Premier's Technology Council

Ahead of the Future

Report on the Emerging Technology Research Project

Prepared by William Koty
Member of the Premier's Technology Council, 2001-2005
Director of Strategic Development, UBC Continuing Studies

January 9, 2006

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Premier's Technology Council

Every effort has been made to consider all information obtained and to be as accurate and consistent as possible in our use and analysis of all research materials. However, errors or omissions may have occurred. Please notify the author of any significant inaccuracies by e-mail at William.Koty@ubc.ca.

Printed in Canada.

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Table of Contents

Figures

Tables

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Acknowledgements

The author would like to thank the many individuals and organizations who helped make the Emerging Technology Research Project possible. This includes first and foremost the leadership of the Premier's Technology Council (PTC)[1] who recognize the importance of emerging technologies to the long-term health of the BC economy: the Honourable Gordon Campbell, Chair; Greg Peet, Co-Chair; Paul Lee, past Co-Chair; Jim Mutter, President; and the many Council members who have supported this project.

This research initiative would not have been possible without major support from the University of British Columbia. In particular, the author wishes to thank Jane Hutton, Associate Vice President, UBC Continuing Studies for her wholehearted encouragement for my participating on the Premier's Technology Council and support for this research project. In addition, gracious thanks to the Office of the Vice President Academic & Provost which provided funding to support student-intern researchers. Also, I wish to thank the staff of the Division of Applied Technology, UBC Continuing Studies for their support of my efforts. They are a terrific team of continuing educators.

In addition, the author wishes to acknowledge the considerable contributions in time and brain power donated by the project's volunteer Advisory Committee. This includes: Aaron Cruikshank, Technology Consultant; Chris Dennis, Healthcare Consultant; Michael DeSandoli, Director, Shared Customer Services, Creo; Geoffrey Hansen, President, Rocket Builders; Victor Jones, former President of the BC Advanced Systems Institute; Dr. Steve Lund, Assistant Professor, Viticulture/Plant Genomics, UBC Faculty of Agricultural Sciences and the UBC Michael Smith Laboratories; and David Roughley, technology-industry consultant.

Furthermore, without the research and investigative prowess of several MBA students from the Sauder School of Business at UBC, this project would not have been as robust as it is. This includes the contributions of James Chang, Kyle Clapham, Indranil Guha, Devin Redlich and Brendon Wilson. In particular the author would like to acknowledge James Chang, currently Development Director at Electronic Arts, Inc., for his additional contribution in helping to document the research process. Lastly, a special thank you to Perry Atwal of the Sauder School of Business for letting the MBA students know about this project in the first place.

[1] For more information about the Premier's Technology Council, visit www.gov.bc.ca/prem/popt/technology_council or send email to TechnologyCouncil@gems8.gov.bc.ca.

Acknowledgements must be given to the early-stage support for this project by former members of the BC Science and Innovation Council (now known as the BC Innovation Council), including Jim Reichert, President, Venie Dettmers, Research Analyst, and Arnel Lim, Co-op Student Researcher from the UBC Faculty of Science.

Additional research and project management was provided by Derek Chee and Tia Tjandisaka, staff researchers on the Premier's Technology Council.

Finally, the author would like to express his gratitude to two members of the Emerging Technology Advisory Committee in particular—Geoffrey Hansen and David Roughley—who spent considerable time reviewing this report and suggesting modifications. The report is all the better for their efforts.

With gratitude to all,

William Koty
January 9, 2006

Executive Summary

Background

The Emerging Technology Research Project was initiated by the Premier's Technology Council in 2003 for the purpose of better understanding the role of emerging technologies to the future of the British Columbian economy. The project's intent was to focus attention on the vital role emerging technologies will have on the long-term growth and vitality of BC's high-tech economy. The project was led by William Koty, a member of the Council, with help from numerous volunteers from government and industry, as well as several student researchers.

This report documents the project's research processes, illustrating a methodology that can be used for further analysis to understand the role of emerging technologies in BC. Preliminary conclusions are drawn and possible scenarios for the future are charted. The scenarios point to how an analysis of emerging technologies can be used by the private and public sectors to help shape positive economic and social futures for the Province. The scenarios are not, however, an endpoint. Rather they anticipate what is possible and seek to stimulate ongoing discussion and debate about the kinds of economic futures that may best serve the interests of the people of BC.

Project Goals

A primary aim of the Emerging Technology Research Project was to highlight the importance of emerging technologies to the future prosperity of the Province so that better informed decision-making can occur in the present. Specific goals included identifying emerging technologies which meet the following general criteria:

- Technology trends that are likely to have a significant impact on the future of the BC economy with both near- and long-term social and economic benefits
- Technologies in which BC companies and industries can take a leadership role on a national and global scale in their development and commercialization
- Technologies that leverage BC's competitive advantages whether those advantages are intrinsic to BC, such as plentiful water, or developed by BC companies, such as inexpensive hydroelectric power

Project Findings

Using a combination of quantitative research and qualitative analysis, twelve emerging technologies were identified as having significant potential to impact the future of the Provincial economy both in the near term (less than 5 years) and longer-term (5, 10 or more years). Each of the twelve technologies have their own timelines, and associated risks and opportunities, and are in addition to the many other technologies and application areas that will impact the future. Combinations of the selected twelve technologies were used to propose plausible future scenarios for technology-driven economic development in the Province.

The approach taken is the idea of scenario-building; that is, anticipating plausible outcomes for a given strategy in a range of possible futures. Although it is inappropriate to “pick winners”, and this research project did not attempt to do so, the dialogue that results from exploring scenarios of “possible winners” is important to gain an understanding of how government, academia and industry can make sure good outcomes for the future are not restrained from achieving their potential. The scenarios point to potential high-tech growth models. Each scenario illustrates a vision of the future that demonstrates how the public and private sectors can provide leadership towards sustaining an innovative economy.

Importance of Emerging Technologies

Emerging technologies represent opportunities for British Columbian companies to develop new products and markets. As part of the Premier's Technology Council's efforts to support technology-related initiatives and industries, the Emerging Technology Research Project was established to examine emerging technologies and their potential impact on the future of the provincial economy.

The aim of this project – as in much of the work of the Premier's Technology Council – is to help make the Province of British Columbia a global magnet for high-tech investment, economic growth and job creation. The study sought to create a framework that can be used to identify emerging technologies that will most positively impact the BC economy. A specific goal included identifying top emerging technologies in which BC may take a leadership role and which leverage the Province's competitive advantages.

Emerging technologies and their impact on the economy are driven by a combination of academic and corporate research, entrepreneurship, venture capital, market developments here and elsewhere, and government support. But the road from technology discovery to commercialization is complex, challenging and wrought with uncertainty. Nonetheless, through close cooperation by government, academia and industry, significant obstacles can be overcome to foster the development of world-class high-tech industries in British Columbia.

For the purposes of this project the term *emerging technology* is defined as a specific technology or technology area that is either new-to-the-world, for example quantum computing or transgenic organs, or an existing technology or technology area that has new applications, for example bioinformatics or fuel cells. In either case, the technology must have the potential to significantly impact the provincial economy in a positive way based on BC's competitive advantages.

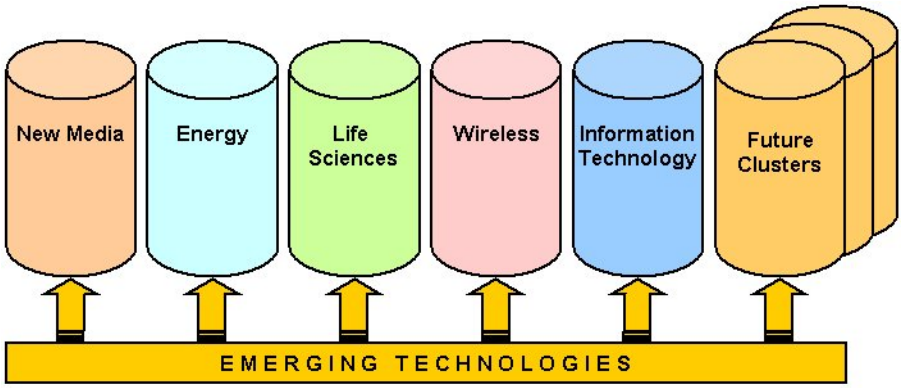
Another key aspect of emerging technologies is that their eventual significance or role in the technological infrastructure is uncertain by virtue of their embryonic or paradigm-shifting nature. Some emerging technologies falter as commercialization proceeds, others take root and find workable niches. Very few have the potential to change industries, economies and, in some cases, the fabric of society. All the technologies we take for granted today began as emerging technologies in the past.

Emerging technologies are key drivers for future prosperity because they help provide the foundation for innovation to occur. An innovative economy continually takes advantage of new technologies, new ideas,

new trends, and new market opportunities to build successful companies and industries. Innovation is the process through which new economic and social benefits are extracted from knowledge.[2] Emerging technologies represent the leading edge of innovation as technical innovation is critical for sustained economic development. As such, it is important for the Province to attempt to consider the impact of specific future technologies with the intent, if feasible, to help guide basic research, idea development, concept and product prototyping, capital formation, business development and product commercialization.

Many new and emerging technologies have already garnered wide interest in the BC research community, and with investors and the business sector. These include technologies such as PEM (proton exchange membrane) fuel-cells, 2- and 3-G wireless, genomics and new media, to mention a few. Significant industry clusters already exist in these and other technology areas and they are expected to continue to have a positive impact on the growth and diversification of the provincial economy. Nevertheless, there are additional emerging technologies that are in earlier stages of development that could have a significant impact on current industries and provide the opportunity for BC companies to take new national and global leadership positions in the future.

Figure 1: Emerging Technologies and Industry Clusters



Precisely what “the future” consists of is unknown, or at best uncertain. Certain emerging technologies will enable the development of other new technologies. In this sense, some technologies are enabling technologies that allow other technologies to be more fully exploited. Many new technologies are also disruptive to existing markets and current business methods. So while an emerging technology may

[2] Industry Canada. Achieving Excellence: *Investing in People, Knowledge and Opportunity*. (Ottawa, Industry Canada, 2002) p. 4.

represent significant opportunities for some firms or industries, it may just as well represent significant threats to others. And some technologies may require convergence with other emerging technologies before they significantly impact the economy. Whether a particular emerging technology is radical, substitutive, incremental, complementary or disruptive to existing technologies, industries and markets, it remains important to investigate its potential impact. The intent of this research project is to help bring some clarity to possible high-tech futures facing the BC economy. At a minimum, wide-spread awareness of emerging technologies enables the economy to be better prepared to rapidly create and adopt new technologies as opportunities present themselves.

Aims and Goals

A primary aim of the Emerging Technology Research Project was to highlight the importance of emerging technologies to the future prosperity of the Province. Both governments and businesses have a natural tendency to focus on short-term issues that have obvious identifiable needs. This is understandable owing to the desire to solve pressing problems as soon as possible. But the tendency to have near-term perspective (often limited by the timeline for the next election campaign or the upcoming corporate annual report) should be balanced by looking more broadly at the future—five, ten, even twenty years into the future. Such forecasting is at best challenging. But maybe more important than the conclusions of such forecasts is the process of inquiry that it initiates. For examining emerging technologies and considering possible economic and social scenarios allows better informed decision-making to occur today. It is ultimately this purpose—to enable smarter decisions to be made by industry, government and academia—that is the motivation for this research project.

While understanding it is not the role of government to pick technology or business winners, it is the role of government to facilitate and nurture overall economic prosperity. Other jurisdictions focus enormous attention on short- and long-term economic growth and development. BC could find itself at a competitive disadvantage if it does not spend equivalent effort. To that end, and to support the general process of economic development, the Emerging Technology Research Project attempted to identify emerging technologies which meet the following general criteria:

- Technology trends which are likely to have a significant impact on the future of the BC economy with both near- and long-term social and economic benefits

- Technologies in which BC companies and industries can take a leadership role on a national and global scale in their development and commercialization
- Technologies that leverage BC's competitive advantages whether those advantages are intrinsic to BC, such as plentiful water, or developed by BC companies, such as inexpensive hydroelectric power

Once these emerging technologies and accompanying scenarios are identified, it is expected that additional research and discussions among business, government and academia may help determine what government policies and actions will best enable BC companies to successfully exploit these technologies. Such conversations are going on continually amongst interested parties. This report is part of that conversation.

Research Processes

The Emerging Technology Research Project created an iterative research process that started with a large number of emerging technologies and then sought to reduce that number to ones that best matched the objectives of the project. This process included both quantitative and qualitative research. The quantitative research was based primarily on factual data garnered from primary and secondary sources. The qualitative research was based on interviews with business and technology leaders and discussions and debate among the Emerging Technology Advisory Committee.

