for the purpose of developing a means of air pollution control.

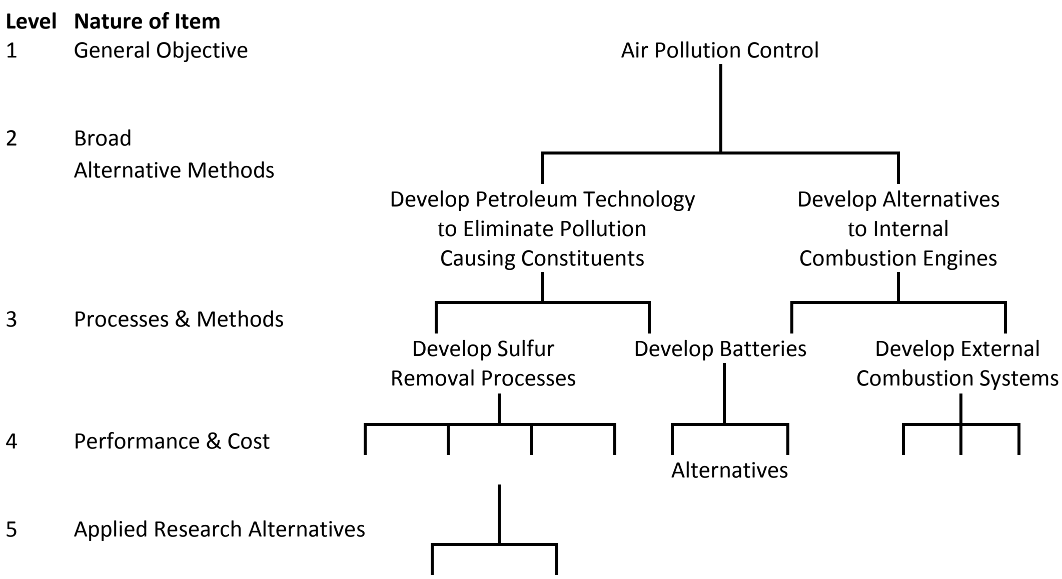


Figure 7: A relevance tree for pollution control
[Martino 1983, 39]

2.7.32.1 Futures Wheel

To construct a futures wheel:

> *the name of a trend or event is written in the middle of a piece of paper; then small strokes are drawn wheel-like from the center. Primary impacts or consequences are written at the end of each spoke. Next, the secondary impacts of each primary impact form a second ring of the wheel. This ripple effect continues until a useful picture of the implications of the event or trend is clear* [Glenn 2009c, 2].

2.7.33 Requirements analysis

Requirements Analysis comes from the software development world. According to SearchSoftwareQuality.com:

> *Requirements analysis, also called requirements engineering, is the process of determining user expectations for a new or modified product. These features, called requirements, must be quantifiable, relevant and detailed* [SearchSoftwareQuality.com 2008].

2.7.34 Risk analysis

According to the Society for Risk Analysis, the definition of risk analysis is:

> *a detailed examination including risk assessment, risk evaluation, and risk management alternatives, performed to understand the nature of unwanted, negative consequences to human life, health, property, or the environment; an analytical process to provide information regarding undesirable events; the process of quantification of the probabilities and expected consequences for identified risks* [SRA 2005].

Table 8 provides a range of techniques that can be used to analyze risk.

UPSIDE RISK	BOTH	DOWNSIDE RISK
Market survey Prospecting Test marketing Research and Development Business impact analysis	Dependency modeling SWOT analysis Event tree analysis Business continuity planning BPEST (Business, Political, Economic, Social, Technological) analysis Real Option Modeling Decision taking under conditions of risk and uncertainty Statistical inference Measures of central tendency and dispersion PESTLE (Political Economic Social Technical Legal Environmental)	Threat analysis Fault tree analysis FMEA (Failure Mode & Effect Analysis)

Table 8: Risk analysis methods and techniques – examples [SRA 2005]

2.7.35 Roadmapping

> *Technology roadmapping is a needs-driven technology planning process to help identify, select and develop technology alternatives to satisfy a set of product needs. It brings together a team of experts to develop a framework for organizing and presenting critical technology-planning information to make the appropriate technology investment decisions and to leverage those investments* [Garcia and Bray 2005].

There are different types of technology roadmaps (product-technology, issue-oriented, emerging, etc.). The emerging technology roadmap focuses on a single technology and describes the way it is expected to develop.

Technology roadmapping projects major technological elements of product design and manufacturing together with strategies for reaching desirable milestones efficiently. Roadmaps typically run several technology or product generations (e.g., 2 to 10 years) ahead [Coates et al. 2001, 9].

2.7.36 Scanning/monitoring

> *Environmental scanning can be thought of as the central input to futures research* [Gordon and Glenn 2009, 4].

The purpose of monitoring is to provide an early alert of any changes that may warrant a revision to current plans. Various scanning techniques exist, but Gordon and Glenn [2009] have identified seven approaches they believe should be considered in creating an environmental scanning system. The seven approaches are summarized in Table 9.

1. Expert panels can be created to 'look out' for changes on the horizon that could be important to implement or accomplish plans...;
2. Database literature reviews provide access to a broad range of information useful to policy makers, planners and strategists;
3. 'Google Alerts'...allows one to pre-select terms that are searched daily and delivered to your e-mail address. 'Web crawlers' can search for sites with new versions that can provided early warning or alert to new information;
4. Many Websites on the Internet offer press releases available to the public...;
5. Hard-copy literature reviews of selected periodicals could also be scanned to detect important incipient changes; however, they are increasingly being replaced by electronic versions;
6. Essays by experts could explore critical long-term issues for recommendations on policy and strategy. These essays could use contemporary software issues such as issues maps;
7. Key person tracking (who knows the most, and how do you keep track of their new insights) and monitoring of key conferencing [sic] on your special interests, in person or on-line via streaming or archived video.

Table 9: Environmental Scanning approaches
[Gordon and Glenn 2009, 4]

> *This is the simplest forecasting technique and the most fruitful. Monitoring involves scanning the environment for information relevant to the topic of the forecast. Information to be monitored resides in computerized databases, the Internet, publications, experts, the physical environment, etc.* [Rossini and Porter 2000, section II 5.5].

2.7.37 Scenarios

The concept of scenario construction for futures research was introduced by Herman Kahn in connection with military and strategic studies conducted by the RAND Corporation in the 1950s. Numerous techniques have been developed to create scenarios. The technique taught by Foresight Canada and Global Business Network Canada[16] in Calgary, Alberta on April 29 and 30th, 2004, is illustrated in Figure 8 and shows that the scenario development process is not strictly linear. The process starts by identifying the focal issue, then investigating past changes, factors, and forces impacting future changes. Critical uncertainties are identified and used to develop the scenario logics. From this information full scenarios are developed. The features of a good scenario are that it is:

- plausible
- recognizable from the signals of the present
- creative in exploring new ground and ideas
- relevant and significant to the organization
- internally consistent
- challenging [GBN and Foresight Canada 2004].

[16] Global Business Network Canada was created by former scenario developers from Shell.

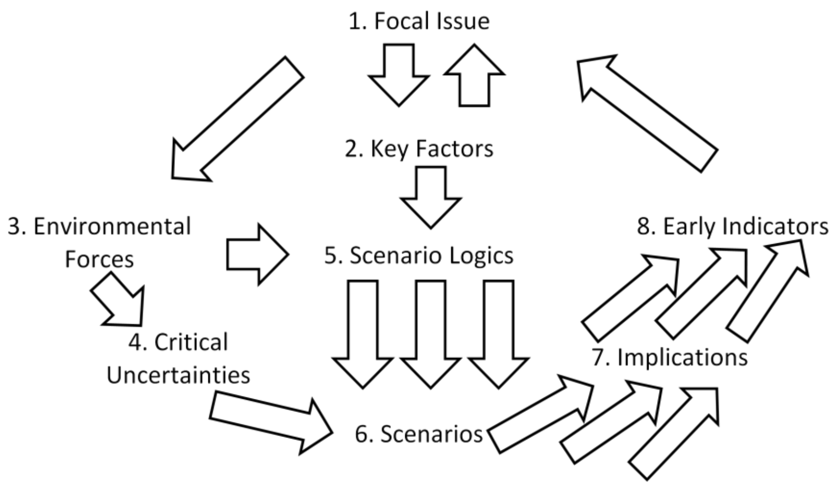


Figure 8: Developing scenarios
[GBN and Foresight Canada 2004]

A focal issue is one around which there is real energy, shared understanding, and a clear timeframe. In most organizations the focal issue will be the biggest challenge facing the organization. This focal issue along with past changes and forces impacting future changes can be elicited through interviews with staff. The interview questions are generally provided ahead of time and the following are examples of some typical questions:

- What has made your organization successful in the past?
- What does this organization "need to forget"? What must it remember?
- What things need to be changed for your organization to be successful in the future?
- What are the barriers to change and innovation?
- How do you learn?

- What are one or two critical decisions on the immediate horizon?
- If you looked back from 10 years hence and your organization had done very well, what went right internally and externally?
- There is a dark spot on the horizon. It is not here and now but could impact the organization in the future. What is it?
- The future is unknowable, but if you could talk with an oracle, what two questions would you ask?
- If your organization had a large one-time capital infusion, how would you spend the money to increase future success? Where would you not spend the money? [GBN and Foresight Canada 2004].

There are numerous types of focal issues. Some examples are: decision focus (i.e., go/no go), strategy development (i.e., focus on firm, focus on division, focus on region, focus on business unit), reassessing core business (e.g., industry restructuring, new competition, new technology, new growth opportunities), and exploratory (e.g., learning, team building, signalling change).

The interview questions offer insight into environmental forces and critical uncertainties as well as factors and forces impacting future changes. Early hypotheses about the focal issue should be developed so that they can be tested in later interviews, but not finalized too early in the process. Since a lot of information will amass as interviews progress, some means of analyzing themes must be selected. A couple of possible techniques are affinity analysis (i.e., Post-it

Note clustering) and the use of a computer database. Development of the scenarios involves integration of the relatively obvious (elements of the business plan, key actors who could influence the focal issues such as competitors, partners, suppliers, regulators, communities, and customers), the relatively less obvious (external social, technological, economic, environmental or political impacts on the business), and the ostensibly outlandish. The ostensibly outlandish influencers are typically obtained through brainstorming sessions.

The identification of critical uncertainties is accomplished through a process of prioritization and discussion in which those factors and forces identified as being the most important and the most uncertain are selected. Next, each critical uncertainty is to be viewed as a continuum or dimension of which the end points must be described. These end points must describe the extreme range of the uncertainty. If the end points do not describe two different future outcomes for the uncertainty, then it must be aborted as it is not a true uncertainty.

Once each critical uncertainty has been defined, they must be paired such that they can be displayed on orthogonal axes as *independent* variables. It is from these orthogonal diagrams that the scenarios themselves are created. Scenarios are stories of the future. A scenario has three primary components: characteristics, a storyline, and a name. The characteristics describe the outcome or end state of the scenario. The storyline describes the path from the present to the future and the name distinguishes the scenario from others. Scenario names should be short and memorable, and should capture a key theme of the scenario.

It is important to remember that the purpose of scenario planning is not to pinpoint future events but to highlight large-scale forces that push the future in different directions. Scenarios are intended to make those forces visible, so that if they do occur, the organization can recognize them and, having thought about them ahead of time, make better decisions about how to deal with them [Wilkinson 2004].

As with a number of foresight methods, scenarios can be used for both normative and exploratory forecasting (see 2.8.4). For normative forecasting, one would gather the relevant group and develop a future scenario such as the group would like to see come to pass.

2.7.38 Scenario-simulation [gaming; interactive scenarios]

2.7.38.1 Gaming

Gaming is:

> *The use of a game that simulates a real situation. For example, games have been developed to represent the operations of a city government. Different players may play the parts of the mayor, city council, real estate lobby, tenants' association, etc. By playing the game, the players can get a clearer understanding of the dynamics of a situation* [Cornish 2004, 295].

2.7.38.2 Interactive Scenarios

The Interactive Scenarios technique was developed by the Millennium Project[17] as a means to allow people to change previously prepared scenarios. The technique involves breaking down a scenario into its composite statements, assigning a probability of occurrence to each statement, and then using a scale of -2 to +2 to represent how the content of the statements are thought to interact (cross impact analysis).

Determining the probability of how the content of each statement influences the others is a rather tedious exercise and the technique, at present, is not suitable for any but the shortest and simplest scenarios [Gordon 2009h, 6].

2.7.39 Science fiction analysis

Science Fiction Analysis represents the review of works of science fiction as an indicator of potential future technologies. Since science-fiction writers produce innumerable fantasies, it is possible to find fictional parallels to subsequent technologies or events in the real world [Cornish 2004, 166]. Cornish provides the example of how "…Jules Verne…described a space rocket in the 1865 novel *From the Earth to the Moon*" [Cornish 2004, 166]. A much more recent example of the use of science fiction to aid in future work was displayed in a Calgary

[17] The Millennium Project is a global participatory futures research think tank of futurists, scholars, business planners, and policy makers who work for international organizations, governments, corporations, non-governmental organizations (NGO), and universities.

Herald headline reading "Science-fiction writers join war on terror". The article describes how "anti-terror chiefs in the United States have hired a team of America's most original sci-fi authors to dream up techniques to help them combat al-Qaeda" [Shipman 2007, p. A11].

2.7.40 Social impact assessment

> *The role of SIA goes far beyond the ex-ante (in advance) prediction of adverse impacts and the determination of who wins and who loses: SIA also encompasses empowerment of local people; enhancement of the position of women, minority groups and other disadvantaged members of society; development of capacity building; alleviation of all forms of dependency; increase in equity; and a focus on poverty reduction* [Vanclay 2003a, 3].

According to Becker and Vanclay's 2003 book, *The International Handbook of Social Impact Assessment: Conceptual and Methodological Advances*, social impact assessment (SIA) is "a developing field of practice". With that in mind, the definition of social impact assessment according to Vanclay is:

> *SIA is the process of analyzing (predicting, evaluating and reflecting) and managing the intended and unintended consequences on the human environment of planned interventions (policies, programs, plans, projects) and any social change processes invoked by those interventions so as to bring about a more sustainable and equitable biophysical and human environment* [Vanclay 2003b, 2].

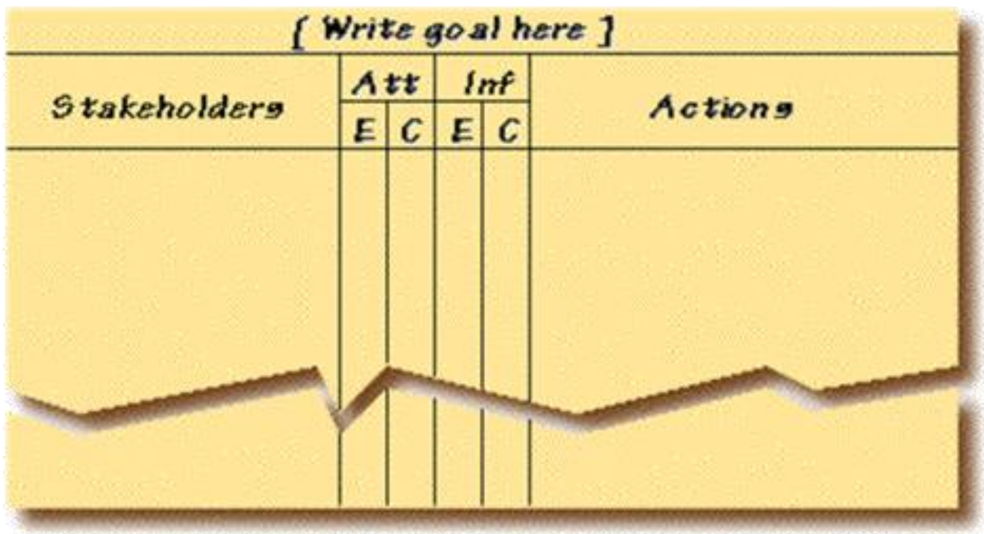
2.7.41 Stakeholder analysis

The TFAMWG provided two references for stakeholder analysis in its paper "Technology futures analysis: Toward integration of the field and new methods": *The Unbounded Mind* by Ian I. Mitroff and Harold A. Linstone and Kerstin Kuhls contribution to the Proceedings of the Innovation Policy Workshop held in Brussels on July 11, 2002, "How to involve stakeholders in the modelling process”. *The Unbounded Mind* does not contain a reference to “stakeholder analysis” in its index nor does Kuhls’ text reference “stakeholder analysis”.

A review of numerous Internet sources for definitions of stakeholder analysis proved that the following is a reasonable description of the process:

1. Draw up the chart

Prepare a chart on electronic whiteboard, or perhaps butcher paper, like this:



Att=attitude Inf=influence E=estimate C=confidence

You will notice that the chart has 6 columns. The four columns in the middle need only be wide enough to contain a three or four letter symbol. You need a little more width in the right-hand column than in the left-hand one.

2. List stakeholders

Identify and list the stakeholders. These may be individuals, or stakeholder groups, or some combination. If stakeholders can be treated as a group, use groups. The most effective way of doing this is to list as many stakeholders as you can on a working sheet of paper. Then transfer them to the left hand column of the chart. It may help to list them in rough order of importance. (You may change your mind about their importance after this analysis.)

3. Estimate attitude and confidence

For columns 2 to 5, work across the page. Record your estimates of the following in the columns. In order, they are:

***Column 2**: Your best estimate of the stakeholder’s attitude, from supportive to opposed. I usually find it is adequate to use a 5-category code --*

++ strongly in favour
+ weakly in favour
o indifferent or undecided
- weakly opposed
-- strongly opposed

***Column 3**: How confident you are about your estimate in column 2. Here you can use*

/ (a tick) for fully confident
? for reasonably confident (some missing information, perhaps, or some doubts about interpretation)
?? for an informed guess
??? for wild guess or sheer fantasy

Unless the group achieves immediate agreement, then at least one question mark is warranted.

***Column 4**: Your best estimate of the influence of the stakeholder. A three-category code is usually enough --*

H high; this person or group has power of veto, formally or informally
M medium; you could probably achieve your goals against this person's or group's opposition, but not easily
L this person can do little to influence the outcomes of your intended actions

***Column 5**: How confident you are about your estimate in column 4. You can use the same codes as in column 2.*

4. Plan strategies

Plan your strategies for approaching and involving each person or group. Your estimates in columns 2 to 5 help you to do this. Your strategy is written in column 6. It usually takes the form of obtaining more information, or of involving the stakeholder in the planning for the change.

In general, question marks indicate a need for more information. The more question marks, and the more influence the person has, the greater the need. On some occasions you will choose to approach the person concerned. On other occasions you may instead approach someone else who can be assumed to know about the person's attitude or influence.

(On occasion, you may want to obtain some of this information before completing the analysis.)

In general, high influence indicates a need to involve the person in some way. (Or, if you choose not to do this, and they are opposed, you may choose to find some way to neutralise their influence.) The people or groups who require most attention are those who are influential and opposed.

For involvement, decide the extent. For example:

- *involved only as informants consulted*
- *directly involved in decision-making*
- *involved as co-researchers and co-actors*
- *or some similar categories.*

Where the stakeholder is a group rather than an individual, you will probably want to include in your decision the style of participation appropriate: for example, direct participation of everyone, or representation [Dick 1997] Image used with Permission.

2.7.42 Systems simulation [system dynamics, KSIM]

The TFAMWG referenced the American Council for The United Nations University's The Millennium Project's Futures Research Methodology (Version 2.0) compact disc (edited by Jerome C. Glenn and Theodore J. Gordon) for systems simulation [system dynamics, KSIM]. The referenced chapter is Chapter 15 "Simulation and Games in Futuring and Other Uses". No precise definition of systems simulation, system dynamics or KSIM is provided in the chapter. Instead, the example of an airplane cockpit simulator is provided and it is pointed out that, for the simulation to be a game, some objective or standard must be met (e.g., arrive at the destination on time) and a player is said to "win" the game if the objective is achieved or the standard is met or exceeded. The chapter mentions a number of other kinds of simulations using scenarios from business, demographics, ecology, economics, ethics, psychology which allow a researcher to explore the outcome of tweaking the scenario in some way.

2.7.43 Sustainability analysis

"Sustainability assessment focuses on the probability of continuation of activities without negatively affecting the environment, social or economic systems." [Boyle 2005, Abstract] The formula for sustainability probability and a sample calculation are provided in Figure 9.

$$SP_T = 1 - \text{(risk of damage)}$$

Where SP = Sustainability Probability
T = time for the damage to occur

Example: If the risk of an activity is 85% that damage to the environment will occur within 50 years, then:

$$SP_{50} = 1 - 0.85$$
$$SP_{50} = 0.15$$

This implies that there is a15% chance that the activity will not cause damage after 50 years.

Figure 9: Sustainability Probability calculation
[Boyle 2005, Abstract and Introduction]

2.7.44 Technology Assessment

Joseph F. Coates, "a guiding force in the Technology Assessment (TA) movement" [Porter et al. 1980, 3], defines TA as:

> *a class of policy studies which systematically examine the effects on society that may occur when a technology is introduced, extended or modified. It emphasizes those consequences that are unintended, indirect or delayed* [Porter et al. 1980, 3].

TA was developed in the United States as a response to a number of major incidents such as the sinking of the U.S.S. *Thresher*, the Apollo spacecraft fire, the grounding of the tanker Torrey Canyon, and a four-state electrical blackout. TA was intended to provide policy-makers with a tool for coping with the many and varied impacts of technology on society.

In contrasting TA with Environmental Impact Assessment in their book titled *A Guidebook for Technology Assessment and Impact Analysis*, Porter et al. indicate that TA usually deals with a technology that could be geographically situated almost anywhere and that it is likely to explore a wide range of possible subsidies, incentives, regulations, and so forth. In the same pages, Porter et al. explain that Sherry Arnstein carefully differentiated TA from other forms of assessment in terms of its:

(1) comprehensive view of complex issues,

(2) requirement of many disciplines, working in an interdisciplinary mode, and

(3) component tasks (beginning with a need to structure the problem and continuing through analysis of policy options).

Table 10 identifies the components of a TA. Although the components are numbered 1 to 10 this does not imply that it is the order of activities since TA is an iterative process in which various components will have to be revisited once additional information from other components has been obtained.

1. Problem definition	6. Impact identification
2. Technology description	7. Impact analysis
3. Technology forecast	8. Impact evaluation
4. Social description	9. Policy analysis
5. Social forecast	10. Communication of results

Table 10: Components of a Technology Assessment

2.7.45 Technological substitution

Technological Substitution can occur when a technology offers customers various benefits that can replace benefits they were getting from products or services based on another technology [Sticky Marketing 2005].

A number of forecasting models are available to explain the time pattern of the substitution process: the Gompertz Curve, the Pearl Curve, the Mansfield Model, the Blackman Model, the Fisher-Pry Model, the Bass Model, the Nonsymetric Responding Logistic (NSRL) Model, the Non-Uniform Influence (NUI) Model, the Sharif-Kabir Model, and the Weibull Distribution Model (or Sharif-Islam Model) [Kang, Han and Yim 1996, 88]. Kang et al. in "An adaptive Framework for Forecasting Demand and Technological Substitution" propose a model since "these models consider the characteristics of time patterns or tendency of historical data, but do not take major factors determining actual market demand for technological products into consideration" [Kang, Han, and Yim 1996, 88]. Kang et al. call their model the "Adaptive Diffusion Model".

2.7.46 Trend extrapolation

Trend extrapolation is based on the assumption that patterns in the past will continue into the future.

> *To perform this method, information is collected about a variable over time, and then extrapolated to some point in the future. This analysis can be either qualitative or quantitative. In the most simple form, trend extrapolation can be based on linear or other straightforward projections. Other foresighting methods that are more elegant variations of simple trend extrapolation (and that can be considered a subset of modeling) include system dynamics, s-curves, regression analysis, and substitution analysis. All of these methods hold a common assumption that the future will follow some pattern based on the past* [Skumanich and Silbernagel 2005].

> *This method has two major weaknesses. First, it is often a fallacy to assume that the future will follow the pattern of the past. While people often make such assumptions due to a lack of better information, any picture of the future that is developed on this basis can be inaccurate. The second weakness of this method is that it typically provides information on only a single variable. Especially in current world conditions, it is rare for any variable to act independently. More often, the influence of outside forces can dramatically alter the future of any one event or condition* [Skumanich and Silbernagel 2005].

2.7.47 Trend Impact Analysis

Trend impact analysis is a forecasting method that permits extrapolations of historical trends to be modified in view of expectations about future events. The method involves two principle steps. In the first, a curve is fitted to historical data to calculate the future trend, given no unprecedented future events. In the second step:

> *expert judgments are used to identify a set of future events that, if they were to occur, could cause deviations from the extrapolation of historical data. For each such event, experts judge the probability of occurrence as a function of time and its expected impact on the future trend, should the event occur. An event with high impact is expected to swing the trend relatively far, in a positive or negative direction, from its unimpacted course* [Gordon 2009c, 2].

2.7.48 TRIZ

> *Triz is basically the produce of a patent attorney, a paten[t] lawyer in Russia who, with his colleagues, surveyed some forty thousand patents and he is now able, on the basis of what is come out of that, to say that if you have a problem there are probably solutions to the analogous problem in other patent domains that you would never think of looking at* [Coates 2004a, 30].

TRIZ (pronounced *trees*) is the Russian acronym for the method developed by Genrikh Altshuller in the Soviet Union during the 1950s and 1960s. An alternative name for TRIZ is "Theory of Inventive Problem Solving". The TRIZ method is an algorithmic approach "…based on a set of Patterns of Evolution, which can be used to generate ideas for developing the next generation of a technological system. TRIZ Technological Forecasting uses the Patterns and Lines of Evolution to 'force' a system's evolutionary development by inventing its future before it would otherwise naturally occur" [Clarke 2000, 136]. TRIZ is suited to solving problems in the following classes:

1. *improvement or perfection of both quality and quantity (considered Contradiction Problems in TRIZ*
2. *search for and prevention of shortcomings (Diagnostics)*
3. *cost reduction of the existing technique (Trimming)*
4. *new use of known processes and systems (Analogy)*
5. *generation of new 'mixtures' of already existing elements (Synthesis)*
6. *creation of fundamentally new technique[s] to fit a new need (Genesis)* [Savransky 2000, preface].

Vary Coates et al. in the paper "On The Future of Technological Forecasting" indicate that "it should be noted that TRIZ has aspects of the morphological approach suggested by Zwicky in the 1940's but is more normative" [Coates 2001, 12].

2.7.49 Visions

A vision is a compelling statement of the preferred future that an organization or community wants to create [Cornish 2004, 74].

2.8 ASSESSMENT OF THE COMMON APPROACHES TO TECHNOLOGY FORESIGHT

One of the difficulties with assessing foresight methods appropriate for use by SMEs is that there is limited standardization of method names. This is because from the late 1940s through the mid 1970s methods were concurrently developed, refined, and used under different names within different companies [Coates et al. 2001, 2]. As a result, different authors refer to the same method using a different name, and very similar sounding names refer to different methods. Coates et al.

[2001] refer to evolving drivers and challenges as the impetus for the development of new approaches. They recognize political science, innovation management, scientometrics, and computer science as related disciplines that methods have evolved from.

Numerous attempts have been made over the last two decades to categorize foresight methods ([Millet and Honton 1991], [Miola 2008], [Skumanich and Silbernagel 1997], [Rossini and Porter 2000], [Reger 2001], [Tegart 2003], [TFAMWG 2004]). None of these attempts have endured and become the de-facto standard of categorization [Glenn 2009a, 7] due primarily to the following three reasons: (1) additional methods are always being developed, (2) given the study of the future is not a structured profession, no person, organization or entity has the authority to declare a categorization as the de-facto standard, and (3) each author hopes that their latest categorization proposal will be received as the de-facto standard.

The following sections will provide a review of the efforts to categorize foresight methods over the last two decades.

2.8.1 Grouping of Methods

2.8.1.1 1991 – Three Broad Categories

In 1991, Millet and Honton assessed the current state of the art of 20 different technology forecasting methods by clustering the methods into three broad categories: trend analyses, expert judgment, and multi-option analyses. In the trend analyses category they placed trend extrapolation (see 2.7.46), time series estimation, regression analysis, econometrics, systems dynamics, S-curves, historical analogies (see 2.7.3), input-output matrices, patent trend analysis, scientific literature analysis, and user created database analysis. In the expert judgment category they placed interviews (see 2.7.23), questionnaires, Delphi method (see 2.7.16), idea generation, and nominal group technique (the latter three methods grouped under the umbrella heading of group dynamics. A description of nominal group technique can be found in 2.7.7.2.). They placed scenarios (see 2.7.37), simulations, paths and trees (see 2.7.32), and portfolio analysis into the multi-option analyses category. In fact, user created database analysis (within the trend analyses category) was not even a bona fide method at the time Millet and Honton wrote their book. The method was their prediction of "a new trend analysis method [to] be developed during the 1990s....because of the combination of three already developing trends in computer hardware, computer software, and data..." [Millet and Honton 1991, 38].

Millet and Honton [1991] made a further categorization of their three broad categories. They classified multi-option analyses methods as having a very different conceptual foundation from those of trend analyses and expert judgment. That is, whereas in the case of trend analyses and expert judgment, the underlying philosophy is that there will be one and only one future and that future can be known or at least approximated before it occurs, the multi-option analyses approach is that although there may ultimately be only one future, we can never know with enough certainty what that future can be. Therefore, numerous potential futures must be generated and planning must occur to accommodate, at a minimum, the most likely potential future, but ideally as many of the potential futures as possible. This approach to categorization of foresight methods is further expounded on in 2.8.4.

2.8.1.2 1997 – Six Major Categories

In 1997, Skumanich and Silbernagel, after qualifying that boundaries between categories are not necessarily firm and that methods can merge from one category into the next, discuss the attributes and weaknesses of six major categories of foresight methods (double the number of categories proposed by Millet and Honton [1991]). These categories are: (1) expert opinion, (2) scenarios, (3) modeling, (4) morphological analysis, (5) scanning/monitoring, and (6) trend extrapolation. Skumanich and Silbernagel's six major categories clearly include two of Millet and Honton's three broad categories – trend analyses and expert judgment – but appear to ignore multi-option analyses. However, recalling the component methods of Millet and Honton's multi-option analyses category – scenarios, simulations, paths and trees, and portfolio analysis – it is apparent that Skumanich and Silbernagel have moved one of Millet and Honton's multi-option analyses methods – scenarios – into a category of its own.

With respect to the remaining methods in Millet and Honton's multi-option analyses category – simulations, paths and trees, and portfolio analysis – Skumanich and Silbernagel [1997] also place two of these three methods in the scenarios category. Regarding portfolio analysis, Millet and Honton [1991] themselves describe it as "...not a forecasting method, because it offers no foresight about the future development or performance of technologies" [1991, 79]. Hence it is not surprising that Skumanich and Silbernagel do not acknowledge it as a foresight method.

In the preamble to their discussion on the attributes and weaknesses of their six major categories, Skumanich and Silbernagel [1997] further group the six major categories into sub-groups of two. They sub-group *expert opinion* and *scenario building* as methods which emphasize human participation in the foresight process; *modeling* and *morphological analysis* as methods which emphasize the use of computer models or other analytic tools to provide analysis of future states; and *scanning/monitoring* and *trend extrapolation* as methods that emphasize the degree to which conditions of the future are based on conditions of the present.

2.8.1.3 2000 – Five Families

Rossini and Porter [2000] identify five families of forecasting techniques: (1) monitoring, (2) expert opinion, (3) trend analysis, (4) models, and (5) scenarios. They exclude Skumanich and Silbernagel's morphological analysis category. This is understandable since Skumanich and Silbernagel [1997] do not identify any specific foresight methods in the morphological analysis category and indicate that morphological analysis, while it examines the possible applications and developments of an object, has the limitation of not being able to address the likelihood of the futures that it forecasts based on current realities, such as funding resources or markets [Skumanich and Silbernagel 2007]. Further, since morphology is defined as a study of structure and form, it is reasonable to argue that morphological analysis can fall under Rossini and Porter's models family. Rossini and Porter indicate that their models family "covers a multitude of techniques, from global modeling using complex systems of equations to judgemental modeling for decision making, to games, to simple boxes and arrows models of institutions involved in the development of a technology" [2000, n.p.]. Alternatively, Skumanich and Silbernagel's morphological analysis category may be missing because some believe morphological analysis to be a complementary technique [The Futures Group International 2003] as opposed to one which may stand on its own.

2.8.1.4 2001 – Three Broad Categories and Eight Sub-Classes

Reger [2001] proposes that foresight methods can be broken into three broad categories – (1) cognitive and appellant methods, (2) statistical and econometric methods, and (3) structural and causal methods – before being further broken down into sub-classes. See Figure 10.

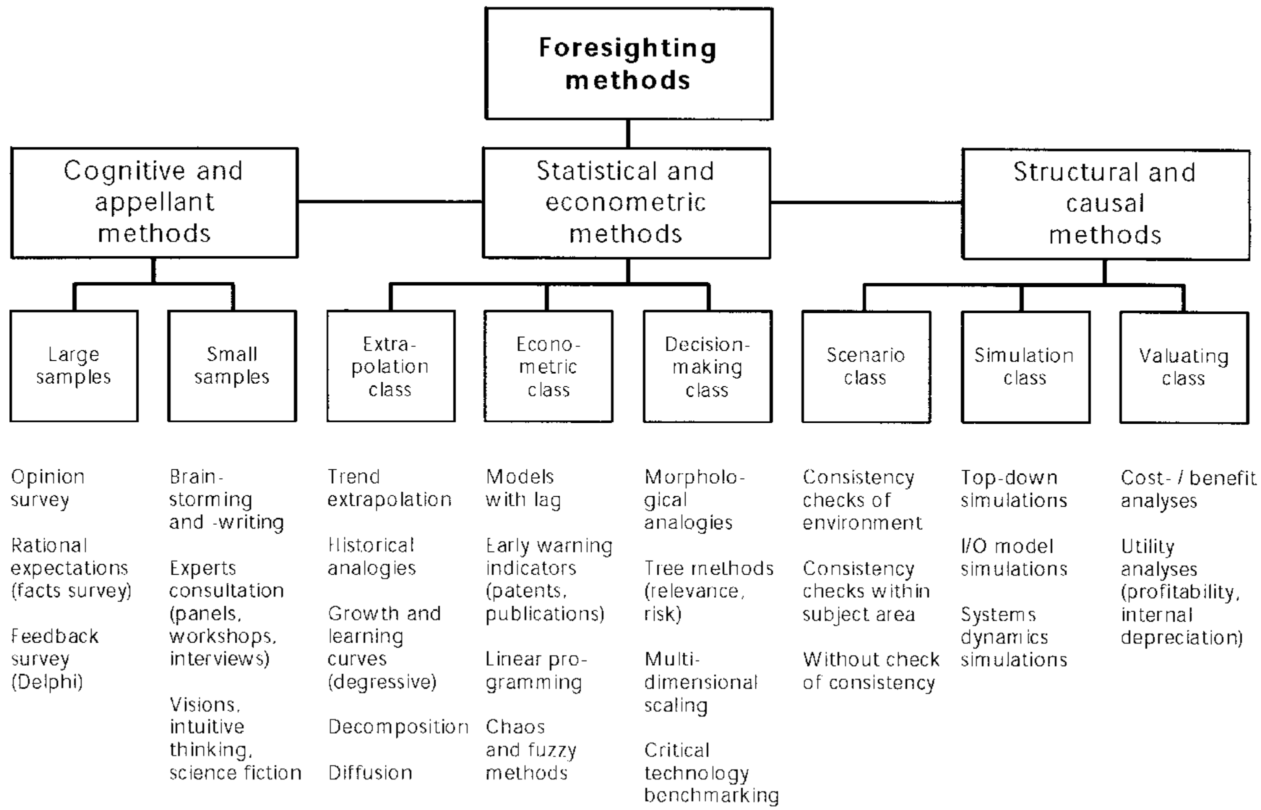


Figure 10: Overview of foresight methods by types and classes
[Reger 2001, 544]

Reger's proposed broad categories differ significantly from previous category proposals. The closest links to previous work are the titles of his extrapolation class under statistical and econometric methods and his scenario class under structural and causal methods. These titles link favourably with the trend analysis and scenarios families of previous authors (Millet and Honton [1991], Skumanich and Silbernagel [1997], and Rossini and Porter [2000]). Reger has not identified a class for methods requiring experts (i.e., to reflect the expert opinion categories presented previously). He instead includes all methods he believes require conscious intellectual activity (whether done by an expert or an average person) within the cognitive and appellant category. Recall that Skumanich and Silbernagel [1997] offered a grouping of their six major categories into sub-groups of two. One of these sub-groups is methods which emphasize human participation in the foresight process and consists of the major categories *expert opinion* and *scenario building*. Reger identifies his scenario class under structural and causal methods.