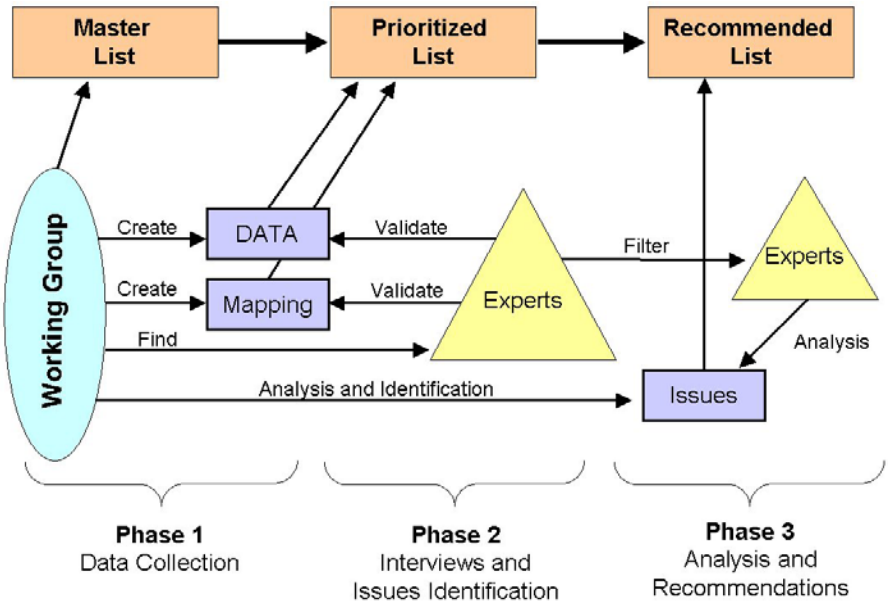
The methodology to achieve the project’s goals included the following tasks:

1. Compilation of a list of key emerging technologies, referred to as the Master List.
2. Identification of particular characteristics relative to the BC economy and collection of data to quantify those characteristics.
3. Ranking the technologies to create a Prioritized List of emerging technologies that appear most attractive to the BC economy.
4. Undertaking additional research activities, including interviews and discussions, to narrow down the technologies to a Recommended List.

The intent was to create a diversified technology portfolio comprising a set of emerging technologies that have high potential economic value to BC and also have a range of short, medium and long-term commercialization timeframes.

The following diagram depicts the overall research process.

Figure 2: Research Process Overview



The research process was designed to be iterative while supporting a large number of data points and a variety of research methods, both quantitative and qualitative. Realizing there is an enormous number of identified emerging technologies that either currently exist or are likely to in the near future, the research team required a process to review large amounts of data and have that data distilled into information that was manageable and meaningful. Therefore the project was divided into three main phases. Each phase had specific deliverables. Phase 1 focused on data collection in order to create the Master List of Emerging Technologies. (See Appendix C for a brief description of the technologies in the Master List.) The purpose was to gather sufficient objective criteria to enable the creation of a prioritized list of emerging technologies in Phase 2. Finally, Phase 3 resulted in a list of technologies which the research team felt were highly supportive of future high-tech growth in the Province. Details of the research process and the findings follow.

Identifying Emerging Technologies

One of the projects early objectives was to develop the Master List of Emerging Technologies to use as the foundation for further investigation and analysis. Depending on the degree of granularity employed in compiling such a list, there are potentially thousands of emerging technologies and their possible applications that could be added to the list. However, the research team decided to track only those technologies that seemingly represented significant overall

economic opportunities. These included general purpose technologies (GPT) and application-specific technologies. Some technologies are actually groups of technologies or potential applications of as yet undefined technologies. For example, quantum computing is an emerging technology that consists of many supporting technologies, techniques and applications. Therefore, quantum computing made it to the Master List, but not a supporting emerging technology such as quantum simulation.

With the above criteria in mind, the research team identified over 160 emerging technologies using primary and secondary research methods. These technologies ranged from quantum computing to biosensors, and from electronic paper to carbon nano-tubes. The sources used to research and select the emerging technologies included:

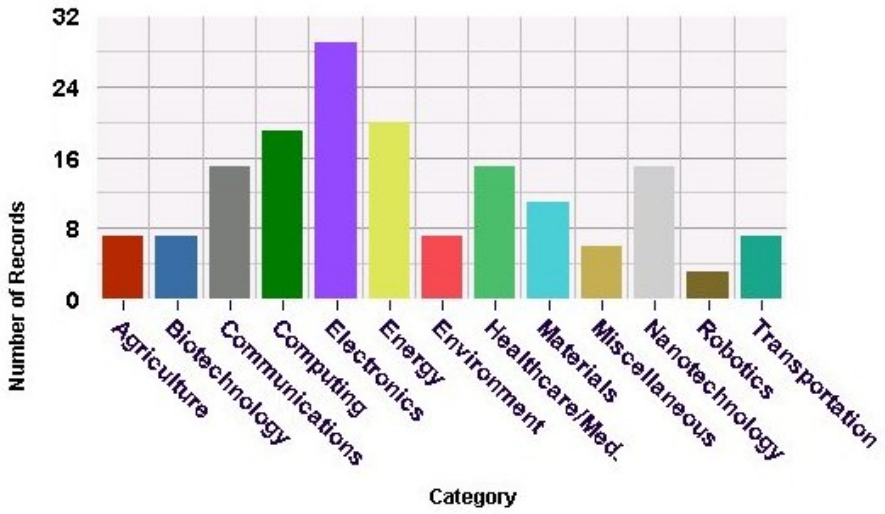
- PriceWaterhouseCoopers Technology Forecast
- Batelle Technology Forecasts
- World Future Society Forecasts
- George Washington University Forecast of Technology and Strategy
- Industry Canada Technology Roadmaps
- Gartner’s Predictions for the Year Ahead: Emerging Trends and Technologies
- MIT's Technology Review
- Scientific American
- Business 2.0
- PhysicsWeb

For a more detailed explanation of the above resources, refer to Appendix A: Sources for Identifying Emerging Technologies. In addition, see Appendix C for a list of all technologies that were investigated and a brief description of each one.

Industry Category

Each emerging technology was grouped within thirteen broad industry categories (including miscellaneous). The following chart shows the number of emerging technologies tracked within specific industries.

Figure 3: Emerging Technologies Researched by Industry



While the largest number of emerging technologies appeared in electronics and the related industries of computing and communications, a large number of technologies were also identified in energy and healthcare. Note that one of the above industries—nanotechnology—does not yet exist, at least not in a large and recognizable way. The reason it was included, however, was the vast number of emerging technologies that can be grouped under the general heading of “nanotech”. Although the emergence of nanotechnology has been occurring in research institutions and various industry sectors for the past two decades, nanotechnology does not yet constitute an industry in its own right, though a higher degree of commercial activity in the last few years has begun to change that situation.

Research Metrics

One of the aims of the project was to make the research process transparent so that other research organizations could extract findings and methods from the research to achieve their own objectives. To that end, the project team decided that the project should have metrics which would enable the compilation of “hard data” about emerging technologies. Such metrics would foster a more objective approach to the analysis and also provide a logical framework to compare and contrast the varied technologies. Consequently, in addition to the industry category, ten metrics were developed to classify the technologies. The following table summarizes each metric.

Table 1: Emerging Technology Metrics

Metric	Explanation
Primary Industries Affected	For any particular technology, industry sectors that create the new technology and drive development of new products and services related to the technology
Secondary Industries Affected	Once applications and commercial opportunities of new technologies are proven, industries that will likely apply the emerging technology in some way within their day-to-day business activities
Estimated Commercialization Timeframe	Approximate date whereby the emerging technology is expected to have significant and large market opportunities measured on a North American or global basis
Market Opportunity Size	Amount of North American or global revenues generated by the technology at its maximum market penetration
Market Opportunity by 2010	Amount of potential market demand by 2010 whether or not the commercialization timeframe has been met
BC University Research Activity	Whether significant basic or applied research related to the technology is currently underway in BC's research universities
BC Commercial Activity	Companies in BC that are currently active with the technology either through research, product prototyping or commercialization.
Anchor Company	Whether or not one or more companies are recognized industry leaders in the area of the emerging technology
Potential Convergence Technologies	Technology areas where a particular emerging technology may have significant impact on their subsequent development and/or commercialization
Leverages BC's Competitive Advantages	Whether BC currently has intrinsic or developed competitive advantages that can be leveraged to develop the technology or its markets

In subsequent analysis, the above criteria, which was gathered during 2003/2004, were used to frame the debates about which emerging technologies would most benefit the BC economy.

Selection of Research Categories—Understanding the Metrics

The ten categories were selected by the research team because they collectively provide a measurement and insight into whether a particular emerging technology is likely to be viable within the context of the BC economy.

Affected Industries

The two categories Primary Industries Affected and Secondary Industries Affected are useful because there is an important difference between an industry that creates a technology and an industry that applies a technology. Certain technologies have a spill-over effect that supports other industries. For example, a particular type of software might be created by the computing industry, but used by the forestry industry. In this case, forestry would be a secondary industry to the technology. And, since forestry is a leading industry in the Province, that particular emerging technology becomes all the more important.

Another example is PEM fuel cells, which are expected to be used by the automobile industry as an alternative and adjunct to traditional petroleum-powered engines. While the technology has been successfully created and developed by the technology's primary industry, namely the energy industry, its biggest impact is expected to be in the automotive industry, which is a relatively minor industry in the Province. As a result, PEM fuel cells may rate high on Primary Industries Affected, but low on Secondary Industries Affected.

Commercialization Timeframes and Market Opportunity

The Estimated Commercialization Timeframe is the year when an emerging technology is expected to reach maximum market impact. This is obviously a gross estimate. It means there will also be market opportunities on either side of that date, often many years in advance as it frequently takes years, and sometimes decades, for markets to reach their full potential. As a result, this metric is located at the midpoint of a market revenue bell curve. The purpose of the Estimated Commercialization Timeframe is to help determine the relative importance of an emerging technology within the near-term because a technology with a longer term horizon is one that is normally more uncertain.

A supporting metric is the Market Opportunity Size. This is a dollar figure indicating how much revenue a particular technology might generate on a North American or global basis. The importance of this figure is that, for example, while an interesting technology may be developed in BC, it may have potentially only a small market impact, possibly measured in the hundreds of millions of dollars, compared to another technology which may have a market impact measured in the billions of dollars.

To better differentiate near-term opportunities from those further out, another category, Market Opportunity by 2010, was developed. The importance of this metric is that even though the largest market opportunities may be well into the future, there may still be significant opportunities in the nearer term which can be exploited. This metric also provides a way of reducing the uncertainty inherent in time; that is, the longer the time horizon, the greater the uncertainty. 2010 opportunities reside in the relative near-term future.

University Research

Many emerging technologies and their early infrastructures have their birth in the university research community. Therefore, university research activity is often critical to the successful creation and early stage commercialization of emerging technologies. The BC University Research Activity metric is a measure of whether an emerging technology or technology area has the support of local basic and applied university research, and whether a critical mass of knowledgeable experts are being developed in that area.

Commercial Activity

BC Commercial Activity is used to gauge the current level of business activity concerning an emerging technology. This category contains companies that are currently researching, prototyping, or selling products and services related to an emerging technology. This is a key metric for analysis as business activities grow over time, often developing into industry clusters. A key metric related to BC Commercial Activity is whether or not there is an Anchor Company for the technology. An Anchor Company is defined as a company that is a recognized leader with an emerging technology and is currently large enough, or growing rapidly enough, to stimulate the creation of spin-off firms, as well as the development of competitive or value-add businesses. In BC, Ballard Power is an example of an anchor company in the energy industry.

Convergence Technologies

Potential Convergence Technologies is a way to determine if a particular emerging technology can potentially impact and support the development of other technologies. The reason for this metric is that emerging technologies can extend established technology and can also sometimes foster new opportunities for existing capabilities. An example of such a technology is PEM fuel cells, which have stimulated the development of micro fuel cells.

In other cases, emerging technologies can leapfrog established technologies in the marketplace and displace or reshape their applications when economic conditions allow. The rise of mobile and

Internet telephony (VoIP) in relation to traditional copper wire telephony is an example of such disruptive technologies.

Competitive Advantages

Leveraging BC's Competitive Advantages is a metric which indicates whether a particular emerging technology takes advantage of natural (intrinsic) or developed competitive advantages. For example, abundant fresh water is a natural competitive advantage for BC, while relatively inexpensive hydroelectric power is a developed competitive advantage. The competitive advantages used in this project included the following:

- Location
- Natural Capital
- Post-Secondary Education and Research Facilities
- Existing (non-technology focused) Industry Clusters
- Existing (technology-focused) Industry Clusters
- Inexpensive Power
- Tax-Advantaged Research and Development
- Corporate Income Tax Rates
- Inexpensive Skilled and Professional Labour
- Skilled Workforce
- Population Diversity
- International Trade Ties
- Airport Transportation (YVR)
- Deep Sea Ports (Vancouver and Prince Rupert)
- Integrated Ground Transportation
- Telecommunications Infrastructure
- Quality of Life (Vancouver)
- Employment Policy

Appendix B contains a description of these competitive advantages.

1st Round Analysis: Early-Stage Findings

After scanning technology forecasts and other secondary research to compile the technology metrics, as an initial step to begin the analysis the research team reviewed the characteristics of all the emerging technologies and assigned each one a rating of 1 to 5 stars. The purpose of the star ratings was to develop a smaller, more manageable, subset of technologies which could be researched more deeply and effectively. The number of stars a technology received was an early indication of its suitability for meeting the project goals. The higher the number of stars, the higher the potential of the technology for the BC economy. The star ratings were made through an analysis of the metrics and discussion among the research team members.

Star Ratings

As a starting point all technologies that received a 4- or 5-star rating would be included in the next stage research. This led a list of 28 technologies. However, the research team felt that there were some 3-star technologies that could potentially have a higher ranking depending on what further research might uncover. In other words, there were several 3-star technologies that had many positive metrics associated with them and the research team felt that many of those deserved closer scrutiny.

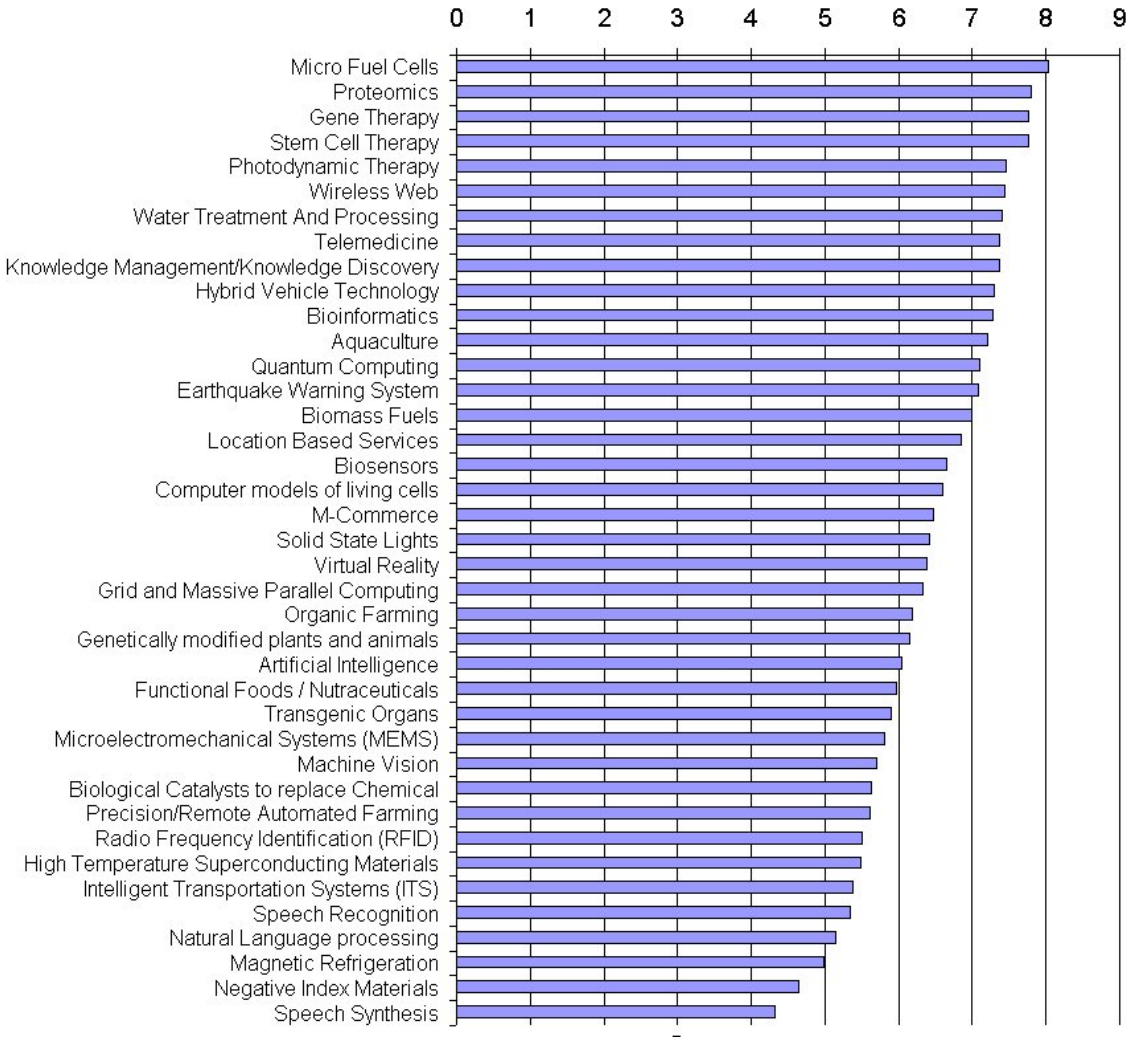
This process eventually led to thirty-nine emerging technologies becoming part of the next step in the research process. This included all twenty-eight 4- and 5-star rated technologies, in addition to thirteen 3-star technologies as having metrics that indicated they may be particularly important to the future of the BC economy.

Expert Interviews

The next step was to test the results of the star ratings by developing a questionnaire to be completed by a selection of business and technology thought leaders. This would be followed by face-to-face interviews to uncover additional opinions, issues and concerns about the emerging technologies. See Appendix D for a list of individuals interviewed.

Eighteen thought leaders completed the questionnaire and rated the technologies by their competitiveness and relative importance to the BC economy. Based on the results of the questionnaire, as well as the earlier star-ratings, the thirty-nine technologies were rated on an arbitrary scale from zero to nine. The higher the number, the more promising the technology. The following chart shows the rankings.

Figure 4: Prioritized List by Expert Interviews



This process led to a finalized list of prioritized technologies and completed the 1st round analysis.[3] Many of these technologies are already having commercial receptivity within the Province. For example, aquaculture (number 12 on the above list) is already an established industry. So why does it appear on a list of emerging technologies? Because the research team felt that many new and emerging technologies could dramatically alter, reshape, and ultimately help the aquaculture industry grow even larger and in a way that is potentially environmentally sustainable. The point being existing technologies and industries will change and adapt as new technologies are developed.

[3] *Note:* Nanotechnology did not appear in the prioritized list generated during the 1st round analysis because it was only later that the research team decided to combine a number of separate nano-related technologies under the general rubric of nanotechnology.

2nd Round Analysis: Reducing the Number of Technologies

The next step was to reduce the prioritized list developed in the 1st round analysis to a smaller, more manageable number of emerging technologies that could be investigated more closely. This was accomplished through further research and analysis with the intent to identify a small number of emerging technologies in which BC can take a leadership position within the context of a highly competitive global economy.

The first step in this 2nd round of analysis was twofold: re-evaluate the prioritized list of technologies to confirm their attractiveness; and secondly, to review once again the 3-star rated technologies to ensure that no attractive technologies had been underrated. After the assessment, the technologies were reordered, recombined, and if warranted, their star-rating reassigned.

The researchers used a background primer on industry development, technology transfer and the existing Premier's Technology Council framework on technology 'pillars' for additional perspective.[4] Though there was controversy due to the differing viewpoints on the relevance or acceptance of the 'pillars' and what they should be, one fact was certain: there was a lot of cutting-edge research underway in the Province, but there appeared to be no collective effort to identify BC's strengths and competitive advantages that would be necessary to allow these emerging technologies to flourish.

Technology Score Sheet

At this stage, the researchers had gained experience in selecting the technologies and gained perspective of a technology's synergy concerning cluster formation, market demand, market size, current research, competitive advantages, etc. But the question was how to use these factors to achieve a better-informed analysis? It was clear that a list of assumptions must be made, and a framework developed, to achieve a deeper level of analysis.

One of the key requirements for such a framework is that the decision-making process is repeatable by other investigators to verify the work and research. To this end, it was determined that the research team needed to work with additional quantifiable data to make objective decisions. As a result a "technology score sheet" was developed that would objectively compare and contrast the various technologies.

[4] See the *Premier's Technology Council Fifth Report*, January 2004, for a discussion of the primary technology pillars that make up the BC economy.

Evaluation Weighting

The initial challenge of using a score sheet was to develop an evaluation methodology to assess the technologies presented. Through on-going discussions, a list of criteria was drawn up that included the initial metrics in addition to other factors.

Table 2: Criteria Scoring Scale (Unit of Measurement)

Criteria	Data Type	Description
Current Ranking	integer	Ranking established in phases 1 and 2
BC University Research	dollars	Investment in BC University research
Market Potential	dollars	Worldwide or North American market potential
BC Commercial Activity	dollars	BC Commercial Activity - Investment Dollars
Relationship to Clusters	integer	Association with existing technology clusters
Relationship to Other Emerging Technologies	integer	Potential spillover from other emerging technologies
Availability of Research	integer	Information available on the emerging technologies
Link to BC's Competitive Advantages	integer	Congruence with existing BC competitive advantages
Sustainability	integer	Potential term of benefit to BC
Link to Global Issues	integer	Relationship to United Nation's global issues
Anchor Companies	integer	Existing anchor companies in BC
Discretionary Adjustment	integer	Adjustment for factors not included above

Furthermore, it was understood that each criteria had a different level of importance to the assessment; therefore a weighting system was implemented as well. Each criteria was selected based on its objective dimensions.

Table 3: Proposed Evaluation Criteria and Weighting

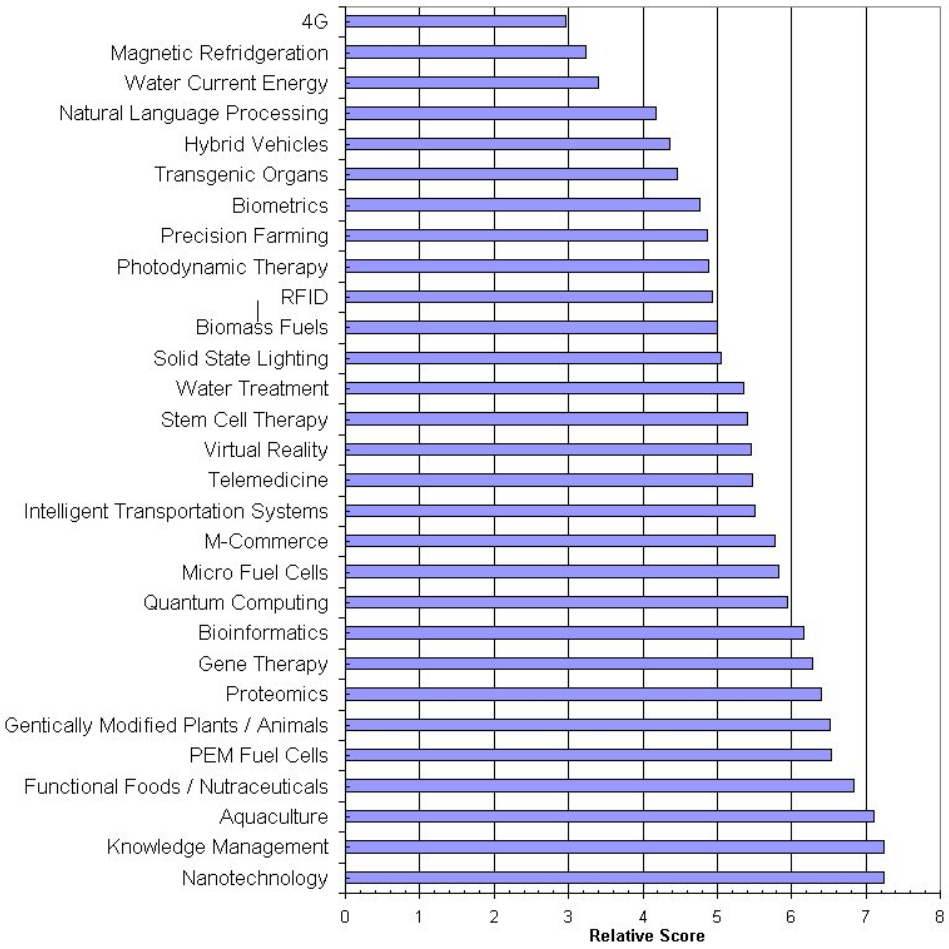
Criteria	Weighting
Current Ranking	12%
BC University Research	6%
Market Potential	10%
BC Commercial Activity	8%
Relationship to Clusters	10%
Relationship to Other Emerging Technologies	5%
Availability of University Research	4%
Link to BC's Competitive Advantages	8%
Sustainability	10%
Link to Global Issues	10%
Anchor Companies	10%
Discretionary Adjustment	7%
Total	**100%**

While there was a lot of discussion concerning the actual weightings, in the end the research team decided that what was ultimately most important was the creation of a transparent and potentially repeatable process. The team recognized that technology forecasting is not an exact science by any means. There is a high degree of arbitrariness in the selection of research methodologies and measurement criteria. As such, the importance of this type of research lies primarily in its ability to create awareness of emerging technologies and an appreciation of their role in future economic development. In other words, the research team recognized that the process was just as important as the results.

Results of the Score Sheet Analysis

Using the formula capabilities of Microsoft Excel, the data was inputted into a complex calculation worksheet to assess the total score of each technology based on the criteria, weighting, and objective data which had been normalized to an integer value using an arbitrary ranking from zero to eight. The results are shown in the following diagram; the higher the number, the more promising the technology.

Figure 5: Technology Score Sheet



Based on this analysis, it would appear that the technology that would be most supportive of the BC economy in the future is nanotechnology. As mentioned previously, nanotechnology is actually a grouping of numerous technologies, mainly in the areas of chemistry, materials and biotechnology. Nanotechnology would be followed by knowledge management technologies, aquaculture, functional foods & nutraceuticals, PEM fuel cells, etc.

However, the research team began to raise arguments as to why these results did not go far enough. More work needed to be done. The research team concluded that the score sheet approach was valuable in helping to focus the prioritized list of emerging technologies, but more qualitative analysis was necessary to make a final selection. This led to the 3rd round analysis and the application of more subjective reasoning based on risk versus opportunity analysis.

3rd Round Analysis: Combining Quantitative and Qualitative Analysis

As indicated earlier, the research team raised concerns about the research methodology employed in the 2nd round analysis. While acknowledging the amount of effort already expended, additional analysis would help build greater certainty regarding the selection of the emerging technologies most supportive of the Province's future economic development. These concerns included the following:

- There was no indication of 'certainty' or 'confidence level' of the objective information researched.
- Quantitative impacts are hard to forecast for the future, so numerical analysis is useful only up to a point.
- The mixture of technologies comprise both GPT (general purpose technologies; that is, technology enablers) and emerging technologies with specific product applications. Which ones will contribute most to the future success of the BC economy?
- There is a difference between what technologies do intrinsically and how they are applied in the marketplace, but from a governmental/regulatory point of view, they are often treated the same. An example is Genetically Modified Organisms (GMO plants or animals) versus Functional Foods & Nutraceuticals. Both the technologies and their potential products are regulated, albeit differently.
- How should emerging technologies that have not matured, but are already being commercialized at the early stage be treated? Should they be considered as truly emerging technologies or extant technologies?
- What will make the emerging technology particularly lucrative for it to remain in BC? That is, technologies are normally easily portable across geographic and national boundaries. What will make an emerging technology sustainable in BC?
- How should a technology be treated when it represents important leading-edge research, but is seemingly of low economic value?