Skumanich and Silbernagel's [1997] sub-group of their major categories *scanning/monitoring* (see 2.7.36) and *trend extrapolation* (see 2.7.46) which they identify as methods that emphasize the degree to which conditions of the future are based on conditions of the present also has an uneasy fit with Reger's statistical and econometric methods. Trend extrapolation is one of the identified methods under Reger's extrapolation class and the early warning indicators (patents, publications) method identified under Reger's econometric class is a reasonable description of scanning/monitoring. However, Reger's statistical and econometric methods also includes the morphological analogies method under the decision-making class and models (with lag) under the econometric class and these methods are the basis for Skumanich and Silbernagel's sub-group emphasizing human participation in the foresight process.

In summary, although there are some slight correlations, Reger's work in categorizing TFA/foresight methods appears to be entirely original except for the fact that he continues the trend of dividing the methods into an increasing number of categories.

2.8.1.5 2004 – Nine Families

In 2004, the TFAMWG proposed nine "families" of TFA methods. Excluding Skumanich and Silbernagel's [1997] morphological analysis category, Skumanich and Silbernagel's [1997] and Rossini and Porter's [2000] matching categories correspond reasonably well to over half of the TFAMWG's [2004] nine families (the corresponding categories have been bolded in the list below):

(1) **Expert Opinion**

(2) **Scenarios**

(3) **Modeling** & Simulation

(4) **Monitoring & Intelligence**

(5) **Trend Analyses**

(6) Statistical

(7) Creativity

(8) Descriptive & Matrices

(9) Valuing/Decision/Economic.

The four new families of TFA methods which the TFAMWG have identified in addition to Skumanich and Silbernagel's [1997] and Rossini and Porter's [2000] categories are: statistical, creativity, descriptive and matrices, and valuing/decision/economic. Two of these new families – statistical and valuing/decision/economic – have some links with Reger's [2001] broad categories (statistical and econometric methods) and sub-classes (valuing class), but it is a muddled as opposed to a direct reflection.

By reviewing the methods which Reger puts in each of his sub-categories, it is possible to see a strong parallel between Reger's cognitive and appellant methods and the TFAMWG's creativity and expert opinion families due to the common methods of brainstorming/brainwriting, visions, science fiction, interviews, and Delphi (see descriptions in 2.7.7, 2.7.49, 2.7.39, 2.7.23, and 2.7.16, respectively). Reger's remaining broad categories are a little more difficult to parallel with the TFAMWG's families, but, again due to the methods identified, Reger's statistical and econometric methods correlate reasonably well with the TFAMWG's monitoring and intelligence methods, trend analysis, statistical methods, and descriptive and matrices families. The methods in Reger's structural and causal methods category correlate reasonably well with the TFAMWG's scenarios, modeling and simulation, and valuing/decision/economics methods.

Each of the TFAMWG's families has a varying number of methods within it (see Figure 11). The statistical family includes: correlation analysis (see 2.7.11) and demographics (see 2.7.17). The creativity family includes: brainstorming, vision generation (see 2.7.49), science fiction analysis (see 2.7.39), creativity workshops (see 2.7.13), and TRIZ (see 2.7.48). The descriptive and matrices family includes: institutional analysis (see 2.7.22), backcasting (see 2.7.5), innovation system modeling (see 2.7.21), checklists for impact identification (see 2.7.9), roadmapping (see 2.7.35), social impact assessment (see 2.7.40), multiple perspectives assessment (see 2.7.28), state of the future index (see 2.5), mitigation analyses, morphological analysis (see 2.7.26), organizational analysis (2.7.29), and analogies (see 2.7.3). Note how Skumanich and Silbernagel's whole category – morphological analysis – has been reduced to a method within one of the TFAMWG's families. This represents the speed and disarray with which the area of futures analysis is changing and growing.

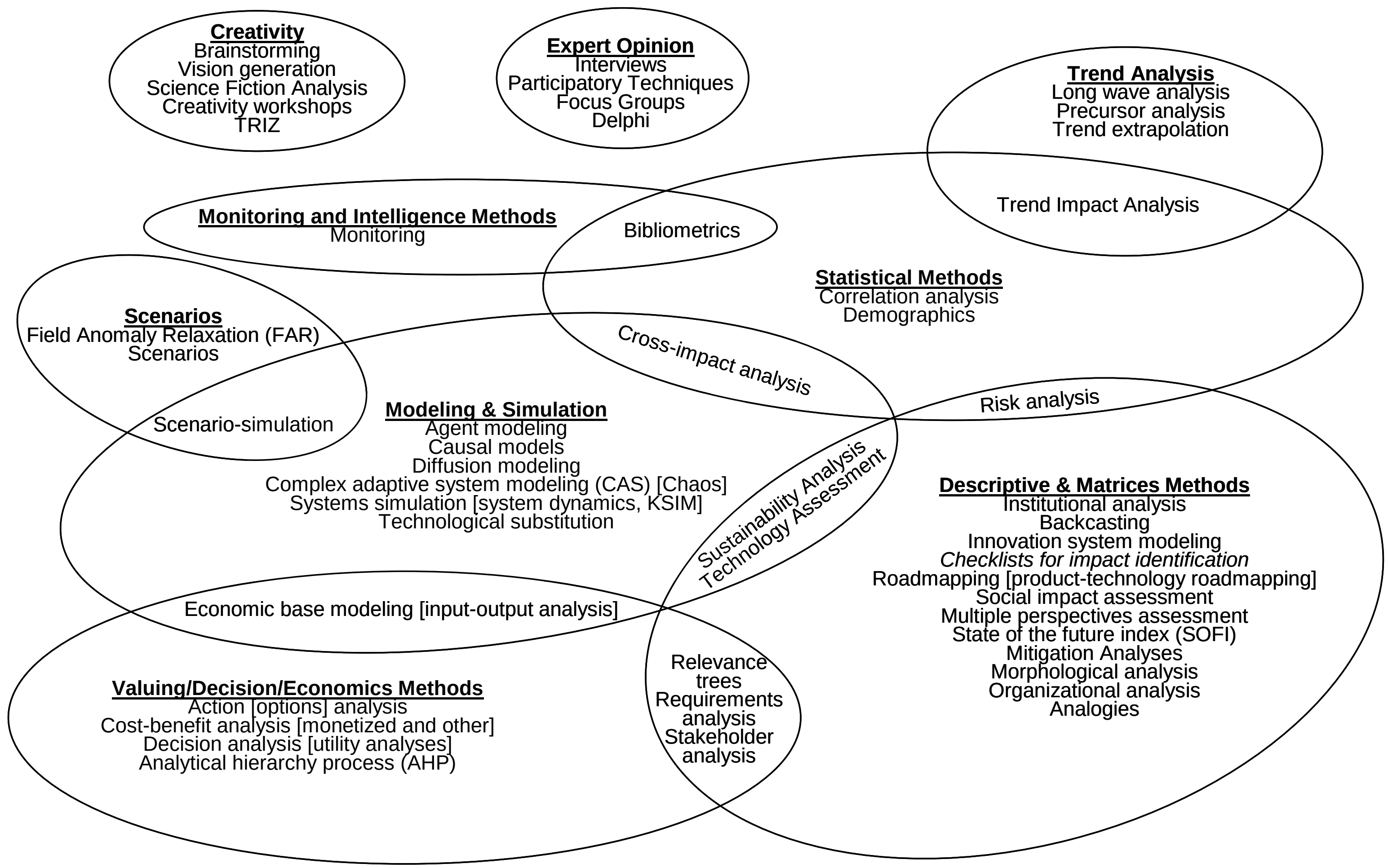


Figure 11: Families of TFA methods
[Phillips, Heidrick, and Potter 2005, 157]

The same year the TFAMWG proposed its nine families of TFA methods in a paper, Cornish [2004, 78] published a book in which he identified the most common techniques for anticipating, forecasting, and assessing future events as:

- scanning
- trend analysis
- trend monitoring
- trend projection
- scenarios
- polling
- brainstorming
- modeling
- gaming
- historical analysis
- visioning.

Six of the 11 techniques Cornish identified as the "most common techniques" echo back to Skumanich and Silbernagel's [1997] six categories; scenarios, modeling, and scanning(/monitoring) are an exact match. Trend extrapolation from Skumanich and Silbernagel's categories shows up as trend projection in Cornish's list. Newly showing techniques – compared to Skumanich and Silbernagel's categories – are: polling, brainstorming, gaming, historical analysis, and visioning. However, brainstorming and visioning can be found under the TFAMWG's creativity family, leaving polling, gaming, and historical analysis as new techniques. It turns out that polling is not a new technique since polling is simply Cornish's general description to encompass the Delphi method [2004, 67]. The Delphi method was part of Skumanich and Silbernagel's [1997] expert opinion category and the TFAMWG's expert opinion family. This leaves gaming and historical analysis as new techniques. Cornish [2004, 79] defines gaming as the simulation of a real-world situation by means of humans playing different roles. An excellent example is the war games that real soldiers and their leaders participate in. Note that what has just been identified as a new technique is being supported by an example which has been around for decades. Such is the nature of futures analysis. Old practices are seen in new light and given new labels.

Cornish [2004, 79] defines the other new technique – historical analysis – as the use of historical events to anticipate the outcome of current developments. This definition is very close to Millet and Honton's description of historical analogies as being used to study historical data from other businesses in an effort to avoid the mistakes these other businesses made and to take advantage of opportunities missed by the other companies [1991, 25].

2.8.2 Forecasting or Foresight

Tegart [2003] offers a much simpler categorization. He divides strategic planning tools under two broad groups: forecasting and foresight. He identifies forecasting tools as those relying on trend data extrapolations or the application of models to develop a unique future. The techniques he groups under foresight he describes as being concerned with the development of a range of possible futures which emerge from alternative sets of assumptions about emerging trends and opportunities. He offers the following six methodologies as a sample of foresight techniques: (1) Delphi surveys, (2) consultation, (3) scenario creation, (4) patent analysis, (5) critical technologies, and (6) technology roadmapping, without attempting to group the methodologies into categories.

2.8.3 Modes of Thinking

Vanston [2003, 47] believes that both the validity and credibility of forecasts can be enhanced by classifying the way that the forecaster views the future into one of five categories. Vanston's five categories are:

1. extrapolators
2. pattern analysts
3. goal analysts
4. counter-punchers, and
5. intuitors.

He provides descriptions of each category of forecaster and their associated methods. Brief descriptions of the five categories along with their associated methods are presented in Table 11.

CATEGORY	BELIEF DESCRIPTION	METHODS
Extrapolators	the future will represent a logical extension of the past	trend extrapolation substitution analysis learning curves
Pattern analysts	the future will reflect a replication of the past	precursor trend analysis morphological analysis
Goal analysts	the future will be determined by the beliefs and actions of a collection of individuals, organizations, and institutions	impact analysis stakeholder analysis patent analysis
Counter-punchers	the future will result from a series of events and actions that are essentially unpredictable and, to a large extent, random	scanning, monitoring, and tracking alternate scenarios cross-impact analysis
Intuitors	the future will be shaped by a complex mixture of inexorable driving forces, random events, and the actions of key individuals and institutions	Delphi surveys nominal group analysis structured and unstructured interviews

Table 11: Vanston's Five Categories of Forecasters
Adapted from [Vanston 2003]

In 2008 Apollonia Miola referenced a different classification of future studies based on modes of thinking about the future:

- "**Probable** futures: *what is most likely to happen?* This category includes forecasting studies which are characterized by a predictive nature and which are mainly focused on trend monitoring and historical data analysis;
- **Possible** futures: *what might happen?* Scenario studies are included in this group and can be categorized as descriptions of possible future states and their developments (Borjeson et al., 2006).
- **Preferable** futures: *what would we prefer to happen?* Studies focusing on normative or desirable futures, such as backcasting and normative forecasting, try to answer the question which characterises this group"

[Miola 2008, 8][18].

2.8.4 Normative or Exploratory

Miola's description for **Preferable** futures (see 2.8.3) includes reference to normative forecasting. Normative refers to another characteristic used to categorize foresight methods. Concerns such as ethics, values, and virtues are part of normative forecasting. Coates and Glenn [2009] describe normative forecasts as consisting of two essential parts: (1) the statement of a goal or set of goals to be accomplished in a specific time period and (2) a detailed analysis of how to reach the goal or goals. Examples of purely normative methods are: analytical hierarchy process (see 2.7.4), backcasting (see 2.7.5), multicriteria decision analyses (see 2.7.27), participatory techniques (see 2.7.30), requirements analysis (see 2.7.33), science fiction analysis (see 2.7.39), and stakeholder analysis (see 2.7.41).

Normative predictions set goals that people attempt to achieve. The theory is that positive images of the future have a power to pull towards a positive future. Foresight exercises are often undertaken in times of crisis and this environment can put the practitioner into a mindset in which negative images of the future can be overemphasized. This overemphasis on the negative can allow a practitioner to become blind to some of the more optimistic potential futures. It is important to

[18] Miola credits Bannister and Stead [2004] for these insights, but this document appears not to include the text.

clarify that seeking positive aspects of the future does not mean adopting a naive belief that good luck will bless the organization and take away all of its problems. Instead, the knowledge that one must seek positive aspects of the future is to acknowledge that negative attitudes towards the future can limit one's capacity to change the course of events [Hines and Bishop 2006, 15].

The counterpart to the normative forecast, described above, is the exploratory forecast. An exploratory forecasting exercise is undertaken for the purpose of examining where the future may go without any consideration of whether people or society want it to go there or not. Examples of purely exploratory methods are: agent modeling (see 2.7.2), analogies (see 2.7.3), bibliometrics (see 2.7.6), causal models (see 2.7.8), checklists for impact identification (see 2.7.9), complex adaptive system modeling (see 2.7.10), correlation analysis (see 2.7.11), cost-benefit analysis (see 2.7.12), cross-impact analysis (see 2.7.14), demographics (see 2.7.17), diffusion modeling (see 2.7.18), economic base modeling (see 2.7.19), innovation system modeling (see 2.7.21), institutional analysis (see 2.7.22), long wave analysis (see 2.7.24), monitoring (see 2.7.36), organizational analysis (see 2.7.29), precursor analysis (see 2.7.31), sustainability analysis (see 2.7.43), systems simulation (2.7.42), technological substitution (see 2.7.45), technology assessment (see 2.7.44), and trend extrapolation (see 2.7.46). Some methods are a combination of both normative and exploratory forecasting. These methods are: action analysis (see 2.7.1), brainstorming (see 2.7.7), creativity workshops (see 2.7.13), decision analysis (see 2.7.15), Delphi (see 2.7.16), focus groups (see 2.7.30.1), interviews (2.7.23), multiple perspectives assessment (see 2.7.28), risk analysis (see 2.7.34), roadmapping (see 2.7.35), scenarios (see 2.7.37), scenario-simulation (see 2.7.38), social impact assessment (see 2.7.40), State of the Future Index (see 2.5), and TRIZ (see 2.7.48).

As with much of the classification performed within the futures environment, there is a lack of consensus regarding whether certain methods are normative, exploratory, or both. There are 19 TFA methods common to publications by the TFAMWG [2004] and The Millennium Project [2009] that each identified as either normative or exploratory or both. The two groups disagreed regarding six of the 19 methods. This disagreement has been captured in Table 12.

Method or [Variation]*	Method**	TFAMWG	The Millennium Project
Field Anomaly Relaxation		Ex/N	Ex
Morphological Analysis		N/Ex	N
Relevance trees	Relevance Trees	N/Ex	N
[Text Mining]	Text Mining	Ex	N/Ex
Trend Impact Analysis		N/Ex	Ex
Vision generation	Visioning	N/Ex	N

* Method name per Technology Futures Analysis Methods Working Group (TFAMWG)
** Method name per The Millennium Project
N = Normative
Ex = Exploratory

Table 12: Normative versus Exploratory Comparison

2.8.5 Hard or Soft

Another means of characterizing TFA methods is whether they are hard or soft. Whether a TFA method is hard or soft (“H or S”) refers to whether it is quantitative (i.e., empirical, numerical) or qualitative (i.e., judgmentally based, reflecting tacit knowledge). Examples of hard methods are: analytical hierarchy process (AHP), complex adaptive system modeling, correlation analysis, cost-benefit analysis, demographics, diffusion modeling, economic base modeling, long wave analysis, multicriteria decision analyses, precursor analysis, sustainability analysis, systems simulation, technological substitution, trend extrapolation, trend impact analysis, and TRIZ [TFAMWG 2004, 290]. Examples of soft methods are: action [options] analysis, backcasting, brainstorming, checklists for impact identification, creativity workshops, decision analysis, Delphi, field anomaly relaxation (FAR), focus groups, innovation system modeling, interviews, institutional analysis, mitigation analysis, monitoring, morphological analysis, multiple perspectives analysis, organizational analysis, participatory techniques, relevance trees, scenario-simulation, science fiction analysis, social impact assessment, stakeholder analysis, and vision generation [TFAMWG 2004, 290].

Like normative and exploratory descriptors, not all TFA methods are hard *or* soft. Some methods have both hard and soft characteristics. Examples of such methods are: analogies, bibliometrics, requirements analysis, risk analysis, roadmapping, scenarios, State of the Future Index, and technology assessment. Again, like normative and exploratory descriptors, the TFAMWG [2004] and The Millennium Project [2009] disagree regarding four of the 19 methods common to each's publication. This disagreement has been captured in Table 13.

Method or [Variation]*	Method**	TFAMWG	The Millennium Project
Agent modeling		H	S
Causal Models	Causal Layered Analysis	H	S
Cross-Impact Analysis		H/S	H
[Text Mining]	Text Mining	H/S	S

* Method name per Technology Futures Analysis Methods Working Group (TFAMWG)
** Method name per The Millennium Project
H = Hard
S = Soft

Table 13: Hard or Soft Comparison

Now that a solid grounding of the history of the various TFA methods and techniques has been established and the definitions of a majority of these methods and techniques have been provided, one can turn to their applicability to SMEs. The next chapter establishes the characteristics of the SME with respect to known theories of the firm and develops a set of criteria based on these characteristics by which to evaluate foresight methods and techniques.

3. TECHNOLOGY FORESIGHT FOR SMES: AN ASSESSMENT

> *The best answer to the question of who should do [technology foresight] is that all those engaged in the technology delivery system should have a sense of what constitutes valid [technology foresight] and appreciate what it can do for them.*
>
> [Coates et al. 2001, 15]

The last chapter provided a history of technology foresight (in North America), descriptions of numerous technology futures analysis (TFA) methods, and an assessment of the common approaches to technology foresight. The assessment of common approaches showed that there is no universally accepted standard for categorizing methods and therefore no means to assess TFA methods for SMEs by an established approach to categorizing methods. In addition, very limited research has been conducted on SMEs with respect to TFA. As a result, this chapter will seek to identify those TFA methods that are suitable for use by SMEs to explore potential business futures by synthesising relevant available research pertaining to the differences between foresight in the public sector and foresight in the private sector, and scoping issues related to any TFA. First, however, the characteristics of an SME will be analyzed.

3.1 CHARACTERIZING THE SME

To begin, it is important to understand the importance of SMEs to an economy. Small- and medium-sized businesses accounted for 54.3% of gross domestic product (GDP) in the Canadian business sector in 2005 [Leung, Rispoli, and

Gibson 2011, 8]. Whereas this thesis has so far referred to small- and medium-sized *enterprises,* it has not strictly defined the characteristics of such an entity. Economists have been defining the parameters of such entities, based on what they identify as the “theory of the firm”, for some time now, and it is their work that will be relied on to identify the characteristics of an SME.

As summarized in Table 14, traditional economic theories of the firm ([Baumol, Panzar, and Willig 1982], [Williamson 1985], [Nelson and Winter 1978, 1982]) indicate that SMEs are at a considerable disadvantage with respect to MNEs as a result of an inability to take advantage of a number of efficiencies [Di Tommaso and Dubbini 2000]: the most obvious being economies of scale. The less obvious efficiency, being economies of scope, refers to the situation where it is less costly to combine two or more product lines in one firm than to produce them separately [Panzar and Willig 1981, 268]. MNEs again enjoy an advantage over SMEs in terms of learning economies since they have the opportunity to gain both new skills and abilities as a result of production experience (economists believe that these type of economies “do not appear where it is not possible to emphasize the division of labour among those taking part in the production process” [Di Tommaso and Dubbini 2000, 18]) and their management teams have an opportunity to grow as well.

	ELEMENT	MNEs	SMEs
Technological	Ability to exploit economies of scale	High	Low
	Ability to exploit economies of scope		
	Ability to exploit learning economies		
Transactional	Ability to exploit internalization economies	High	Low

Table 14: Comparison of individual efficiency between large[19] and small[20] firms
Created based on [Di Tommaso and Dubbini 2000, 18-19]

The first three economies discussed in the previous paragraph are considered by economists to be of a technological nature due to their link to the benefits a particular technology might offer. The final aspect of traditional economics by which SMEs are disadvantaged is considered to be of a transactional nature as it concerns the minimizing of the costs emerging from transactions within firms. These internal costs can be optimized by different governance regimes within a firm such that an integrated enterprise is considered advantageous over a chain of non-related independent small enterprises [Di Tommaso and Dubbini 2000, 19]. This series of factors generally summarizes the disadvantages the SME encounters compared to the MNE from a classical economic individual firm perspective. The following paragraphs present the numerous factors which more

[19] Large firms are represented in this table by multi-national enterprises (MNEs).
[20] Small firms are represented in this table by small- and medium-sized enterprises (SMEs).

modern economists have identified which support the profitable existence of SMEs. It is upon some of these factors which the analysis of methods conducted later in this chapter will rely.

Di Tommaso and Dubbini [2000], in their efforts to develop a "theory of the small firm," identify a series of specifications and empirical regularities of small firms. These are summarised in Table 15. The last entry in Table 15 mentions the SME's aptitude for innovation. Innovation is currently a very prolific research topic (a few examples of journals on the topic include the International Journal of Management Innovation Systems, Environmental Innovation and Societal Transitions, Journal of Blindness Innovation and Research, Journal of Library Innovation, Law, Innovation & Technology, and the Journal of Innovation Economics). Therefore, to complete the descriptive identification of the small firm, following are the three factors that Statistics Canada uses to characterize small- and medium-sized enterprises:

- *"Innovation is consistently found to be the most important characteristic associated with success.*
- *Innovative enterprises typically achieve stronger growth or are more successful than those that do not innovate.*
- *Enterprises that gain market share and increasing profitability are those that are innovative"* [Tidd and Bessant 2009, 5].

	ELEMENT
Empirical Regularities	1. The organization's degree of learning is a key element dependent on "the role and characteristics of the human resources present in the firm organization."
	2. Generally, in small firms, qualifications being equal, salaries are less than in big firms.
	3. "...higher worker turnover in small firms compared with others."
	4. "...presence of a greater number of workers belonging to the 'discriminated against' labour market categories (women, immigrants, young people)."
	5. "...the small firm has a lower attractiveness with regard to resources."
	6. "...small firm[s] often benefit[s] from a certain elasticity in the application of work law which permits it to employ a greater organisational flexibility."
	7. "...the small firm usually has difficulty obtaining credit and is more sensitive to recession from a liquidity point of view."
	8. "...small firms seem to be privileged for exploitation of the potentialities of collective efficiency[21] in complex systems of firms (clusters, districts and networks)."
Specificities	1. The SME leader (typically an entrepreneur) "often has multi-purpose abilities and a practical, manual culture while organisation appears informal and characterized by the absence of management and middle management for key roles."
	2. There is a family aspect to many small firms that includes both positive and negative consequences.
Both	"...vivacity of small firms in introducing innovations in sectors with a high number of qualified workers."

Table 15: Summary of empirical regularities and specificities of small firms
Created based on Di Tommaso and Dubbini [2000, 36-38]

Augustine, Bhasi, and Madhu [2012, 260] summarize the contents of Table 15 well in their statement: "Even though SMEs operate with less resources and managerial expertise they attract research attention due to the ease of management, flexibility in operations and more reactive response to market changes."

From the perspective of innovation, Tidd and Bessant [2009, 61] summarize the

[21] "Collective efficiency" refers to "the competitive advantage derived from local external economies and joint action" [Schmitz 1995, 529].

advantages and disadvantages for small firm innovators in Table 16. Cross-referencing the empirical regularities and specificities of small firms captured by Di Tommaso and Dubbini (see Table 15) with the advantages and disadvantages noted by Tidd and Bessant (see Table 16), one is able to identify the characteristics of SMEs which are liable to limit their ability to use certain TFA methods. Starting with Di Tommaso and Dubbini's empirical regularity that the organization's degree of learning is dependent on the role and characteristics of the human resources present in the firm organization (see Table 15), and linking this to the disadvantage that small firm innovators lack key skills and experience (see Table 16), one may conclude that the ability of an SME to execute a TFA will be highly dependent on the education level, risk tolerance, and decision-making style of the finite group of individuals that make up the firm [Augustine, Bhasi, and Madhu 2012, 260]. Per Specificity 2 in Table 15, it is the SME leader (typically an entrepreneur) who is most likely to possess, amongst his or her "multi-purpose" abilities, the skills necessary to conduct a TFA.

ADVANTAGES	DISADVANTAGES
Speed of decision making	Lack of formal systems for management control e.g. of project times and costs
Informal culture	Lack of access to key resources, especially finance
High quality communications – everyone knows what is going on	Lack of key skills and experience
Shared and clear vision	Lack of long-term strategy and direction
Flexibility, agility	Lack of structure and succession-planning
Entrepreneurial spirit and risk taking	Poor risk management
Energy, enthusiasm, passion for innovation	Lack of application to detail, lack of systems
Good at networking internally and externally	Lack of access to resources

Table 16: Advantages and Disadvantages for small firm innovators
[Tidd and Bessant 2009, 61]

Of important note is the “lack of long-term strategy and direction” disadvantage that Tidd and Bessant identify for small firm innovators in Table 16. This reference reinforces the need for the research that this thesis has undertaken. By identifying foresight methods suitable for SMEs, this research provides the opportunity for SMEs to improve their ability to develop a long-term outlook and, by doing so, aid their ability to innovate. In this way, small firms that have a recognized vivacity in introducing innovations (in sectors with a high number of qualified workers) (see Table 15) can create the best situation in which to take full advantage of their energy, enthusiasm, and passion for innovation (see advantages in Table 16).

Having provided the characteristics of SMEs as distinct from MNEs, principally the lack of human resources, this investigation will move on to examine what available research about SMEs and fore*casting* may be applied to SMEs and fore*sight*. Given that the act of technology fore*casting* over time expanded into the concept of technology fore*sight* (see Literature Review), it is anticipated that this research will be useful.

Smith III et al. [1996] and Flores, Stading, and Klassen [2007] – the latter being a study of Canadian manufacturing and service firms – identify three differences between forecasting behaviour in large and small firms which will be seen to directly impact the selection of foresight methodologies suitable for SMEs. These differences relate to: communication characteristics, the duration between forecast and results, and resource limitations.

Smith III et al. [1996, 39] describe three circumstances relevant to a small firm's ability to forecast:

1. *"the founders of the company are totally involved in producing and selling their product;*
2. *communication among all employees is open; and*
3. *management reacts immediately to market feedback."*

The second characteristic – that of open communication among all employees – is important with respect to an SME undertaking a foresight exercise because it reduces the efforts which must be taken to keep everyone in the organization informed.

Smith III et al. [1996, 46] found “the duration between forecast and results received is shorter for smaller firms than larger firms.” This is an important finding since it provides an insight into an important characteristic of the application of TFA methods by an SME. This insight is that the time scope of forecasts (the length of time a forecast covers) completed by SMEs is of a shorter duration than those of a large company. This implication is relevant to upcoming section 3.2.

Finally, the limited resources available to SMEs in their forecasting efforts is noted numerous times in both Smith III et al. [1996] and Flores, Stading, and Klassen [2007]. With Smith III et al. ultimately concluding that “the larger the company, the more people involved in the forecasting process” [1996, 45] and Flores, Stading, and Klassen stating “Large businesses...may be better positioned to deploy resources in order to use more sophisticated forecasting techniques” [2007, 388].

3.2 PUBLIC VERSUS PRIVATE FORESIGHT: IMPLICATIONS FOR SMES

As SMEs clearly belong to the private sector, it is perhaps counterintuitive to suggest that much can be learned from examining the differences between foresight in the public sector and foresight in the private sector. Doing so, however, the comparison will highlight some of the human resource gaps between the public and the private sector with respect to conducting a foresight exercise;

this will offer an appreciation of the limited resources available to SMEs. Section 3.3 will explore known issues relating to the execution of a TFA study. These issues are categorized as relating to either the TFA method content or its execution process.

As Ruff [2004] has argued, there are key differences between foresight in the public sector and foresight in the private sector (see Table 17). A careful review of these differences will highlight the specific implications for SMEs. Per the first row in Table 17, it is the common general objective of most technological foresight exercises to aid the researcher in anticipating and coping with the direction and rate of technological change [Ruff 2004]. However, per the second row, the specific objectives of a foresight exercise conducted by a company are different than those of a foresight exercise conducted for a nation. Governments are typically interested in generating ideas and visions for technology and innovation, and in identifying and/or prioritizing the related policy measures. A company, on the other hand, regardless of its size, is more interested in identifying specific opportunities and/or risks in its markets, with its technologies, and in the business environment.

	Foresight in the public sector	Foresight in the private sector/in companies
General objective	Anticipation of future developments in science, technology, economy, politics and society	
Specific objectives	▪ Generating ideas and visions for technology and innovation ▪ Identifying/prioritizing related policy measures	▪ Identification of opportunities/risks in markets, technologies, and the business environment ▪ Identifying strategic options
Major actors	▪ Government bodies ▪ Expert communities ▪ NGO's	▪ Strategic planning units ▪ Research and Technology divisions ▪ Corporate think tanks
Time scope	5-20 (50) years	2-15 years
Duration of typical projects	1 to 3 years (periodically repeated)	3 months to 1 year (periodically repeated)
Major methods	Delphi-Studies Expert interviews Technology Monitoring/Scanning Scenarios Quantitative models Trend research (and others)	Analysis of patents/licenses Expert interviews Technology Monitoring/Scanning Scenarios Quantitative models Trend research (and others)

Table 17: Foresight in the public and private sector
Adapted from [Ruff 2004]

Although an SME may share a common interest with a multi-national enterprise (MNE) in its desire to identify specific opportunities and/or risks in its markets, with its technologies, and in the business environment, it seldom has a sufficiently large staff to achieve this (see 3.1). The third row of Table 17 identifies strategic planning units, research and technology divisions, and corporate think tanks as the major actors for foresight in the private sector. Companies with resources sufficient to support strategic planning units and R&T divisions are larger than the SMEs that this thesis is targeting. Similarly, the targeted SMEs are not typically financially capable of hiring think tanks to conduct their foresight exercises.[22]

Turning to the fourth row of Table 17, “time scope”: it is typical for foresight conducted by nations to look further into the future than foresight conducted by companies. Although there are no agreed upon definitions, [Adam] Gordon [2009, 20] categorizes forecasts into five categories: short-term (zero to one year), short-medium (one to three years), long-medium (three to ten years), long-term (ten to twenty-five years), and ultra-long term (twenty-five to 10,000 years) and notes that ultra-long terms forecasters “put themselves outside any common business, policy, or institutional frame.” With respect to long-term forecasts, he states “There is still some conceivable usefulness in organizational planning and decision making, but it is slight” [Adam Gordon 2009, 20]. [Adam] Gordon [2009, 20] identifies long-medium forecasts as having a broader strategic purpose, short-medium forecasts as short-term forecasts which have been extended to accommodate longer planning horizons for operational purposes and short-term forecasts as “bread-and-butter operational forecasts used in day-to-day planning, supply chain and inventory management.” Clearly there is a discrepancy between [Adam] Gordon’s “bread-and-butter” zero to one-year forecasts compared with Ruff’s [2004] shortest time scope starting at two years for foresight in the private sector/in companies. However, there is no evidence to dispute either claim. There

[22] The last statement is not supported by research since the cost to perform forecasting or foresighting studies has not appeared in published research.

is also no evidence available to suggest that an SME would not want to look the same distance into the future as that of a huge, well-financed organization. However, given [Adam] Gordon's perspective, it seems reasonable to anticipate that an SME will be interested in a study with a time scope of one to ten years.

Table 17 identifies the duration of typical foresight projects in the private sector or in companies as being three months to one year (periodically repeated). As a year seems to be a long period of time for an SME to await the outcome of a foresight exercise, and, per the characteristics of the SME in 3.1, the time scope of forecasts completed by SMEs is of a shorter duration than those of a large company, it is likely that the duration of a typical foresight project for an SME will fall in the three- to six-month range.

Finally, according to Table 17, the only difference that Ruff [2004] identifies between the "major methods" for foresight in the public sector and foresight in the private sector/in companies is the use of Delphi studies by the public sector and the analysis of patents/licenses in the private sector/in companies. The lack of use of Delphis by the private sector/in companies is not surprising. As described in 2.7.16, such studies require the identification and use of experts. Further, Delphis are difficult to perform (since the questions must be prepared very carefully to avoid ambiguity) and they are time-intensive. At least four months should be budgeted for a three-round Delphi [Gordon 2009i, 11].

In summary, using Ruff's findings [2004], a comparison of foresight in the public sector to foresight in the private sector/in a company suggests the following expectations regarding the application of TFA methods to SMEs:

- the specific objective of applying technology foresight to an SME is the same as that of an MNE: to identify specific opportunities and/or risks in its markets, with its technologies, and in the business environment;
- SMEs are operating in a vastly different resource environment than are larger entities. They lack strategic planning units, research and technology divisions, and corporate think tanks. This factor will make many of the available TFA methods evaluated in 3.3 unsuitable for use by SMEs;
- SMEs are likely to be interested in a study time scope of one to ten years;
- the duration of a typical foresight project for an SME will likely fall in the three- to six-month range;
- the major methods for application are likely to be: analysis of patents/licenses (bibliometrics), expert interviews, technology monitoring/scanning, scenarios, quantitative models, and trend research, along with other unnamed methods.

By evaluating TFA methods against the known issues associated with conducting a future study, the next section will determine whether the major methods predicted by Ruff [2004] for foresight in the private sector/in companies are also appropriate for SMEs.