These and other questions indicated that additional levels of analysis needed to be done. It was necessary to implement more subjective forms of data interpretation than could be achieved through purely objective criteria and analysis. Since there is always an element of imperfect and incomplete information in technology forecasting, particularly in areas that are rapidly changing, any amount of objective research will be susceptible to inaccurate or misleading data. The team

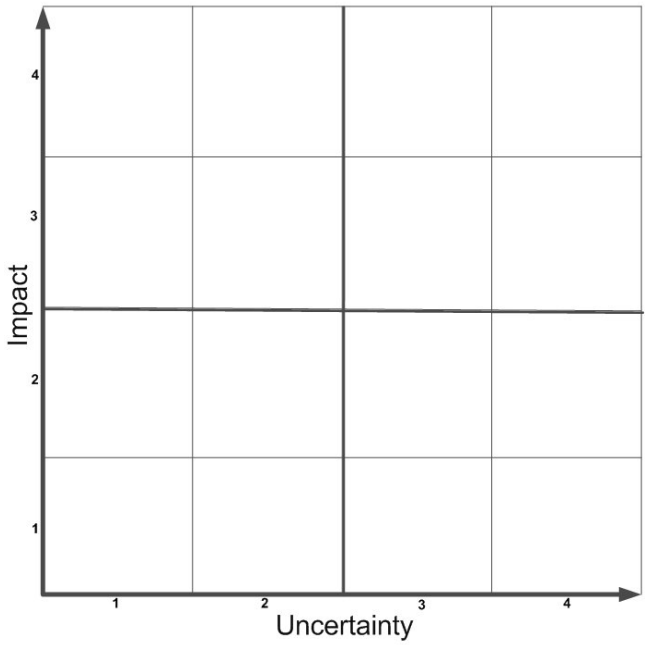
needed a different kind of analysis, a way of bringing the intuitive knowledge of experts into the decision-making process. What was needed was a method of using the broad-based experience of the full research team to take the analysis to the next level. As well, it was important that the method of applying this knowledge and experience could be a model used by other experts in the future as a test of bias and objectivity.

Risk Versus Opportunity Analysis

After continued discussions, there was agreement that another approach should be undertaken—one that enabled more qualitative and intuitive, hence subjective, research to enter the process. A new framework was proposed which became known as the Uncertainty/Impact Analysis Tool[5] (abbreviated herein as U/I analysis).

The following graphic depicts a generic U/I analysis chart that enables topics to be grouped into quadrants according to their assessed feasibility and importance.

Figure 6: Uncertainty/Impact Chart for Qualitative Analysis



Uncertainty/Impact analysis is a comparative technique which relies on the input of expert opinions. U/I analysis benefits from objective proof,

[5] David Roughley, a volunteer on the Emerging Technology Advisory Committee, suggested the use of the Uncertainty/Impact analysis which is a nonproprietary representation used by SRI Consulting Business Intelligence, www.sric-bi.com, amongst others, to chart complex data.

but rather than stopping at a simple data array, it aims to quantify that information in terms that are more significant to principal decision makers. The exercise enables participants to compare and contrast technologies and thereby investigate the hidden (or feel) factors that subliminally influence their choices. In essence, U/I analysis provides a method to enable intuitive reasoning to be part of the overall research process. It also supports a group dynamic whereby experts can discuss and evaluate the relative position of various technologies in respect to one another.

The premise behind U/I analysis is because there is a relative position between the potential impact of a technology versus its uncertainties, subjective evaluations of the risk are not only unavoidable, but actually desirable. While single-point forecasting methods are widely used to estimate near-term market growth for established technologies, they nonetheless rely on a predictable growth or decline in market revenues or applications based on actual data. They do not deliver guaranteed answers when longer timelines are considered. Emerging technologies—with their long lead times, more uncertain technological importance, and unknown applications—may also be defined in terms of known data, but in most cases the data points are less reliable and/or more difficult to generate, which limits the value of this approach. That is to say, the closer to commercialization a technology is, the easier it is to predict its subsequent development. U/I charting and analysis takes account of the fact that longer-term technologies are typically more uncertain, yet still require the analyst to examine the known facts in equivalent groups of technologies to evaluate them.

The question now was—what risks and what opportunities to assess?

Uncertainty/Impact Assessment Ratings

U/I charts can be used in a variety of ways to reveal texture in complex data sets. After some discussion, the project team arrived at the following representation:

1. Measuring technological uncertainty/risk on the horizontal axis
2. Measuring local (i.e. BC) impact on the vertical axis
3. Measuring global impact/need in the third dimension

To determine potential global impact of a technology, it was decided that reference to the global issues identified by the United Nations would offer useful insight. In other words, for any particular technology, would there be a significant socio-economic opportunity? And if so, does that opportunity represent significant commercial potential?

The following table contains a list of the United Nations global issues listed in alphabetical order.

Table 4: United Nations List of Global Issues[6]

Africa	Demining	Financing, International	International Law	Social Development
Ageing	Development Cooperation	Food	Labour	Outer Space
Agriculture	Disabilities, Persons with...	Governance	Law of the Sea and Antarctica	Statistics
AIDS	Disarmament	Health	Least Developed Countries	Sustainable Development
Atomic Energy	Drug Control and Crime Prevention	Human Rights	Millennium Assembly	Terrorism
Children	Education	Human Settlements	Peace and Security	Trade and Development
Climate Change	Elections	Humanitarian and Disaster Relief Assistance	Population	United Nations
Crime Prevention	Energy	Indigenous People	Question of Palestine	Volunteerism
Culture	Environment	Information Communications Technology	Refugees	Water
Decolonization	Family	Intellectual Property	Science and Technology	Women
				Youth

The research team felt that these three dimensions—uncertainty, local impact and global opportunity—were the most pertinent measurements to consider when selecting a relative portfolio of emerging technologies. Each of these three dimensions would have a rating scale from 1 to 4. This simplified rating scale, it was felt, would make any movement in a rating (for example, from a 3 to a 4) on the U/I chart significant, thereby requiring sound reasoning to support the new rating. The following table notes the extremes of the rating scale used for the U/I chart analysis.

Table 5: U/I Analysis Rating Scale and Criteria

Measurement	Rating Criteria
Uncertainty/Risk (horizontal axis)	1 = Technological realization and implementation is considered imminent in the near-term (between 1 to 5 years). 4 = Complexity and interaction of factors such as technological dependencies, competing technologies, industry standards, potential governmental legislative control, heavy resource

[6] Source: United Nations Website: http://www.un.org/issues/

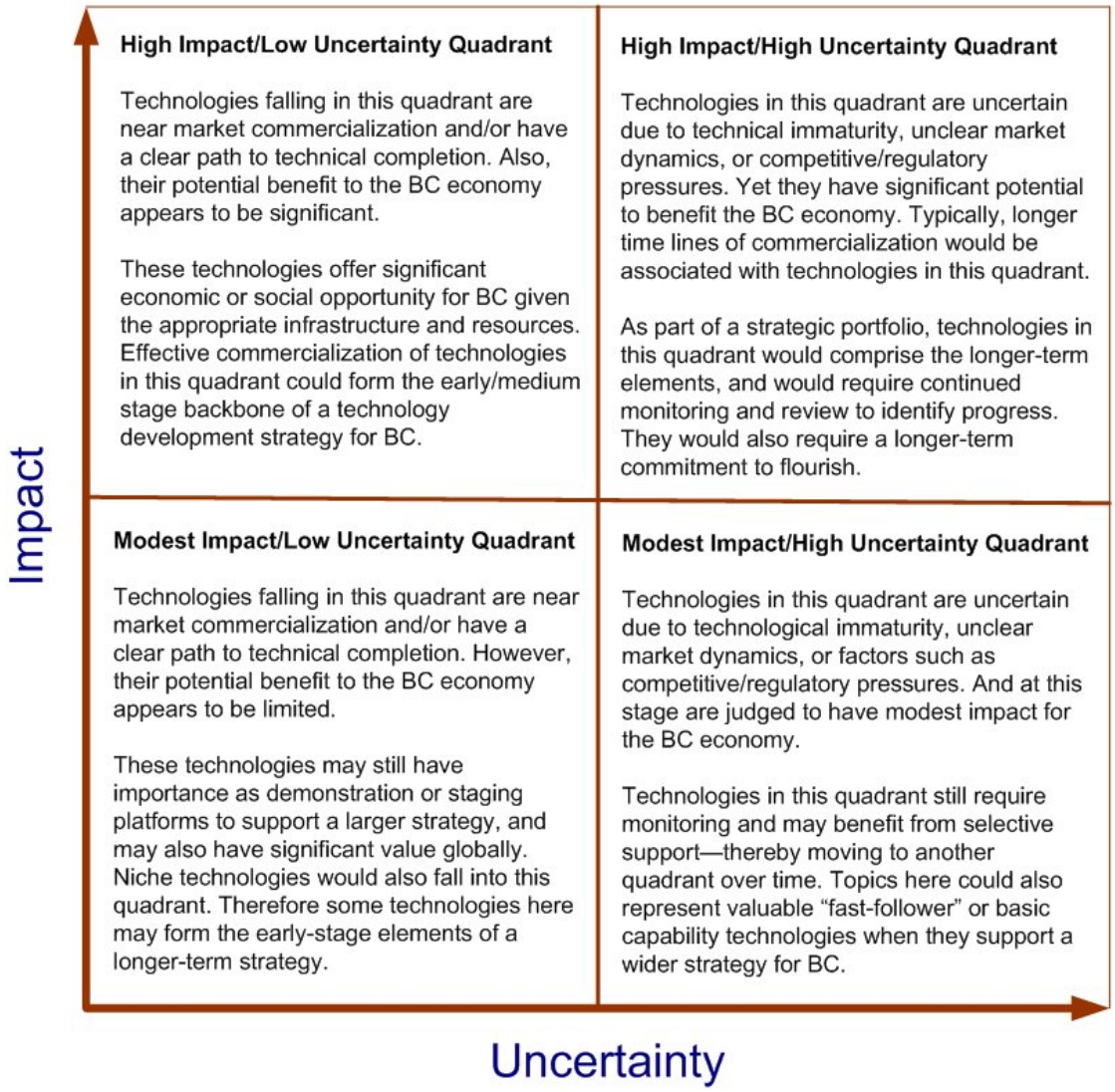
Measurement	Rating Criteria
	demand, complex process requirements, heavy reliance on public-private funding, or with an implementation timeframe of 20 years or greater.
BC Impact (vertical axis)	1 = Affecting regional, local or niche areas or sectors with minimal socio-economic benefit amounting to less than $100 million in market potential.
	4 = Affecting socio-economic and environmental welfare of BC to a large extent such as increased employment opportunities and contributing to multiple industries and technology sectors with sustainable economic activity amounting to $100 billion or more on a North American or global scale.
Global Impact (size of the oval)	1 (smallest oval) = Indirectly addresses the needs of only a handful of nations where there is minimal improvement to the welfare of the people in the areas listed in the UN Issues Agenda and are therefore of relative lower priority.
	4 (largest oval) = Directly addresses one or more needs of many nations, where the technology is revolutionary and dramatically improves the welfare of people in the areas listed in the UN Issues Agenda and are therefore high priority.

Intermediate ratings (2 and 3) provided the means to add extra texture to the representation. A rating of 2, therefore, meant that the technology is closer to the criteria identified as a 1 rating, while 3 was closer to the criteria of a 4 rating.

Uncertainty/Impact Quadrants and Portfolio Selection

By the above definitions, technologies can be grouped according to which quadrant of the U/I chart they occupy. In this sense, technologies with similar impact/uncertainty profiles can be reviewed in greater detail to understand their distinctions, whilst technologies in separate quadrants can be contrasted with each other to understand their relative importance. The following figure illustrates some key points based on the chosen set of definitions for this project.

Figure 7: Technology Quadrants and Their Meaning



Short List of Emerging Technologies for U/I Analysis

During this process, additional research was conducted on 27 technologies from the prioritized list developed in the 2nd round. After a series of meetings and on-going discussions, the research team finalized a list of 12 technologies that would be used for the U/I analysis. These 12 technologies represented a portfolio of technologies containing near-term opportunities (3 to 5 year horizons), mid-term opportunities (5 to 10 years), and longer-term opportunities (10 years or more). Those technologies are reviewed in the following table.

Table 6: Final 12 Emerging Technologies for U/I Analysis

Note: This list is in no particular order

Emerging Technology	Brief Description
Proteomics	Proteomics is a technology area that catalogues all human proteins and works to understand their interactions with each other, leading to new diagnostic tests and avenues for treatment of disease.
M-Commerce	M-commerce encompasses the technologies and software that allow goods and services to be purchased and sold through portable wireless devices such as mobile phones and PDAs.
Knowledge Management / Knowledge Discovery	Knowledge management and knowledge discovery encompass the technologies that derive useful knowledge from a large quantity of raw information. This includes data mining and novel visualization techniques.
Gene Therapy	Gene therapy treats disease by either modifying genes or correcting abnormal genes.
Micro Fuel Cells	Micro fuel cells are small fuel cells used to power portable devices such as cell phones and laptops.
Bioinformatics	Bioinformatics is the application of computers to store and manage genomics, proteomics, and other biological information, allowing researchers to find useful relationships in a complex set of data.
Solid State Lights	Solid-state lights are Light Emitting Diodes (LEDs) with long life, low energy consumption, and high intensity with the ability to control both colour and intensity at the same time.
Genetically Modified Plants and Animals (to produce medicine, chemicals, fuels, and other useful goods) and Functional/Therapeutic Foods and Nutraceuticals (GMPA / FFN)	Bacteria, plants, and animals are genetically modified to produce a specific chemical more cheaply and quickly than with traditional chemical methods. Nutraceuticals and functional foods provide health benefits such as reducing the risk of chronic diseases, in addition to their

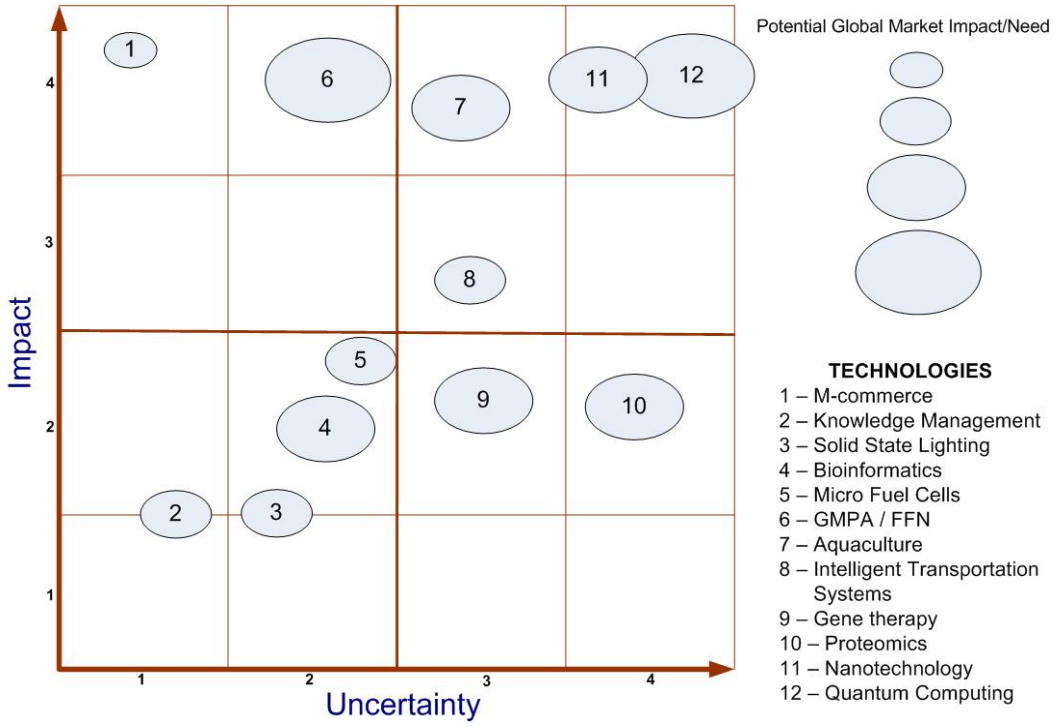
Emerging Technology	Brief Description
	basic nutritional value.
Nanotechnology	The tools, processes, and methods by which the atomic and molecular structures of materials are developed or manipulated to achieve or enhance properties and performance for functional applications
Aquaculture	Aquaculture is an emerging technology field that deals with genetics, health and feed that impact the cultivation of fish, shellfish and aquatic plants.
Quantum Computing	Quantum computing uses the principles of quantum mechanics to produce non-binary results. Each additional quantum bit used by the quantum computer increases the computer's power exponentially, while traditional computers increase power linearly with each additional bit, allowing moderately-sized quantum computers to solve certain types of problems far faster than very large traditional computers.
Intelligent Transportation Systems (ITS)	ITS is the integration of a broad range of communications, information, control, and electronics technologies into vehicles and transportation infrastructure. These technologies help monitor and manage traffic flow, reduce congestion, and provide alternate routes to travelers.

The research team then created more in-depth reports (referred to as technology-resumes) for each of these 12 technologies. The resumes would also be used later by the Advisory Committee during their U/I analysis meetings.

Preliminary Uncertainty/Impact Analysis

To test the research team's U/I analytical framework and assessment scale, the 12 technologies were plotted on a preliminary U/I chart as shown in the following figure. The analysis was based on reviewing the metrics developed in the 2nd round of analysis (listed in Table 1). The following chart can be understood as illustrating the quantitative results of the research in a format that is qualitative.

Figure 8: Preliminary Uncertainty/Impact Chart



Each bubble in the chart represents one of the 12 final emerging technologies. The size of the bubble indicates their potential global impact with the larger the bubble, the greater the impact. In addition, each technology is located in one of four quadrants. Refer to Figure 7 for a description of the meaning of each quadrant.

Understanding the Placement of Technologies

From this initial exercise, m-commerce (bubble 1) appeared to have the potential to highly impact the Provincial economy. It also had the lowest risk, but did not, nevertheless, significantly contribute to solving global issues. Hence, the commercial opportunities for m-commerce would likely be limited. Genetically Modified Plants and Animals / Functional-Therapeutic Foods and Nutraceuticals (bubble 6), on the other hand, had similar high impact to m-commerce, though slightly greater uncertainty of success. Nevertheless, the potential global impact of GMPA / FFN technologies is much greater than m-commerce, which could translate to significantly greater market opportunities.

In this first round U/I analysis, the technology with the greatest potential impact to BC and the world was quantum computing (bubble 12). Its certainty of success, however, was beyond the visible timeframe, making it the most uncertain, and hence risky, of the 12 technologies. Other technologies, such as knowledge management (bubble 2) and solid state lighting (bubble 3), had less uncertainty, but

their prospective global impact appeared to be lower relative to some of the other technologies.

Limitations of the Process

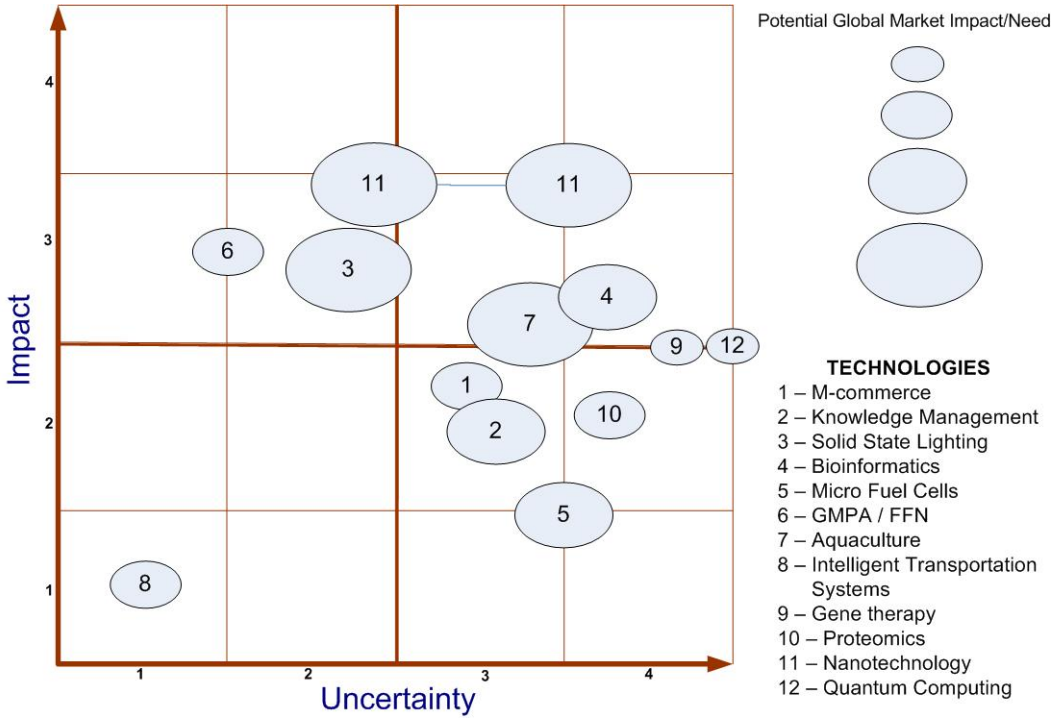
This preliminary exercise showed that charting the technologies relative to each other was certainly a useful exercise to visually represent the potential a technology might have in the economy. But it must also be understood that the positions on the chart are relative to only the final technologies out of more than 160 that were initially considered. This means that all final technologies can potentially greatly contribute to economic growth in the Province.

Furthermore, the results of the preliminary U/I analysis made the research team suspect that quantifiable data is insufficient for a robust analysis of the future. The location of some technologies on the chart just didn't "feel" right. For example, was m-commerce really the technology that had the greatest potential impact on the BC economy with the least risk? Was quantum computing truly a technology that could help solve many of the world's problems? The currently available data and trends appeared to have limitations. What was needed was more qualitative analysis in order to give greater confidence to the U/I charting process.

Final Round of Uncertainty/Impact Analysis

The next step was to present the results of the preliminary U/I analysis to the full advisory committee. The intent was to have the members of the committee discuss and debate the relative positioning of the 12 technologies within a roundtable format. Each technology, in turn, would be considered by the committee. The final location of each technology would be determined through consensus. If a member felt ardently about a technology's location or the need to change a technology's previously agreed-to location, that person would have to convince the rest of the committee. The result was a process that was both informative and provocative. The outcomes of the committee's deliberations are shown in the following figure.

Figure 9: Final Uncertainty/Impact Chart



Though both the research team and the advisory committee used the same research data (summarized in the technology-resumes), the resulting charts showed quite different technology landscapes. This was because the advisory committee brought to bear their many years of collective experience in business, technology and research. They added a qualitative dimension to the analytical process to augment the quantitative data generated by the research team. For example, an understanding of BC's competitive advantages (as referenced in Appendix B) could influence a member's thinking about how a particular technology may develop overtime. Thus, intangible factors, which are difficult to quantify, could enter the analysis.

The results of the final U/I charting process were quite different than the preliminary one. For example, m-commerce (bubble 1) moved from the top-left quadrant to the bottom-right quadrant. This indicated that the committee felt that m-commerce had less potential impact and more uncertainty relative to the other technologies than would be indicated solely by the technology's quantitative metrics. (Refer to Table 1 for a complete list of research metrics.) Solid state lighting, on the other hand, changed from having relatively low impact to substantially greater impact on the BC economy. The committee felt it had significantly greater potential to help solve some of the world's pressing problems as it provides a type of lighting that could help

reduce the world's energy consumption, while also bringing the many benefits of lighting and illumination to much of the Third World.

One technology on which the committee did not reach consensus was nanotechnology. While everyone felt that nanotechnology had potentially the highest impact on the BC economy and could help solve many of the world's major issues, there was disagreement to the certainty of nanotechnology's success in the Province, particularly as it has fairly long commercialization timelines. This is why nanotechnology ended up in two locations—one having relatively low uncertainty and the other higher uncertainty. Nevertheless, it was the one technology which the committee believed could most positively contribute to the future success of the Provincial economy, though in a longer-term timeframe.

Research Conclusions

For the Premier's Technology Council this research is expected to provoke fresh thinking about the role of emerging technologies in the BC economy. Certainly, everyone involved in the Emerging Technology Research Project gained substantial insight into the many facets and issues related to researching emerging technologies, as well as developing a better understanding of the state of high-technology research and development in BC. The team found that the process of evaluating technologies and their impacts and risks to society and the economy are just as important as assessing the technology itself. It must be acknowledged, however, that that role is one of contention and debate. The future lies in a haze of doubt and uncertainty, and the further out one attempts to forecast, the more perilous such forecasts become.

Despite this situation, decision makers frequently need to make their choices based on imperfect data. Their decisions are often more commitments to a considered course of action rather than sure-fire programs of success. Even with imperfect data however, it is possible—with continued monitoring—to test the assumptions and expectations on which decisions are based, and to develop mitigation strategies that would take account of new data, or unanticipated changes in the technological or business landscape.

The approach taken by the team was the creation of scenarios in which plausible outcomes for a given strategy are explored within a range of possible futures. Although, as mentioned earlier, it is inappropriate to pick winners, the dialogue that results from exploring scenarios of possible winners is important to gain an understanding of how government, academia and industry can make sure good outcomes for the future are not restrained from achieving their potential.

Scenario Planning

While this study only mentions in brief the value of scenario planning, the technique has been developed and applied successfully by futurists[7] and various major consulting groups, including SRI International in Menlo Park, California. It is an effective tool to test the sensitivity of a strategy to an uncertain future, and thereby perceive the risk/reward profile of a given set of choices. In one adaptation, the method constructs best-case and worst-case future scenarios in the time frame of interest, considering such external factors as geopolitical uncertainty, economic cycles, energy prices, interest rates, and so on. The subject of interest (in this case, the emergence of new technologies) is then considered in light of these external factors. However, as Peter Schwartz writes in his book *The Art of the Long View* "scenarios are not predictions…rather they are vehicles for helping people learn…they present alternative images of the future…they do not merely extrapolate the present."

These types of ideas have, of course, been widely promoted in the financial services industry and lead to the familiar concept of the investment portfolio, in which one balances risk and reward in the long- and short-term by holding investments and instruments offering complementary features—reducing risk while optimizing return according to the defined investment strategy. Similar decision processes can apply in the area of emerging technologies.

Selected Scenarios

Without rigorous or formal attention to the scenario process, the project team has—for illustration purposes—suggested possible representative technology portfolios that could form part of a wider BC technology strategy. These scenarios are explained briefly in the following table.

Table 7: Representative Technology Portfolio Scenarios

Scenario	Description
BC Advantage Scenario	Whereby emerging technologies are analyzed in relation to their compatibility with BC's natural and competitive advantages
Cluster Growth Scenario	Focuses on analyzing emerging technologies based on their ability to contribute to growing and sustaining existing high-tech clusters
Wealth Creation Scenario	Whereby emerging technologies are analyzed to determine which ones will most likely contribute to high rates of new jobs and higher

[7] See for example *The Art of the Long View*, Peter Schwartz, Doubleday ,1991.