3.3 ASSESSING TFA METHODS FOR SMES: SCOPING ISSUES

Per the previous section, Ruff [2004] has suggested that the major methods for foresight in companies are: analysis of patents/licenses (bibliometrics), expert interviews, technology monitoring/scanning, scenarios, quantitative models, trend research, and other unnamed methods. This section will investigate whether this applies to SMEs. In assessing the appropriateness of specific TFA methods to SMEs, our most important analytical criterion will be *scope*. "Scope" refers to an area over which activity, capacity, or influence extends, and impacts two aspects of any technology futures analysis: the future study's content and the process by which the future study is conducted. Table 18 summarizes both the content and the process scoping issues related to TFA methods.

Scoping issue	**Some implications**
Content issues	
Time horizon	data needed, suitable methods
Geographical extent	data (proximity affects direct vs. secondary access)
Level of detail micro (company), meso (sector), macro (national, global)	process – nature of interaction of stakeholders
Process issues	
Participants (number, nature – experts or broader, disciplinary mix)	how expertise is tapped, how study is conducted
Decision processes (operational, strategic, visionary)	choice of experts
Study duration (minutes to years)	methods usable
Resources available (funding, data, skills)	methods suitable; modes of access to expertise
Methods used	data needed, analytical outputs
Organization	methods suitable, staffing, process management
Communication flows (internal, external)	process management, nature of participation
Representation of findings (technology information products)	usability by various audiences

Table 18: TFA content and process scoping issues
[TFAMWG 2004]

Per Table 18, scoping issues with respect to content refer to three elements: the geographic extent to which the analysis applies, the level of detail in which the study is to be conducted, and the selected time horizon for the study. Using the study in *The Limits to Growth: A report for the Club of Rome's project on the predicament of mankind* [Meadows et al. 1972] as an example, the three content scope elements of this study of the future are:

- geographic extent – the world
- level of detail – a computer simulation model (called World 3)
- time horizon – to the year 2100 [TFAMWG 2004].

An SME using a particular TFA method will have to determine its own geographic extent. Some SMEs may engage with the world, others conducting business on a more local basis may identify their city, province, or country as their geographic extent. In terms of level of detail, an SME will use a micro level (the company), rather than the meso (sector) or macro (national, global) levels. However, this scoping issue may be tied to resource availability as it is possible that with additional human resources, additional detail may be investigated. Referring back to section 3.2, one can anticipate an SME to be interested in a study with a time horizon of one to ten years.

Whereas there were three scoping issues relating to content, Table 18 indicates that there are many more scoping issues relating to the process by which a future study is conducted: participants, decision processes, study duration, resources available, methods used, organization, communication flows, and representation of findings. Study duration has already been addressed in section 3.2 (recall that the duration of a typical foresight project for an SME will likely fall in the three- to six-month range), and the remaining issues can be separated into two categories: those key to SMEs and those essentially irrelevant to SMEs.

The reduced number of individuals making up an SME so minimize the influence of organization, communication flows, and representation of findings on TFA studies by SMEs that they can be considered irrelevant. Implications relating to issues of organization, communication flows, and representation of findings all have to do with managing information or activity amongst large numbers of people. Tidd and Bessant [2009, 61] recognize both high quality communications and good internal networking as advantages enjoyed by small firm innovators. Staffing and process management (implications of the organization scoping issue) are minimal in SMEs[23] due to their small size. Similarly, there is minimal process management in a small or medium organization where all employees know each other's roles and there tends to be a consistent representation of findings since there is a single audience (the SME itself). The key issues with SMEs conducting

[23] This should not be interpreted to mean that staffing is not a critical element of an SME. Having the correct individuals performing tasks that they are uniquely suited for is particularly critical in an SME.

foresight studies are: participants, decision processes, resources availability, and the selection of the methods to be used.

Decision processes refer to the type of decision the technology foresight exercise is intended to inform. Per Table 18, these can be decisions around operational matters, strategic matters or visionary matters. An exploratory method such as visioning would not be suitable for making an operational decision such as whether to invest in a specific technology because visioning does not give detailed enough information to support a specific decision. The format of the problem in this thesis does not specify what type of decision an SME may be making. It seeks only to determine whether a method can be employed by an SME. Therefore, decision processes will not be further examined.

The remaining three key process issues are: participants, resource availability, and selection of the methods used. Each of these key issues will be examined in the sections below with the intent of eliminating from consideration those TFA methods which do not meet the criteria being developed; thereby identifying those TFA methods which answer the research question “Are there technology foresight (TF) or technology futures analysis (TFA) methods available to aid SMEs in their technological decision-making?”.

3.3.1 Participants

Table 18 identifies some of the implications around the process issue of participants (number, nature, and disciplinary mix). These include “how expertise is tapped” and “how the study is conducted”. The number and nature of the participants is critically relevant when an SME undertakes a technology foresight exercise. Human resource availability is important in terms of who will actually be performing the work. Di Tommaso and Dubbini [2000, 37] identify the “personal figure of the entrepreneur” as being pre-eminent in small firm activities. Thus, the particular skills and abilities of this individual will be paramount. Beyond the entrepreneur herself, Di Tommaso and Dubbini [2000, 37] (see Table 15) also identify the role and characteristics of the human resources present in the firm organization as impacting the organization’s degree of learning. Unfortunately, they do not delve into any additional detail.

How far outside the organization an SME is willing or able to engage resources may be influenced by available project funds and/or the desire to keep the activity confidential. Regarding project funding, Di Tommaso and Dubbini [2000, 37] identify that small firms “usually” have difficulty obtaining credit and that under-capitalization is also typical of a small firm. Relying on this information, the ensuing evaluation of methods will be based on the assumption that the SME does not have funding to engage outside resources.

Turning back to the concern of confidentiality, should an SME be engaged in a TFA project for the purpose of gaining or maintaining a competitive advantage, it is likely that the company would prefer not to make this information general knowledge by employing an external group of experts who may be prone to talk both amongst themselves and to outsiders regarding the project. Supporting the assumption stated in the previous paragraph, the use of internal corporate resources is likely the least expensive approach, and the one ensuring the greatest confidentiality.

Based on the assumption that the SME does not have funding to engage outside resources, those TFA methods which require the use of experts must be eliminated from consideration. This results in the elimination of TFA methods expert interviews and Delphi. There are three additional TFA methods whose general descriptions identify the involvement of experts. These are: cross-impact analysis [Gordon 2009a], roadmapping [Gordon 2009d], and trend impact analysis [Gordon 2009c].

Turning to the number of participants; in consideration of this work intending to identify those TFA methods available to aid SMEs in their technological decision-making, this work will take the extreme approach of limiting the number of participants to one. Mintzberg identifies this organization archetype as the "simple structure". According to Mintzberg [Tidd and Bessant 2009, 108], key features of the simple structure are "...centrally controlled but can respond quickly to changes in the environment. Usually small and often directly controlled by one person. Designed and controlled in the mind of the individual with whom decision-making authority rests. Strengths are speed of response and clarity of purpose. Weaknesses are the vulnerability to individual misjudgement or prejudice and resource limits on growth."

By assuming a simple structure, the particular number of employees within an SME becomes irrelevant (as explained in 1.2, "There are many definitions of SMEs, which can be categorized by size according to the number of employees, the value of annual sales, annual revenues or borrowing capacity" [Government of Canada 2011]. This inconsistency in definitions is irrelevant to the focus of the work in this thesis).

Limiting the number of participants to one means that methods requiring more than one person are not considered suitable for SMEs. This eliminates methods such as analytical hierarchy process (AHP), brainstorming, creativity workshops, field anomaly relaxation (FAR) [Coyle 2009], participatory method (e.g., focus groups), roadmapping [Garcia and Bray 2005], scenarios [de Jouvenel 2000], and stakeholder analysis [Dick 1977]. These methods typically require the involvement of teams or large numbers of individuals. In addition, the scenario-simulation [gaming; interactive scenarios] method has certain characteristics which make it unsuitable for SMEs. For example, gaming is the use of a game to simulate a real situation. Most games involve multiple players. The other method identified under scenario-simulation – interactive scenarios – is a method that involves breaking down a previously prepared scenario, but it is identified as not being suitable for anything but the shortest and simplest scenarios [Gordon 2009h, 6].

Examining the number and nature of the participants required to accomplish specific TFA methods for SMEs has eliminated those methods requiring experts as well as those methods requiring more than one person. The next section will seek to examine the impact of resource availability on the TFA methods suitable for SME use.

3.3.2 Resources available

Table 18 refers to funding, data, and skills when it references resource availability. Funding has been reviewed previously and it has been shown that SMEs have difficulty accessing external funding, so funding of the foresight exercise is anticipated to fall to the SME itself and, as a result, be limited. It is assumed that data, as a resource, flows well within an SME since Tidd and Bessant [2009, 61] identify two advantages for small firm innovators that support the easy availability of data within the SME. These are that SMEs have high quality communications which translates into everyone knowing what is going on and that they are good at networking internally. Skills, as a resource, are a more complicated consideration and represent an area of crossover with the process issue relating to participants (just discussed in 3.3.1).

Section 3.3.1 limited the TFA method practitioners to those individuals available within the SME since it was assumed that tight financial constraints would not allow the SME to employ experts (then the section further limited the number of individuals to one). The availability of skills within an SME is an area of extreme uncertainty as these depend both on the business function of the SME as well as the non-job-related skills and abilities that each employee inherently carries.

One of the rare studies to be found on SMEs and foresight was described by Major, Asch, and Cordey-Hayes [2001]. It was a study undertaken in the United Kingdom to gain an understanding of the depth and breadth of knowledge of foresight in industry based on the "take-up of foresight concepts and the Foresight programme[24] in small companies." The research involved interviews with managers in forty-nine small companies. Twenty-seven of the companies were in the specialist organic chemicals sector and twenty-two were in the electronic sensors sector. The criteria used to select the sectors were that they should be "technologically progressive, highlighted as priority areas by the Foresight programme, be accessible for research, form discrete samples and come with recommendation of informed personnel" [Major, Asch, and Cordey-Hayes 2001, 97]. An important finding was that "the impact of managerial attitudes and attributes is central...foresight knowledge was attributed to individual staff rather than to company systems and procedures" [Major, Asch, and Cordey-Hayes 2001, 100]. Thus, although the study could be seen as self-serving in that it sought out,

[24] The UK's Foresight programme aimed to use foresight concepts to inform Government spending priorities, and to shape a national culture of innovation throughout industry [Major, Asch, and Cordey-Hayes 2001, 91].

as part of its criteria, sectors which came with the recommendation of informed personnel and then sighted as an important finding the impact of foresight knowledge by individual staff as important, it is easy to believe this to be true of SMEs.

As a result of previous decisions regarding limitations placed on this research, the sole resource available to the SME to perform the foresight or technology futures analysis method shall be the owner/entrepreneur. As each entrepreneur is unique, it is impossible to identify the average skills of such an individual. As a result, additional assumptions regarding limitations will be made in the following sections.

The first assumption will be that the lone entrepreneur who will be applying the selected TFA methods will not have any unusually unique skills. There are a number of TFA methods which require very particular skills to be able to execute them. Science fiction analysis ([Cornish 2004], [Shipman 2007]) is such an example. Science fiction analysis involves the review of science fiction as an indicator of potential future technologies or the use of science fiction writers to dream up future technologies. In either case there is a strong link to the world of science fiction. Unless the entrepreneur has a penchant for science fiction, this method would require the hiring of someone external to the SME with special knowledge of the genre. As a result, the science fiction analysis method will be eliminated from consideration as being a suitable method to aid SMEs in their technological decision-making.

Demographics, or more likely population studies (as discussed in 2.7.17), is another such method. Demography is, strictly, the study of population structure and change. Population projection can be accomplished by one of two methods: the mathematical method and the component method. The mathematical method is quick, simple, and requires little in the way of data [Hinde 1998, 199]. However, it is most likely that an SME would be most aided by a population study. Population studies go beyond and additionally study the relationships of population to economic, social, cultural, and biological processes. Regarding a *Population Bulletin* which attempts to answer three questions about the relationships between population, health, and environment, De Souza, Williams and Meyerson state [2003, 3] “Addressing these questions means delving into the complexity of population, health, and environment relationships and reaching out to experts in diverse fields.” In addition, they go on to say “Natural and social scientists who study demographic trends, political structure, land use, agriculture, climate change, biodiversity loss, and an array of other specialists can all contribute to a greater understanding of population, health, and environment relationships” [De Souza, Williams, and Meyerson 2003, 4]. Coupling the lack of a described methodology from the TFAMWG with a reference to the need for specialists, demographics will be eliminated from consideration as being a suitable method to aid SMEs in their technological decision-making.

Similarly, the analogies method and the correlation analysis method each require an individual to have special knowledge. In the case of the analogies method, the practitioner must have keen historical knowledge of technologies to perform a systematic comparison of the technology to be forecast with some earlier technology that is believed to have been similar in all or most important respects [Martino 1983, 39]. In the case of correlation analysis, the practitioner must have sufficient specific knowledge to be able to correlate one technology with another.

Finally, there is one method which requires extensive knowledge of the TFA method itself to be able to execute it. TRIZ ([Clarke 2000], [Coates 2004a]), or the Theory of Inventive Problem Solving, is an algorithmic approach which requires knowledge of the algorithm.

The second assumption is that the lone entrepreneur who will be applying the selected TFA methods does not have any computer modeling skills. Methods requiring such skills are agent modeling ([Gordon 2009j]), causal models, complex adaptive system (CAS) modeling ([Koppl 2005]), and systems simulation [System Dynamics Society 2008].

Two more skill sets are also assumed not to be enjoyed by the lone entrepreneur who will apply the foresight methods. These are action [options] analysis and economic base modeling. Action [options] analysis ([McGrath and MacMillan 2000], [SDG 2007a]) requires one to be familiar with the concepts of acquiring options in the world of finance, and economic base modeling [input-output analysis] requires knowledge of economics.

Examining the funding, data, and skills required to accomplish specific TFA methods for SMEs has eliminated those methods requiring niche skills which not every SME can be assumed to have such as: broad and deep knowledge of science fiction in the case of science fiction analysis and knowledge of computer modeling skills in the case of agent modeling, causal models, CAS modeling, and systems simulation. One of the few SME-specific studies found highlighted the importance of having someone within a company familiar with futures research.

The next section will examine the impact of the TFA method itself on its suitability for SME use. This is the final process scoping issue to be examined before presenting those methods which are deemed to meet the various needs of an SME.

3.3.3 Methods

It is this basic process scoping issue that this thesis is addressing. There are numerous methods which are simply not suited to addressing the future or potential futures of an SME. The best example of this is the State of the Future Index (SOFI) method. The SOFI (detailed in 2.5) was created to quantify global progress on 15 specific challenges and in so doing to assess whether the future is improving or getting worse [Gordon 2000f, 1]. The SOFI reports are "intended to provide a context for global thinking and improved understanding of global issues, opportunities, challenges and strategies [Glenn, Gordon, and Florescu 2011, n.p.]. Therefore, although an annual SOFI may be useful input to an SME's investigation of its future, it is not appropriate as a core method of investigating its future.

Other methods which have a particular focus or outcome which does not align with addressing the future or potential futures of an SME are: cost-benefit analysis (CBA), decision analysis, innovation system modeling, institutional analysis, morphological analysis, multiple perspectives assessment, precursor analysis, relevance trees, social impact assessment, sustainability analysis/life cycle analysis, and technology assessment. The tasks that these methods are focused on can be separated into three broad groups: informing social issues, solving specific problems, and solving specific technology issues.

Those methods best suited to informing social issues are: CBA, social impact assessment, and technology assessment. The broad purpose of CBA is to help social decision making [Boardman et al. 2001, 1] (i.e., not to help individual corporate decision making). CBA is typically applied to policies, programs, projects, regulations, demonstrations, and other government interventions. Similarly, technology assessment examines the effects on society that may occur when a technology is introduced, extended, or modified [Porter et al. 1980, 3] and focuses on policy study. Social impact assessment is the process of analyzing and managing the intended and unintended consequences on people of policies, programs, and projects in an attempt to initiate a more equitable social development, particularly for minority groups and other disadvantaged members of society [Vanclay 2003a]. These methods may be very useful for an SME to evaluate the impact of one of its projects or products on a particular group of society – or society at large – but they are not appropriate to aid in a general corporate foresight exercise for an SME.

The methods designed to problem-solve are: decision analysis, morphological analysis, and relevance trees. These methods, fully defined in 2.7.15, 2.7.26, and 2.7.32, respectively, therefore require a particular problem which must be resolved as their starting point. As described in 2.7.15, the purpose of decision analysis is to help a decision maker think systematically about complex problems and to improve the quality of the resulting decisions [Clemen 1996, 10]. As analytical techniques that subdivide and organize information, relevance trees and morphological analysis are also excellent methods for solving problems, but only once those problems have been defined. The future (or futures) of an SME, however, is not a "problem to solve". It is an opportunity to develop or explore the organization's future.

At this point the following TFA methods have been eliminated from consideration in terms of answering the research question: interviews, participatory techniques, focus groups, Delphi, cross-impact analysis, roadmapping, trend impact analysis, brainstorming, creativity workshops, field anomaly relaxation (FAR), scenarios, analytical hierarchy process (AHP), stakeholder analysis, scenario-simulation, science fiction analysis, demographics, cost-benefit analysis (CBA), decision analysis, innovation system modeling, institutional analysis, morphological analysis, multiple perspectives assessment, precursor analysis, relevance trees, social impact assessment, sustainability analysis/life cycle analysis, and technology assessment. The tasks that these methods are “better suited for” can be separated generally into three broad groups: solving social issues, solving specific problems and solving specific technology issues

Multiple Perspectives Assessment (described in 2.7.28), was initially developed to assist with decisions in technology management, examines an issue from three classes of perspectives: the technical, the organizational, and the personal [Linstone 2009]. Whether used for examining an issue or to assist with a decision in technology management, the method is not suited to speculating on, or aiding in, the planning of the future of an SME.

Methods intended to resolve specific technology issues are: institutional analysis, precursor analysis, sustainability analysis/life cycle analysis, and innovation system modeling. Institutional analysis [Porter et al. 1980] provides a means to evaluate the organizations (e.g., governmental agencies, special interest groups, cultural organizations) having a bearing on the delivery system of a particular technology and evaluate options to improve that delivery system. Thus the method is best suited to a technology which is believed to be missing out on market share due to institutional factors. The theory behind precursor analysis is that there are precursor events which make it possible to predict the eventual breakthrough of new technologies. This may be a very useful method for an SME to use to predict the breakthrough of one of the new technologies it is taking to market (should it have a particular technology in this stage). However, the method is tied too specifically to a particular product to be used to explore or develop the SME's future. Sustainability analysis/life cycle analysis focuses on the probability of the continuation of activities without negatively affecting the environment, social or economic systems [Boyle 2005, Abstract]. Therefore, the method is typically best suited to the evaluation of a particular product or the comparison of the impact of two or more products on the environment. If this is the interest of the SME, this method can be very useful. However, it is not particularly helpful in considering the future or futures of an entire organization. Innovation system modeling refers to the process of creating a model to describe how innovation occurs. This is too specific in nature to a particular corporate process instead of the future of the entire corporation.

Before concluding this chapter by presenting the TFA methods that are suitable to explore potential business futures of SMEs, it is important to note some of the human frailties associated with all aspects of foresight. The considerations discussed in the following section should be taken into account when making any business decision. However, they are known to be associated with decisions concerning the future and are therefore included to inform any technology foresight activity. Due to the limited numbers of individuals performing technology foresight for an SME, any known biases should be identified and efforts made to offset them.

3.3.3.1 Human Considerations when Conducting a Foresight Activity

TFA methods are valuable in their ability to allow the user to systematically explore, create, and test both possible (exploratory) and desirable (normative) futures to improve decisions. The use of TFA methods also enhances an organization's ability to react to a variety of circumstances since the applications of the methods has forced the organization to consider future events and their consequences (strategically it is better to anticipate, rather than just respond to change).

Despite the benefits of TFA mentioned above, one must also be aware of known limitations on people's ability to assess future (or generally uncertain) events. There is a significant body of research in this area, and therefore not full agreement on all matters. Without attempting to weight the certainty of each limitation, this section will describe the primary limitations and their potential impacts on TFA before offering some ideas about how to compensate for man's innate biases.

3.3.3.1.1 Natural Bias

Not all bias is manipulative and cynical. Natural bias is not necessarily bad or even an error; it is simply inevitable as a result of the human experience. No matter how a person may try to evaluate free of bias, everyone has a point of view shaped and influenced by their culture, education, and personal experiences. According to Immanuel Kant, all knowledge is "produced" in one's mind and this filtered perception of the world is the only one available to an individual.

In-depth analysis of natural bias is the task of cognitive psychologists and brain researchers. However, an important consideration which can be taken away from research to date is that the effect of natural bias means that even though the same factually valid and technically accurate information is provided to two different people to evaluate, the resulting conclusions or forecasts may not be the same. One of the reasons may be that certain individuals may be intrinsically incapable of predicting certain outcomes. The example provided by Gordon [Gordon, Adam 2009, 89] involves the studies of "the vase versus two faces" and "old hag versus busty young woman" images (known as figure-ground studies). According to Gordon, in more complex examples of such images some people cannot see both images, no matter how hard they try.

3.3.3.1.2 Confirmation Biases

Confirmation biases are those related to what a person's own experiences have been and what they know; specifically, the tendency to perceive more support for these beliefs than actually exists in the evidence at hand and to be more critical of those beliefs with which a person does not have personal experience. This bias can lead to a willingness to gather facts that support certain conclusions but disregard other facts that support different conclusions [Ross and Anderson 1982, 149].

Another bias is that we tend to accept the first alternative that looks like it might work. This can lead to a premature termination of the search for evidence.

3.3.3.1.3 Bias of Availability

There are situations in which people make probability judgments based on the ease with which they come to mind. The family to which this bias belongs is referred to as "availability" and refers to the mental retrievability of an idea, thought or concept. The two primary examples of availability are familiarity and saliency. For example, a familiarity bias means that an individual may conclude that wind generation is the "best" technology having been unduly influenced by numerous recent media reports pertaining to wind energy. Salience refers to a phenomenon in which one is more liable to predict solar generation if one is staring out a window at solar panels, even though all technologies have been fully researched in the literature.

3.3.3.1.4 Biases of Imaginability

Human beings are also susceptible to biases of imaginability. Biases of imaginability involve placing extra weight on unlikely potentially negative outcomes. For example, developing plans to address reasonable contingencies is a prudent step in the planning of an adventurous expedition. However, the risk which the bias of imaginability poses is that imagination takes off and *un*reasonable contingencies begin to be voiced which overshadow the goal of the expedition and make it look exceedingly risky. The other end of the imaginability bias occurs if contingencies are grossly underestimated. This can occur if some possible dangers are either difficult to conceive of, or simply do not come to mind [Tversky and Kahneman 1982, 13].

3.3.3.1.5 Anchoring and Adjustment

Anchoring and adjustment refers to another family of biases in which decisions are unduly influenced by initial information that shapes one's view of subsequent information. The initial information becomes the "anchor" and subsequent decisions regarding it are the "adjustments". It has been shown that these adjustments to the initial information are typically insufficient [Tversky and Kahneman 1982, 14].

3.3.3.1.6 Bias of Peer Pressure

All of the TFA methods are susceptible to influence by the bias of "group think" or peer pressure, but certain techniques in the TFAMWG's creativity family, as a result of their requirement for the gathering of people, are more susceptible. These methods are brainstorming, vision generation, and creativity workshops. Some of the TFAMWG's expert opinion methods (participatory techniques, focus groups, and Delphi) also run the risk of individuals conforming to the opinions held by the group. This may have devastating effects on the activity since it may be these contradictory opinions or outlying positions which hold the value.

3.3.3.1.7 Bias of Hindsight

Those TFA methods which rely on using the past to forecast the future, such as those in the trend analysis family, may be impacted by a known bias of hindsight. The bias of presentism, for which there is no proven antidote [Fischhoff 1982a, 429], refers to the inability of researchers to suspend their knowledge of present day realities. In other words, we know things that those living in the past did not. In hindsight, people consistently exaggerate what could have been anticipated in foresight [Fischhoff 1982b, 341].

3.3.3.1.8 Zeitgeist Bias

"Zeitgeist bias" refers to the intellectual views, analytical approaches, political and social concerns, etc., that people in an era share. The word "zeitgeist" is a German word meaning spirit of the times. This bias is another one which may cause those analysing the future to be blind to the occurrence of certain events.

Adam Gordon [2009, 94] provides as an example a collection of forecasts made by Chicago experts and notables of the day at Chicago's World Fair in 1893. While a few forecasters saw technology and social outcomes consistent with what transpired, most focused on agriculture and agricultural trade, Europe, and European ways of doing things. The forecasts had strong elements of unionism, labour politics, and anarchism, which were typical of concerns in the 1890s, but not of the 1990s.

3.3.3.1.9 Compensating for Bias

The above sections provide known limits to people's ability to assess the future (or generally uncertain events). Most of these are inherent biases and it will be up to the cognitive psychologists and brain researchers to determine how to compensate for such biases. Glenn [2009b, 12] provides some tactics for maintaining the integrity of group dynamics. Prior to the actual meeting, it must be confirmed that the initiators of the process must be interested in the whole process as opposed to only a portion of it. He indicates that if a participatory process were designed to create an agreement on the energy system or systems which should be developed over the next twenty-five years to reduce the greenhouse effect, then the initiators should not come from only the solar power lobby or the nuclear industry. It is important for the initiators to remain unprejudiced. It is similarly and more important for the coordinator to remain just. That is, to be willing to discuss the full range of views and to allow the process to determine its own direction toward the purpose.

Other more specific aspects in avoiding bias in a group setting include:

- ensuring everyone in the group gets an opportunity to participate (i.e., shy non-talkers) to the extent of directly asking those who are quiet if they have any ideas to contribute
- ensuring no ideas get ridiculed
- mixing participants to break up cliques which can be hotbeds for peer pressure.

Another approach to compensating for bias is to make very clear recognition of it so as to appropriately weight any information coming from individuals or groups with known biases. For example, if one is seeking information on world affairs, one should consult both *The Guardian*[25] for a left-of-centre political stance and the *Daily Telegraph*[26] for a conservative political stance and understand that an unbiased reality lies somewhere in between. Likewise, in the Canadian context, to get an unbiased sense of environmental issues one should consult The Pembina Institute (with offices in Calgary, Drayton Valley, Edmonton, Ottawa, Toronto, Vancouver, and Yellowknife) whose mission is “to advance sustainable energy solutions through innovative research, education, consulting, and advocacy” [The

[25] *The Guardian* is a British national daily newspaper owned by the Guardian Media Group. Founded in 1821, it is unique among major British newspapers in being owned by a foundation (the Scott Trust, via the Guardian Media Group).
[26] *The Daily Telegraph* is a British national daily newspaper owned by David and Frederick Barclay. The newspaper was founded in June 1855.

Pembina Institute 2010] for an aggressive environmental stance and the Fraser Institute (with offices in Calgary, Montreal, Toronto, and Vancouver) which "measures and studies the impact of markets and government interventions on the welfare of individuals" for a balancing economic perspective [Fraser Institute 2010]. For an SME where a lone individual may be conducting the foresight exercise, it may be a matter of a known optimist reviewing the outcomes if the individual conducting the foresight exercise is a known pessimist, or vice-versa.

3.4 EIGHT TFA METHODS SUITABLE FOR SMES

In summary, from the comparison with public foresight, it was determined that:

- the specific objective of applying technology foresight to an SME is the same as a MNE; to identify specific opportunities and/or risks in its markets, with its technologies, and in the business environment;
- SMEs are operating in a vastly different resource environment from larger entities when applying TFA methods. SMEs lack strategic planning units, research and technology divisions, and corporate think tanks. This factor will make many of the available TFA methods evaluated in 3.3 unsuitable for use by SMEs; and
- SMEs are likely to be interested in a study time scope of one to ten years;
- the duration of a typical foresight project for an SME will likely fall in the three- to six-month range.

After discarding the methods that are unsuitable to explore potential business futures of SMEs, the methods suitable for this purpose are:

1. backcasting
2. bibliometrics
3. diffusion modeling[27]
4. long wave analysis
5. monitoring
6. technological substitution[27]
7. trend extrapolation
8. vision generation

If one eliminates from Ruff's list (see Table 18) those methods requiring experts or significant human resources (i.e., expert interviews and scenarios), the eight methods listed above include all the remaining methods that Ruff [2004] identified as the major methods for foresight in the private sector or/in companies (these were: analysis of patents/licenses (bibliometrics), technology monitoring/scanning, quantitative methods, trend research "(and others)"). The additional methods in the list above not specifically mentioned by Ruff (but which may well fall into his category of "other methods" at the end of his list) are:

[27] Diffusion modeling and technological substitution are so closely related that Kwaśnicki and Kwaśnicka identified the two terms as equivalent [1996, 32].

backcasting, diffusion modeling, long wave analysis, technological substitution, and vision generation.

The arrival at some of the most basic foresight methods for the use of SMEs is appropriate since the United Nations Industrial Development Organization (UNIDO), referring to large companies, reports [2005] "In quite a number of firms, rather simple tools predominate": and goes on to identify the following methods: brain storming exercises, intuitive thinking, expert consultations, patent and publication analysis, benchmarking exercises, and market forecasts.

Chapter 4 will demonstrate the application of two of the above eight methods to an SME in more detail.

4. APPLICATION OF BIBLIOMETRICS AND LONG WAVE ANALYSIS FOR SMES

Based on the analysis completed in the previous chapter, eight foresight methods – backcasting, bibliometrics, diffusion modeling/technological substitution, long wave analysis, monitoring, trend extrapolation, and vision generation – have been identified as suitable for use by SMEs to explore potential business futures. As described in 2.8, the eight methods also represent a good mix of TFA approaches:

- forecasting tool (trend extrapolation)
- foresight tool (bibliometrics, specifically patent analysis)
- probable futures (trend extrapolation)
- possible futures (long wave analysis)
- preferable futures (backcasting)
- normative method (backcasting)
- exploratory method (visioning)
- hard method (bibliometrics)
- soft method (visioning).

It is good news for SMEs that more than one TFA method is suitable for their use. As several researchers have emphasized, foresight methods are the most powerful when they are used in combination with each other ([Millet and Honton 1991, 92], [Bell 2009, 241], [Land and Schneider 1987, 26]). Using a combination of methods allows the methods used to compensate, to the extent possible, for weaknesses in any one approach.

This chapter does two things: (1) it demonstrates the application of two of the above-listed methods – bibliometrics and long wave analysis – to a hypothetical SME involved in an unspecified area of sustainable energy technology and (2) it describes how the bibliometric method can be beneficially combined with another TFA method which was not evaluated as appropriate – correlation analysis. The demonstration is limited to two of the eight methods to control the length of the document. Bibliometrics and long wave analysis were chosen for a variety of reasons. The demonstration of bibliometrics provides an opportunity to work with concrete data rather than the abstract concepts that some of the other methods require. Whereas it is relatively easy to imagine how to accomplish monitoring, trend extrapolation, and vision generation, application of the long wave analysis method is not so commonly understood. Finally, it was possible to demonstrate both methods using a simple hypothetical company.

This hypothetical company has interests in the general area of sustainable energy technologies that support the sentiment behind the definition of sustainable development proposed by Gro Harlem Brundtland in 1987. Brundtland defined sustainable development as: "development which meets the needs of the present without compromising the ability of future generations to meet their own needs" [1987]. The purpose of providing the hypothetical company with such a generous range of potential activities is to best illustrate the strengths and weaknesses of the two methods.

To illustrate the types of benefits that technology foresight can provide to SMEs, the application of bibliometrics and long wave analysis to the hypothetical company described above is presented in the following sections.

4.1 BIBLIOMETRICS

A full description of bibliometrics is provided in 2.7.6. Briefly, bibliometrics refers to the counting of publications or other bibliometric items (examples of bibliometric techniques are: research profiling, patent analysis, and text mining). Software is available to assist with this counting; the attributes of the various packages (described in sections 2.7.6.2.1 to 2.7.6.2.5) are summarized in Table 19.

SOFTWARE	DEVELOPER	COST	YEAR	COMMENTS
The Bibliometrics Toolbox	Terrence A. Brooks	Freeware	Sometime in 1980s	• Programs written under DOS 2.0. • Measures the bibliometric aspects of a literature
Dataview/Matheo Analyzer	Centre de Recherche Rétrospective de Marseille (CRRM)	$4,850	Unknown	• Bibliometric software which analyzes patents • Designed as a software tool for experts
Bibexcel	Olle Persson	Freeware	2000	• Intent is to generate data files that can be imported to Microsoft Excel (or any program that takes tabbed data records) for further processing.
BibTechMon	Austrian Research Centres Seibersdorf	$20,680	Unknown	• Primary use appears to be for knowledge management purposes
TechOASIS / VantagePoint	Alan L. Porter and Scott W. Cunningham	US$7,500	Unknown	• TechOASIS is a specially branded version of VantagePoint

Table 19: Bibliometric software comparison

Given that this thesis seeks to identify those TFA methods which will provide an SME with a least cost approach, the software reviewed – Dataview/Matheo Analyzer, BibTechMon, and TechOASIS/VantagePoint – will be eliminated from consideration based on having a cost. This leaves freeware programs The Bibliometrics Toolbox and Bibexcel remaining for investigation.

The Bibliometrics Toolbox was investigated first. Some of the files which make up the Toolbox are of a vintage that they use a Disk Operating System (DOS) that dominated the IBM PC-compatible market between 1981 and 1995 but is no longer popular. It proved difficult to open some of these files, and it was determined that a full understanding of the software could not be obtained without the ability to open all of the files. Efforts to apply The Bibliometrics Toolbox were therefore aborted.

The example provided with the Bibexcel software Instruction Guide indicates that it is capable of producing some very interesting information regarding a specific topic, such as relations – connections and disconnections – among research topics, who is doing the research, which institutions they are located at, and the journals which are publishing the research. However, an SME would require a learning period prior to being able to apply the software that could be as long as a week. This was deemed prohibitive for an SME, so the application of Bibexcel to an SME was not pursued.

As a consequence, the simplest and least expensive bibliometric analysis that can be performed appears to be a simple manual search of the same types of databases that were used in the literature search done for this thesis:

- National Technical Information Services (NTIS) Bibliographic Database – provides unrestricted technical reports from 1899 to present from U.S. and non-U.S. government sponsored agencies,

- Compendex (Engineering Index) – the primary database for searching engineering literature from 1884 to present. This index has international coverage of all fields of engineering and technology,
- ENG*netBASE* – is an engineering handbooks database which covers general engineering, including structural, civil, chemical, mechanical, environmental, electrical, electronics, biomedical, technology management, etc.,
- Knovel Library – provides full-text engineering handbooks, many with interactive tables, graph plotters, and equation plotters,
- ProQuest Dissertation and Theses – provides full text doctoral and masters theses from 1861 to present from over one thousand North American and European post-secondary schools.

Note that the above databases represent only a small sample of the databases available. Should one know more specifically what information he is searching for, more purpose-built databases can be accessed. For instance, if the SME markets a technology intended to reduce corrosion incidents on pipelines (e.g., less corrosion, less pipe replacement, less environmental impact), one could search the Corrosion Abstracts database which provides indexes of articles from 1980 to present relating to testing, characteristics, preventive measures, materials construction and performance, and equipment.

Using a sample list of sustainable energy technologies (SETs) which an SME may be involved with, simple searches to identify the number of times each of the technologies is found on each of the databases discussed were completed. Table 20 provides the results. This type of information may be used by an SME as a form of comparison of its product with respect to its competitors. This is a somewhat inconsequential analysis due to the generous range of potential activities assigned to the hypothetical company, but it illustrates the power of a "hard" TFA method and will lead to an interesting illustration of the power of combining TFA methods.