Scenario	Description
	rates of pay to BC workers
EnviroTech Scenario	Approaches emerging technologies from the perspective of their ability to contribute to sustainable, environmentally sensitive businesses and industries
Cohesion Scenario	Whereby the technologies are analyzed based on the perceived ability to cross fertilize and support one another
PacRim Scenario	Analyzes emerging technologies in terms of which ones may most significantly contribute to future integration with Asian economies
Bioeconomy Scenario	Examines emerging technologies from the perspective of how they might enable BC companies to integrate globally with emerging bio-based industries

To stimulate continuing discussion and debate about the usefulness of scenario planning, two of these representative technology portfolios are illustrated in more detail: the EnviroTech model and the Bioeconomy model.

EnviroTech Model as a Representative Scenario

British Columbia is already well known for its growing alternative energy sector, its strong awareness of environmental issues, and its significant resources in terms of water and clean energy generation. In 2002 *The Canadian Fuel Cell Industry: Capabilities Guide* identified around 200 participants in the fuel cell sector alone, of which 40 were located in BC. The NRC's Institute for Fuel Cell Innovation (IFCI) is also located in Vancouver, providing a bridge for the commercialization of technology into industry. Beyond fuel cells, many other companies exist that specialize in niche aspects of resource management, clean energy, and/or the environment. The idea behind the EnviroTech model is that BC has significant experience, and academic and commercial presence in a number of fields relating both to the management of natural resources (forestry, mining, fishing, freshwater, etc) and the conscientious preservation of the environment. These two aims frequently clash, but thoughtful application of existing and emerging technological capabilities could not only reduce such conflicts, but actually provide BC with an advantageous platform of skills and capabilities that would be in demand globally.

The creation of an EnviroTech focus in BC would not only underpin better stewardship of resources locally, but would become a skill set on which economic development could take place. For example, nanotechnology offers potential benefits in improved catalysts (for fuel

cells), remediation processes (for the recovery of toxic elements), and water purification, to name a few. Micro-fuel cells would also fit into this model as an alternative clean-energy solution. The low-energy aspects of solid-state lighting also contribute to this strategy. Elements of bioinformatics, GMPA, and aquaculture also feed into the idea of a technology platform that not only addresses local interests, but becomes a wealth creation engine for the Province in the future.

With EnviroTech as a strategic aim, we can see from the U/I chart that nearer-term (and moderately certain) opportunities could exist in GMPA/FFN, nanotechnology, and solid-state lighting, with less certain (longer-term) opportunities arising in aquaculture, more advanced nanotechnology systems, and bioinformatics.

Bioeconomy Model as a Representative Scenario

The Bioeconomy consists of bio-related technologies, which include biotechnology, life sciences (including agriculture), medicine, bio-analytical instruments and software. The Bioeconomy opportunity with respect to biotech products is forecasted to be US$526 billion dollars by 2010 (McKinsey). Investments in bio-related emerging technologies have the potential to position the Province at the forefront of this growing opportunity.

The Bioeconomy scenario we envision for BC's future is one where a variety of bio-related technologies form the basis of an industry that will play a central role in British Columbia's future – creating wealth, jobs and opportunity. The emerging technologies presented in the final round of analysis which could contribute to the Bioeconomy scenario include:

- Bioinformatics
- Proteomics
- Nanotechnology
- Aquaculture
- Gene Therapy/Stem Cell Therapy
- Functional Foods/Nutraceuticals/Genetically Modified Plants and Animals

This wide range of bio-related technologies could also leverage whatever innovations BC can offer from information technology, wireless and other areas of technology innovation in the region. The anticipated results could entail positive impacts on BC’s resource industries, as well as on the quality of life through better nutrition and healthcare.

Canada is widely considered the number two biotech player in the world, and BC is leading the growth in this position. BC has the beginnings of a strong research base in both academia and industry for these emerging technology areas. However, for BC to capitalize on the opportunity and achieve the potential envisioned in this scenario, BC must nurture the development of both leading-edge research and commercialization capacity. At the same time, there is a need to establish key linkages into the global economic framework that will evolve with the advent of the bioeconomy and with the world's emerging needs for sustainable technologies. Since the products that form the foundation of this economic revolution tend to be convergence products that combine innovation and expertise from diverse disciplines of science and engineering, it is important that BC also forms linkages within our own research institutions and commercial organizations.

Economic integration to enable cross-fertilization of products, services and new markets remains a core requirement for long-term high-tech growth and development, not only in the bioeconomy scenario, but in other scenarios as well.

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Appendix A: Sources for Identifying Emerging Technologies

- PriceWaterhouseCoopers. Technology Forecast: 2002-2004, Volume 1: Navigating the Future of Software. This document covers a variety of topics related to enterprise software. http://pwcglobal.com/extweb/service.nsf/docid/D75141A62E48EF5185256B9A0051725C
- PriceWaterhouseCoopers. Technology Forecast: 2002-2004, Volume 2: Emerging Patterns of Internet Computing. This document covers computing infrastructure. http://www.pwcglobal.com/ie/eng/ins-sol/publ/tf_vol2_131202.html
- Batelle. Technology Forecasts. Battelle's team of technology forecasters provides insight into the technological innovations that will spell success for industry and government in the future. http://www.battelle.org/forecasts/default.stm
- World Future Society Forecasts. Each year since 1985, the editors of THE FUTURIST have selected the most thought-provoking ideas and forecasts appearing in the magazine. Over the years, Outlook has spotlighted the emergence of such epochal developments as the Internet, virtual reality, and the end of the Cold War. http://www.wfs.org/forecasts.htm
- George Washington University. Forecast of Technology and Strategy. The GW Forecast fills the need by bringing experts together online to forecast forthcoming breakthroughs and strategically plan for their impact. It can be thought of as a "virtual think-tank" that conducts its work electronically. The Forecast pools the collective knowledge of the world's best authorities, and then automatically distributes the most accurate possible forecasts based on this data to you -- anywhere in the world, on any prominent emerging technology or strategic issue, in real time. http://gwforecast.gwu.edu/index.asp
- Industry Canada. Technology Roadmaps. Technology Roadmapping is a planning process driven by the projected needs of tomorrow’s markets. It helps companies to identify, select, and develop technology options to satisfy future service, product or operational needs. Via the process, companies in a given sector can pool their resources and work together with academia and governments, to look from 2-10 years into the future and determine what their specific market will require. This process is led by industry, and facilitated by government. Technology Roadmaps have been completed for 11 sectors and being developed in five more.

http://strategis.ic.gc.ca/epic/internet/intrm-crt.nsf/vwGeneratedInterE/Home/

- Gartner Group. Predictions for the Year Ahead: Emerging Trends and Technologies. http://www.gartner.com/pages/story.php.id.3077.s.8.jsp
- MIT's Technology Review. www.technologyreview.com
- Scientific American. www.sciam.com
- Business 2.0. www.business2.com
- PhysicsWeb. www.physicsweb.org

Appendix B: Summary of BC's Competitive Advantages

Intrinsic Advantages

Table 8: British Columbia's Intrinsic Competitive Advantages

Advantage	Sustainable?	Description
Location	Yes	Located midway between Europe and Asia, BC can communicate with both continents during the regular course of the business day, allowing BC to be a true Europe, Asia, Americas hub, not just a gateway. In terms of transportation, Vancouver is located central to the world: 9 hours by air to London, 5 hours to New York, 3 hours to Los Angeles and 9 hours to Tokyo.
Natural Capital	Yes	Abundant natural resources are a source of construction materials, food, minerals, water, and energy. BC's inventory of natural resources includes: 948,191 km^2 of land 4,753,803 hectares of agricultural reserve land 60 million hectares of forests, 58% of which is protected Large reserves of "conventional oil and gas, coalbed methane, offshore oil and gas, coal and alternative and renewable energy sources." 8% of the world's fresh water supply In addition to providing raw materials, BC's environment is a major tourist attraction. Properly managed, these resources are renewable and can be sustained indefinitely, providing the basis of major competitive advantage over other provinces and counties.

Developed Advantages

Table 9: British Columbia's Developed Competitive Advantages

Advantage	Sustainable?	Description
Post-	Yes	British Columbia supports a public post-

Advantage	Sustainable?	Description
Secondary Education and Research Facilities		secondary education system that includes: Five universities; Twenty-two university-colleges; Over one hundred research centers; and 14 Network Centres of Excellence. In addition, secondary school students receive exceptional education, achieving some of the highest scores on international academic tests. With appropriate government funding and programs to maintain and enhance institutions, facilities and programs, thus advantage could be sustained indefinitely.
Existing (non-technology focused) Industry Clusters	No	Existing clusters in the interior of BC focused on wood products (central and northern BC), food, wine and beverages (Okanagan), energy and mining (northeast BC), and transportation and logistics (central interior BC). Despite not being involved developing new technologies, these sectors are increasingly dependent on technology. Application of technology allows traditional commodity goods, such as hothouse vegetables, to transform into premium products. In addition, Vancouver is North America's third-largest film production center after Hollywood and New York, and a creative center for digital film animation and special effects. These clusters have the potential to serve as the first customers for many of the products created by the province's technology-focused clusters.
Existing (technology-focused) Industry Clusters	No	Traditional science and technology focused clusters exist primarily in the Lower Mainland and Victoria area. These are concentrated in the areas of information technology, fuel cells, wireless, and biotechnology.
Inexpensive Power	Yes	BC is the third largest generator of reliable hydroelectricity and second largest natural gas producer in Canada. Power costs in BC (Vancouver) average between 2.2 and 3.0 cents per kilowatt-hour, compared to between 10.3 and 13.3 in California (San Diego), and are among the lowest in North America.
Tax-Advantaged Research and Development	No	According to the Ministry of Science, Competition and Enterprise: "100% immediate deduction of eligible current R&D costs (salaries, supplies and overheads) and R&D equipment, 20% federal income tax credit for eligible R&D costs, 10% British Columbia

Advantage	Sustainable?	Description
		income tax credit for eligible R&D costs, no annual R&D expenditure limit for earning credits, 10 year carry-forward of credits not used in the year earned." In addition, the tax advantages do not require companies to increase spending about a base amount in order to qualify for tax credits, unlike in the United States.
Corporate Income Tax Rates	No	Corporate income tax now lower than the combined municipal, state, and federal corporate income taxes in the United States (39.4%, down to 33.4% by 2007).
Inexpensive Skilled and Professional Labour	No	Base salaries for technology professionals and skilled technicians are typically 30 to 40% lower in British Columbia and 20 to 33% lower for skilled and semiskilled production personnel. Employee benefits costs are almost 40% lower – due mainly to dramatically lower health insurance costs compared to the US. Mandatory payroll taxes are about 50% lower. A comparative analysis using KPMG's Competitive Alternatives Cost Model, shows average annual operating cost savings in British Columbia, relative to the West Coast states, of approximately 33% in software development, 20% in electronics manufacturing, 30% in biotechnology research and development, and 20% in biopharmaceutical manufacturing.
Skilled Workforce	Yes	High quality labour pool of 2.2 million people, of which: 64% has post-secondary education; and 19% has a university degree. British Columbia is a national leader in co-operative education programs, providing about 3,000 person-years of career-related work experience annually. 15,700 university degrees were awarded in 2001 – one-third in sciences and engineering – plus 5,000 technology and industrial diplomas from British Columbia's Institute of Technology. The province has committed to double the number of graduates in information technology fields over the next five years.
Population Diversity	Yes	Strong international immigration is a key source of language and cultural skills from Europe, Asia and Latin America - 35% of British Columbian are foreign born. Between 1992 and 2001, more than 130,000 people immigrated to British Columbia in the skilled worker category. This immigration is also encouraged by the fast track

Advantage	Sustainable?	Description
		immigration process in place for highly skilled foreign workers. This immigration provides the language and cultural skills required to participate in international trade, opening the doors to export opportunities.
International Trade Ties	Yes	Under the North American Free Trade Agreement (NAFTA), firms locating in British Columbia can access markets in the United States and Mexico duty-free – regardless of corporate nationality. Materials and equipment can also be sourced duty free from the US and Mexico.
Airport Transportation (YVR)	Yes	YVR is ranked the top medium-sized airport in North America and one of the top 10 in the world. Canada's second busiest airport, served by more than 20 international carriers. 15 million passengers and 120,000 tonnes of air cargo handled annually, and providing over 700 direct flights weekly to US destinations, 100 to Asia and 40 to Europe. YVR is a growing freight distribution hub with a new free trade zone.
Deep Sea Ports (Vancouver and Prince Rupert)	Yes	The Port of Vancouver is Canada's largest and North America's second largest port in terms of foreign trade, handling 73 million tonnes of cargo annually, more than any other port on the west coast of the Americas. Vancouver is the third-largest port for foreign container traffic on the West Coast, and the closest to China, Hong Kong, Taiwan, Japan and Korea. British Columbia's northern port of Prince Rupert is ice-free year round, and the closest bulk commodity port to Asia. Prince Rupert is 30 hours' sailing time closer to Asia, the shortest route between Asia and North American markets, and the closest port to open water, all of which offer shippers significant shipping savings. In addition, Prince Rupert is the deepest harbour in North America, enabling it to handle even the super-ships of tomorrow.
Integrated Ground Transportation	Yes	CPR, CN, BC Rail operate/lease track lines through Vancouver that connect to the rest of North America. Integrated ground transportation systems provide freight customers with cost-effective service to US and Canadian markets via truck and rail. Truck delivery is 24 hours from Vancouver to Silicon Valley and the Bay Area. Rail delivery to Chicago is within four days.
Telecommunications	Yes	An extensive high-speed optical network employing SONET and ATM technologies, with

Advantage	Sustainable?	Description
Infrastructure		general access to ISDN, ADSL, frame relay, DS3, T1/3 and E10/100 services A full range of network services – security, network management, Web-hosting and e-business. Direct connections from Vancouver to Canada's intercity IP backbone with extensions into the US via several major points of presence. 100% digital switching.
Quality of Life (Vancouver)	Yes	Vancouver has ranked among the top three cities in the world for livability for the past five years. Places Rated Almanac rated Vancouver #1 for health care in North America. Overall crime rate has decreased steadily over the past five years despite population increase. The United Nations Human Development Index represents a broad index that combines a large number of individual quality of life measures, including education, healthcare, housing, income, and more. In 2001, Canada ranked third on a global basis, the US sixth, the Netherlands eighth, and Japan ninth. All of the countries studied were ranked in the top 20.
Employment Policy	No	British Columbia's employment standards legislation allows for flexible shift schedules – 24/7 business operations are common. New "averaging agreements" allow employers and employees to create mutually beneficial modified work patterns based on a 40-hour week standard. For example, 160 hours of work can be averaged over four weeks. Designated professionals, including high-technology workers, are fully exempt from hours of work provisions in the Employment Standards Act.

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Appendix C: Emerging Technology Descriptions

The Emerging Technologies Research Project began by uncovering over 160 emerging technologies and technology areas to determine ones in which BC might be able to take a leadership position. This appendix lists these emerging technologies and provides a brief description of each one along with the industry category in which it is apart.

Note that not all these technologies have been shown to be feasible at this stage, some have not been demonstrated, and some are still semi-fictional, though possible. The purpose of compiling a large initial list of varied technologies was to create a starting point to instigate further research and analysis.

Table 10: Emerging Technology Descriptions

Category	Emerging Technology	Brief Description
Agriculture	Aquaculture	Aquaculture is an emerging technology field that deals with genetics, health, and feed that impact the cultivation of fish, shellfish, and aquatic plants.
Agriculture	Artificial Food	Artificial foods are foods synthesized directly from raw materials instead of being harvested from plants and animals.
Agriculture	Functional/Therapeutic Foods/Nutraceuticals	Nutraceuticals and functional foods provide health benefits such as reducing the risk of chronic diseases in addition to their basic nutritional value.
Agriculture	Genetically Modified Crops.	Plants genetically modified to improve their resistance to drought, pesticides, pests, as well as to improve other traits such as nutritional value.
Agriculture	Genetically modified plants and animals to produce medicine, chemicals, fuels, and other goods.	Bacteria, plants, and animals are genetically modified to produce a specific chemical more cheaply and quickly than with traditional chemical methods.
Agriculture	Organic Farming	Organic farming is a technology area that focuses on ways of using biodegradable materials and symbiotic plants and animals to maintain soil fertility and provide pest control.
Agriculture	Precision/Remote Automated Farming	Precision farming is the convergence of geographic information systems, automated machines, remote sensing devices, mobile computing, and telecommunications to care for livestock and manage farms.
Biotechnology	Proteomics	Proteomics is a technology area that

Category	Emerging Technology	Brief Description
		catalogues all human proteins and works to understand their interactions with each other, leading to new diagnostic tests and avenues for treatment of disease.
Biotechnology	Neuroinformatics	Neuroinformatics consists of the tools and databases to aid neuroscientists manipulate, store, and share their data.
Biotechnology	Glycomics	Glycomics is an emerging technology area that analyses carbohydrate and sugar structures to better understand molecular sequencing and cell communication, which can lead to new diagnostic tests and treatments for diseases.
Biotechnology	Computer models of living cells	A computer model of living cells would allow the effects of drugs on the body to be simulated, predicting efficacy and side effects. This ability to simulate the effects of drugs will reduce the cost of discovering and testing new drugs, since unsuitable drug candidates can be eliminated sooner.
Biotechnology	Biosensors	Biosensors use a biologically-based or -derived sensor to detect specific chemicals or pathogens cheaply, accurately, and quickly.
Biotechnology	Biomimicry or Biomimetics	Biomimicry is the technique of copying features or processes from natural examples to produce new or more efficient products.
Biotechnology	Biological catalysts to replace chemical reactors	Enzymes are biological catalysts that allow chemical reactions to take place at lower temperatures and higher rates, as opposed to the high temperatures and pressures required by some chemical reactions currently used.
Communications	Zigbee	Zigbee is a low-cost, standards-based wireless networking standard that supports low power consumption, security, and reliability at the expense of lower data rates, making it ideal for security and building automation applications.
Communications	XM Satellite Radio	Satellite-based radio can provide CD quality audio entertainment coast-to-coast. Like satellite TV, it carries more channels than the typical local market.
Communications	Wireless Web	The wireless web is a network that allows people to access the Internet from cell phones, handheld computers, and other portable devices.
Communications	Voice over IP (VoIP)	Voice over IP is the two-way transmission of voice traffic over a packet-switched IP (Internet Protocol) network. VoIP is more bandwidth efficient than ordinary telephones, allowing more telephone conversations to be sent over

Category	Emerging Technology	Brief Description
		the same line. VoIP allows a single network to carry both data and voice traffic, allowing communications providers to lower costs and offer additional services.
Communications	Ultra Wide Band	Ultra Wideband uses very short radio pulses to offer very high bandwidths, very low power consumption, and no interference with other equipment using the same spectrum. It also has location tracking and radar capabilities.
Communications	Tele-immersion	Tele-immersion is a communications medium that creates the illusion that the user is in the same room as other people and allows them to manipulate virtual objects together, even though the participants are in different locations.
Communications	Semantic Web	The semantic web is a set of standards and formal language that give content on the Web meaning that is machine-readable. This results in improved searches and should allow for increased automation and software agents.
Communications	Quantum Teleportation	Quantum teleportation is the transfer of quantum information from one particle to another, theoretically transporting it from one location to another without traveling through the distance in between.
Communications	M-Commerce	M-commerce encompasses the technologies and software that allow goods and services to be purchased and sold through portable wireless devices such as mobile phones and PDAs.
Communications	Location Based Services	Location based services use location-finding technologies to offer specific services and information based on the current location of the wireless device's user.
Communications	Internet 2	Internet 2 technologies consist of high-speed applications such as video conferencing over the high speed infrastructure being built between government and research institutions.
Communications	Free Space Optics	Free space optics uses beams of light to transmit information without cables.
Communications	Bluetooth	Bluetooth is a wireless standard that delivers short-range radio communication between electronic devices, allowing disparate devices to communicate with each other.
Communications	4G	This is the next generation of packet data cellular networks capable of higher data rates and is "always on, always connected".

Category	Emerging Technology	Brief Description
Computing	Extreme UV (EUV) Lithography	Extreme UV lithography uses very small wavelengths of light to etch transistors in silicon, allowing for higher speeds and lower power consumption.
Computing	Virtual Reality	Virtual reality consists of systems that enable one or more users to move and react in an immersive computer-simulated environment.
Computing	Natural Language and Gesture processing	Natural language and gesture processing allows computers to correctly interpret the meaning of speech and gestures without relying on a pre-programmed vocabulary.
Computing	Swarm and Biological Computing	Swarm and biological computing consists of computers operating like a swarm of insects, tackling a number of simple operations in coordination to produce a solution to a complex problem.
Computing	Speech Synthesis	Speech synthesis will allow computer generated voices to produce pleasing, expressive voices to respond to users with correct intonation and pronunciation.
Computing	Speech Recognition	Speech recognition will allow computers to accurately interpret a user's voice commands with a large vocabulary but without special training, allowing for variations in accent.
Computing	Bioinformatics	Bioinformatics is the application of computers to store and manage genomics, proteomics, and other biological information, allowing researchers to find useful relationships in a complex set of data.
Computing	Head-mounted Displays	Displays mounted on helmets, visors, and glasses that display computer-generated information.
Computing	Grid and Massive Parallel Computing	Grid computing transforms computing power into a utility service that is available on demand. Program instructions are divided among multiple computers in a network, allowing computations to be performed by computers at other locations that are not necessarily owned by the user.
Computing	Genetic Programming	Genetic programming uses the principles of evolution to find optimum solutions to problems, with the best individual after several generations taken as the best solution to the problem.
Computing	DNA Computing	DNA can store vast quantities of information in its sequence of four bases, and natural enzymes can manipulate this information in a parallel manner. It has been used to solve the

Category	Emerging Technology	Brief Description
		Hamiltonian path problem, also known as the traveling salesman problem, which has applications for network and supply chain management.
Computing	Knowledge Management / Knowledge Discovery	Knowledge management and knowledge discovery encompass the technologies that derive useful knowledge from a large quantity of raw information. This includes data mining and novel visualization techniques.
Computing	Computer Immune Systems	Computer immune systems identify processes as "self" and "non-self", allowing them to detect computer viruses and worms without relying on exact descriptions. This capability would allow new viruses and worms to be detected and blocked without regular updates to antivirus software.
Computing	Cognitronics	Cognitronics is a direct interface between the human brain and devices such as computers, sensors, and prosthetics.
Computing	Biometrics	Biometrics are automated methods of recognizing a person based on a physiological or behavioral characteristic such as face, fingerprint, or voice recognition.
Computing	Autonomic Computing	Autonomic computing is a computer and network managing technology that automatically allocates tasks to different components, and can manage itself by restarting components that stop or crash as necessary without the user's attention. This would reduce the maintenance costs of ever-expanding databases and servers.
Computing	Augmented Reality	Augmented reality is a computer display that adds virtual information to a user's sensory perceptions. An example is a see-through device that overlays graphics and text over a user's view of his or her surroundings.
Computing	Artificial Intelligence	Artificial intelligence consists of neural networks and expert systems to perform pattern recognition and respond appropriately.
Computing	Wireless Local Loop	Wireless local loop is a technology that allows high speed wireless access between a subscriber's building and the public telephone network without the need for copper wires and fibre optic cables.
Computing	Quantum Cryptography/Encryption	Quantum cryptography uses quantum entanglement to transmit secure encryption keys and detect the presence of any eavesdroppers in the communications channel.

Category	Emerging Technology	Brief Description
Electronics	OLED (Organic Light Emitting Diodes)	OLEDs consist of polymers that emit light when electrically charged. Unlike traditional LCDs, a backlight is unnecessary, saving weight and electrical power.
Electronics	Optical Computers	Optical computers use beams of light and photons in place of electricity and electrons to transmit and manipulate information. As microprocessors shrink, they will approach a quantum mechanical limitation for electrons that photons are not subject to.
Electronics	Optical Interconnects	Optical interconnects transmit information from one device to another within a computer using pulses of light instead of electricity.
Electronics	Organic Semiconductors	More flexible and potentially much cheaper than silicon, organic semiconductors can be printed on plastic, allowing sensors, memories, and displays to bend like paper.
Electronics	Ovonic Unified Memory (OUM)	Ovonic unified memory uses the same material as rewritable CDs and DVDs to store information by changing the phase and properties of this material. This allows for memory storage that persists even in the absence of electrical power, but is cheaper than Flash RAM.
Electronics	Parallel Chips	Parallel chips are processors composed of many simple processors working in parallel at the chip level, on the same piece of silicon.
Electronics	Plasma and Liquid Crystal Display	Plasma and Liquid Crystal Displays are thin monitors that vary in size from 34" to 61".
Electronics	Power suit	Power suits are computer controlled, strength enhancing suits that detect and amplify muscle movements.
Electronics	Radio Frequency Identification (RFID)	RFID tags are small microchips that listen for a radio query and respond by transmitting their unique ID code. Most RFID tags have no batteries and use the power from the initial radio signal to transmit their response.
Electronics	Solid State Lights	Solid state lights are Light Emitting Diodes (LEDs) with long life, low energy consumption, and high intensity with the ability to control both color and intensity at the same time.
Electronics	Spintronics	Electronics that use electron spins to store and manipulate information instead of moving electric charges. This should result in lower power consumption and higher speeds, as electron spins are easier to move than the whole electron.