	SETs	NTIS	Compendex	ENG*netBASE*[a]	Knovel	ProQuest
A	Distributed energy technologies	14,768	35,399	1	8	255
B	fuel cells	7,519	39,104	500	251	1,691
C	gas-fired reciprocating engines	27	33	12	3	2
D	industrial turbines	2,475	12,804	18	74	5
E	Microturbines	63	805	82	42	17
F	wind generation combined with diesel generation	145	672	0	0	4
G	photovoltaic generation combined with battery storage	153	447	0	0	2
H	photovoltaic generation combined with diesel generation	75	318	0	0	2
I	fuel cell generation combined with microturbine generation	25	101	0	0	0
J	Biomass generation	1,688	7,559	10	49	4
K	Sustainable energy biotechnologies	17	241	0	0	1
L	biofuels	537	2,785	116	71	105
M	bio-gasoline	2	4	0	1	0
N	biodiesel	254	2,785	77	75	150
O	bio-jet fuel	2	31	0	0	0
P	clean coal technologies	2,484	3,101	29	15	52
Q	oil sands energy	1,129	1,491	0	16	105
R	Nanotechnology-involved resource extraction technologies	0	8	0	0	0
S	"information intensive" extraction	236	3,082	0	0	62
T	Bioprocessing	317	7,647	116	57	71
U	Solar generation	7,533	23,051	13	88	6
V	Hydrogen-based energy solutions	10	23	0	0	1
W	Hydrogen extraction technologies	572	1,754	0	0	29
X	Nuclear generation	26,714	63,625	47	205	11
Y	Clean transportation technologies	881	1,535	0	3	24
Z	Hydro generation	1,167	6,195	17	64	11
AA	Scrubbing technologies	752	1,044	5	14	4
BB	Wind generation	9,139	23,564	64	96	37
CC	Geothermal generation	1,212	3,320	7	36	0

[a] ENG*netBASE* will show a maximum of the 500 best matches to a search.

Table 20: Database search results[28]

[28] All searches conducted on October 11 and 12, 2009.

Given that the first two databases searched – NTIS and Compendex – deal with technical reports and engineering literature, the quantities resulting from these searches are much higher than for the databases represented in the last three columns. ENG*netBASE* and Knovel deal with engineering handbooks; ProQuest contains doctoral and masters theses. To better illustrate this difference, the data in Table 20 have been graphed in Figure 12. Note how the NTIS and Compendex lines (purple (large X) and turquoise (large *), respectively) are almost consistently higher than the remaining lines. This phenomenon would have been consistent except that the search for microturbines resulted in 82 matches on ENG*netBASE* and only 63 on NTIS.

Note also the similarity of the trends reflected in the sources searched. The NTIS and Compendex searches of technical reports and engineering literature mimic each other very closely. The most significant discrepancy is that NTIS did not yield any search results for the multi-termed “nanotechnology-involved resource extraction technologies”. With respect to the majority of the other technologies, NTIS and Compendex peak and valley over the same technologies. There is much greater variety amongst the ENG*netBASE*, Knovel, and ProQuest results.

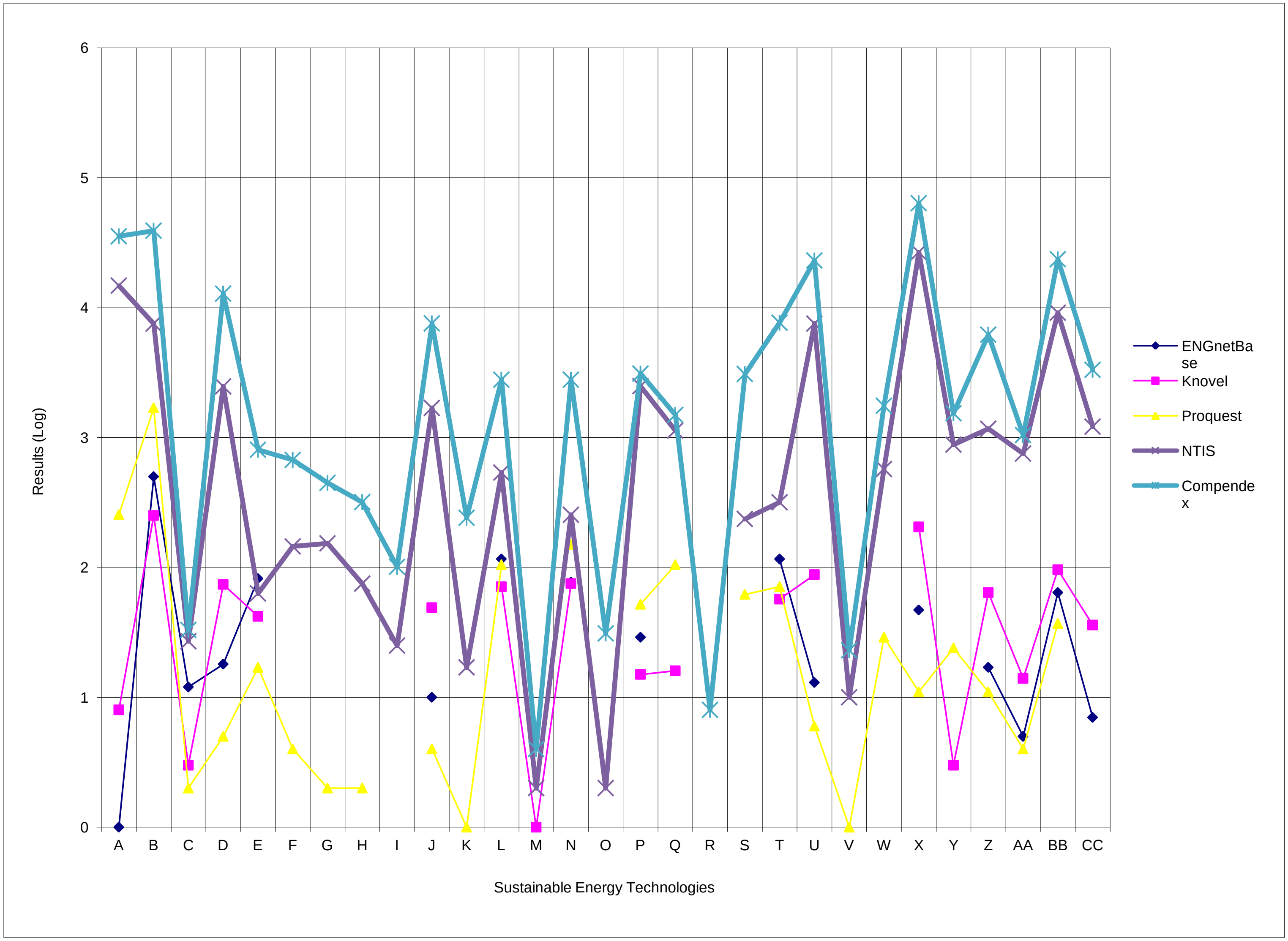


Figure 12: Number of records for each Technology – ENG*netBASE*, Knovel, ProQuest, NTIS, and Compendex

Fuel cells were the topic of the greatest number of records on the ENG*netBASE*, Knovel, and ProQuest databases, while nuclear generation was the topic with the highest number of records on both the NTIS and Compendex databases. For a research-focused SME that aims to keep pace with the current vogue in research, this may indicate that it should initiate, or enhance, either its fuel cell or nuclear research area.

Although only the hard numbers from the searches have been presented, it should be noted that both NTIS and Compendex databases provide useful additional information. They offer the names of the authors, in decreasing number of citations, of the records searched. As well, authors' affiliations are identified in decreasing number of citations. Both of these pieces of information can be very useful to an SME that desires to increase its research in a particular area since there may be the opportunity to hire the expertise in the form of a prolific author.

SMEs will also benefit from approaching the sources, and the databases that capture them, with a critical eye. The different nature of the ENG*netBASE* and Knovel databases – the fact that they reflect more established resources (i.e., books typically take a longer time to plan and publish than a journal article) – may influence what weight an SME places on them with respect to its future plans. The topic of fuel cells has again been identified as most often written about. It is possible that this may reflect that they are less in need of research if there are full text books being written on the subject. This connection could be a topic for further research beyond this thesis.

Recognizing that the five databases discussed above have a fee for their use, a basic Internet search was also conducted to see how the results would compare with the results from pay-to-use databases. Table 21 presents the results of searches conducted using Google.ca as the search engine and the website of The United States Patent and Trademark Office (USPTO). Use of patent numbers makes this search a specific technique of the bibliometric method called patent analysis.

SUSTAINABLE ENERGY TECHNOLOGY	Google.ca HITS[29]/ HITS[30] with quotes	PATENTS[31]
Distributed energy technologies	164,000,000 / 12,300	116,570
fuel cells	11,100,000 / 6,180,000	31,346
gas-fired reciprocating engines	23,100 / 2,920	37
industrial turbines	3,250,000 / 26,300	4,829
microturbines	189,000 / n/a	161
wind generation combined with diesel generation	46,200 / 9	0
photovoltaic generation combined with battery storage or diesel generation	63,100 / 6	–
fuel cell generation combined with microturbine generation	17,800 / 4	–
Biomass generation	2,260,000 / 17,200	4,191
Sustainable energy biotechnologies	2,480,000 / 0	–
biofuels	5,500,000 / n/a	180
bio-gasoline	15,500,000 / n/a	0
biodiesel	8,730,000 / n/a	415
bio-jet fuel	203,000 / 4,340	0
Clean coal technologies	891,000 / 157,000	1,371
Oil sands energy	968,000 / 2,500	2,928
Nanotechnology-involved resource extraction technologies	479,000 / 0	–
“information intensive” extraction	19,200 / 3	60
bioprocessing	932,000 / n/a	728
Solar generation	11,200,000 / 89,600	11,092
Hydrogen-based energy solutions	263,000 / 211	57
Hydrogen extraction technologies	221,000 / 130	8,784
Nuclear generation	21,200,000 / 130,000	35,506
Clean transportation technologies	147,000,000 / 1,750	2,167
Hydro generation	341,000 / 67,800	3,902
Scrubbing technologies	352,000 / 4,660	1,927
Wind generation	13,900,000 / 630,000	14,910
Geothermal generation	246,000 / 11,900	1,170

Table 21: Internet and patent search results

The first number for each row in Table 21 represents a free search of all the words

---

[29] All searches conducted on March 8, 2009.
[30] All searches conducted on March 8, 2009.
[31] All searches were conducted on http://patft.uspto.gov/ on March 8, 2009. Note: Patents from 1790 through 1975 on the database are searchable only by issue date, patent number, and current U.S. classification. Therefore, numbers reflect patents granted from 1976 to present.

contained in the Sustainable Energy Technology column, whereas the second number in the column represents a search of the exact phrase. A search of the exact phrase consistently produces fewer hits than the free search. This is clearly illustrated in Figure 13.

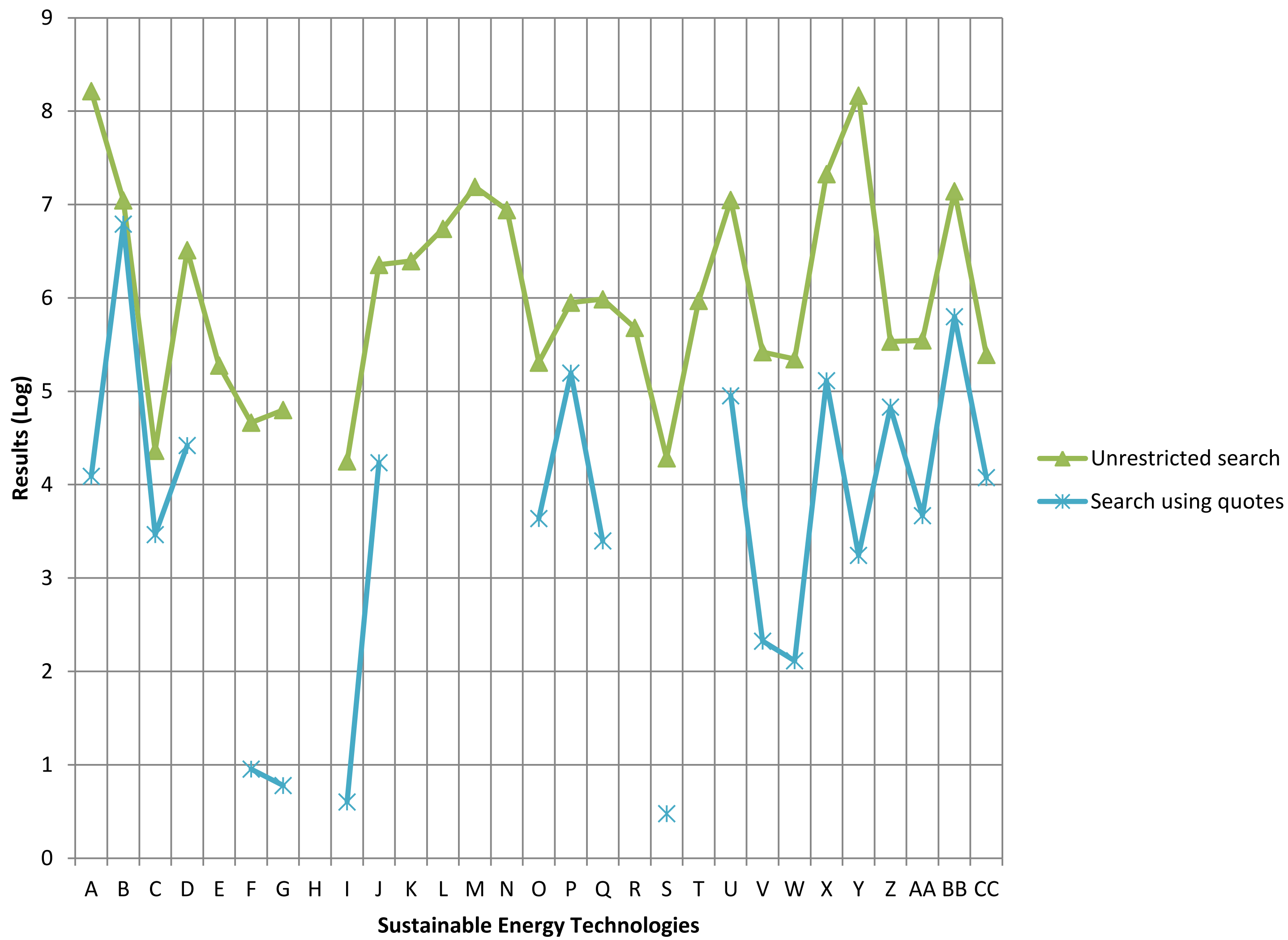


Figure 13: Unrestricted Internet search results

The Internet search showed that distributed energy technologies and fuel cells garnered the most hits based on a free search and a constrained search, respectively, of all the words contained in the SETs column. Nuclear generation (the top result for the NTIS and Compendex databases) generated the third largest number of hits (behind distributed energy technologies and clean transportation technologies) on the free search and the fourth most number of hits (behind fuel cells, wind generation, and clean coal technologies) on the constrained search.

The patent search revealed that the largest number of patents has been secured for distributed energy technologies (116,570), followed by nuclear generation (35,506), fuel cells (31,346), and wind generation (14,910). Table 22 provides a comparison of the results from the various sources. The patent database results identify the top result from the ENG*netBASE*, Knovel, and ProQuest databases – fuel cells – in third place and the top result from the NTIS and Compendex databases – nuclear generation – in second place. The top result from the patent search was the second place technology according to the ProQuest and NTIS searches. This example suggests that a company can obtain useful information without expending any more cost than an Internet connection – something most organizations – including SMEs – already have.

ENG*netBASE*	Knovel	ProQuest	NTIS	Compendex	Hits	"Hits"	Patents
Fuel cells	Fuels cells	Fuel cells	Nuclear generation	Nuclear generation	Distributed energy technologies	Fuel cells	Distributed energy technologies
Biofuels	Nuclear generation	Distributed energy technologies	Distributed energy technologies	Fuels cells	Clean transportation technologies	Wind generation	Nuclear generation
Bioprocessing			Wind generation	Distributed energy technologies	Nuclear generation	Clean coal technologies	Fuel cells
Microturbines			Solar generation	Wind generation	Bio-gasoline	Nuclear generation	Wind generation
			Fuel cells	Solar generation	Wind generation	Solar generation	Solar generation
				Industrial turbines	Solar generation	Hydro generation	Hydrogen extraction technologies

Table 22: Comparison of results

4.1.1 Coupling Bibliometrics and Correlation Analysis

Bibliometrics involves the counting of elements, but it is possible that the graphing of the resulting numbers of elements may also yield valuable information. For example, it may be possible to determine a correlation between the number of patents and installed capacity. Martino [1983] reports that there is a constant relationship between total industry capacity and the size of the largest single installation in many industries (in 1983, when Martino published his book, there was a correlation between the total installed steam turbine capacity in the United States and the maximum size of a single steam turbine electric generator). This correlation allowed one to forecast the largest size of a steam turbine electric generator based on the forecast total industry capacity.

Figure 14 shows the number of nuclear patents from 1959 to 1989 [FreePatentsOnline 2010] graphed against the nuclear generating MWh of the United States (since data for installed capacity were not available) [Nuclear Energy Institute 2010]. All data in the table have been normalized. Figure 14 provides patent search results with word stemming both on and off. Although fewer results are returned with word stemming off, this research has not investigated whether or not "more" (i.e., a higher number of patents) is necessarily better; as "more" could be picking up less relevant patents. Once normalized, as can be seen in Figure 14, there is very little difference between the word stemming off and the word stemming on curves.

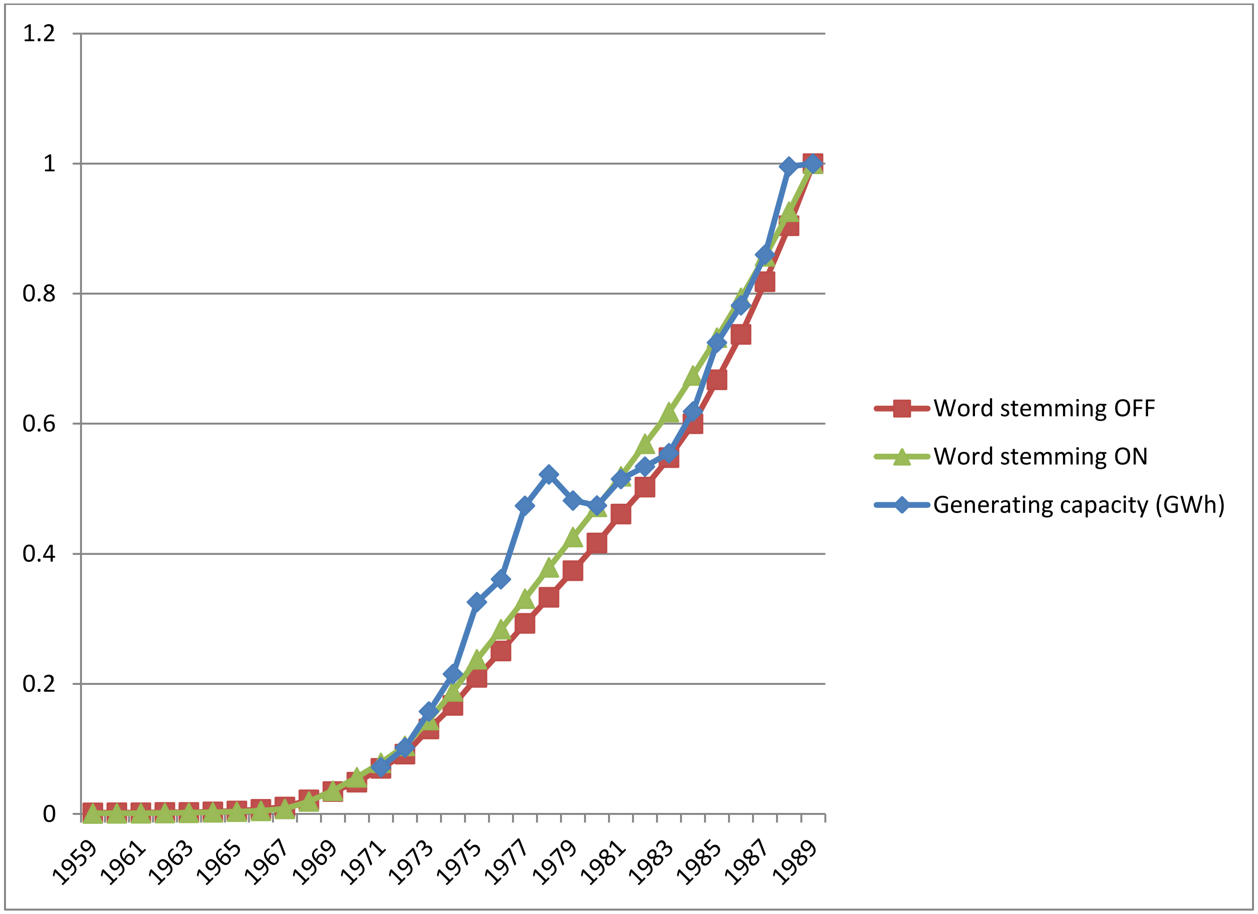


Figure 14: Number of patents versus US nuclear generating GWh

Contrary to Rodrigues' contention that "the infancy of technological products is often marked by a peak in patents" [2001, 183], there is no discernible peak in patents prior to the installation of nuclear generating capacity in Figure 14. However, the nuclear generating capacity curve appears to correspond closely with both the "word stemming off" and "word stemming on" curves, except that neither of the latter curves mirror the blip in the nuclear generating capacity curve occurring between approximately 1973 and 1983.

Graphing the first derivative of the word stemming on and off data yields the results shown in Figure 15. All data in the table have been normalized. Figure 15 shows that both curves start to rise approximately five years before installed capacity is recorded. This may indicate a tool by which one can predict the initial installation of a SET.

In addition, Figure 15 shows that a blip corresponding to some extent with the one in the nuclear generating capacity curve (occurring between approximately 1973 and 1983) has emerged in the first derivative with word stemming on curve (between approximately 1974 and 1976). Whereas the generating capacity curve peaks in 1978, the first derivative curve peaks in 1975; the first derivative with word stemming on therefore provides a three-year advance warning – if one were able to interpret it as such without the subsequent data. Also, this peak is not the ultimate peak, so that if one had acted in 1975 to take advantage of the technology being at its peak, he may ultimately have been disappointed.

For nuclear generating capacity, therefore, the first derivative of the “word stemming on” data provides a reasonable two- to three-year leading indicator of installed generating capacity. One must temper this result with the knowledge that nuclear generation has a unique quirk which is not typical of other generating methods. This is the fact that the number of nuclear generation patents obtained may be skewed by the inclusion of patents actually dealing with nuclear weapons development.

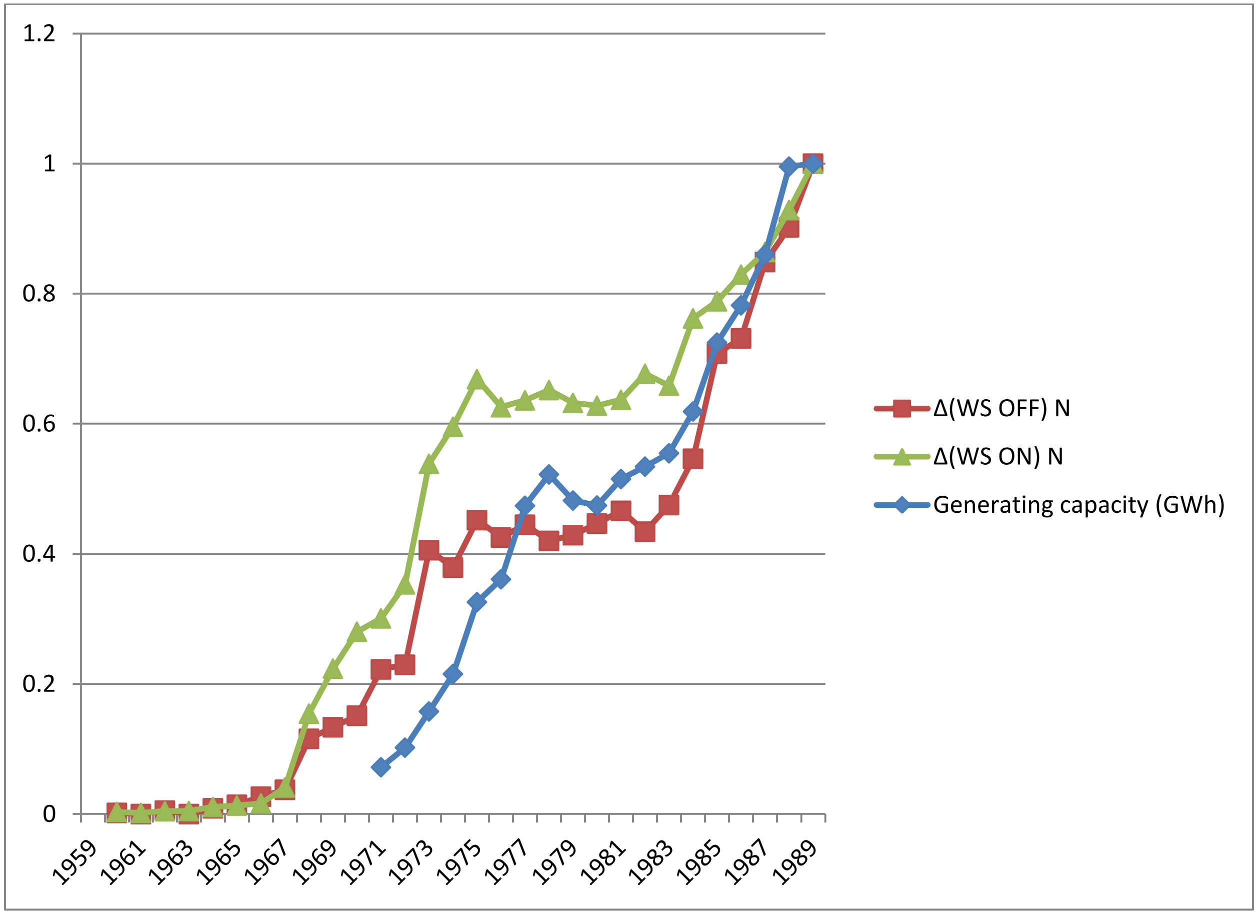


Figure 15: US nuclear generating capacity (GWh) versus first derivative of number of patents

Turning to wind generation to test the possibility that graphing of patent data can predict the initial installation of a SET, Figure 16 shows the number of patents [FreePatentsOnline 2010] versus MW of wind generation installed (in the U.S.) [U.S. DOE 2010] and Figure 17 shows wind generation installed in the U.S. versus the first derivative of the number of patents with word stemming on and off. All data in the tables have been normalized. Again contrary to Rodrigues' contention that "the infancy of technological products is often marked by a peak in patents" [2001, 183], Figure 16 shows that no peak in patents occurred prior to the installation of wind generation in approximately 1998. Instead, it appears that a marked increase in patents provides approximately a 30-year advance warning (1968 – 1998) of wind generating capacity being installed. The first derivative curves in Figure 17 provide an additional year of advance warning as a result of their increase occurring in approximately 1966.

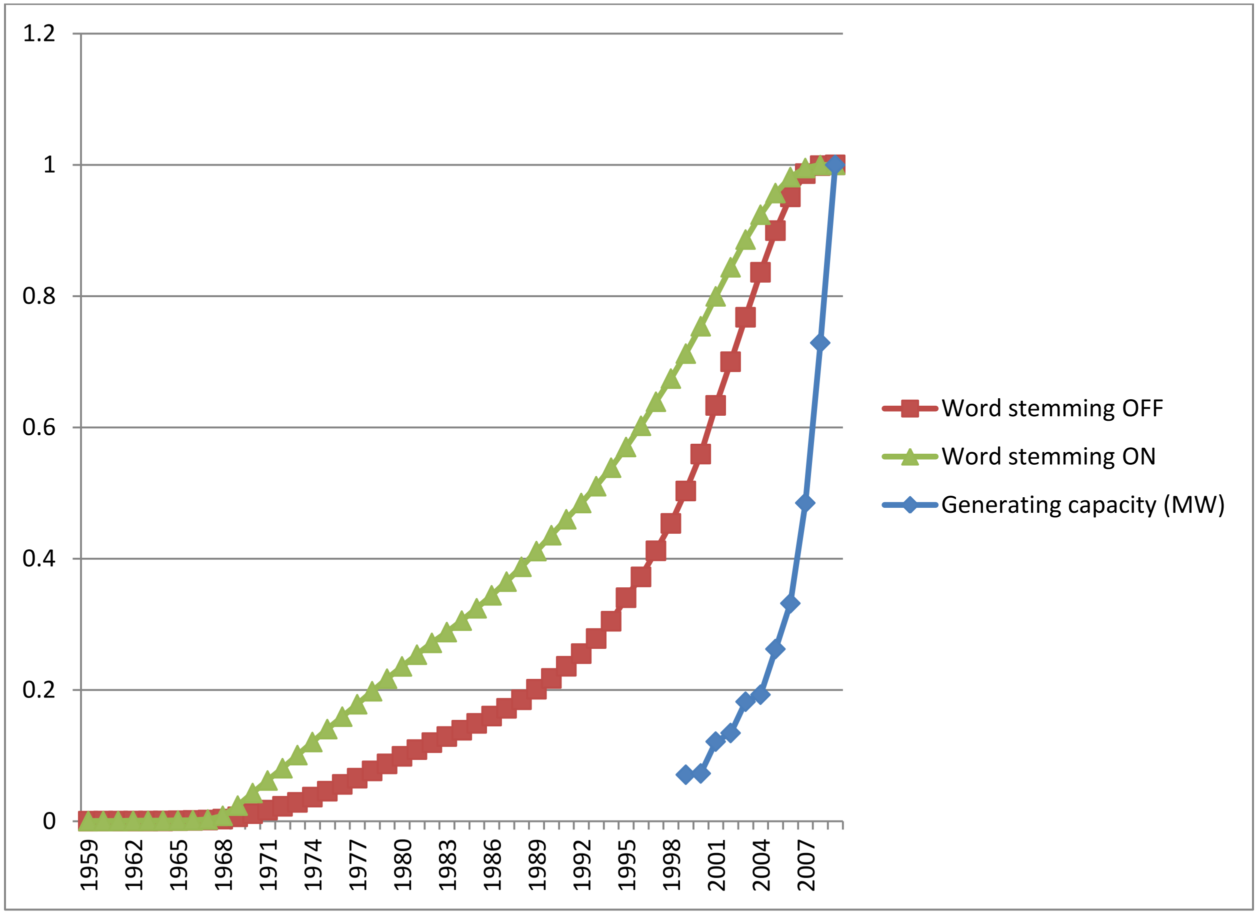


Figure 16: Wind generation installed MW (in U.S.) versus number of patents

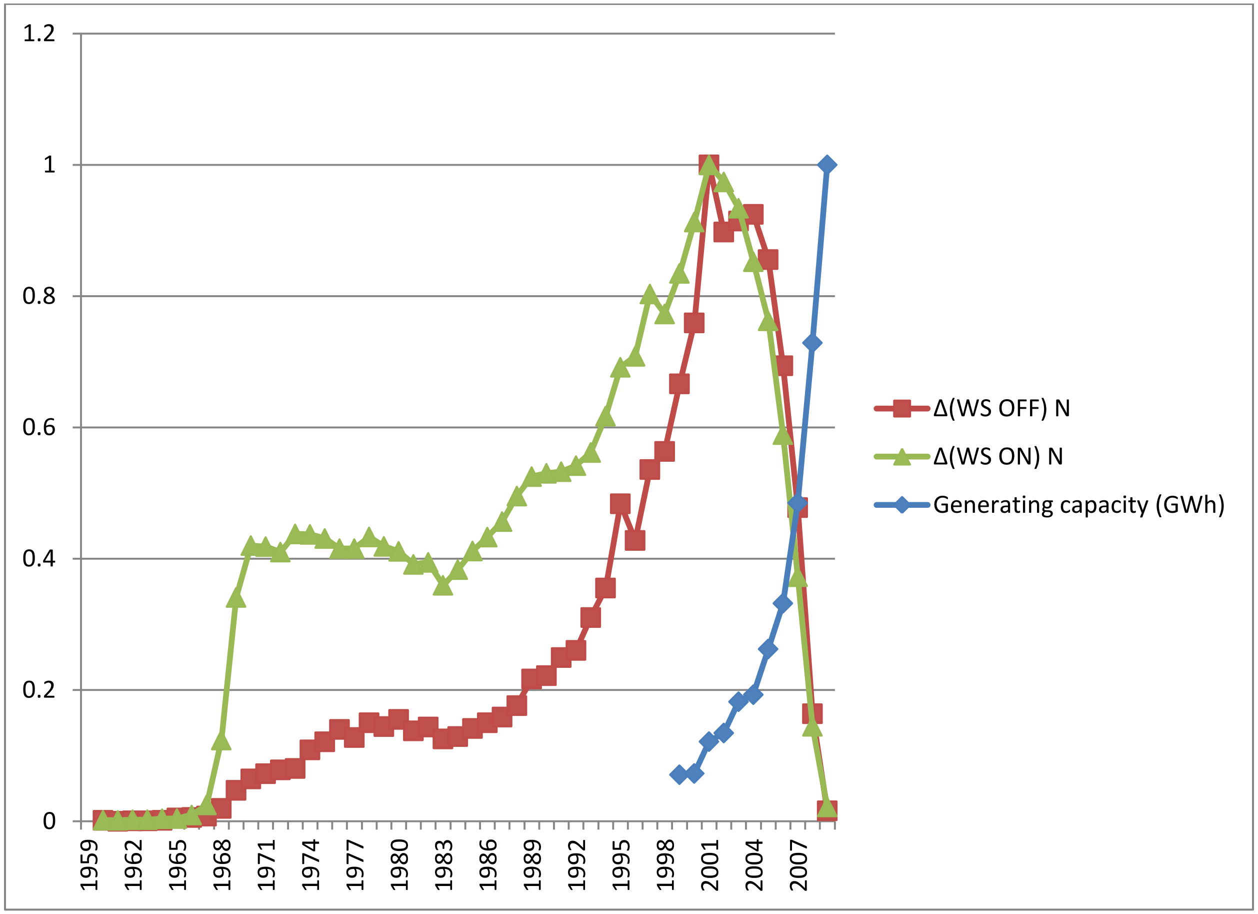


Figure 17: Wind generation installed GW (in U.S.) versus first derivative of number of patents

Figure 18 shows an increase in solar generation patents [FreePatentsOnline 2010] preceded installed capacity [Earth Policy Institute 2010] by approximately 9 years. The first derivative curves in Figure 19, as well as providing more advanced warning (about 14 years); also approximately correlate the lack of any significant additional installed solar generation capacity between 1991 and 2006.

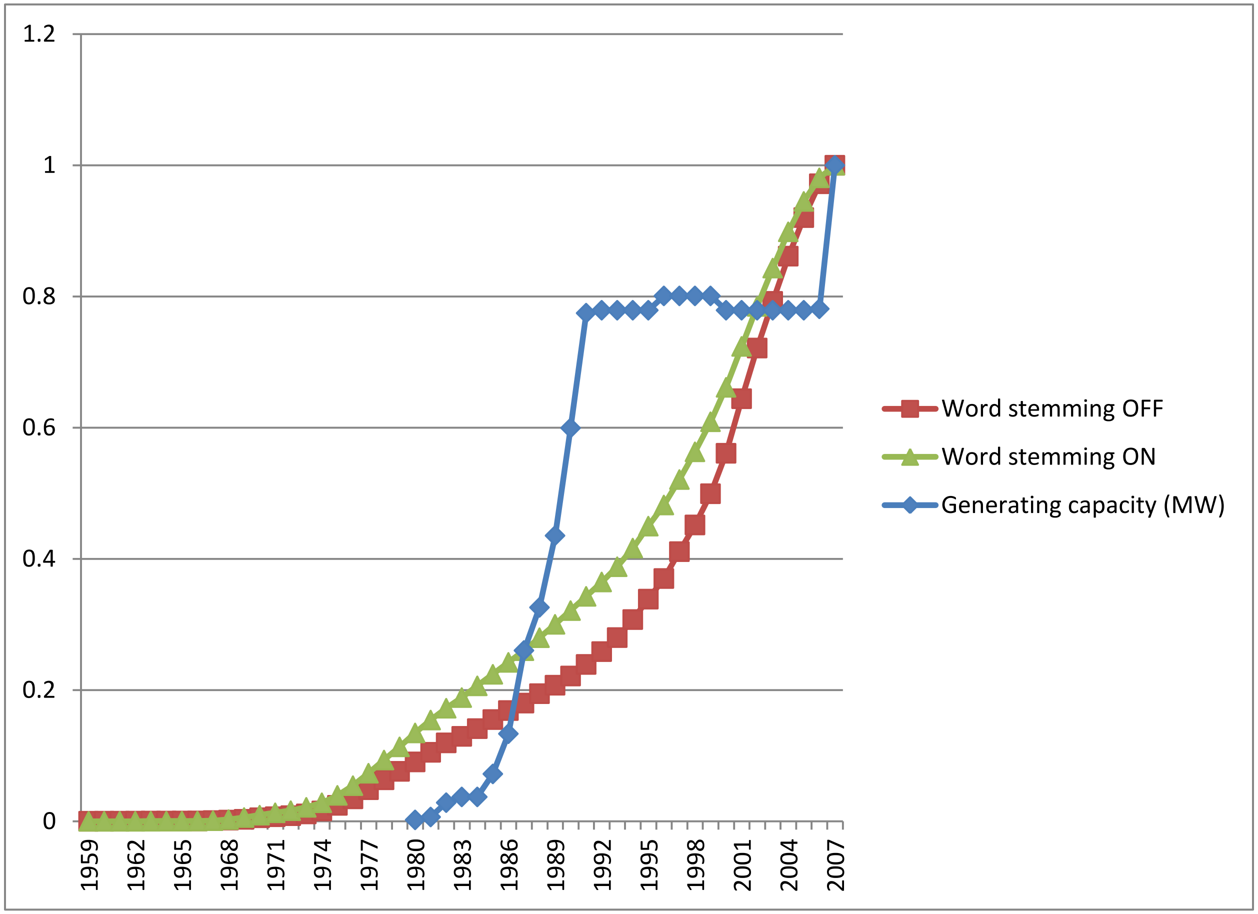


Figure 18: World installed solar thermal power capacity versus number of patents

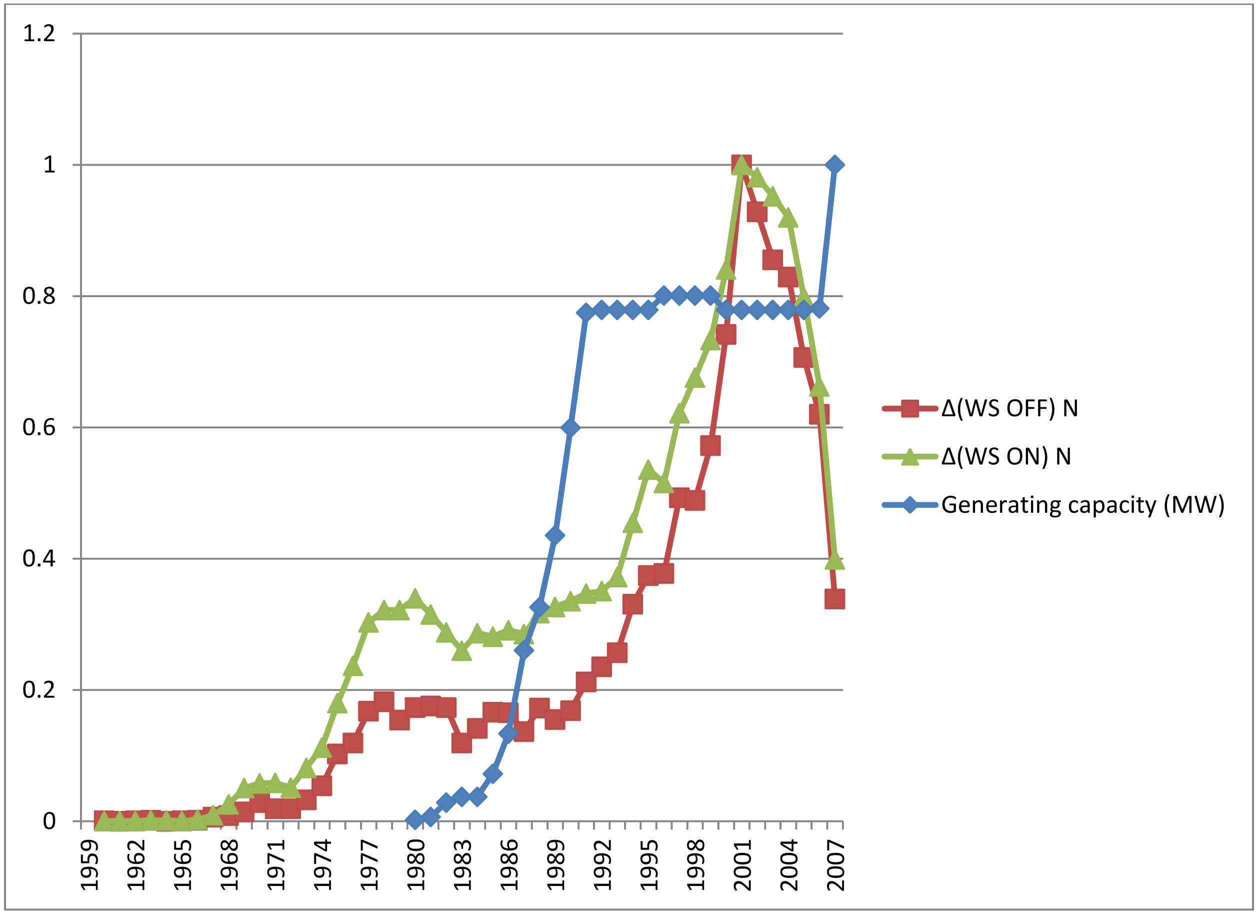


Figure 19: World installed solar thermal power capacity versus first derivative of number of patents

The examined data showing a potential correlation between the number of patents and installed capacity for various forms of generation indicate how commonly available information may be used to provide an SME with insight into the future. This insight may be very valuable in making decisions or the timing of the decision that is made.

The next section will illustrate how the long wave method can be used by an SME to aid in its technological decision-making.

4.2 LONG WAVE ANALYSIS

A complete description of long wave analysis is provided in 2.7.24. Briefly, long wave analysis is based on an economic prosperity-recession-depression-recovery cycle which some believe repeats itself approximately every 200 years. It should be noted that not everyone supports long wave analysis. According to Cornish [2004, 44], the method remains "quite uncertain and controversial". Although Cornish recognizes that the long wave theory has theoretical significance, his main criticisms are that "the long-term cycle is irregular and unpredictable due to the operation of chance factors and the operations of chaos" [2004, 44]. Linstone [2002, 333] also provides a number of caveats that may devalue the assistance from the long wave method. For example, he states "the pattern of the last 200 years may, of course, face alteration or termination." He proposes that an increase in the longevity of humans may, by impacting their effective working life, trigger a change in long wave periodicity.

Although not supported by all, long wave analysis is used outside of the TFA area. Vancouver-based investment advisor and market historian, Ian Gordon, is the president of Long Wave Analytics. Gordon divides the cycle into the four seasons of the year (starting with spring) and believes the cycle that we're currently in started in 1949. Spring represents the rebirth of the economy, and stocks perform as the economy performs. The spring time of our current cycle ended in 1966 when the bull market topped in June. Summer has always corresponded to inflation in the cycle as a result of war ("In the first cycle – and I'm using the U.S. – it was the War of 1812. In the second cycle, it was the U.S. Civil War. In the third, it was the [First] World War and in the fourth cycle, it was the Vietnam War" [Milner 2009, B12]). When the stock market peaks, winter has started and represents the death of the economy because debt has to be taken out of the system. Gordon believes that this is the point of the cycle that the economy is currently experiencing [Milner 2009, B12].

Having noted its detractors, it is important to remember that technology foresight is not about accurate prediction of the future, but rather "...purposeful and systematic attempts to anticipate and understand the potential direction, rate, characteristics, and effects of technological change, especially invention, innovation, adoption, and use" [Coates et al. 2001, 1]. In this light, until the long wave is proven not to exist, it is a useful tool with which to attempt to anticipate and understand the potential direction, rate, characteristics, and effects of technological change.

According to Figure 20, 2009[32] represented a growth phase or upswing. An upswing represents economic expansion and knowledge consolidation while a downswing is characterized as a phase of knowledge innovation. During a downswing a cluster of technological innovations and inventions is observed. During an upswing the innovations created in the preceding downswing are exploited and incremental improvements are the norm [Linstone 2002, 319].

According to Linstone [2002, 319], each cycle is dominated by an "Overarching Technology". As Figure 20 shows, the Overarching Technology was railroads between the 1st and 2nd waves, steel between the 2nd and 3rd waves, oil between the 3rd and 4th waves, and information technology between the 4th and 5th waves. Linstone predicts that the Overarching Technology between the 5th and 6th waves will be biotechnology. University of Alberta professor Dr. Ted Heidrick [Heidrick 2010] disagrees and believes that nanotechnology may just as likely be the overarching technology between the 5th and 6th waves. Cornish [2004, 24] considers nanotechnology to be a potential fifth technological revolution following biotechnology. Strathern [2007, 97] states biotechnology is expected to peak at around 2030, "followed by a wave of nano-engineering that will peak in

[32] Since some of the Technology Futures Analysis (TFA) methods reviewed in this thesis require a specific identification of the time frame (i.e., a future of 35 years from today), a "today" year had to be set. The "today" year was set as 2009 for this research.

the year 2090". Canton [2008, 209] believes the convergent streams of quantum mechanics, computers, biotech, and telecommunications are driving the emerging nanotech revolution and that the biotechnology era will culminate with nanotechnology. An SME must be aware of these contrary views (and this can be accomplished by adopting a monitoring program).

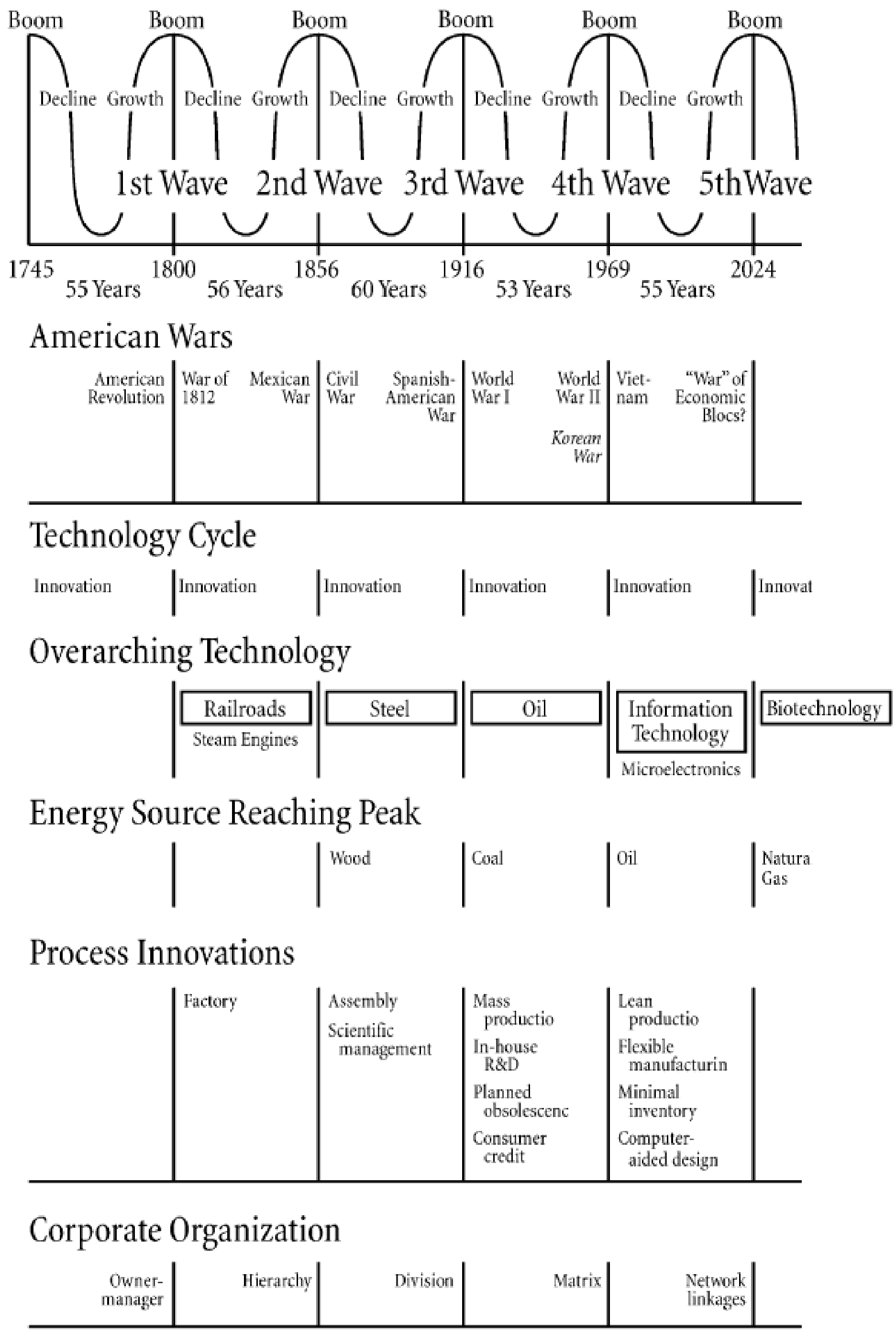


Figure 20: Long wave cycles
[Linstone 2002, 318] Used with permission

A focus on biotechnology would give favour to those SMEs doing business in this sector. Jaccard [2005, 19] predicts that biotechnology will make revolutionary changes; however, he does not see the most important changes being applications in energy. He believes the most important applications are likely to lie in biotechnology's potential for enhancing the physical, mental, and emotional capabilities of humans themselves. An SME may view this information as an opportunity to tailor, combine or adjust its product offering(s) to involve or support biotechnology. In addition, an SME may also find it useful to know in which phase of the cycle the long wave theory identifies the economy as being in (prosperity, recession, depression, or recovery) to enhance its decision-making.

In consideration of the dissenting views, an SME must consider what impact it would have on its business if the overarching technology were nanotechnology instead of biotechnology. According to Canton [2008, 205], nanotechnology will do everything from "provide the ultimate convergence of computers, networks, and biotech, and create products never before even imagined" to "create new choices that will alter human evolution, raise dramatic ethical issues, and challenge social norms."

Long wave analysis provides SMEs with one perspective of what the technological world will look like in the future and, by doing so, provides them the opportunity to prepare their businesses for that world.

The next section will summarize the insights that the hypothetical SME may gain from its application of both the bibliometric and long wave analysis methods.

4.3 SUMMARY: TFA METHOD APPLICATION FOR SMES

Two technology foresight methods – bibliometrics and long wave analysis – were demonstrated in this chapter to show how they are able to aid a hypothetical SME in the sustainable energy technology sector with its technological decision-making. Both methods provided different pieces of information about the potential futures that lie ahead.

The application of the bibliometric method to SETs showed that expensive databases may not be required to gain insight into one's industry. A simple Internet connection and use of free patent databases (i.e., those of The United States Patent and Trademark Office (USPTO) or FreePatentsOnline) produced very similar results. Additional research is required to determine if similar results would be achieved for other business sectors or focuses.

The complementary nature of TFA methods (i.e., bibliometrics and correlation analysis) was demonstrated in the application of the bibliometric method. Graphing of the first derivative of patent results against the installed capacities of nuclear, wind and solar thermal generating capacities indicated correlations between the patent and installed generating capacity curves except that the first derivative patent curves lead the installed capacity curves (by 2 to 3 years in the case of nuclear, 30 years in the case of wind and 14 years in the case of solar thermal). Knowledge of such a correlation for an SME's product may allow the SME to judge how its research is doing in comparison to the general market or when its complementary technology may experience a surge in purchases. Despite the fact that much additional research is required to test the advance warning potential of the first derivative patent results for nuclear, wind and solar thermal generation, the example shows how readily a little bit of easily accessible datum can be turned into useful information.

Turning to the insights that long wave analysis can provide to an SME, it is apparent that this method offers the most optimistic indication for those SMEs in the biotechnology area as biotechnology is predicted by Linstone as the overarching technology for the upcoming wave. However, it should be noted that those technologies of previous waves have not disappeared, goods are still moved by steam engines on railroads (the first overarching technology), steel (the second overarching technology) remains a significant infrastructure component, and oil (the third overarching technology) garners current newspaper headlines.

The examination of the long wave also illustrated the value of expert opinion. Although Linstone predicted biotechnology as the overarching technology for the upcoming wave, Heidrick predicts that it will be nanotechnology. The wisest SME may be the one that tailors its product offering to succeed regardless of whether the next overarching technology is biotechnology or nanotechnology.

This chapter has applied two well-documented TFA methods to SMEs. The next chapter will introduce a new TFA technique to address the unique needs of an SME.

5. A NEW TECHNIQUE: SCENARIO RECYCLING

> *The strength of scenarios is in bringing to light those contingencies that a company was unaware that it was unaware of.*
>
> [Florescu 2012]

The last chapter examined the application of bibliometrics and long wave analysis; two of the eight TFA methods that were deemed suitable for use by SMEs (see Chapter 3). The reader will recall that the scenarios method was eliminated for consideration for use by SMEs in 3.3.1 due to its requirement for more than one individual to perform the method. This chapter will re-introduce the method and propose a unique and original insight into a new technique which may render the method suitable for SME use.

By eliminating the steps in the scenarios method which require more than one participant, a new technique is demonstrated in this chapter showing that there may be another way for scenarios to benefit SMEs. This technique shall be called *scenario recycling*. In scenario recycling, an SME is shown to benefit from using scenarios already developed by others, instead of developing its own scenarios.

Scenario Recycling refers to the analysis of a scenario or scenarios prepared by others (e.g., non-governmental organizations, individual futurists, and government agencies) for their own purposes, in order to gain insight and stimulate discussion on the future of the SME. This involves three steps. The first step is to select a number of scenarios relevant to the SME's business. The next step is to read the scenarios thoroughly to identify all the predictions they make regarding information relevant to the SME's business. The final step is to analyze the collected information.

The purpose of the final analysis step is to "anticipate and understand the potential direction, rate, characteristics, and effects of technological change, especially invention, innovation, adoption, and use" [Coates et al. 2001, 1]. In this regard, the analysis will seek to discern trends, determine whether any surprises are encountered, and identify if there are any contradictions amongst the scenarios.

Like Chapter 4, which considered the suitability of the bibliometric method and long wave analysis, this chapter will apply the technique in question to a hypothetical SME. In this case, however, more detail will be provided regarding the hypothetical SME and it will be given a name. The SME shall be called Sunshine Inc. (Sunshine). Sunshine is a company that designs, builds and markets solar inverter technologies. Solar inverter technologies (also known as photovoltaic (PV) inverters) convert the variable direct current (DC) output of a PV solar panel into a utility frequency alternating current (AC).

The remaining sections in this chapter will describe the steps Sunshine should take to apply the scenario recycling technique.

5.1 STEP 1: SELECTING SCENARIOS TO RECYCLE

The concept of scenario construction for futures research was introduced by Herman Kahn in connection with military and strategic studies conducted by the RAND Corporation in the 1950s. Since then, numerous scenarios have been produced by a variety of companies and nations for a range of reasons. The largest collection of scenarios found was The Millennium Project's annotated scenario bibliography. The bibliography can be accessed at www.millennium-project.org/millennium/futuresmatrix.html. The first row of the Futures Matrix provided on this website provides access to six of the seven domains that the bibliographies have been grouped into:

- Demographics and Human Resources
- Environmental Change and Biodiversity
- Technological Capacity
- Governance and Conflict
- International Economics and Wealth
- Integration or Whole Futures

The Millennium Project has introduced a new domain – Regions and Nations – in its annual State of the Future report, and it includes the bibliography as an appendix on the compact disc (CD) accompanying the report. The scenario summaries should be reviewed carefully by the SME to select those with the most relevance to the SME and/or the SME's area of interest about the future. The scenarios used in this chapter to demonstrate the scenario recycling technique were not specifically selected for this work. Although they were selected and evaluated by the author for research into sustainable energy technologies in general, they are acceptable for demonstration purposes.

The seven scenarios to be used are:

- *The Next Two Hundred Years: A Scenario for America and the World*[33]
- *Global Warming: Are We Entering the Greenhouse Century?*
- *Future Mind: Artificial Intelligence*
- *The Great Turning: Personal Peace, Global Victory*
- "The Capitalist World-Economy: Middle-run Prospects"
- *A Short History of the Future*
- *History of the Future: A Chronology*

The selected scenarios represent a variety of time scopes from twelve years (in the case of *Global Warming: Are We Entering the Greenhouse Century?* and *Future Mind: Artificial Intelligence*) to 1,010 years (in the case of *History of the Future:*

---

[33] Published in 1976, this was the oldest scenario to be found in The Millennium Project's scenarios bibliography. It was found within the Integration or Whole Futures domain.

A Chronology). Although there are no agreed-upon definitions, [Adam] Gordon [2009] refers to forecasts within the twenty-five to 10,000 year range as being the province of dreamers; they are therefore not often taken seriously. As a result, those forecasts of greater than twenty-five years may not have been the best ones to base this research on and future research could select scenarios with time scopes of less than twenty-five years.

Two of the selected scenarios have time scopes with a range approved by [Adam] Gordon. These are *Global Warming: Are We Entering the Greenhouse Century?* and *Future Mind: Artificial Intelligence.* The end-dates of the time scopes of the other five scenarios have not yet been exceeded. The heavy bar in Table 23 separates the two scenario publications whose time scopes have already elapsed from those whose time scopes have yet to pass.

SCENARIO PUBLICATION	**ENDING YEAR**	**TIME SCOPE (YEARS)**
Global Warming: Are We Entering the Greenhouse Century?	2001	12
Future Mind: Artificial Intelligence	2001	12
The Great Turning: Personal Peace, Global Victory	2025	36
The Capitalist World-Economy: Middle-run Prospects	2050	61
The Next Two Hundred Years: A Scenario for America and the World	2176	200
A Short History of the Future	2200	211
History of the Future: A Chronology	3000	1010

Table 23: Time scopes of recycled scenarios

Having made these selections, analysts can move on to Step 2. This involves reading the scenarios thoroughly to identify any and all the predictions they make regarding information relevant to Sunshine's solar inverter business.

5.2 STEP 2: EVALUATING THE RECYCLED SCENARIOS

Seven scenarios were selected in Step 1 of the recycling scenarios technique. These will be referred to from this point forward by the following abridged names. The author's names follow in brackets:

- The Next Two Hundred Years (Kahn, Brown, and Martel)
- Global Warming (Schneider)
- Future Mind (Glenn)
- The Great Turning (Schindler and Lapid)
- The Capitalist World-Economy (Wallerstein)
- A Short History of the Future (Wagar)
- History of the Future (Lorie and Murray-Clark)

Since solar inverter technology is such a specific topic, it is unlikely that it will garner focussed attention in any single scenario. As a result, it is necessary to identify an umbrella topic of a more general nature which can be assumed to include implications for a solar inverter technology business. In this case, energy was chosen as the umbrella topic due to its broader nature. Energy and energy-related technologies predictions should not only cover implications for solar inverter technologies, but potential competing technologies.

Each of the selected scenarios should be scanned, reviewed or read, whatever depth of examination is required to determine if it holds any insight into energy and energy-related technologies. In the case of the seven scenarios named above, three – Global Warming, The Great Turning, and The Capitalist World-Economy – offer few specific ideas relating to energy or energy-related technologies. However, this does not mean that they are of no value.

Global Warming is as much a history lesson as it is a scenario of the future. Schneider presents a 12-page scenario in the first chapter of the book "...meant to provide a feeling for what a year in the greenhouse century might have in store for us if nothing is done to deal with the growing problem of global warming" [Schneider 1989]. It describes such serious effects of climate change as droughts, severe flooding, air pollution crises, heat-stress days, brownouts, and forest fires without going into any specific details other than to conclude with the comment that "...[the scenarios] are based upon extensive studies" [Schneider 1989]. The remainder of the book presents the case for policy changes necessary to avert the scenario, but it does not go into any detail with respect to energy technologies. Sunshine may find these policy proposals useful in its efforts to anticipate and be prepared for policy changes which may impact its business.

The Great Turning predicts a "profound" change in energy producing technologies. There is no specific reference to solar inverters in this scenario and the concept of solar energy is lumped in with other renewable energy sources. In terms of evaluating the scenario to date, although Canada's use of renewable energy sources has been increasing, Canada has not reduced its fossil fuel consumption (with respect to electricity generation). From 1990 to 2009, utility energy consumption increased by fifteen percent [Nyboer and Lutes 2011, Executive Summary]. This is the only scenario which presents no new insights for Sunshine.

Wallerstein's primary energy prediction in The Capitalist World-Economy is that new energy sources will be sufficiently perfected to sustain major worldwide leading industrial sectors. His paper is primarily concerned with issues relating to the economy and he uses Kondratieff waves in the description of the world-system from 1945 to 1988. Wallerstein's reference of Kondratieff waves may prompt Sunshine to investigate the long wave method and learn what the over-arching technology predictions are for the coming periods and align its technologies with the over-arching technologies.

Having dispensed with those scenarios holding scant information relevant to Sunshine's business interests, the following sections will detail the evaluation of the remaining scenarios with respect to any *energy* predictions the scenarios made versus what has actually transpired. It is intended that the SME will be presented with some possibilities it hadn't previously speculated on. This state of expanded enlightenment should aid the SME in identifying "those contingencies that [it] was unaware that it was unaware of." (see the quote which begins this chapter). However, the analysis related to the identification of those contingencies will be left to the third step of the scenario recycling process in 5.3.

5.2.1 The Next Two Hundred Years

The U.S. Energy Information Administration (EIA), which produces an annual International Energy Outlook (IEO) stated that "Renewable energy is the fastest-growing source of electricity generation in the *IEO2011* Reference case." [U.S. EIA 2011, 88]. This is consistent with some of Kahn, Brown, and Martel's renewable energy predictions. However, their contention that "the world's best hope lies in the use of the solid fossil fuels, especially coal" [Kahn, Brown, and Martel 1976, 65] until the eternal sources take over also matches well with what is happening.

Only one of Kahn, Brown, and Martel's "eternal power sources" – wind electric power – has been developed on the large commercial scale as they predicted, while the status of some of the others, such as bio-conversion (BC) and photovoltaic (PVP), may better be described as emerging. The heating and cooling of buildings through the direct use of solar radiation as a heat source (HCB) has not "become standard in new structures in the United States" despite some experts' 1976 predictions that it would do so during the 1980s or 1990s.

In the case of ocean thermal power, Kahn, Brown, and Martel indicated in their scenario that “the development to prove its validity will clearly require another 10 to 20 years” [Kahn, Brown, and Martel 1976]. In 1974 the Hawaii State Legislature created the Natural Energy Laboratory of Hawaii (NELH), mandated to provide a support facility for research on the ocean thermal energy conversion (OTEC) process and its related technologies. For a time, however, the focus of research appeared to have shifted to other areas. In 1985, the Legislature created the Hawaii Ocean Science and Technology (HOST) Park on adjacent land and in 1990, HOST Park and NELH were melded into the NELH Authority (NELHA) attached to the Department of Business, Economic Development & Tourism of the Hawaii State Government. Early in 2012, however, OTEC International, a Baltimore-based company, proposed a plant for HOST Park to “demonstrate integration of components that use temperature difference between warm surface ocean water and cold deep water to produce electricity” [Miller 2012]. The plant is expected to generate up to one megawatt.

Kahn, Brown, and Martel proposed that “STP[34] will not become commercially competitive until well into the next century”. This prediction appears to be on track. About 1.17 gigawatts of STP power plants are currently online (582 megawatts in Spain, 507 megawatts in the United States and 62 megawatts in Iran) and about 17.54 gigawatts of projects are under development worldwide

[34] STP is an acronym for solar thermal power.

according to a 2011 article in Renewable Energy World Magazine [Wang 2011]. The article notes, however, that due to the unexpected cost reduction in photovoltaic panels, STP projects are experiencing competition from concentrating photovoltaic (CPV) technology for optimal project sites (both technologies work best in extremely sunny locales with few clouds).

STP plants maintain the advantage over CPV plants of allowing storage. This means STP plant energy can be used after the sun has gone down. Whereas a PV power plant's output typically drops significantly in the late afternoon, right when energy demand peaks (due to people arriving home from work and turning on televisions and appliances).

Research is being done into the variety of technologies used in STP; the most popular technology uses parabolic trough reflectors and power-tower receivers. The other two primary technologies are one which uses a central tower instead of power-tower receivers and one which uses Stirling engines. The latter technology embodies both the thermal and electric generation mechanisms within the Stirling engine and uses gas rather than fluid to transfer the sun's heat. As a result, new heat-storage materials that are stable at high temperatures and methods that maximize the thermal energy storage capacity at low costs are being researched [Wang 2011].

Kahn and his team correctly identified the top solar energy alternative as wind electric power. Wind power has held the title of the world's fastest growing energy source for a number of years. The Canadian Wind Energy Association's web site (www.canwea.ca) reports that Canada's current installed capacity is 5,641 megawatts. In June 2012, the Alberta Electric System Operator (AESO) identified Alberta's power sources as [AESO 2012, 71]:

Coal (44%): 5,782 megawatts

Gas (41%): 5,371 megawatts

Hydro (7%): 879 megawatts

Wind (6%): 777 megawatts

Other (e.g., biomass, solar, run-of-river hydro) (2%): 203 megawatts.

With respect to timing and cost, Kahn, Brown, and Martel were optimistic. Both wind power and bio-conversion (BC) were introduced to Alberta as a result of special pricing resulting from the Small Power Research and Development Act (SPRDA) introduced by the Alberta government in 1988. Plants were built in the early 1990s (a decade later than the installation "during the early 1980s" predicted by Kahn, Brown, and Martel). The SPRDA required Alberta electric utilities to enter into long-term (20-year) power purchase contracts with eligible power producers at legislated prices. The original SPRDA had provisions for an "allocation" of up to 125 MW. The allocation process under the program was closed by the government as of December 31, 1994. Before the program was closed, approximately 108 MW of capacity was allocated. Forty-five percent of the total allocated MW capacity was hydro, 36 percent was wood waste (BC), and 19 percent was wind power [Whitmore and Bramley 2004].

The eligible power producers had the choice of two legislated prices for their energy. Fourteen producers chose to be paid a rate that escalated with the Alberta Consumer Price Index. This index is declared by the Government of Alberta each year. Three producers chose a blocked pricing scheme. Their price, which will continue to be paid until the end of their contracts, is 6 cents per kWh. This meant that even though the electric utility industry deregulated as of January 1, 1996, and all other generators in the province had to offer their power into the competitive power pool, suppliers under the SPRDA were guaranteed a rate for their power. For comparison purposes, fossil fuel generation in 1996 cost 1.4 cents per kWh while wind energy generation cost 5.4 cents per kWh [AESO 2009]. This is a substantially higher cost than Kahn, Brown, and Martel expected; they predicted that the latter would cost “less than that of most current conventional sources”.

Alberta currently has five biomass power facilities with a total capacity of 178 MW. Wood waste from pulp and saw mills is the primary fuel for biomass generation plants in Alberta, while a small amount of agriculture waste is also used for fuel. Generation from biomass is generally restricted to locations at the source of the fuel due to transportation costs [AESO 2009].

How did Kahn, Brown, and Martel fare on the nuclear front? They recognized concerns with nuclear fission and identified the possibility of a moratorium on the construction or use of nuclear energy in the United States, but did not dismiss the potential for nuclear power in the future. It seems that very little has changed in the thirty-six years since *The Next 200 Years* was written. The concerns noted in 1976 remain valid today; people are still worried about accidents, sabotage, the use of nuclear materials for nuclear weapons proliferation and the fact that the issue of waste disposal has not yet been resolved.

A moratorium on the construction or use of nuclear energy in the United States has yet to come to pass and, in recent years, there has been a renewed interest in nuclear energy in both Canada and the U.S. Unfortunately, Canada's CANDU-type reactors have not had the anticipated market take-up despite their purportedly superior efficiency over light water reactors. In Alberta, Energy Alberta Corporation entered into an exclusivity agreement with Atomic Energy of Canada Limited (AECL) to market, own, and operate CANDU units in Alberta, and in May 2007 announced it was proceeding with twin Advanced CANDU Reactor (ACR) 1000s in the Peace River area. In March 2008, Bruce Power Alberta purchased the assets of Energy Alberta Corporation relating to nuclear power plant development and filed an application with the Canadian Nuclear Safety Commission to prepare a site in the Peace River area near Lac Cardinal for potential construction. However, Bruce Power Alberta subsequently withdrew its application due to the proximity of the site to a significant aquifer and is said to be considering reapplying for a nearby site [AESO 2009]. The AESO stated in its 2009 Long-term Transmission System Plan that there is potential for the development of nuclear power in Alberta, but that public consultation, environmental approvals, and construction time put the possibility beyond 2017 [AESO 2009]. The possibility was moved out to 2020 in the AESO's 2012 Long-term Transmission System Plan [AESO 2012].

Commercially viable fusion power has not yet occurred, so the door has been closed on the possibility that it "will be established by the early 1990's", nor does it appear that a practical laser fusion process is apt to become operational to qualify as being "early in the 2000s". In fact, the web site for the ITER[35] experiment, currently under construction in the south of France, states – in response to the Frequently Asked Question (FAQ) "Will commercial fusion be available early enough to contribute to the energy transition needed to fight climate change and to replace fossil fuels" – "The timescale to commercial fusion therefore extends until at least the middle of this century, depending strongly on the political will to invest in this area of research" [ITER 2012].

The ITER experiment was conceived as the necessary experimental step on the road to a demonstration fusion power plant. ITER has been designed to produce

[35] ITER means "the way" in Latin, and the acronym stands for International Thermonuclear Experimental Reactor.

500 MW of output power for 50 MW of input power – or ten times the amount of energy put in. The current record for released fusion power is 16 MW (held by the European JET (Joint European Torus) facility located in the United Kingdom) [ITER 2010]. According to the University of Saskatchewan's Plasma Physics Laboratory's website, Canada is the only G8 country not participating in the ITER program [U of S 2010].

Turning to the first of the two developments that Kahn, Brown, and Martel deemed likely to occur regarding energy systems in the 22nd century; available data does support the claim that electricity may be the form of the majority of energy produced on a large scale. Between 1973 and 2010, the share of electricity within the world's total final fuel consumption increased by 8.3 percent. The only other fuels which increased their share of total final consumption over this period were "other" which includes geothermal, solar, wind, heat, etc. (1.8 percent), and natural gas (1.2 percent) [IEA 2012].

The use of hydrogen, the second development described by Kahn, Brown, and Martel, has not gained any significant traction in today's world. As Jaccard [2005] points out, in order for hydrogen to gain significance as a sustainable global secondary energy system in which combustion of conventional gasoline and diesel has declined, it must outperform both recognized and new competitors. Natural gas, propane, and butane are already relatively clean-burning in mature technologies. Methanol, ethanol, synthetic middle distillates, dimethyl ether, and biodiesel are all newer fuels with unconfirmed potential.

Focusing on Jaccard's point, it is relevant to note that the world has not yet reached a time where the combustion of conventional gasoline and diesel has significantly declined. Jaccard does not project hydrogen gaining a toehold until after 2050. He ultimately projects that it will attain a thirty to forty percent share of the secondary energy market by 2100 [Jaccard 2005].

Turning back to electricity production, Kahn, Brown, and Martel predicted with confidence that most of the energy produced on a large scale would be in the form of electric power. As a result of this prediction, they concluded that whatever concept for major long-term energy sources (e.g., solar, geothermal, fusion) is pursued, the production will be based out of central plants.

There is currently little to indicate that electric power will not continue to be a dominant form of secondary energy. However, it is no longer appropriate to assume that electricity will be produced at "central plants". Likely due to the restructuring of the electric utility industry, independent power producers are able to succeed with smaller generating facilities. In fact, there is an international organization whose mission is to "accelerate the worldwide development of high efficiency cogeneration, onsite power, and decentralized renewable energy systems that deliver substantial economic and environmental benefits" [WADE 2012]. The group is called the World Alliance for Decentralized Energy or

WADE.

Analysis of how the above information can assist SMEs in their technological decision-making is presented in 5.3.1.

5.2.2 Future Mind

Future Mind by Glenn describes three scenarios. The primary scenario presented in the book depicts the world converting to a future described as Conscious Technology. As much of Glenn's primary scenario focuses on space travel, and space travel has not advanced at the rate he predicted, his scenarios do not seem to be bearing out. One must keep in mind, however, that Glenn's book is titled "...in the 21st Century", as a result, there are still many years for his scenario to occur.

Of the timeline Glenn provided in 1989, none of the accomplishments predicted in the years which have passed has occurred:

1992 or 1994: Joint robotic missions to Mars via the Martian moon, Phobos (based on signed agreements among USSR, France, USA)

1998 First Internationally Controlled Permanent Space Station in low earth orbit. (USA lead nation)[36]

1999 First human landing on Phobos, followed by shuttle craft with humans landing on Mars and return to earth (USSR or joint USSR and USA)

2006 First international lunar base (US lead)

2010 Geostationary Orbital International Space Station

---

[36] Construction of a low Earth orbit multinational project (representing the work of 16 nations) called the International Space Station (ISS) *began* in 1998.

Nor does it appear that any of the subsequent accomplishments will occur on the schedule that was proposed by Glenn:

2015 *If no joint Mars landing with USSR, then second nation to land human on Mars (USA)*

2020 *Moons of Jupiter and asteroid mining*

2025 *Geostationary Space Community of 5,000 citizens* [Glenn 1989]

The Soviet Union – formally dissolved in December 1991 – has not yet landed a man on Mars. No giant solar satellites that have the capability to receive solar energy twenty-four hours a day and then beam it down to earth have been deployed, (defying O'Neill's prediction that these solar power satellites would be in operation by 2004 to 2009) and the predicted mechanical space spiders are not spinning photovoltaic sheets.

With respect to non-space related predictions, the air is not being cleaned through the use of hydrogen fuel produced in offshore fusion power plants. However, Glenn's so-called "Third World Car" appears to be a reality. In July 2009, Tata Motors delivered the first Tata Nano to a customer in Mumbai, India [tatanano.com 2012]. The car cost approximately $2,500.

None of the remaining three scenarios places much emphasis on energy. Swapping Third World debt in exchange for local projects which would stall greenhouse warming, per the High Tech – Low Mystic scenario, is not occurring on any significant scale.

Analysis of how the above information can assist SMEs in their technological decision-making is presented in 5.3.2.

5.2.3 A Short History of the Future

Wagar's scenario includes a number of very specific predictions about energy sources. Wagar was considerably optimistic about the pace that the world would reduce its reliance on fossil fuels projecting that fossil fuels would provide only 78 percent of the world's energy by 1995 and 74 percent by 2010. Figure 21 shows the percentages have gone in the opposite direction.

Wagar also seems overly optimistic about the use of renewable energy sources. He predicts that by 2030 seven percent of the world's energy needs will be supplied by hydro, six percent will be supplied by wind energy, and thirteen percent will be met by other sources of energy. In 2010, the percentage of the world's energy needs supplied by hydro power was 2.3 percent and by other forms of power was 0.9 percent [IEA 2012]. Other forms of energy include geothermal, solar, wind, heat, etc.

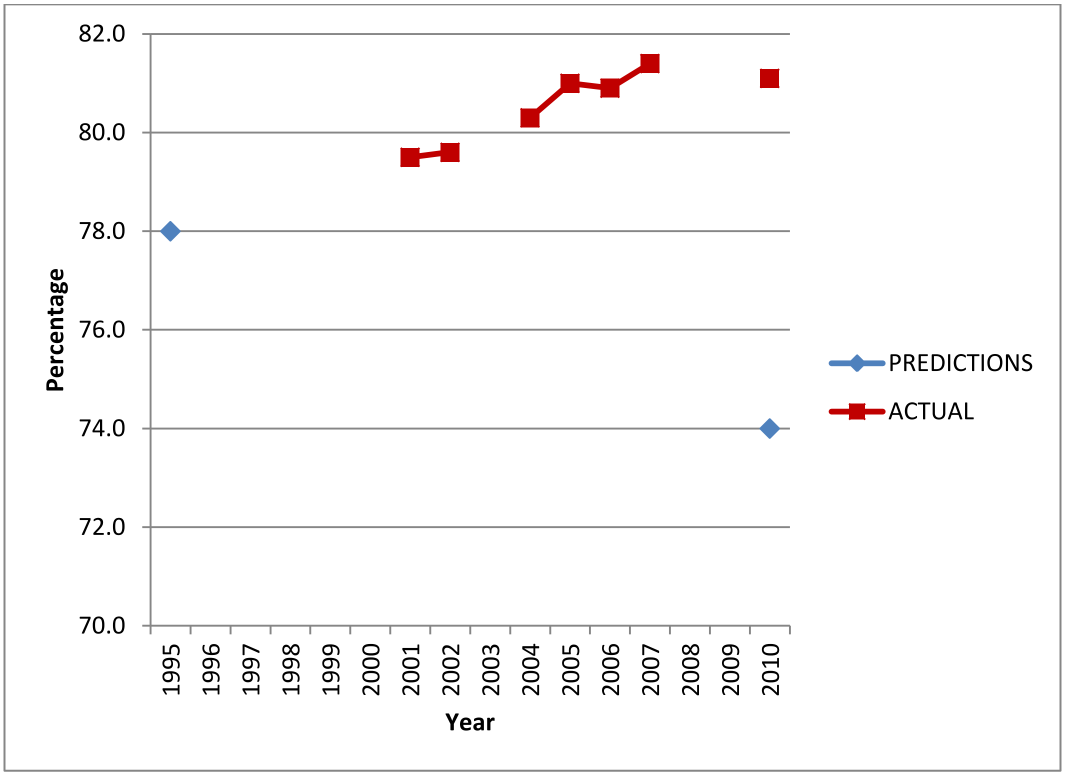


Figure 21: Wagar's world energy source predictions versus actual

Contrary to Wagar's prediction that most of the nuclear fission reactors would cease operation in the early years of the new century, nuclear energy constituted 5.7 percent of the world total primary energy supply in 2010 [IEA 2012]. However, per Figure 22, the world's reliance on nuclear energy has been steadily declining. The forecast reduction was to be due to the "perfection" of fusion reactors. These have not yet been perfected (see a brief discussion of the ITER experiment in section 5.2.1).

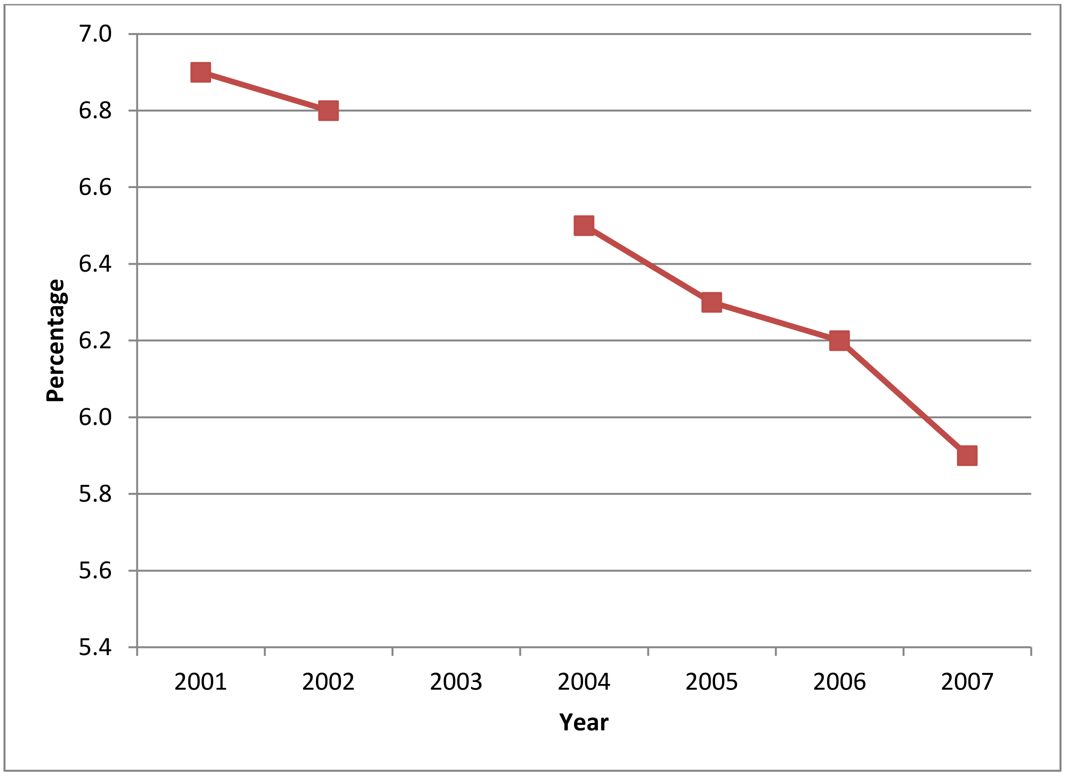


Figure 22: Nuclear energy's percentage of world total primary energy supply [IEA 2003], [IEA 2004], [IEA 2006], [IEA 2007], [IEA 2008], [IEA 2009]

Wagar [1989] offers three reasons for what he called the "glacial velocity of the shift from fossil fuels to alternative energy technologies" and at least two of the three seem to have proven out to a large extent. Harvesting of the sun, the wind, the tides, etc., has proven easier in the laboratory than the marketplace and safe waste disposal continues to be a significant issue for this form of generation. However, if any political manoeuvres aimed at enslaving the Third World and/or the countries of the Middle East took place, they do not appear to have been successful.

The exact definition of proven exploitable reserves of oil varies from company to company and from country to country. This allows numbers disclosed by national governments of a country's reserves to be manipulated. However, according to the International Energy Agency (an autonomous body within the Organization for Economic Cooperation and Development), global proven reserves of oil, not including unconventional oil, were estimated in 2001 to be about one trillion barrels. This makes Wagar's prediction of the world's proven exploitable reserves of oil in the year 2000 as "exceeding 1.4 trillion barrels", a very good estimate. Wagar was correct when he predicted that large corporations and governments would continue to rely on fossil fuels since they are the most economical source of energy.

Wagar predicted that temperatures would increase 4.2 degrees Centigrade in the 60-year period between 1980 and 2040. The year 2040 has not yet arrived, but the temperature increase over the 20-year period between 1980 and 2000 was approximately 0.34 degrees Centigrade (0.17 degrees Centigrade per decade [Balling 2003]). The temperature over the next twenty-eight years will have to increase dramatically for a scenario like Wagar's "Life in a greenhouse" to occur. If temperature continues to rise at the current rate of 0.17 degrees Centigrade per decade, perhaps the world will avoid the major disasters that Wagar predicts will start in 2039. It should be noted that, like proven oil reserves, temperature records can cause dispute. They contain biases from urbanization, distribution of measurement stations, instrument changes, time-of-observation, along with a variety of issues involved with measuring temperatures in ocean areas [Balling 2003].

Wagar's prediction that the amount of CO_2 in the atmosphere would be 365 parts per million (ppm) in 2000 is remarkably close to the actual amount of 368.77 +/- 0.10 (ppm) as measured by the U.S. Department of Commerce's National Oceanic and Atmospheric Administration's Earth System Research Laboratory (NOAA/ESRL) [NOAA/ESRL 2010]. The amount of CO_2 in the atmosphere was 365 parts per million (ppm) in 1998. Scientists continue to argue over the exact cause of the earth's warming that has occurred since the 1980s.

Analysis of how the above information can assist SMEs in their technological decision-making is presented in 5.3.3.

5.2.4 History of the Future

History of the Future covers a period of so many years that the only predictions which can really be evaluated are the ones regarding four-stroke internal combustion engines (ICEs). Lorie and Murray-Clark's two contentions were that: (1) they will still be around for the beginning of the 21st century but that they will be made of ceramics and metal alloys and (2) all engine functions will be computer monitored, including suspension. Regarding (1), one-tenth of the way into the 21st century four-stroke ICEs are still around and it is predicted that the combined market for electric vehicles (the most visible competitor) will represent only 2.5 percent of the total vehicle market over the next decade [Gartner and Wheelock 2009]. Ceramics and metal alloys are becoming common materials for vehicle *parts* in automobile designers' quest to reduce weight and increase efficiency. However, ceramic engines have not made their way into production vehicles. Challenges with ceramic engines include issues with sealing and lubrication.

Regarding (2), computer control of automobile functions through a vehicle's Engine Control Unit (ECU) has become standard and this phenomenon is only increasing. The recently unveiled (September 15, 2009) Ferrari 458 Italia allows the driver to adjust the car's suspension, stability control, traction control, launch control, steering boost and shift speed from the driver's seat.

Step 2, the reading of the scenarios and the identification of any and all the predictions they make regarding energy – used as an appropriate topic to capture information relevant to Sunshine's solar inverter business – has been completed. The next section will describe Step 3 (the final step) in the recycling scenarios technique: the analysis of the information collected in Step. 2.

Analysis of how the above information can assist SMEs in their technological decision-making is presented in 5.3.4 of the following section where an explanation is provided regarding how all of the above evaluations should aid the

SME in identifying “those contingencies that [it] was unaware that it was unaware of.” (see the quote which begins this chapter).

5.3 STEP 3: ANALYSIS OF THE RECYCLED SCENARIOS

In the final step of the recycling scenarios technique, Step 3, the energy-related information gleaned from the recycled scenarios in Step 2 will be analysed in the same order that the scenarios were presented in sections 5.2.1 to 5.2.4.

5.3.1 The Next Two Hundred Years

Kahn, Brown, and Martel’s scenario provides some direct references to solar energy, recognizing it as one of the “eternal power sources”. As noted in section 5.2.1, the heating and cooling of buildings by direct use of solar radiation as a heat source (HCB) has not become the standard that some experts had predicted, nor has solar thermal power (STP). This situation should prompt Sunshine to investigate why this has happened. Has it been a societal, a political or a global reason? Or, is it, perhaps a technical reason? If it is a technical reason, is it an obstacle that Sunshine’s unique technology or technological intellectual property can overcome? Perhaps this line of thinking will spark some creativity within the company which results in a new product or product line. Are there any particular aspects of STP’s storage advantage that can be taken advantage of today or in the foreseeable future? These are the types of questions that the recycled scenarios should elicit.

Kahn and his team’s scenario has been remarkably close to what has actually transpired. So, when Kahn, Brown, and Martel propose that “STP will not become commercially competitive until well into the next century”, some extra thought should be expended on scanning the industrial and academic literature to gain a sense of when and/or if this is happening and being prepared in the case that it does. Being prepared may mean adjusting product lines, developing product lines or merging with a competitor that has better experience in this area. It may mean something else entirely, as long as it means that Sunshine moves itself into the best possible position to take advantage of a world in which STP becomes the next focus technology.

Section 5.2.1 shows that as recently as 2009 the Natural Energy Laboratory of Hawaii Authority (NELHA) solicited requests for proposals for a solar array to be built at the facility. Although the focus of the facility currently appears to be providing seawater to a variety of research tenants, it may not remain so in the future. Sunshine may develop a project which interests NELHA and the two entities may be able to work together in some way. In a totally different vein, the concept of a Solar Energy Laboratory may cause Sunshine to consider the benefits of developing a facility at which companies could come to test its products.

Section 5.2.1 also describes the introduction of the Small Power Research and Development Act (SPRDA) by the Alberta government and its impact on those small power producers who took advantage of the Act. It is, however, apparent that there was some available capacity left when the program was closed (up to 125 MW could have been allocated, but only 108 MW was allocated before the program closed). Sunshine should determine whether it would be interested in a government program, if one were to be announced, and if it could respond in a timely fashion to such a program. Another relevant piece of information from the analysis is that there was no solar energy projects included in the program. This may create an opportunity for Sunshine to lobby government that the program was too early for solar energy and another Act should be introduced focusing on solar energy.

Even though Kahn, Brown, and Martel's prediction that most of the electric energy would be based out of central plants does not appear to be the case, this possibility should still be explored as a philosophical exercise to ensure that Sunshine could survive if this is what transpires in the years ahead. Perhaps through ingenuity and innovation Sunshine could decide to make this prediction come true.

5.3.2 Future Mind

Glenn's primary scenario of Conscious Technology reflects the merging of the human being with technology. It is the literal interpretation of this concept that may be of relevance to Sunshine since Glenn is referring to technologies such as cochlear implants whereby a technology is embedded into human consciousness. Sunshine should consider its product offering and if it could respond to any of the medical needs of a surgically implanted device. Considerations in this area should generate a discussion about the possibilities that nano-technologies may present to Sunshine or ways in which Sunshine technology or its technological intellectual property may profit nano-technological devices. These inquiries or ideas do not have to be acted on immediately, awareness of a potential opportunity and appropriate preparation to get involved when the appropriate time has come are the hallmarks of being prepared for one's future.

Glenn's primary scenario focussed significantly on space travel. However, space travel has not advanced at the rate he predicted. Does Sunshine possess some technological insight which could aid the space industry? Is Sunshine aware that at one point in history it was thought that giant solar satellites would receive solar energy 24 hours a day and beam it down to earth? If so, does it know the status of this idea and if not, why not? If so, does it have a complementary technology which would contribute to this goal? Would Sunshine like to make this the company's goal?

Similarly, is Sunshine aware that at one point in history it was thought that mechanical space spiders would spin photovoltaic sheets? If so, does it know the status of this idea and if not, why not? Does the discussion of space travel, giant solar satellites beaming energy down to earth and space spiders spinning photovoltaic sheets get the innovative ideas flowing around the Sunshine meeting table? That in itself is a valid result from a scenario exercise.

5.3.3 A Short History of the Future

Wagar's scenario was largely incorrect regarding the pace at which the world would reduce its reliance on fossil fuels and concurrently ramp up its reliance on renewable energy sources and nuclear energy from fusion reactors. He also appears to be incorrect about his projected temperature increase by 2040. However, he was largely correct with his predictions around proven exploitable oil reserves and the amount of CO_2 in the atmosphere. What if he's right about his projected temperature increase by 2040? How would that change the world? How would Sunshine's products react in a hotter world? Would their efficiency increase?

5.3.4 History of the Future

History of the Future, like Global Warming and The Great Turning, does not mention solar inverters or anything about solar energy in particular. The scenario envisions a world of advanced engine materials and controls. Do any of these advanced materials positively impact any of Sunshine's current products or product offerings? Is there any aspect of these advanced engine controls which can solve a known issue with Sunshine's inverter control systems?

5.4 SUMMARY

The above application of the new technique of scenario recycling has created a diversity of avenues for Sunshine to pursue in its quest to anticipate and understand the potential direction, rate, characteristics, and effects of technological change. Despite the fact that only the first scenario – The Next Two Hundred Years – provides direct references to solar energy, there are many different insights for Sunshine within the seven scenarios analyzed.

Since it mentions solar energy specifically, The Next Two Hundred Years scenario provides the most ideas for Sunshine to explore:

- the heating and cooling of buildings by direct use of solar radiation as a heat source (HCB) has not become the standard that some experts had predicted, nor has solar thermal power (STP).
- Kahn, Brown, and Martel propose that "STP will not become commercially competitive until well into the next century".
- as recently as 2009 the Natural Energy Laboratory of Hawaii Authority (NELHA) solicited requests for proposals for a solar array to be built at the facility.
- the concept of a Solar Energy Laboratory
- the introduction of the Small Power Research and Development Act (SPRDA) by the Alberta government and its impact on those small power producers who took advantage of the Act. Additionally that there were no solar energy projects included in the program the Act supported.
- prediction that most of the electric energy would be based out of central plants.

Each of the above bullet points provides an opportunity for Sunshine to reflect and determine if the idea:

- is worthy of further investigation
- presents a situation which Sunshine is prepared for
- presents a potential business opportunity for Sunshine.

Five of the six remaining scenarios provide the following ideas:

- Global Warming presents Sunshine with an opportunity to examine policy implications.
- Future Mind provides the concept of the merging of the human being with technology and space opportunities including giant solar satellites beaming energy down to earth and space spiders spinning photovoltaic sheets.
- The Capitalist World-Economy provides an endorsement for the use of the Long Wave method.
- A Short History of the Future forces Sunshine to imagine a hotter world and the impact of this on its products.
- History of the Future introduces the concept of a future of advanced engine materials and controls and the impact of this on its products.

Again, Sunshine should reflect on each of the above ideas to determine if the idea is worthy of pursuit, if Sunshine is prepared for such a situation and if there are any potential business ideas.

The Great Turning is the only scenario analysed which presents no new insights for Sunshine.

This chapter has presented a new technique to make the scenarios method accessible to SMEs since it is assumed that developing scenarios from scratch would be too costly to SMEs with respect to human and financial resources. The following chapter will discuss the use of proven TFA methods and the Scenario Recycling techniques by SMEs.

6. DISCUSSION

Several dozen foresight methods/techniques have been assessed based on the particular resource characteristics of SMEs and have been pared down to the eight methods which may most universally be applied to an organization with extremely limited financial and manpower resources. The bibliometrics and long-wave analysis methods have been applied to a hypothetical SME to demonstrate how they can be accessible to SMEs. The proposal of the scenario recycling approach is a unique and original idea that is worthy of further research.

The application of bibliometrics and long wave analysis (in Chapter 4) and scenario recycling (in Chapter 5) to a hypothetical SME engaged in the sustainable development field produced numerous avenues of potential inspiration and investigation for the SME. The monitoring method, although not applied specifically in the case of the hypothetical SME, offers an identified means of keeping track of what is occurring in these areas.

It is important to note that none of the methods or their techniques has produced such striking results that an unmotivated individual will become motivated (to plan for the future). Foresight is not an activity which will often result in an earth-shattering revelation of the next step any organization (large or small) should take. What it will provide for any organization in an increasingly complex business environment is the breadth of possibilities that a strong, resilient company should be prepared for. This thesis has identified foresight tools suitable to aid the small- to medium-sized enterprises since these sized organizations have not generally been availing themselves of this ability in the past.

Along with eight relatively well-known foresight methods, this thesis has also proposed a new scenario technique which SMEs can apply. Two of the eight methods were applied to one hypothetical SME in Chapter 4 and the new scenario technique – scenario recycling – was applied to a different hypothetical SME in Chapter 5. Unlike long wave analysis, which remains consistent for all applications, the bibliometric method and the recycling scenarios technique involve processes with the potential to create a unique search experience each time they are applied. The following sections will discuss some of the specific aspects of these two tools with respect to SMEs.

6.1 KNOWN METHOD – BIBLIOMETRICS

Of the two methods applied in Chapter 4, bibliometrics resulted in a display of some of the numerous insights that bibliometric data can offer. An important preliminary finding of this research is that the graphing of patent search data may provide decades of advance warning that a SET will start to be installed. When such data were graphed against installed generation capacity for nuclear, wind, and solar thermal generation, an upturn in the number of patents was shown to precede installed capacity by five, thirty and nine years, respectively. When the first derivatives of patent numbers were graphed again against installed capacity, an upturn in the first derivative of the number of patents was shown to precede installed capacity by two to three, thirty-one and fourteen years for nuclear, wind, and solar thermal generation, respectively.

Whereas the data gathered in the examples above provide a snapshot, the power of the bibliometric method for an SME may be in tracking the changes to the data for a specific technology over time. This is an example of the value of using TFA methods together. In this case, the monitoring method with the bibliometric method. By monitoring the changes to the bibliometric data at regular intervals, the SME will become more familiar with it and, by doing so, become more likely to be able to discern trends.

Becoming adept at bibliometrics can also provide an SME with information such as who the recognized experts are in a field. Per Lotka's Law (see 2.7.6), small numbers of researchers tend to make a large contribution in the form of publications. Both NTIS and Compendex databases provide the names of authors, in decreasing number of citations, for any records searched. Since both databases also provide an author's affiliations, it is relatively easy to determine the experts in a field and the organizations for which they work.

One of the hardships of the bibliometric search is the rigorous data preparation required. This can be both tedious and time consuming. It is critical to know exactly the information being sought prior to embarking on a bibliometric quest using a database of any size. "Citation searching works best after you have identified key articles critical to your research" [Reichardt 2009]. In this respect, bibliometric analysis is better suited to normative foresight where one has defined goals and can more easily identify the parameters for a search. Expert knowledge may also be essential to ensuring that one has selected the correct search subjects.

Rigorous data preparation can be avoided by conducting simple searches of prepared databases as has been done in 4.1. Although such searches are unlikely to reveal nuances, whatever information is revealed will be more information than an organization not conducting such searches would otherwise have. As a result, an SME conducting even rudimentary bibliometric searches may have a slight competitive advantage over those that do not. Porter [2009, 5] describes how he augments analysis of databases which require a fee to use with Internet searches; in this manner compensating for the fact that database content lags in comparison to the Internet. The lag associated with databases is due to the time it takes most sources to make information available (e.g., publication processes may take a year or more and patents can take many years).

In summary, the counting of elements such as publications, papers or authors (bibliometrics) can provide insight into the status and potential future of specific technologies. The intelligence that can be gained extends beyond an indication of a technology's future. It can also provide the names of the most prolific researchers of the technology. This type of information may aid a company in locating appropriate staff or identify a company that it would be advantageous to partner with. A certain degree of intelligence can be obtained without cost (beyond the cost of Internet service) and without the aid of experts. However, specialized database services (which a user must pay for) and the use of experts should be considered since each is likely to improve the bibliometric analysis.

In terms of the actual search, there are some data considerations that SMEs should be aware of and these are offered in the following sections.

6.1.1 Selecting bibliometric search terms

Getting the correct word or words to search is one of the critical tasks of the bibliometric method. The United States Patent and Trademark Office (USPTO) – used due to its larger database (than for Canada) – allows a "quick search" where a searcher enters two terms. However, as one can see in Table 21, this particular database did not handle long descriptions well, such as those for the last three distributed energy technologies (wind generation combined with diesel generation, photovoltaic generation combined with battery storage or diesel generation and fuel cell generation combined with microturbine generation). It returned a result of zero in the case of wind generation combined with diesel generation and failed to provide a result in the cases of photovoltaic generation combined with battery storage or diesel generation and fuel cell generation combined with microturbine generation. This fact emphasizes that the user must select the most specific and concise description of the technology being investigated.

What the results of the bibliometric search may indicate to the person conducting the search depends on what the search conductor was expecting. If the search conductor's organization has infinite skills, infinite resources, and the ability to change its business focus very quickly, it may conclude that distributed energy technologies, with the most Google hits and the most patents, is an active area of the marketplace and one that it wants to pursue. A different company, looking for a niche to fit into, may decide that this is simply too popular an area of technology to compete in and may shy away.

Based on the snapshot in Table 21, fuel cell generation combined with microturbine generation received the least number of hits (although the patent search was inconclusive due to the number of descriptive terms involved). Fewer hits imply that this technology is not receiving as much attention as some of the others. It may be that for-profit organizations have not been able to financially justify research into the technology and it is therefore in greater need of advancement by a publicly funded organization (that may be able to justify research on a "public good" basis).

A further challenge in selecting search terms is that the names of some research areas can evolve over time. For example, what used to be referred to as mind control or brainwashing is now commonly referred to in academia as coercive persuasion, coercive psychological systems or coercive influence [F.A.C.T.net

2010]. With reference to nanotechnology, *nano-* (one billionth) represents a current phenomenon; inserting a prefix onto an existing term to coin a new word. Of course, the *nano-* prefix is appropriately used for many new things in the nanotechnology sphere, but the prefix is also appearing in front of a number of unrelated words; for example, nanosundae, nanopublishing, nanofont, nanocorp, and Nano-care (a trademarked technology that creates wrinkle-resistant and liquid-repelling pants) [McFedries 2004, 64].

This prefix fad may have cast its shadow on the work of this thesis with respect to the prefix *bio-* which means “life” or “biology”. Searches for terms such as biomass generation, sustainable energy biotechnologies, biofuels, bio-gasoline, biodiesel, bio-jet fuel, and bioprocessing may not have returned Internet hits or patents when trying to replicate past searches if these SETs were known by different names in the past.

6.1.1.1 Spelling

As well as ensuring that one is searching the appropriate granularity of a topic, one must also be sensitive to the spelling of the technology being searched. Table 24 shows the impact of spelling and use of the singular or plural on search results. Google returned different numbers of hits for the three different spellings of microturbines that were tested (microturbines, micro-turbines, and micro turbines). There are seven times the number of patents for micro turbines as there are for microturbines, which in turn has a little over double the number of patents than for micro-turbines.

SUSTAINABLE ENERGY TECHNOLOGY	Google.ca HITS[37]/ HITS with quotes[38]	PATENTS[39]
Microturbines	189,000 / n/a	161
Micro-turbines	418,000 / n/a	77
Micro turbines	264,000 / 40,200	1,244
bio-gasoline	15,500,000 / n/a	0
biogasoline	3,480,000 / n/a	0
Clean coal technologies	891,000 / 157,000	1,371
Clean coal technology	71,200,000 / 348,000	3,110
Oil sands energy	968,000 / 2,500	2,928
Oilsands energy	3,490,000 / 2,750	14

Table 24: Effect of spelling on searches

One must also be conscious that different results may be achieved if one is searching for the singular as opposed to the plural of a technology. Table 24 shows that clean coal technologies (plural) achieved less than a million hits, while clean coal technology (singular) achieved over 71 million hits on Google. On the patent side, clean coal technology (singular) had over double as many patents as clean coal technologies (plural).

Another sensitivity of search words relates to technical colloquialism. To

[37] All searches conducted on March 8, 2009.
[38] All searches conducted on March 8, 2009.
[39] All searches were conducted on http://patft.uspto.gov/ on March 8, 2009. Note: Patents from 1790 through 1975 on the database are searchable only by issue date, patent number, and current U.S. classification. Therefore, numbers reflect patents from 1976 to present.

someone with an electric utility background, the generation of electricity using biomass is referred to as “biomass generation”. However, someone from a different background may refer to the generation of electricity using biomass as bioenergy. The difference that such subtle word changes can make is illustrated in Table 25 and Table 26.

SUSTAINABLE ENERGY TECHNOLOGY	**Google.ca HITS[40]/ HITS[41] with quotes**		
	GENERATION	**POWER**	**ENERGY**
Biomass	2,260,000 / 17,200	1,290,000 / 416,000	2,940,000 / 761,000
Solar	11,200,000 / 89,600	29,400,000 / 11,100,000	33,200,000 / 17,700,000
Nuclear	21,200,000 / 130,000	34,100,000 / 19,600,000	31,800,000 / 18,600,000
Hydro	341,000 / 67,800	11,200,000 / 1,390,000	5,050,000 / 174,000
Wind	13,900,000 / 630,000	34,400,000 / 9,140,000	36,100,000 / 7,510,000
Geothermal	246,000 / 11,900	716,000 / 577,000	1,890,000 / 1,400,000

Table 25: Impact of technical description on Internet hits

[40] All searches conducted on March 8, 2009.
[41] All searches conducted on March 8, 2009.

	PATENTS[42]		
SUSTAINABLE ENERGY TECHNOLOGY	**GENERATION**	**POWER**	**ENERGY**
Biomass	4,191	2,625	4,950
Solar	11,092	28,447	30,671
Nuclear	35,506	36,290	40,452
Hydro	3,902	7,064	7,092
Wind	14,910	40,082	25,887
Geothermal	1,170	2,136	2,435

Table 26: Impact of technical description on number of patents

6.1.1.2 Experts

As alluded to in the product description for Dataview/Matheo Analyzer (i.e., "Dataview was designed as a software tool for experts of scientific and technological information processing"), there is the possibility that to obtain the information that one is seeking, one will have to go beyond one's own enterprise to seek an individual with the appropriate expertise in either the bibliometric method, the technology, or both.

Porter [2009, 6] identifies the engagement of experts to review and interpret the output received from bibliometric searches as critical. He also describes the use of experts much earlier in the process too, to assist in the definition of the terms to be searched. Further he references an individual – Ron Kostoff – who he identifies as a leader in technological text mining as proposing that heavy

---

[42] All searches were conducted on http://patft.uspto.gov/ on March 8, 2009. Note: Patents from 1790 through 1975 on the database are searchable only by issue date, patent number, and current U.S. classification. Therefore numbers reflect patents from 1976 to present.

involvement of substantive experts in the process is essential.

6.1.1.3 Relevancy

A final consideration when using this method is the relevancy of the hits. It is a simple matter to count Internet hits. The resulting count, however, is more relevant if all of those hits have actually pertained to the topic being searched. As an example, a search of scrubbing technologies intended to address technologies which scrub flue gas, also returned hits relating to a foam scrubbing system that had as its primary purpose the cleaning of floors.

Moving from a tried and true method, to a newly proposed method, the next section will discuss some of the strengths and weaknesses of scenario recycling.

6.2 NEW TECHNIQUE – SCENARIO RECYCLING

The introduction of the scenario recycling technique is a significant aspect of this thesis and much testing of the proposed technique will be required. However, the sections below will compare the use of a group of recycled scenarios to the known characteristics of a good original scenario. The features of a good original scenario are that it is:

- plausible
- recognizable from the signals of the present
- creative in exploring new ground and ideas

- relevant and significant to the organization
- internally consistent
- challenging [GBN and Foresight Canada 2004].

Plausibility (the first bullet point above) is subjective since it depends on an individual's knowledge and experience. However, it seems safe to assume that all recycled scenarios were plausible at the time they were written. However, their plausibility in the new time frame that they are to be used in may prove to be a useful selection factor regarding which scenarios are suitable for recycling.

Turning to the remaining bullets, those scenarios which addressed Sunshine's area of business – generally solar energy – offered some signals which are recognizable from the signals of the present, albeit in a retro fashion. Some of the signals – like space travel – have had their heyday, but it is impossible to predict that they won't return to the spotlight again in the future. The fact that these scenarios were published in and of itself tends to support that they were internally consistent and (at least at the time) were creative in exploring new ground and ideas and were challenging.

The hardest characteristic to address with a recycled scenario is its relevance and significance to the organization. Examining what perspectives these seven scenarios would provide to an organization shows, per Table 27, that at least three of the scenarios share a focus on renewable energy or reducing fossil fuel consumption (The Next 200 Years, The Great Turning, and A Short History of the Future). However, at least three other perspectives are also offered: the dire consequences of global warming if global warming is left unchecked (Global Warming), a future focused on space travel (Future Mind), a perspective on internal combustion engines (History of the Future) and a perspective on the overall world economy (The Capitalist World-Economy). This thesis has shown how most of these perspectives can be considered relevant to the hypothetical organization Sunshine Inc. However, whether these perspectives are relevant and significant to a real-life organization requires that the proposed scenario recycling technique be tested by applying it to a real-life SME.

SCENARIO	**FOCUS**
The Next 200 Years	Renewable energy generation (wind, solar, ocean thermal, biomass), nuclear, fusion power, hydrogen
Global Warming	The dire consequences of global warming if left unchecked
Future Mind	Space travel
The Great Turning	Reduced fossil fuel consumption
The Capitalist World-Economy	World economy
A Short History of the Future	Reduced fossil fuel consumption
History of the Future	Internal Combustion Engines

Table 27: Focus of Scenarios

Even if a particular recycled scenario fails to address a specific element that is relevant and significant to the SME, it is important to remember that the purpose of scenario planning is not to pinpoint future events, but to highlight large-scale forces that push the future in different directions. Scenarios are intended to make those forces visible, so that if they do occur, the organization can recognize them and, having thought about them ahead of time, make better decisions about how to deal with them [Wilkinson 2004]. For example, in Global Warming, after the initial 12-page scenario is presented, the remainder of the book presents the case for policy changes necessary to avert the scenario. The prospect of policy changes is a future which all companies (including SMEs) should prepare for.

Seven scenarios are analyzed in the sections above with respect to whether they offer predictions about sustainable energy technologies and whether or not those predictions are representative of what has actually transpired over the time period which the scenario covers which has already passed. These scenarios are then reviewed with respect to how hypothetical SME Sunshine Ltd. may use them. One scenario is long and detailed – The Next Two Hundred Years. Another scenario is short and fairly superficial – Schneider's Global Warming. One (History of the Future) covers such a vast period of time, that it would be very difficult for the author to be specific about anything. The remaining scenarios provide a range of detail somewhere between the two. As the scenarios have not been developed for the primary use of the SMEs, this phenomenon is not unexpected. What is important to note is that at least six previously prepared scenarios were encountered which provided insight into the area of interest of the hypothetical SME (i.e., solar inverters). This number of relevant scenarios may be difficult to obtain if the focus of the SME were something more obscure or something more specific. Only further testing of the proposed technique will prove or disprove this.

Continuing with respect to content, as surprisingly correct as Kahn, Brown, and Martel's scenario is in The Next Two Hundred Years, Glenn's scenario in Future Mind is surprisingly incorrect due to its reliance on anticipated advances in space travel and development. However, this is appropriately typical of the scenario method which is supposed to cover a wide span of possible futures [Hines and Bishop 2006]. It may also be a sign of the times in which Kahn, Brown, and Martel produced their scenario. Herman Kahn (the father of scenario construction) typically produced three alternative scenarios regarding any subject: a best-case scenario based on good management and good luck, a worst case scenario based on mismanagement and bad luck and a business-as-usual scenario that extrapolated the current trends and accounted for the interaction of these trends. This approach has been replaced with the goal of writing a set of four scenarios, *none* of which reflect a business-as-usual situation (in the present context, scenarios are generated based on the identification of a number of critical uncertainties for the organization and the viewing of each as a continuum or dimension of which the end points must be described. These end points must describe the extreme range of the uncertainty. If the end points do not describe two different future outcomes for the uncertainty, then using these end points must be aborted as it is not a true uncertainty. Once each critical uncertainty has been defined, they must be paired such that they can be displayed on orthogonal axes as *independent* variables. It is from these orthogonal diagrams that the four scenarios themselves are created [Glenn and The Futures Group International 2009]).

It is worth pointing out that whereas four is the typical number of scenarios to be generated in an original scenario development process nowadays [Glenn and The Futures Group International 2009], the hypothetical SME – Sunshine Ltd. (Sunshine) – using recycled scenarios has been provided the benefit of seven to reflect upon.

Of the seven scenarios, one is a reasonable prediction of what transpired – The Next Two Hundred Years. Another could be considered a worst case scenario representing extreme global warming – Global Warming. A third scenario one may characterize as a best case scenario in which the world moves from a reliance on fossil fuels to a reliance on alternative energy technologies (The Great Turning*)*. In addition, all of the remaining scenarios offer a variety of insights. These insights appear relevant to a hypothetical SME and the nature of the field in which the hypothetical SME was selected to operate in as determined by a non-expert in the field. It is anticipated that better insights and ideas would be generated by someone with an intimate knowledge of the SME's operations. Further study is required to determine if the types of insights offered by the scenario recycling technique would be relevant to a real-life SME. Such further testing should also determine whether or not the same quantity of seemingly useful scenarios would be found.

The next chapter will summarize the conclusions that can be drawn from the research conducted in this thesis and propose areas for further research.

7. CONCLUSIONS AND RECOMMENDATIONS

This research sought to analyze and address a fundamental research question "Which technology foresight (TF) or technology futures analysis (TFA) methods can resource-limited SMEs use with ease to assist in their technological decision-making?" It found that the following known methods are suitable for aiding SMEs in their technological decision-making:

1. backcasting
2. bibliometrics
3. diffusion modeling
4. long wave analysis
5. monitoring
6. technological substitution
7. trend extrapolation
8. vision generation

It is worth noting that two of the methods on the above list – diffusion modeling and technological substitution – are so closely related that Kwaśnicki and Kwaśnicka identified the two terms as equivalent [1996, 32].

In addition to the above eight known methods, a new and original technology foresight technique was introduced by this thesis – Scenario Recycling. This method promises also to be useful to SMEs. Based on the review conducted in this thesis using a hypothetical SME, scenario recycling appears appropriate due to the low cost of applying it and the small number of individuals required to conduct the technique. However, rigorous testing of the technique by real-world SMEs is necessary. One area of inquiry which must be pursued in such studies focuses on the question of whether or not the time horizon of a recycled scenario impacts its usability to an SME. Two of the scenarios studied for this research were ultra-long term forecasts, which are not always taken seriously [Gordon, Adam 2009, 21]. It is also important to note that a general focus on sustainable energy technologies was presumed to be the business focus of the hypothetical SME in this thesis. Hence, future research should also address the question of whether or not a different business focus impacts the quantity of "recycled scenarios" offering insights to an SME.

Although the output generated by some of the methods may appear to be so vague as not to be valuable, the key benefit in adopting them may lie in forcing the SME to peer into its technological future. In an increasingly complex business environment, where numerous strategic decisions are required, it is often easy for practical activities – such as planning for the future – to be neglected unless a structured exercise is presented.

The application of the bibliometric method to a hypothetical SME, using the Internet as the primary resource, likewise suggested four distinct areas for further research. The first area became clear following a search of five databases for the number of references to twenty-nine specific sustainable energy technologies (including fuel cells and nuclear generation). Fuel cells were the topic of the greatest number of records on the ENG*netBASE*, Knovel, and ProQuest databases, while nuclear generation was the topic with the highest number of records on both the NTIS and Compendex databases. It was postulated that since both the ENG*netBASE* and Knovel databases reflect resources that take longer to publish (i.e., books as opposed to journal articles), fuel cells may be considered to be further along the commercialization track and therefore less in need of research than nuclear generation, even though the latter has the greatest number of references on the NTIS and Compendex databases – given that these databases reflect resources that are quicker to publish (i.e., journal articles). Further research is required to determine whether this postulation is valid.

The application of the bibliometric method to a sample of sustainable energy technologies also prompted the conclusion that a simple Internet search may be as informative as a search of fee-for-use databases such as those mentioned in the previous paragraph. Therefore, the second area of additional research is to determine whether this conclusion is correct.

The third area warranting further research with respect to the application of the bibliometric method to a hypothetical SME is whether the concept of *more* patents resulting from a database search using a "word stemming on" search approach is actually better than a search using a "word stemming off" approach (where the word stemming "on" approach generally delivers a greater number of patents found) or if the additional patents being found as a result of turning word stemming “on” are actually patents of less relevance to the search.

The final area of research with respect to the bibliometric method, relates to the discovery that graphing the derivatives of patent search results against installed generating capacity for nuclear, wind, and thermal generation showed an upturn in each graph as many as thirty years prior to the installation of generation capacity. Additional research is required to determine whether this advance warning phenomenon is repeatable for other sustainable energy technologies.

Finally, numerous foresight methods were determined to be inapplicable to SMEs in this thesis due to the requirement that a group of people perform the method. However, there are various ways that SMEs can overcome this limitation. Additional research is required with respect to SMEs engaged in technology foresight using networks, communities of practice, social media, cooperatives, etc., as ways to access not only additional opinions, but potentially expert opinions at very little cost. The availability of expert opinions would open up a greater number of foresight methods for SME use.

An aspect which has not been explored in this thesis, but has been raised in other research [Major, Asch, and Cordey-Hayes 2001], is the extent of the knowledge of those individuals associated with the SME with regard to technology foresight. An important finding of one of the rare studies to be found on SMEs and foresight, undertaken in the United Kingdom (U.K.), was that “the impact of managerial attitudes and attributes is central...foresight knowledge was attributed to individual staff rather than to company systems and procedures" [Major, Asch, and Cordey-Hayes 2001, 100]. The U.K. study appears to indicate that even if the foresight methods are suitable for an SME, there is an element beyond methodology which is dependent on managerial attitudes and attributes and the particular foresight knowledge of individual staff which may impact the outcome.

In summary, this research has shown that technology futures analysis methods can be used by SMEs to assist them in making technology-related decisions pertaining to the future. An SME intending to introduce technology foresight to its strategic management toolbox could use the approach suggested in Figure 23.

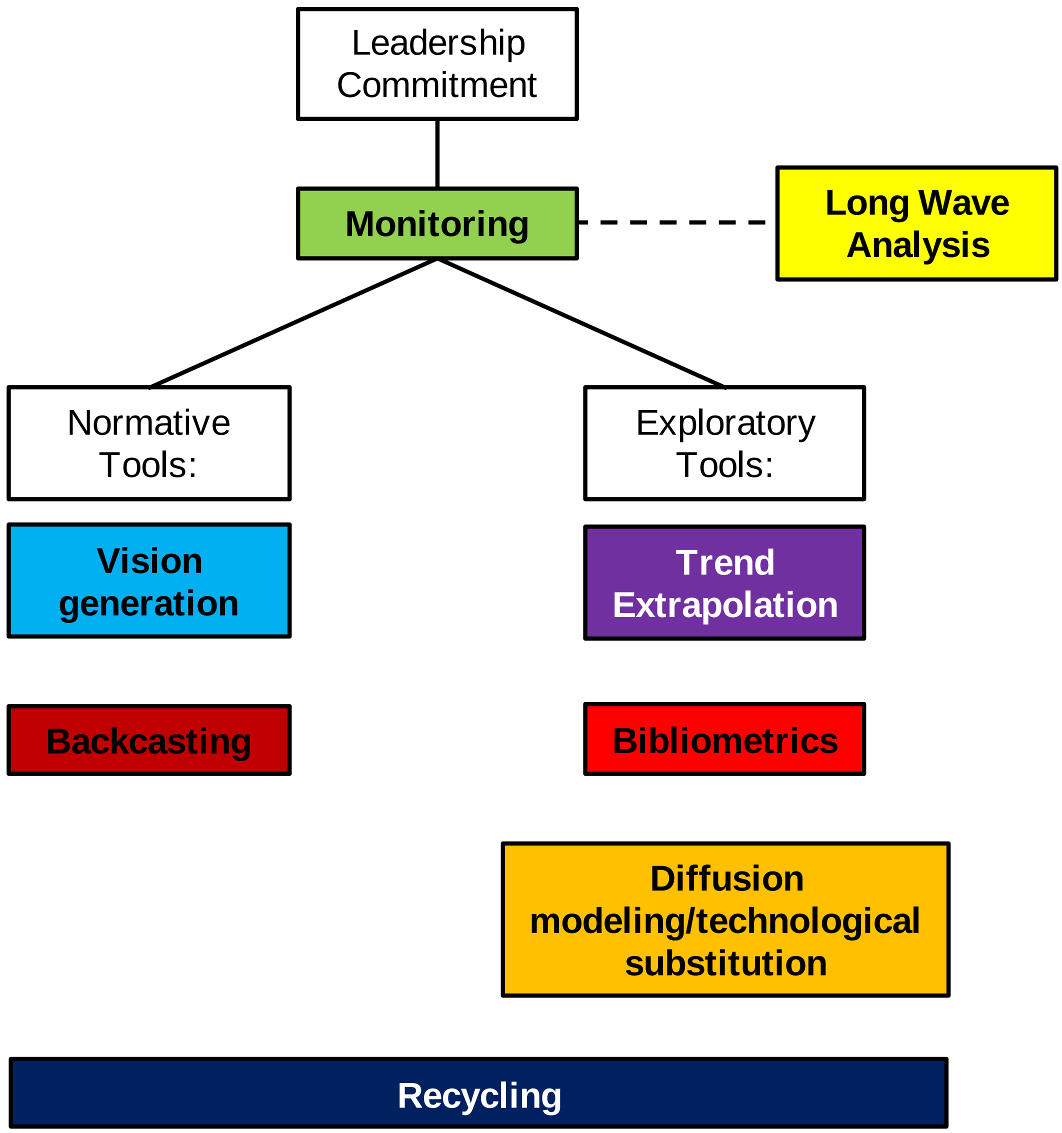


Figure 23: Technology Foresight Steps for SMEs

To introduce technology foresight as a strategic management tool into any organization, it is imperative to have the full support of management. Per Major, Asch, and Cordey-Hayes [2001, 100], "the impact of managerial attitudes and attributes is central". Since it is difficult to attribute a return on investment (ROI) to a foresight exercise, it is important that there be implicit support from senior management to expend the effort. Resting on a solid base of support, the first step in any foresight project is the development of a monitoring program to provide an early alert of any changes that may warrant a revision to current plans. Various scanning techniques exist, but two of the simplest approaches are literature reviews and 'Google Alerts'. In parallel with a sound monitoring program, an additional method to consider is long wave analysis. As noted, however, this is not a universally supported method.

As stressed throughout this thesis, foresight methods are the most powerful when used in combination. Therefore, an SME should endeavour to employ as many TFA methods or techniques as possible. There are two primary groups of techniques which can be employed: normative tools for situations where the SME is aware of a future state that it would like to achieve and exploratory tools for situations where the SME is seeking information about possible futures. In the former case, vision generation and backcasting should be employed while in the latter case, trend extrapolation, bibliometrics and diffusion modeling/technological substitution are best used.

If an SME has established a sound and on-going monitoring program, assessed the usefulness of long wave analysis to its business, and examined the normative or exploratory tools (as the situation dictates), it should then investigate what benefit it may gain from recycling scenarios or recycling other foresight exercises performed by others.

8. BIBLIOGRAPHY

Aaltonen, Mika. 2009. Appendix titled *Evaluation and Organization of Futures Research Methodology – Version 3.0* to *Integration, Comparisons, and Frontiers of Futures Research Methods* by Theodore J. Gordon and Jerome C. Glenn in The Futures Research Methods Series in *Futures Research Methodology – V3.0,* eds. Jerome C. Glenn and Theodore J. Gordon, [CD-ROM]. Washington, D.C.: The Millennium Project.

AESO (Alberta Electric System Operator). 2007. *Guide to wind power in Alberta.* Calgary: AESO.

AESO (Alberta Electric System Operator). 2009. *AESO Long-term Transmission System Plan.* Calgary: AESO.

AESO (Alberta Electric System Operator). 2010. www.aeso.ca/transmission/281.html. Accessed on 27 August.

AESO (Alberta Electric System Operator). 2012. *AESO Long-term Transmission System Plan.* Calgary: AESO.

Allison, Graham. 1971. *Essence of Decision: Explaining the Cuban Missile Crisis*. Boston: Little Brown & Co.

Anderson, P. Dannemand, Holst Birte Jorgensen, Lars Lading and Birgitte Rasmussen. 2004. Sensor foresight – Technology and market. *Technovation*. 24: 311-320.

APEC Center for Technology Foresight. 2012. http://www.apecforesight.org/index.php?option=com_content&view=article&id=51&Itemid=58 accessed on 9 May.

Armstrong, J. Scott. 2001a. "Judgmental Bootstrapping: Inferring Experts' Rules for Forecasting" in *Principles of Forecasting: A Handbook for Researchers and Practitioners,* ed. J. Scott Armstrong. Accessed on March 6. http://marketingnpv.com/content/5-ways-better-forecasts.

Armstrong, J. Scott. 2001b. "Selecting Forecasting Methods" in *Principles of Forecasting: A Handbook for Researchers and Practitioners,* ed. J. Scott Armstrong. Accessed on March 6. http://marketingnpv.com/content/5-ways-better-forecasts.

Armstrong, J. Scott. 2001c. "Combining Forecasts" in *Principles of Forecasting: A Handbook for Researchers and Practitioners,* ed. J. Scott Armstrong. Accessed on March 6. http://marketingnpv.com/content/5-ways-better-forecasts.

Armstrong, J. Scott. 2001d. "Evaluating Forecasting Methods" in *Principles of Forecasting: A Handbook for Researchers and Practitioners,* ed. J. Scott Armstrong. Accessed on March 6. http://marketingnpv.com/content/5-ways-better-forecasts.

Armstrong, J. Scott. 2001e. "Expert Systems for Forecasting" in *Principles of Forecasting: A Handbook for Researchers and Practitioners,* ed. J. Scott Armstrong. Accessed on March 6. http://marketingnpv.com/content/5-ways-better-forecasts.

Armstrong, J. Scott. 2001f. "Standards and Practices for Forecasting" in *Principles of Forecasting: A Handbook for Researchers and Practitioners,* ed.

J. Scott Armstrong. Accessed on March 6. http://marketingnpv.com/content/5-ways-better-forecasts.

Armstrong, J. Scott. 2001g. “Role Playing: A Method to Forecast Decisions” in *Principles of Forecasting: A Handbook for Researchers and Practitioners,* ed. J. Scott Armstrong. Accessed on March 6. http://marketingnpv.com/content/5-ways-better-forecasts.

Armstrong, J. Scott and J. Thomas Yokum. 2001. Potential Diffusion of Expert Systems in Forecasting. *Technological Forecasting and Social Change* 67: 93-103.

AS@UVA. 2012. American Studies at the University of Virginia. Accessed at http://xroads.virginia.edu/~1930s/DISPLAY/39wf/frame.htm on 8 April.

Augustine, Biju, M. Bhasi and G. Madhu. 2012. Exploring the Forecasting Behaviour: Findings from Indian SMEs. *International Journal of Emerging Technology and Advanced Engineering* (March), Vol. 2, Issue 3: 260-267.

Balling, Robert. 2003. *The Increase in Global Temperature: What is Does and Does Not Tell Us.* Washington: George C. Marshall Institute. September.

Banister, D. and D. Stead. 2004. The Impact of ICT on Transport, *Transport Reviews*, Vol. 24 (5), pp. 611-632.

Baumol, W.J., J.C. Panzar and R.D. Willig. 1982. *Contestable Markets and the Theory of Industry Structure*, New York: Harcourt Brace Jovanovich.

Bell, Wendell. 2002. “A community of futurists and the state of the futures field,” *Futures* 34: 235-247.

Bell, Wendell. 2009 *Foundations of Futures Studies: History, Purposes, and Knowledge.* Transaction Publishers: New Brunswick.

Betz, Frederick. 2000. New Ventures for Technological Innovation in *Technology Management Handbook*, ed. C. Dorf. Boca Raton: CRC Press.

BIPE Conseil, CIFS (Copenhagen Institute for Futures Studies), and the Institute for the Future. 1992. *Wild Cards: A Multinational Perspective,* Institute for the Future.

Biz.yahoo. 2008. Accessed on 24 August. http://biz.yahoo.com/ccn/071121/200711210427128001.html?.v=1.

Black, Paul E. 2004. “Bradford’s law, in Dictionary of Algorithms and Data Structures”. U.S. National Institute of Standards and Technology. Accessed on 24 October. http://www.nist.gov/dads/HTML/bradfordsLaw.html.

Boardman, Anthony E., David H. Greenberg, Aidan R. Vining, and David L. Weimer. 2001. *Cost-Benefit Analysis: Concepts and Practice*, 2nd ed. (Upper Saddle River, N.J.: Prentice Hall,): 1.

Borgonovo, E., C.L. Smith, G.E. Apostolakis, S. Deriot, and J. Dewailly. 2005. Insights from using influence diagrams to analyze precursor events. Accessed 20 January. http://nuclear.inl.gov/docs/papers-presentations/psam5_influence_diagrams_precursors.pdf.

Boyle, Carol. 2005. Sustainability Assessment – A management tool beyond LCA. Auckland, N.Z.: University of Auckland, Civil and Resource Engineering. Accessed on 11 January. http://www.icser.auckland.ac.nz/graduate/BoyleSA.doc.

Breiner, Sibylee. 1996. Foresight in Science and Technology: Selected Methodologies and Recent Activities in Germany in *Knowledge, Technology Transfer and Foresight*, ed. Annamária Inzelt and Reinhard Coenen, NATO ASI Series, 4. Science and Technology Policy, vol. 8. Dordrecht, Boston, London: Kluwer Academic Publishers.

Brundtland, Gro Harlem. 1987. World Commission on Environment and Development. *Our Common Future*. New York: Oxford University Press.

Busby, Rebecca L. 2005. *Hydrogen and Fuel Cells: A Comprehensive Guide.* Tulsa: PennWell Corporation.

Campbell, Sandy. 2009. Librarian, University of Alberta. Interview by author, Edmonton, AB, 23 September.

Canton, James. 2007. The Extreme Future: The top trends that will reshape the World in the next 20 years. London: Plume Printing. Original edition, Institute for Global Futures, Inc. 2006.

Canton, James. 2008. Technofutures: How leading-edge innovations will transform business in the 21st century. San Francisco: Next Millennium Press.

Clarke, Sr., Dana W. 2000. Strategically Evolving the Future: Directed Evolution and Technological Systems Development. *Technological Forecasting and Social Change* 64.

Claussen, Eileen, Vicki Arroyo Cochran and Debra Davis. 2001. *Climate Change: Science, Strategies, & Solutions*. Arlington, Virginia: Pew Center on Global Climate Change.

Clemen, Robert T. 1996. *Making Hard Decisions: An Introduction to Design Analysis*, 2nd ed. Belmont, CA: Duxbury Press.

Clemen, Robert T. and Robert L. Winkler. 1999. "Combining Probability Distributions From Experts in Risk Analysis," *Risk Analysis*, vol. 19, No. 2: 187–-203.

Coates, Joe. 2004a. Plenary Session 1: FTA in Context: insights into EU vs US / public vs private recent trajectories, New Horizons and Challenges for Future-oriented Technology Analysis. *Proceedings of the EU-US Scientific Seminar: New Technology Foresight, Forecasting and Assessment Methods held in Seville 13–14 May 2004,* edited by Fabiana Scapolo and Eamonn Cahill. Spain: European Commission.

Coates, Joe. 2004b. Plenary Session 2: Reports from the Parallel Sessions. *Proceedings of the EU-US Scientific Seminar: New Technology Foresight, Forecasting and Assessment Methods held in Seville 13–14 May 2004*, edited by Fabiana Scapolo and Eamonn Cahill. Spain: European Commission.

Coates, Joseph F. 1976. Technology Assessment – A Tool Kit. *Chemtech* (June): 372-383, quoted in Porter et al., *A Guidebook for Technology Assessment and Impact Analysis*, vol. 4. New York: Elsevier North Holland, Inc., 1980.

Coates, Joseph F. and Jerome C. Glenn. 2009. Introduction to The Futures Research Methods Series in *Futures Research Methodology – V3.0,* eds. Jerome C. Glenn and Theodore J. Gordon, [CD-ROM]. Washington, D.C.: The Millennium Project.

Coates, Joseph F. with Jerome C. Glenn. 2009. Normative Forecasting in *Futures*

Research Methodology – V3.0, eds. Jerome C. Glenn and Theodore J. Gordon, [CD-ROM]. Washington, D.C.: The Millennium Project of the American Council for the United Nations University.

Coates, Vary, Mahmud Farooque, Richard Klavans, Koty Lapid, Harold A. Linstone, Carl Pistorius, and Alan L. Porter. 2001. On the Future of Technological Forecasting in *Technological Forecasting and Social Change* 67: 1-17.

Collins, Jim and Jerry I. Porras. 1994. *Built to Last: Successful Habits of Visionary Companies.* HarperCollins Publishers.

Conway, Maree. 2012. Foresight Learning from the Future. Accessed at www.academia.edu on 25 August.

Cornish, Edward. 2004. *Futuring: The Exploration of the Future*. Bethesda: World Future Society.

Coyle, Geoffrey R. 2009. Field Anomaly Relaxation (FAR) in *Futures Research Methodology – V3.0*, eds. Jerome C. Glenn and Theodore J. Gordon, [CD-ROM]. Washington, D.C.: The Millennium Project.

Crutchfield, J. P., J. D. Farmer, N. H. Packard, and R. S. Shaw. 1986. "Chaos," *Scientific American* (December) quoted in Theodore J. Gordon and David Greenspan, "Chaos and Fractals: New Tools for Technological and Social Forecasting." *Technological Forecasting and Social Change* 34 (1988): 1 – 25.

Cuhls, K. 2003. From forecasting to foresight processes – New participative foresight activities in Germany. *Journal of Forecasting* 22: 93-111.

Dator, Jim. 2012. Futures Studies in *Leadership in Science and Technology: A Reference Handbook Volume 1: General Principles.* Thousand Oaks: SAGE Publications, Inc.

De Geus, Arie. 2002. *The Living Company: Habits for Survival in a Turbulent Business Environment.* Harvard Business Review Press.

de Jouvenel, H. 2000. A brief methodological guide to scenario building. *Technological forecasting and social change* 65: 37-48.

Department of National Defence, Directorate of Land Concepts and Design. 2007. *Land Operations 2021: Adaptive Dispersed Operations: The Force Employment Concept for Canada's Army of Tomorrow*. Kingston, Ontario: Government of Canada.

De Souza, Roger-Mark, John S. Williams and Frederick A.B. Meyerson. 2003. Critical Links: Population, Health, and the Environment. *Population Bulletin* 58, no. 3. Washington, DC: Population Reference Bureau.

Dess, Gregory, G.T. Lumpkin, Alan Eisner and Theodore Peridis. 2011. *Strategic Management: Creating Competitive Advantages.* McGraw-Hill Ryerson Higher Education.

Dick, B. 1997. Stakeholder analysis. Accessed on 18 January. http://www.scu.edu.au/schools/gcm/ar/arp/stake.html.

Di Tommaso, Marco R. and Sabrina Dubbini. 2000. *Towards a theory of the small firm: theoretical aspects and some policy implications.* Santiago, Chile: Restructuring and Competitiveness Network, Division of Production,

Productivity and Management.
Dortmans, Peter J. 2005. "Forecasting, backcasting, migration landscapes and strategic planning maps," in *Futures* 37: 273-285.
Dou, H., V. Leveille, S. Manullang and J.M. Dou, Jr. 2005. Patent Analysis for Competitive Technical Intelligence and Innovative Thinking. *Data Science Journal* v4, 31 December 2005.
Downey, Jim and Technical Information Service. 2007. *Strategic Analysis Tools* in Topic Gateway Series. The Chartered Institute of Management Accountants. London.
Dubois, Alain. 2002. *Lecture 1.3.1: The Analytical Hierarchy Process* (Université de Genève Centre universitaire d'écologie humaine et des sciences de l'environment, 2002). Accessed on 1 July 2007. From http://ecolu-info.unige.ch/~dubois/Mutate_final/Lectures/Lect_1_3_1/lect_1_3_1.htm.
Duperrin, J.C. and M. Godet. 1975. "SMIC 74 – A method for constructing and ranking scenarios," *Futures*, August: 302-312.
Durand, Thomas. 2003. Twelve Lessons from 'Key Technologies 2005': the French Technology Foresight Exercise. *Journal of Forecasting* 22: Published online in Wiley InterScience (www.interscience.wiley.com): 161-177.
Duval, A., E. Fontela, and A. Gabus. 1974. "Cross Impact: A Handbook of Concepts and Applications," Geneva: Battelle-Geneva.
Earth Policy Institute. 2010. Accessed on 7 June at www.earthpolicy.org/datacenter/xls/update73_all.xls.
Effinger, Anthony. 2007. The Next Wave: Startups battle to develop tide power. *Calgary Herald*, 13 May.
Enzer, Selwyn. 1980. "Interax: An Interactive Model for Studying Future Business Environment," *Technological Forecasting and Social Change*, Vols. 2 and 3.
F.A.C.T.net (Fight Against Coercive Tactics Network). 2010. How does mind control work? A technical overview of mind control tactics. Accessed on 20 August. http://www.factnet.org/rancho1.htm.
Fischhoff, Baruch. 1982a. Debiasing in *Judgment under uncertainty: Heuristics and biases*, Daniel Kahneman, Paul Slovic and Amos Tversky eds. Cambridge: Cambridge University Press.
Fischhoff, Baruch. 1982b. For those condemned to study the past: Heuristics and biases in hindsight in *Judgment under uncertainty: Heuristics and biases*, Daniel Kahneman, Paul Slovic and Amos Tversky eds. Cambridge: Cambridge University Press.
Fischhoff, Baruch. 1998. From Risk Perception to Risk Communication in *The Earthscan Reader in Risk and Modern Society*, Ragnar Löfstedt and Lynn Frewer eds. London: Earthscan.
Fisher, J. And R. Pry. 1971. A simple substitution model of technological change. *Technological Forecasting and Social Change*, 3, 75-88.
Flores, Benito E., Gary L. Stading, and Robert D. Klassen. 2007. The business forecasting process: a comparison of differences between small and large Canadian manufacturing and service firms. *International Journal of*

Management and Enterprise Development, Vol. 4, Number 4/2007, 387-402.
Florescu, Elizabeth. 2012. Personal conversation on November 2.
Foresight Canada. 2012. Strategic foresight. Accessed on August 5 at http://www.foresightcanada.ca/node/28.
Fouracre, P. ed. 2008. *Environmental Impact Assessment and Management* (TRL Limited). Accessed on 13 January from http://www4.worldbank.org/afr/ssatp/Resources/HTML/rural_transport/knowledge_base/English/Module%205%5C5_4a%20Environmental%20Impact%20Assessment.pdf.
Fraser Institute. 2010. Accessed on 28 August. http://www.fraserinstitute.org/about-us/what-we-do.aspx
FreePatentsOnline. 2010. Accessed on 28 May at www.FreePatentsOnline.com.
Fryer, Peter. 2005. A brief description of Complex Adaptive Systems and Complexity Theory. Accessed on 20 January from http://www.trojanmice.com/articles/complexadaptivesystems.htm.
Futures Group International, The. 2003. Relevance Tree and Morphological Analysis in *Futures Research Methodology – V2.0*, eds. Jerome C. Glenn and Theodore J. Gordon, [CD-ROM]. Washington, D.C.: The Millennium Project of the American Council for the United Nations University.
Futures Group International, The. 2009. Relevance Trees in *Futures Research Methodology – V3.0*, eds. Jerome C. Glenn and Theodore J. Gordon, [CD-ROM]. Washington, D.C.: The Millennium Project.
Garcia, Marie L and Olin H. Bray. 2005. *Fundamentals of Technology Roadmapping.* Accessed at www.sandia.gov/Roadmap/home.htm on 18 January.
Garner, Bryan A, ed. 1999. *Black's Law Dictionary*. St. Paul: West Group.
Gartner and Wheelock. 2009. Research Brief *Electric Vehicles: 10 Predictions for 2010.* Pike Research LLC and hybridCARS.com.
Garud, Raghu, Praveen Rattan Nayyer, and Zur Baruch Shapira, eds. 1997. *Technological Innovation: Oversights and Foresights*. Cambridge: Cambridge University Press.
GBN (Global Business Network Canada) and Foresight Canada. 2004. *"Creating Strategic Scenarios" Scenario Training Workshop.* April 29 and 30. Calgary, Alberta.
Gillett, Stephen L. 2002. *Nanotechnology: Clean Energy and Resources for the Future – White Paper for Foresight Institute.* Foresight Institute.
Gillis, C. 2010. "1970-1979" *American Cultural History*. Lone Star College-Kingwood Library, Kingwood, TX. Retrieved from http://wwwappskc.lonestar.edu/popculture/decade70.html on 8 April 2012.
Glänzel, W. 2003. Course handouts from Bibliometrics as a Research Field: A Course on Theory and Application of Bibliometric Indicators. Accessed on 10 January 2005 from http://www.norslis.net/2004/Bib_Module_KUL.pdf.
Glenn, Jerome C. 1989. *Future Mind: Artificial Intelligence: The Merging of the Mystical and the Technological in the 21st Century*, Washington, DC: Acropolis Books, Ltd.

Glenn, Jerome C. 2009a. Introduction to The Futures Research Methods Series in *Futures Research Methodology – V3.0,* eds. Jerome C. Glenn and Theodore J. Gordon, [CD-ROM]. Washington, D.C.: The Millennium Project.

Glenn, Jerome C. 2009b. Participatory Methods in *Futures Research Methodology – V3.0*, eds. Jerome C. Glenn and Theodore J. Gordon, [CD-ROM]. Washington, D.C.: The Millennium Project.

Glenn, Jerome C. 2009c. The Futures Wheel in *Futures Research Methodology – V3.0,* eds. Jerome C. Glenn and Theodore J. Gordon, [CD-ROM]. Washington, D.C.: The Millennium Project.

Glenn, Jerome C. and The Futures Group International. 2009. Scenarios in *Futures Research Methodology – V3.0,* eds. Jerome C. Glenn and Theodore J. Gordon, [CD-ROM]. Washington, D.C.: The Millennium Project.

Glenn, Jerome C. and Theodore J. Gordon. 2003. *2003 State of the Future*. Washington: American Council for the United Nations University.

Glenn, Jerome C. and Theodore J. Gordon. 2006. *2006 State of the Future.* Washington, D.C.: The Millennium Project of the American Council for United Nations University.

Glenn, Jerome C., Theodore J. Gordon and Elizabeth Florescu. 2011. *2011 State of the Future.* Washington, D.C.: The Millennium Project.

Global Ideas Bank, The. 2005. Description of Future Workshops – how to create desirable futures by Robert Jungk. Accessed on 17 January. www.globalideasbank.org/site/store/detail.php?articleId=79.

Gordon, Adam. 2009. *Future Savvy: Identifying Trends to Make Better Decisions, Manage Uncertainty, and Profit from Change*. New York: American Management Association.

Gordon, Ian. 2009. A bear's bear: We're only at beginning of collapse. *The Globe and Mail*, 2 April, sec. B.

Gordon, Theodore J. 2003. A simple agent model of an epidemic. *Technological Forecasting & Social Change* 70: 397-417.

Gordon, Theodore J. 2009a. Cross-Impact Analysis in *Futures Research Methodology – V3.0*, eds. Jerome C. Glenn and Theodore J. Gordon, [CD-ROM]. Washington, D.C.: The Millennium Project.

Gordon, Theodore J. 2009b. Uses of Chaos Analysis in Forecasting in *Futures Research Methodology – V3.0*, eds. Jerome C. Glenn and Theodore J. Gordon, [CD-ROM]. Washington, D.C.: The Millennium Project.

Gordon, Theodore J. 2009c. Trend Impact Analysis in *Futures Research Methodology – V3.0,* eds. Jerome C. Glenn and Theodore J. Gordon, [CD-ROM]. Washington, D.C.: The Millennium Project.

Gordon, Theodore J. 2009d. Science and Technology Roadmapping in *Futures Research Methodology – V3.0,* eds. Jerome C. Glenn and Theodore J. Gordon, [CD-ROM]. Washington, D.C.: The Millennium Project.

Gordon, Theodore J. 2009e. Substitution Analysis in *Futures Research Methodology – V3.0,* eds. Jerome C. Glenn and Theodore J. Gordon, [CD-ROM]. Washington, D.C.: The Millennium Project.

Gordon, Theodore J. 2009f. State of the Future Index (SOFI) Method in *Futures*

Research Methodology – V3.0, eds. Jerome C. Glenn and Theodore J. Gordon, [CD-ROM]. Washington, D.C.: The Millennium Project.

Gordon, Theodore J. 2009g. The Real-Time Delphi Method in *Futures Research Methodology – V3.0,* eds. Jerome C. Glenn and Theodore J. Gordon, [CD-ROM]. Washington, D.C.: The Millennium Project.

Gordon, Theodore J. 2009h. Interactive Scenarios in *Futures Research Methodology – V3.0,* eds. Jerome C. Glenn and Theodore J. Gordon, [CD-ROM]. Washington, D.C.: The Millennium Project.

Gordon, Theodore J. 2009i. The Delphi Method in *Futures Research Methodology – V3.0,* eds. Jerome C. Glenn and Theodore J. Gordon, [CD-ROM]. Washington, D.C.: The Millennium Project.

Gordon, Theodore J. 2009j. Agent Modeling in *Futures Research Methodology – V3.0,* eds. Jerome C. Glenn and Theodore J. Gordon, [CD-ROM]. Washington, D.C.: The Millennium Project.

Gordon, Theodore J. and Jerome C. Glenn. 2009. Environmental Scanning in *Futures Research Methodology – V3.0,* eds. Jerome C. Glenn and Theodore J. Gordon, [CD-ROM]. Washington, D.C.: The Millennium Project.

Government of Canada. 2011. Accessed at www.sme-fdi.gc.ca on 9 November.

Government of the Province of Alberta. 2000. *The Engineering, Geological and Geophysical Professions Act* (Chapter E-11.1 Revised Statutes of Alberta, 2000).

Grant, Tavia, Barrie McKenna and Richard Blackwell. 2012. The Disappearing Middle. *The Globe and Mail*, 2 June.

Havas, Attila. 2003. Evolving Foresight in a Small Transition Economy. *Journal of Forecasting* 22: 179-201.

Heidrick, Ted. 2010. Mechanical Engineering Professor, University of Alberta. Meeting with author, Edmonton AB, 25 August.

Hérubel, Jean-Pierre V.M. 1999. "Historical bibliometrics: Its purpose and significance to the History of Disciplines." Libraries & Culture 34, no. 4 (Fall): 380-388.

Hinde, Andrew. 1998. *Demographic Methods.* New York: Oxford University Press.

Hines, Andy and Peter Bishop. 2006. *Thinking about the Future: Guidelines for Strategic Foresight*. Social Technologies.

Hörlesberger, Marianne and Edgar Schiebel. 2004. Visualised Indicators of Links in the World Wide Web: Biotechnology and Information Science. Manuscript for International Association for Management of Technology, Washington, D.C., April 3–7.

Idier, D. 2000. Science fiction and technology scenarios: comparing Asimov's robots and Gibson's cyberspace. *Technology in Society* 22: 255-272.

IEA (International Energy Agency). 2001. *World Energy Outlook: Assessing Today's Supplies to Fuel Tomorrow's Growth*. Accessed at http://www.iea.org/textbase/nppdf/free/2000/weo2001.pdf on July 4, 2010.

IEA (International Energy Agency). 2003. *Key World Energy Statistics.* Accessed at http://www.tsl.uu.se/uhdsg/Data/IEA_Key_Stats/IEA2003.pdf on July 3,

2010.
IEA (International Energy Agency). 2004. *Key World Energy Statistics.* Accessed at http://www.tsl.uu.se/uhdsg/Data/IEA_Key_Stats/IEA2004.pdf on July 3, 2010.
IEA (International Energy Agency). 2006. *Key World Energy Statistics.* Accessed at http://www.tsl.uu.se/uhdsg/Data/IEA_Key_Stats/IEA2006.pdf on July 3, 2010.
IEA (International Energy Agency). 2007. *Key World Energy Statistics.* Accessed at http://www.tsl.uu.se/uhdsg/Data/IEA_Key_Stats/IEA2007.pdf on July 3, 2010.
IEA (International Energy Agency). 2008. *Key World Energy Statistics.* Accessed at http://www.iea.org/publications/free_new_Desc.asp?PUBS_ID=1199 on July 3, 2010.
IEA (International Energy Agency). 2009. *Key World Energy Statistics.* Accessed at http://www.iea.org/publications/free_new_Desc.asp?PUBS_ID=1199 on April 5, 2010.
IEA (International Energy Agency). 2012. *Key World Energy Statistics.* Accessed at http://www.iea.org/publications/freepublications/publication/kwes.pdf on November 8, 2012.
If looks could kill. 2008. *The Economist*, 23 October 2008. Accessed at www.economist.com on 15 November.
Industry Canada. 2008. Scenario Planning: An Adaptive Tool for Effective Positioning of Canada's Resource Processing Industries – Engagement Workshop Booklet. Ottawa: Industry Canada, Resource Processing Industries Branch.
Industry Canada. 2011. *Technology Roadmaps*. Accessed at www.ic.gc.ca/eic/site/trm-crt.nsf/eng/h_rm00052.html on 11 September.
Industry Canada, Small Business Branch. 2012. *Key Small Business Statistics: July 2012.* Accessed at www.ic.gc.ca/sbstatistics on 23 August.
Inayatullah, Sohail. 2009. Causal Layered Analysis: An Integrative and Transformative Theory and Method in *Futures Research Methodology – V3.0*, eds. Jerome C. Glenn and Theodore J. Gordon, [CD-ROM]. Washington, D.C.: The Millennium Project of the American Council for the United Nations University.
ITER (International Thermonuclear Experimental Reactor). 2010. 4 April accessed at www.iter.org.
ITER (International Thermonuclear Experimental Reactor). 2012. 8 November accessed at www.iter.org/faq.
Jaccard, Mark. 2005. *Sustainable Fossil Fuels: The Unusual Suspect in the Quest for Clean and Enduring Energy*. Cambridge: Cambridge University Press.
Johnson, Thomas. n.d. http://www.cpac.missouri.edu/library/johnsontg/agec442/inputoutput/Inputoutput.html.
Jussawalla, Meheroo, Tadayuki Okuma, and Toshihiro Araki, eds. 1989. *Information Technology and Global Interdependence*. Westport, CR:

Greenwood Press.
Kahn, Herman, William Brown and Leon Martel. 1976. *The Next 200 Years: A Scenario for America and the World.* New York: William and Morrow Company, Inc.
Kahneman, Daniel and Tversky, Amos. 1979. "Prospect Theory: An Analysis of Decision under Risk," *Econometrica*, XLVII, 263-291.
Kameoka, Akio, Yoshiko Yokoo and Terutaka Kuwahara. 2004. A challenge of integrating technology foresight and assessment in industrial strategy development and policymaking. *Technological Forecasting and Social Change* 71: 579-598.
Kang, Byungryong, Chimoon Han and Chu-Hwan Yim. 1996. An Adaptive Framework for Forecasting Demand and Technological Substitution. *ETRI Journal*, vol. 18, no. 2 (July): 87-106.
Karagiannis, Giannis. 1993. The theory of the firm under risk and uncertainty. Ph.D. diss., Ottawa: National Library of Canada.
Kasztler, Andrea and Karl-Heinz Leitner. 2002. Bibliometric Analysis and Visualisation of Intellectual Capital. *Journal of Universal Computer Science*, vol. 8, no. 5: 516-525.
Keenan, Michael. 2003. Identifying Emerging Generic Technologies at the National Level: The UK Experience. *Journal of Forecasting*. 22: 129–160.
King, David and Keith Peters. 2007. Letter from King and Peters to The Rt Hon Alan Johnson MP 18 May. From http://www2.cst.gov.uk/cst/business/files/real-options.doc accessed on 15 April.
Kirkey, Sharon. 2008. Listeriosis web searches foretold outbreak. *Calgary Herald*, 13 March.
Koivisto, Raija, Nina Wessberg, Annele Eerola, Toni Ahlqvist, Sirkku Kivisaari, Jouko Myllyoja, Minna Halonen. 2009. Integrating future-oriented technology analysis and risk assessment methodologies. *Technological Forecasting & Social Change* 76: 1163-1176.
Kopcsa, Alexander, Michaela C. Topolnik and Andreas Schibany. 1999. *Bibliometric Network Analysis (BibTechMon) of the 4th Framework Programme of the EU based on CORDIS data*. Presentation prepared for the workshop of the OECD-NIS Focus Group on Innovative Firm and Innovative Firm Networks, Vienna, 18–19 November.
Koppl, Roger. 2005. Complex Adaptive Systems. Accessed on 20 January from http://alpha.fdu.edu/~koppl/note14.htm#_ftn1.
Krippendorff, Klaus. 1986. Accessed 18 January 2008. http://pespmc1.vub.ac.be/ASC/INPUT-_ANALY.html.
Kwaśnicki, Witold and Halina Kwaśnicka. 1996. Long-Term Diffusion Factors of Technological Development: An Evolutionary Model and Case Study. *Technological Forecasting & Social Change* 52: 31-57.
Land, Kenneth C. and Stephen H. Schneider (eds.). 1987. *Forecasting in the Social and Natural Sciences.* Dordrecht, Holland: D. Reidel.
Leonard, Allenna with Stafford Beer. 2009. The Systems Perspective: Methods

and Models for the Future in *Futures Research Methodology – V3.0*, eds. Jerome C. Glenn and Theodore J. Gordon, [CD-ROM]. Washington, D.C.: The Millennium Project of the American Council for the United Nations University.

Leung, Danny, Luke Rispoli and Bob Gibson. 2011. *Small, Medium-sized and Large Businesses in the Canadian Economy: Measuring Their Contribution to Gross Domestic Product in 2005.* Ottawa: Statistics Canada, Economic Analysis Division, 11F0027M No. 069, ISSN 1703-0404, ISBN 978-1-100-18505-7.

Linstone, H.A. 1984. *Multiple Perspectives for Decision Making*, New York: North-Holland.

Linstone, H.A. 2002. Corporate planning, forecasting, and the long wave. *Futures*, vol. 34: 317-336.

Linstone, Harold A. 2009. The Multiple Perspective Concept in *Futures Research Methodology – V3.0*, eds. Jerome C. Glenn and Theodore J. Gordon, [CD-ROM]. Washington, D.C.: The Millennium Project.

Lipsett, Michael G. 2010. Mechanical Engineering Professor, University of Alberta. Meeting with author, Edmonton AB, 13 September.

Lombardo, Thomas. 2006a. *Contemporary Futurist Thought: Science Fiction, Future Studies, and Theories and Visions of the Future in the Last Century*. Bloomingdale: AuthorHouse.

Lombardo, Thomas. 2006b. *The Evolution of Future Consciousness: The Nature and Historical Development of the Human Capacity to Think about the Future*. Bloomingdale: AuthorHouse.

Lorie, Peter and Sidd Murray-Clark. 1989. *History of the future: a chronology*, New York : Doubleday.

Major E., D. Asch, and M. Cordey-Hayes. 2001. "Foresight as a core competence". *Futures: The Journal of Forecasting and Planning* 33 (2): 91-107.

Mankind 2000. 2012. http://www.m2000.org/docs/overview.php#hist. Accessed on 24 March.

Mansfield, Edwin. 1961. Technical Change and the Rate of Imitation. *Econometrica* 29, No. 4 (Oct): 741-766.

Marien, Michael. 2002. "Futures studies in the 21st Century: a reality-based view," *Futures* 34: 261-281.

MarketingNPV. 2008. Accessed 4 August. http://www.marketingnpv.com/articles/features/how_bass_diffusion_predicted_market_size_for_satellite_tv.

Martin, Ben R. 1995. Foresight in Science and Technology. *Technology Analysis & Strategic Management*, Vol. 7, No. 2.

Martin, Ben R. 2010. The origins of the concept of 'foresight' in science and technology: An insider's perspective. *Technological Forecasting & Social Change*, Vol. 77: 1438-1447.

Martino, Joseph. 1983. *Technological Forecasting for Decision Making* 2nd ed. New York: Elsevier Science Publishing Co., Inc.

McDaniels, Carl. 1989. *The Changing Workplace: Career Counseling Strategies for the 1990s and Beyond.* San Francisco: Jossey-Bass Publishers.

McFedries, Paul. 2004. "Technically Speaking: The (Pre) Fix Is In," *IEEE Spectrum*. August: 64.

McGrath, Rita Gunther and Ian C. MacMillan. 2000. Assessing technology projects using real options reasoning: The STAR approach. *Research-Technology Management*, July–August: 35-49.

Meadows, Donella H., Dennis L. Meadows, Jørgen Randers, and William W. Behrens III. 1972. *The Limits to Growth: A report for the Club of Rome's project on the predicament of mankind*. New York: Universe Books, Publishers.

Merriam-Webster. 2008. Accessed 11 August. http://www.merriam-webster.com/dictionary/divination.

Millennium Project, The. 2009. *Futures Research Methodology – V3.0,* eds. Jerome C. Glenn and Theodore J. Gordon, [CD-ROM]. Washington, D.C.: The Millennium Project.

Millennium Project of the American Council for the United Nations University, The. 2010. Accessed on 16 March at http://www.acunu.org/millennium/information.html.

Miller, Erin. 2012. "Ocean Thermal Energy Conversion Plant Proposed," *West Hawaii Today,* 6 February.

Miller, Ronald E. and Peter D. Blair. 2009. *Input-Output Analysis: Foundations and Extensions,* 2d ed. New York: Cambridge University Press.

Millet, Stephen M. and Edward J. Honton. 1991. A Manager's Guide to Technology Forecasting and Strategy Analysis Methods. Battelle Press: Columbus.

Milner, Brian. 2009. "A bear's bear: We're only at beginning of collapse," *Globe and Mail,* 2 April, Globe Investor.

Miola, Apollonia. 2008. *Backcasting approach for sustainable mobility* in JRC Scientific and Technical Reports. Luxembourg.

Modelski, George. 2005. Accessed on 16 January. http://faculty.washington.edu/modelski/IPEKWAVE.html.

Morrissy, John. 2008. On the cusp of a clean revolution. *Calgary Herald*, 25 November, sec. D.

Nash, Jonathan G. and Roger-Mark De Souza. 2002. *Making the Link*: *Population, Health, Environment.* Washington: Population Reference Bureau.

Nasseri, Touraj. 2004. *Knowledge Management*. Course notes for Knowledge Management: ENGM 670. University of Alberta. 6 January.

Natural Energy Laboratory of Hawai'i Authority. 2009. *Fiscal 2008 – 2009 Annual Report: The future is here and now at NELHA*. Hawaii: NELHA.

Nelson, R and S. Winter. 1978. "Forces generating and limiting concentration under Schumpeterian competition," in *Bell Journal of Economics,* Vol. 9.

Nelson, R and S. Winter. 1982. *An Evolutionary Theory of Economic Change,* Cambridge (Mass.): Harvard University Press.

Nicolaisen, Jeppe and Birger Hjørland. 2007. Practical potentials of Bradford's

law: a critical examination of the received view. *Journal of Documentation,* vol. 63, no. 3: 359-377.
NOAA/ESRL (National Oceanic and Atmospheric Administration/Earth System Research Laboratory. 2010. Accessed on 4 July. http://www.esrl.noaa.gov/gmd/about/aboutgmd.html.
Noll, Margit and Doris Frölich. 2002. *Knowledge Maps of Knowledge Management Tools – Information Visualization with BibTechMon.* Presentation at Fourth International Conference on Practical Aspects of Knowledge Management, Vienna, Austria, 2–3 December.
Nuclear Energy Institute. 2010. Accessed on 7 March at http://www.nei.org./resourcesandstats/documentlibrary/reliableandaffordableenergy/graphicsandcharts/usnucleargeneratingstatistics/.
Nyboer, John and Kristin Lutes. 2011. A Review of Energy Consumption and Production Data: Canadian Electricity Generation Industry 1990 to 2009. Canadian Industrial Energy End-use Data and Analysis Centre: Simon Fraser University, Burnaby, BC.
O'Flynn, Julian. 2008. Design for manufacturability of a composite helicopter structure made by resin transfer moulding. Ph.D. diss., McGill University.
Orrell, David Ph.D. 2007. *Apollo's Arrow: The Science of Prediction and the Future of Everything*. Toronto: HarperCollins.
Pacinelli, Antonio. 2009. The Futures Polygon in *Futures Research Methodology – V3.0,* eds. Jerome C. Glenn and Theodore J. Gordon, [CD-ROM]. Washington, D.C.: The Millennium Project.
Panzar, John C. and Robert D. Willig. 1981. "Economies of Scope," *The American Economic Review,* Vol. 71, No. 2, Papers and Proceedings of the Ninety-Third Annual Meeting of the American Economic Association. 268-272.
Pembina Institute, The. 2010. Accessed on 28 August. http://www.pembina.org/about/mission#.
Persson, Olle. 2009. Accessed on 10 Oct. http://www8.umu.se/inforsk/Bibexcel/.
Peterson, John L. and Karlheinz Steinmüller. 2009. Wild Cards in *Futures Research Methodology – V2.0,* eds. Jerome C. Glenn and Theodore J. Gordon, [CD-ROM]. Washington, D.C.: The Millennium Project of the American Council for the United Nations University.
Phaal, R., C.J.P. Farrukh and D.R. Probert. 2004. Technology roadmapping – A planning framework for evolution and revolution. *Technological Forecasting and Social Change.* 71: 5-26.
Phillips, Joanne G. 1997. Is the Time Right for Wind Power in Alberta? (M.Eng. work, Course No. ENME 619.85, Department of Mechanical Engineering, University of Calgary).
Phillips, Joanne G., Ted R. Heidrick and Ian J. Potter. 2005. Technology Futures Analysis Methodologies for Sustainable Energy Technologies. In *Technology Management: A Unifying Discipline for Melting the Boundaries,* edited by Timothy R. Anderson, Tugrul U. Daim, and Dundar F. Kocaoglu. Portland: Portland State University. 155-165.

Popper, Rafael. 2008. How are foresight methods selected? in *Foresight*. Emerald Group Publishing Limited. Vol. 10, No. 6: 62-89.

Population Reference Bureau. 2008a. Accessed on 29 July. http://www.prb.org/Datafinder/Topic/Bar.aspx?sort=v&order=d&variable=24.

Population Reference Bureau. 2008b. Accessed on 23 August. http://www.prb.org/pdf/aoe_data.pdf.

Porter, Alan L. 2009. Text Mining of Science & Technology Information Resources for Future-Oriented Technology Analyses in *Futures Research Methodology – V3.0*, eds. Jerome C. Glenn and Theodore J. Gordon, [CD-ROM]. Washington, D.C.: The Millennium Project.

Porter, Alan L., F.A. Rossini, S.R. Carpenter, and A.T. Roper. 1980. *A Guidebook for Technology Assessment and Impact Analysis*, vol. 4. North Holland: New York.

Porter, Alan L. and Scott W. Cunningham. 2004. *Tech Mining: Exploiting New Technologies for Competitive Advantage*. John Wiley & Sons, Incorporated: Hoboken.

Portland State University (PSU). 2010. Biomedical Informatics. Accessed on 7 March at http://www.pdx.edu/sites/www.pdx.edu.admissions/files/media_assets/fact_sheets/biomedical_informatics.pdf.

RAND Corporation. 2005. Appendix E: Group Process Methods. Accessed on 17 January at http://www.rand.org/publications/MR/MR1267/mr1267.appe.pdf.

Rausch, Erwin with Frank Catanzaro. 2003. Simulation and Games in Futuring and Other Uses in *Futures Research Methodology – V2.0*, eds. Jerome C. Glenn and Theodore J. Gordon, [CD-ROM]. Washington, D.C.: The Millennium Project of the American Council for the United Nations University.

Reeves, Richard. 2000. Research and Development in *Technology Management Handbook*, ed. C. Dorf. Boca Raton: CRC Press.

Reger, Guido. 2001. *Technology Foresight in Companies: From an Indicator to a Network and Process Perspective* in Technology Analysis & Strategic Management. Vol. 13, No. 4.

Reichardt, Randy. 2009. Research Services Librarian (Engineering), University of Alberta. E-mail correspondence September 14, 2009.

Reichardt, Randy. 2009. Research Services Librarian (Engineering), University of Alberta. Interview by author, Edmonton AB, 22 September.

Remington, Robert. 2006. Imagining the future in Our Future: A Calgary Herald Magazine Series Exploring Alberta's Next Century, Calgary Herald, Issue 1.

Rhyne, R. 1981. "Whole-Pattern Futures Projection Using Field Anomaly Relaxation," *Technological Forecasting and Social Change*, 19, 331-360.

Rigby, Darrell and Barbara Bilodeau. 2011. *Management Tools & Trends 2011*. Bain & Company.

Roberts, Kirthi. 2008. Beyond energy futures: an exploration of sustainability-driven and transition dynamics-driven approaches to guiding socio-technical change. Ph.D. diss., Ottawa: Library and Archives Canada.

Rodrigues, Ronald J. 2001. "Industry Expectations of the New Engineer," *Science & Technology Libraries* vol. 19, no. 3/4: 179-188.

Rogers, Everett M. 1995. *Diffusion of Innovations*. New York: The Free Press.

Ross, Lee and Craig A. Anderson. 1982. Shortcomings in the attribution process: On the origins and maintenance of erroneous social assessments in *Judgment under uncertainty: Heuristics and biases*, Daniel Kahneman, Paul Slovic and Amos Tversky eds. Cambridge: Cambridge University Press.

Rossini, Frederick A. and Alan L. Porter. 2000. Technology Forecasting in *Technology Management Handbook*, ed. C. Dorf. Boca Raton: CRC Press.

Rostaing, Hervé. 2010. Responsable du Master Veille Technologique et Innovation Universite Paul Cezanne Aix-Marseille III Faculte des Sciences et Techniques. E-mail correspondence January 8.

Ruff, Frank. 2004. Society and Technology Foresight in the context of the Multinational Company, New Horizons and Challenges for Future-oriented Technology Analysis in *Proceedings of the EU-US Scientific Seminar: New Technology Foresight, Forecasting and Assessment Methods held in Seville 13–14 May 2004*, edited by Fabiana Scapolo and Eamonn Cahill. Spain: European Commission

Salo, Ahti, Tommi Gustafsson, and Ramakrishnan Ramanathan. 2003. Multicriteria Methods for Technology Foresight. *Journal of Forecasting* 22: 235-255.

Savransky, Semyon D. 2000. *Engineering of Creativity: Introduction to TRIZ Methodology of Inventive Problem Solving*. Boca Raton: CRC Press.

Schindler, Craig F. and Gary G. Lapid. 1989. *The Great Turning: Personal Peace, Global Victory.* Santa Fe., NM: Lapid Bear & Company Publishing.

Schmitz, Hubert. 1995. "Collective Efficiency: Growth Path for Small-Scale Industry," *Journal of Development Studies*, Vol. 31, No. 4.

Schneider, Stephen H. 1989. *Global Warming: Are We Entering the Greenhouse Century?* San Francisco: Sierra Club Books.

Scotton, Geoffrey. 2006. Harnessing the wind in Our Future: A Calgary Herald Magazine Series Exploring Alberta's New Century, Calgary Herald, Issue 2.

SDG (Strategic Decisions Group). 2007a. Accessed on 15 April. http://www.sdg.com/home.nsf/sdg/AboutSDG--Home.

SDG (Strategic Decisions Group). 2007b. Accessed on 15 April. http://www.sdg.com/home.nsf/sdg/Competencies--RealOptionsAnalysis.

SearchSoftwareQuality.com. 2008. Accessed on 26 January. http://searchsoftwarequality.techtarget.com/sDefinition/0,,sid92_gci1248686,00.html.

Seifi, Hamid Reza and Azam Sazvar. 2012. *Strategic Analysis & Strategic Planning Barriers Ranking using MADM Techniques in High Tech organizations* in Interdisciplinary Journal of Contemporary Research in Business. Vol. 3, No. 11: 851-859.

Shell. 2012. Accessed on 26 March. http://www.shell.com/home/content/aboutshell/our_strategy/shell_global_scenarios/.

Shipman, Tim. 2007. Science-fiction writers join war on terror. *Calgary Herald*, 10 June.

Silverstein, Ken. 2007. Coal-to-Liquids is Doable. *EnergyBiz Insider*. June 6. [e-mail newsletter]. Available from http://www.energycentral.com/site/newsletters/ebi.cfm?id=334.

Skumanich, Marina and Michelle Silbernagel. 1997. Foresighting Around the World: A Review of Seven Best-in-Kind Programs. Seattle: Battelle Seattle Research Center.

Slaughter, Richard A. 2002. *Developing and Applying Strategic Foresight.* An earlier version of this paper was published in 1997 in the ABN Report, Vol. 5, No. 10, Sydney, Prospect.

Slaughter, Richard A. 2006. Preface in *Thinking about the Future: Guidelines for Strategic Foresight*, ed. Andy Hines and Peter Bishop, v-vi. Washington: Social Technologies.

Smith III, Henry C., Paul Herbig, John Milewicz, and James E. Golden. 1996. "Differences in forecasting behaviour between large and small firms". *Journal of Marketing Practice: Applied Marketing Science*. Vol. 2, No. 1: 35-51.

Smits, Ruud. 2002. Innovation Studies in the 21st century: Questions from a user's perspective. *Technological Forecasting & Social Change* 69: 861-883.

Snyder, David Pearce. 1993. Monograph: "The Futures Wheel: A Strategic Thinking Exercise," The Snyder Family Enterprise, Bethesda, Maryland.

Solar Developments. 2010. Accessed on 4 April. http://www.solardev.com/SEIA-makingelec.php.

SRA (Society for Risk Analysis). 2005. Accessed on 27 January. http://www.sra.org/.

Stover, John. 1975. "The Use of Probabilistic System Dynamics an Analysis of National Development Policies: A Study of the Economic Growth and Income Distribution in Uruguay," *Proceedings of the 1975 Summer Computer Conference*, San Francisco, CA.

Sticky Marketing. 2005. Accessed on 20 January. http://www.sticky-marketing.net/glossary/technological_substitution.htm.

Strathern, Oona. 2007. *A Brief History of the Future: How visionary thinkers changed the world and tomorrow's trends are "made" and marketed*. New York: Carroll & Graf.

Sutton, Bettye. 1999. "1930-1939" *American Cultural History*. Lone Star College-Kingwood Library, Kingwood, TX. Retrieved from http://wwwappskc.lonestar.edu/popculture/decade30.html on 8 April 2012.

System Dynamics Society. 2008. Accessed on 14 January. http://www.systemdynamics.org/.

Taleb, Nassim Nicholas. 2007. "The Black Swan: The Impact of the Highly Improbable"

Tarapanoff, Kira, Luc Quoniam, Rogério Henrique de Araújo Júnior and Lillian Alvares. 2001. Intelligence obtained by applying data mining to a database of French theses on the subject of Brazil. *Information Research*, Vol. 7 No. 1, October. Accessed on 19 September 2009 at http://informationr.net/ir/7-

1/paper117.html.
tatamotors.com. 2010. Accessed on 24 May. http://tatanano.inservices.tatamotors.com/tatamotors/index.php?option=com_content&task=view&id=291&Itemid=207.
tatanano.com. 2012. Accessed at http://www.tatanano.com/faqs.htm# on November 8.
Tegart, G. 2003. Technology foresight: Philosophy and principles in *Innovation: Management, Policy and Practice*. Vol. 5, Nos. 2-3, pp. 279-285.
TFAMWG[43]. 2004. Technology futures analysis: Toward integration of the field and new methods. *Technological Forecasting and Social Change* 71: 287–-303.
Thatcher, Chris. 2006. Future Force: Incorporating more than the military. *Vanguard: Canada's Premier Defence and Security Magazine.*
The Queen v. Mohan, Supreme Court of Canada. 1994. Accessed on 15 September 2009 at www.lexisnexis.com/ca/legal/frame.do?tokenKey=rsh-20.652456.3818002009&tar....
Tichy, Gunther. 2004. The over-optimism among experts in assessment and foresight. *Technological Forecasting & Social Change* 71: 341-363.
Tidd, Joe and John Bessant. 2009. *Managing Innovation: Integrating Technological*, *Market and Organizational Change,* 4th ed. West Sussex: John Wiley & Sons Ltd.
Townsend, Robert C. 1975. Back cover of *The Limits to Growth: A report for the Club of Rome's project on the predicament of mankind*, 2d ed. by Donella H. Meadows et al. New York: The New American Library Inc.
Turoff, Murray. 1972. "An Alternative Approach to Cross Impact Analysis, "*Technological Forecasting and Social Change*," Vol. 3, No. 3, 309-339.
tutor2u. 2012. Accessed on 4 August at http://tutor2u.net/business/strategy/what_is_strategy.htm.
Tversky, Amos and Daniel Kahneman. 1982. Judgment under uncertainty: Heuristics and biases in *Judgment under uncertainty: Heuristics and biases*, Daniel Kahneman, Paul Slovic and Amos Tversky eds. Cambridge: Cambridge University Press.
Uchino, Kenji. 2009. *Entrepreneurship for Engineers*. CRC Press.
U of A (University of Alberta). 2005. School of Business. Accessed on 18 January. http://www.bus.ualberta.ca/PhD/programs/orga.htm.
U of A (University of Alberta). 2009. Department of Biological Sciences. Accessed on 7 September. http://www.biology.ualberta.ca/.

[43] The TFAMWG consists of Alan L. Porter (U.S.), W. Bradford Ashton (U.S.), Guenter Clar (EC & Germany), Joseph F. Coates (U.S.), Kerstin Cuhls (Germany), Scott W. Cunningham (U.S. & The Netherlands), Ken Ducatel (EC, Spain & UK), Patrick van der Duin (The Netherlands), Luke Georghiou (UK), Theodore Gordon (U.S.), Harold Linstone (U.S.), Vincent Marchau (The Netherlands), Gilda Massari (Brazil), Ian Miles (UK), Mary Mogee (U.S.), Ahti Salo (Finland), Fabiana Scapolo (EC, Spain & Italy), Ruud Smits (The Netherlands), and Wil Thissen (The Netherlands).

U of S (University of Saskatchewan). 2010. Plasma Physics Laboratory. Accessed on 4 April. http://plasma.usask.ca/storm/index.php.

UNIDO (United Nations Industrial Development Organization). 2005. *UNIDO Technology Foresight Manual: Volume 2: Technology Foresight in Action.* Vienna.

U.S. DOE (Department of Energy). 2010. Accessed on 7 March at http://www.windpoweringamerica.gov/wind_installed_capacity.asp

U.S. EIA (Energy Information Administration). 2011. *International Energy Outlook 2011,* DOE/EIA-0484(2011), September.

Vanclay, F. 2003a. Social Impact Assessment in *Responding to Global Environmental Change* in M. Tolba, ed. (vol. 4, of *Encyclopedia of Global Environmental Change,* series ed.: Ted Munn), Chichester: Wiley: 387-93 quoted in Frank Vanclay, Conceptual and methodological advances in social impact assessment in *The International Handbook of Social Impact Assessment: Conceptual and Methodological Advances.* Northampton, MA: Edward Elgar.

Vanclay, Frank. 2003b. Conceptual and methodological advances in social impact assessment in *The International Handbook of Social Impact Assessment: Conceptual and Methodological Advances*. Northampton, MA: Edward Elgar.

van der Veer, Jeroen. 2008. *Shell energy scenarios to 2050.* Shell International BV. Accessed on 7 March 2009 from www.shell.com.

VanGundy, Arthur B., Ph.D. 2005. *Brainwriting*. Accessed on 17 January from http://www.creativityatwork.com/articlesContent/brainwriting.htm.

Vanston, John H. 2003. Better Forecasts, Better Plans, Better Results. *Research Technology Management.* Jan/Feb, Vol. 46, Issue 1, pp. 47-58.

VantagePoint. 2009. Accessed on 19 September. http://www.thevantagepoint.com/vantagepoint/pricing.cfm.

Wack, Pierre. 1985a. “Scenarios: Uncharted Waters Ahead,” *Harvard Business Review.* September-October: 73-89.

Wack, Pierre. 1985b. “Scenarios: shooting the rapids,” *Harvard Business Review*. November-December: 139-150.

WADE (World Alliance for Decentralized Energy). 2010. Accessed on 5 April. www.localpower.org.

WADE (World Alliance for Decentralized Energy). 2012. Accessed at http://www.localpower.org/abt_mission.html on November 8.

Wagar, W. Warren. 1989. *A Short History of the Future.* Chicago: University of Chicago Press.

Wallerstein, Immanuel. 1989. The Capitalist World-economy: Middle-run Prospects. *Alternatives* XIV:3 279-288.

Wang, Ucilia. 2011. “The Rise of Concentrating Solar Thermal Power,” *Renewable Energy World Magazine*, June 6.

Watts, Robert J. and Alan L. Porter. 1997. Innovation Forecasting. *Technological Forecasting & Social Change* 56: 25-47.

Williamson, O.E. 1985. *The Economic Institutions of Capitalism: Firms, Markets, Relational Contracting,* New York: The Free Press.

Whitmore, Johanne and Matthew Bramley. 2004. *Green Power Programs in Canada – 2003: Overview of Government Green Power Policies, Utility Green Power Implementation Initiatives, Green Power and Certificate Marketing Programs, and Their Benefits.* The Pembina Institute for Appropriate Development.

wiki.answers.com. 2012. Accessed on 4 August. http://wiki.answers.com/Q/What_is_strategic_analysis.

Wildershares. 2008. Accessed on 4 August. http://www.wildershares.com/about.html.

Wiley W.A.V.E. 2005. Accessed on 20 January. http://www.wiley.com/college/dec/meredith298298/resources/addtopics/addtopic_s_02m.html.

Wiley W.A.V.E. 2012. Accessed on 4 August. http://www.wiley.com/college/dec/meredith298298/resources/addtopics/addtopic_s_02b.html.

Wilkinson, Lawrence. 2004. How to build Scenarios: Planning for 'long fuse, big bang' problems in an era of uncertainty in supporting material provided with Creating Strategic Scenarios: Scenario Training Workshop presented by Foresight Canada & Global Business Network Canada 29, 30 April, Calgary, Alberta.

Wiskel, Bruno. 2006. *The Emperor's New Climate: Debunking The Myths of Global Warming*. Colinton, Alberta: Evergreen Environmental Company.

World Commission on Environment and Development. 1987. *Our Common Future.* New York: Oxford University Press.

World Wind Energy Association. 2009. *World Wind Energy Report 2008*. Accessed on 30 December 2009 from http://www.wwindea.org/home/images/stories/worldwindenergyreport2008_s.pdf.

www.tokamak.info. 2009. Accessed on 4 April.

Zgurovskii, M.Z. and N.D. Pankratova. 2003. An Information Platform for Scenario Analysis in Technology Foresight Problem. *Cybernetics and Systems Analysis* (July/August): 565.