Category	Emerging Technology	Brief Description
Electronics	Three-Dimensional Microchips	Microchips have traditionally been produced as a single layer, with the semiconducting parts of the circuits confined to a single plane. Three-dimensional microchips have multiple layers, with the semiconducting parts of circuits extending vertically as well as horizontally.
Electronics	Wearable Computer Devices	Wearable Computer devices are computers small enough to be worn much like glasses, wrist watches, and clothes are worn.
Electronics	Protein Arrays	Protein arrays allow proteins to be cheaply and quickly identified, characterised, and screened.
Electronics	157-nm Flourine Lithography	157-nm flourine lithography uses light from a flourine source with a wavelength of 157-nm to etch smaller transistors in silicon, allowing for higher speeds and lower power consumption.
Electronics	Adaptive Optics	Adaptive optics consist of mirrors that deform rapidly by small amounts in response to commands from a sensor to adjust for distortions, such as those introduced by the atmosphere.
Electronics	Asynchronous Chips	Traditional chips are synchronous and operate with a clock. Asynchronous chips do not use a clock, and their transistors can switch independently of one another and operate at their own speed instead of at the speed of the slowest component. Unused portions of the chip can be shut down, reducing power consumption.
Electronics	Chip Cooling Techniques	Chip cooling techniques reduce the heat produced by smaller, denser chips or dissipate them more effectively. Chip cooling is becoming an issue as the heat power density of computer chips approach those of a nuclear reactor.
Electronics	Directed Sound Generators	Directed sound generators are devices that can project ultrasonic waves to cause a surface to vibrate at lower frequencies and at lower volumes, allowing speech and other sounds to be directed at one person only.
Electronics	Electron Projection Lithography (EPL)	Electrons are projected in a beam to etch smaller transistors in silicon, allowing for higher speeds and lower power consumption.
Electronics	Electronic Paper	E-paper is a portable, reusable, and flexible storage and display medium that looks like paper but can be repeatedly written on by electronic means thousands or millions of times.
Electronics	EMR Hard Disk Drives	By using extraordinary magnetoresistance

Category	Emerging Technology	Brief Description
		(EMR), much higher data densities can be achieved in hard drives, allowing for higher capacity drives that are physically smaller.
Electronics	Ferroelectric RAM (FRAM)	Ferroelectric RAM cells use a capacitor to store information. The capacitor has a permanent electric dipole from its insulator. Data is either 1 or 0, depending on whether the dipoles in the insulator points up or down.
Electronics	FinFET	The FinFET is a 3D structured transistor that achieves faster operation and less power consumption that existing transistors.
Electronics	Gallium Nitride Transistors	Transistors fabricated from gallium nitride instead of silicon are capable of operating at much higher power levels and frequencies than any other semiconductors known today. They are also capable of operating at higher temperatures than silicon, reducing the need for cooling mechanisms.
Electronics	Low Capacitance Films	Low capacitance films used in manufacturing microprocessors will allow signals to propagate faster, resulting in a higher speed processor.
Electronics	Magnetoresistive RAM (MRAM)	MRAMs store information in the orientation of magnetic domains. This memory will consume less electricity than current flash RAMs and capture data faster.
Electronics	Non-volatile Random Access Memory (NRAM)	NRAM memory chips use an array of single-walled carbon nanotubes to store digital data without requiring electrical power to maintain the data.
Energy	Water Current Energy Generation	Water current energy generation makes use of tidal currents and other forms of water current (rivers, creeks, etc) to generate power without the size, cost and environmental damage associated with traditional hydroelectric generation facilities.
Energy	Sonofusion	Sonofusion uses the high temperatures and pressures produced by collapsing bubbles in a liquid to initiate a series of short fusion reactions.
Energy	Solid Oxide Fuel Cells	Fuel cells are electrochemical devices that combines hydrogen with oxygen to produce electricity, heat, and water. The solid oxide fuel cell (SOFC) uses a hard ceramic electrolyte instead of a liquid and operates at temperatures up to 1000 degrees C.
Energy	Solar Power	Efficient photovoltaic cells that will capture and store large quantities of solar energy in a cost-effective manner.

Category	Emerging Technology	Brief Description
Energy	Quantum Nucleonics	Quantum nucleonics is a method of extracting energy from atomic nuclei without using either fission or fusion.
Energy	PEM Fuel Cells	PEM fuel cells harness the eletrochemical reaction of oxygen and hydrogen using a proton exchange membrane (PEM) to produce electricity.
Energy	Nuclear Fusion	Nuclear fusion of light nuclei such as hydrogen isotopes release energy.
Energy	Next-generation nuclear power plant: Water cooled nuclear reactor	This next-generation nuclear reactor design encloses the entire coolant system inside a damage-resistant pressure vessel. This design is smaller and simpler than traditional water cooled reactors.
Energy	Next-generation nuclear power plant: Gas cooled nuclear reactor	This next generation nuclear reactor uses self-contained, pebble-sized fuel elements that are inherently safer than a traditional nuclear reactor. This system operates at a higher efficiency level than traditional reactors and operates using smaller modules which can be added as necessary.
Energy	Next generation nuclear power: fast spectrum nuclear reactor	Fast-spectrum reactors make new fuel and destroy long-lived wastes from traditional reactors. They deliver much more energy from uranium and reduce the amount of waste that needs to be disposed.
Energy	Microbial Fuel Cells	Microbial fuel cells use microbes such as bacteria and yeast to produce hydrogen from glucose to power the fuel cell.
Energy	Micro Fuel Cells	Micro fuel cells are small fuel cells used to power portable devices such as cell phones and laptops.
Energy	Methane hydrate crystal mining	Methane hydrate crystal mining consists of the technologies required for the commercial retrieval of the rich deposits of frozen natural gas crystals on the ocean bottom.
Energy	Lithium Polymer Batteries	Lithium polymer batteries have high energy densities and can be shaped or moulded as necessary for different applications.
Energy	Hydrogen-on-Demand	Hydrogen-on-Demand technology obtains hydrogen using borax. It is safer and cheaper than conventional hydrogen storage, which uses either high pressure hydrogen tanks or liquid hydrogen.
Energy	Geothermal Power	Geothermal power production operates by extracting steam from the Earth's crust to power turbines. Extra water can be injected to

Category	Emerging Technology	Brief Description
		replenish subterranean reservoirs.
Energy	Gas to Liquid Conversion	Gas to liquid conversion technology is a chemical engineering process that transform hydrocarbon compounds from gases to liquids.
Energy	Flywheel Batteries	Flywheel batteries store energy in a rotating mass in a vacuum. They can accept and deliver large amounts of energy in a very short time and charge and discharge energy without degrading.
Energy	Quantum Computing	Quantum computing uses the principles of quantum mechanics to produce non-binary results. Each additional quantum bit used by the quantum computer increases the computer's power exponentially, while traditional computers increase power linearly with each additional bit, allowing moderately-sized quantum computers to solve problems more quickly than very large traditional computers.
Energy	Biomass Fuels	Biomass fuels are extracted from biomass resources such as sawdust and landfills.
Energy	Downwind Windmills	Downwind windmills have their blades downwind of the turbine and tower, allowing lighter and cheaper blades to be used. Traditional windmills have their blades upwind, to avoid turbulence, and must be made stiffer to avoid touching the tower.
Environment	Water Treatment And Processing	Water treatment and processing is a technology area that deals with the treatment and purification of water for human consumption or the removal of pollutants from industrial discharges.
Environment	Recyclable Electric/Electronic products	Electric applicances and electronic products have more recyclable components and less toxic or hazardous materials.
Environment	Thermal Depolymerization - Pressure cooking of waste	Thermal depolymerization breaks carbon chains in plastics and other carbon-based substances, producing oil and other chemicals from waste.
Environment	Green Integrated Technology (GrinTech)	Green Integrated Technology is the convergence of a variety of technologies such as advanced sensors, advanced sensors, new materials, computer systems, energy systems, and manufacturing technologies to eliminate waste and make products completely recyclable.
Environment	Earthquake Warning System	Earthquake warning systems detect the approach of earthquakes a few seconds before

Category	Emerging Technology	Brief Description
		the damaging portion of the quake arrives, allowing computer controls to shut down gas and water pipelines beforehand to reduce damage.
Environment	Carbon Dioxide Sequestration	Carbon dioxide sequestration consists of the different technologies that remove carbon dioxide from the air without using photosynthesis.
Environment	Automobile Air Filters	Automobile air filters capture air from outside the vehicle and remove the hydrocarbons and nitrogen oxides by burning them in the engine and catalytic converter.
Healthcare/Medicine	Phage Therapy	Phage therapy uses viruses that infect only a specific type of bacteria to replace antibiotics as treatments for bacterial diseases.
Healthcare/Medicine	Wavefront Analysis	Wavefront analysis allows a 3D map of changes to a patient's cornea to be generated prior to laser eye surgery. This map is positioned over the eye, allowing more accurate and effective laser eye surgeries to be performed.
Healthcare/Medicine	Transgenic Organs	Transgenic organs increase the supply of organs for transplant. These organs taken from animals genetically modified with human genes to reduce the transplant rejection reaction.
Healthcare/Medicine	Telemedicine	Telemedicine is the use of electronic communication and information technologies to provide or support clinical care at a distance.
Healthcare/Medicine	Stem Cell Therapy	Stem cell therapy is the technology field associated with the isolation, cultivation, and transplantation of stem cells to cure degenerative diseases such as Alzheimer's and diabetes.
Healthcare/Medicine	Signal-Responsive Missile Drugs	Signal-responsive missile drugs are drugs with packaging that only releases their active ingredients in the presence of cellular signals produced by diseased cells.
Healthcare/Medicine	Rupture Event Scanning	Rupture event scanning is a novel diagnostic technique using the piezoelectric effect of quartz crystals that can detect the presence or absence of a particular microbe or protein.
Healthcare/Medicine	Photodynamic Therapy	Photodynamic therapy uses drugs that are activated by the presence of a specific wavelength of light. This allows treatment to be targeted to specific areas of the body without affecting other parts.

Category	Emerging Technology	Brief Description
Healthcare/Medicine	Photobiomodulation	Photobiomodulation is the use of light in the far-red to near-infrared wavelengths to help wounds heal more quickly and stimulate growth.
Healthcare/Medicine	Implantable Sensors	Implantable sensors in the body retain their sensitivity, specificity, stability, and response time for long durations and do not provoke reactions from the immune system.
Healthcare/Medicine	Gene Therapy	Gene therapy treats disease by either modifying genes or correcting abnormal genes.
Healthcare/Medicine	Conjugated Monoclonal Antibodies	Monoclonal antibodies are proteins made by the immune system to bind to a specific invader and identify them for destruction by immune cells. Combining them with radioisotopes or toxins would allow them to directly kill the cells they target.
Healthcare/Medicine	Combination Treatments	Combination treatments consist of combinations between drugs, medical devices, and information technology such as implantable drug pumps and drug coated stents.
Healthcare/Medicine	Artificial Organs	Artificial organs refers to the technologies required to build human organs and tissues from scratch. This technology includes the ability to supply the new organs with essential nutrients.
Healthcare/Medicine	Angiogenesis Therapy	Angiogenesis therapy seeks to control the growth of blood vessels in the body. By either stimulating or inhibiting blood vessel growth, different conditions including cancer and heart disease can be treated.
Materials	Metal Powder Injection Molding	Metal powder injection molding is a manufacturing process for fine parts that reduces the machining required for complex components, especially with materials that are difficult to machine with conventional methods.
Materials	i-Textiles or e-Textiles	i-Textiles are the technologies that allow electronic circuits and sensors to be built into fabrics. These fabrics look and feel normal, are easy to care for, and can be woven easily.
Materials	Plasma Spray	Plasma Spraying is an extremely versatile thermal coating process. Complex alloys, elemental materials, composites and ceramics can often be produced with this technique for use in material fabrication.
Materials	Shape Memory Polymers (SMP)	Shape memory polymers are special plastic materials able to change their shape in response to temperature. They can be

Category	Emerging Technology	Brief Description
		deformed and then restore themselves to their original shape by applying heat. They are more deformable than shape memory alloys, which have similar properties.
Materials	Reverse Selective Membranes	Reverse-selective membranes are filter materials that are permeable to large molecules but block small molecules.
Materials	Biodegradable Plastics	Biodegradable plastics are plastics and polymers that decompose at high temperatures in the presence of water. These plastics can be composted and will degrade in landfills.
Materials	Fine Grain Metals	Fine grain metals are composed of tiny microscopic grains that vary in size. The strength, toughness, and corrosion resistance of metals are improved by decreasing the grain size.
Materials	High Temperature Superconducting Materials	High temperature superconducting materials allow electrical conduction without losses at higher temperatures. Traditional superconductors require liquid helium cooling, while current high temperature superconductors require liquid nitrogen.
Materials	Magnetorheological (MR) Fluids	MR fluids are fluids that solidify within milliseconds in the presence of a magnetic field. When the magnetic field is removed, they return to their original state.
Materials	Negative Index Materials	Negative index materials are materials that bend certain EM waves in the opposite direction of other materials. These can lead to smaller, cheaper antennas and optical devices.
Materials	Photonic Crystals	Photonic crystals are microscopically structured materials that perfectly reflect photons at specific wavelengths. Photonic crystals can be used to produce more compact optical components such as splitters, couplers, and filters.
Miscellaneous	Atomic Mirrors	An atom mirror is a device that reflects impinging atoms in an analogous manner to the way a regular optical mirror reflects an incoming light beam.
Miscellaneous	Combinatorial Chemistry	Combinatorial chemistry is the technique of taking a large library of chemicals that can be efficiently screened for desirable interactions with new chemical receptors as they are discovered.
Miscellaneous	Electronic Voting	Electronic voting consists of the technologies that allow voters to exercise their votes electronically while providing for accountability

Category	Emerging Technology	Brief Description
		and reliability.
Miscellaneous	Microfluidics	Microfluidics is the technology area that deals with devices that manipulate tiny amounts of liquids. They pump solutions through narrow channels, controlling the flows with small valves and electric fields.
Miscellaneous	Microelectromechanical Systems (MEMS)	MEMS are devices that have microscopic moving parts made using computer chip manufacturing techniques.
Miscellaneous	Magnetic Refrigeration	Magnetic refrigeration is an energy efficient cooling mechanism that replaces compressors with large magnets. It is more energy efficient than traditional refrigeration, and may make the production of liquid hydrogen economically feasible.
Nanotechnology	General Usage	The tools, processes, and methods by which the atomic and molecular structures of materials are developed or manipulated to achieve or enhance properties and performance for functional applications
Nanotechnology	Artificial Muscle	Artificial muscles are materials that work by contracting and expanding like human muscles in the presence or absence of electric fields, but at many times the strength.
Nanotechnology	Carbon Nanotubes	Carbon nanotubes are tiny tubular structures composed of one or more layers of carbon atoms. Single walled carbon nanotubes are 100 times as strong as steel, but much lighter. They can act as superconductors and have electrical properties similar to silicon that allows them to be used in logic circuits.
Nanotechnology	Catalysts	Nanotechnology catalysts are nanometer scale particles that facilitate chemical reactions without being consumed by the reactions themselves.
Nanotechnology	Contrast agents for imaging	New contrast agents enhance the performance of medical imaging devices, allowing problems to be detected at earlier, more treatable stages.
Nanotechnology	Data Storage	Nanotechnology data storage are nanometer scale structures that hold data that can be read and written. Disk drives with nanoscale layering attain highly dense data storage.
Nanotechnology	Drug Delivery	Nanotechnology drug delivery technologies are small structures enclosing drugs that allow them to be ingested through the stomach and reduce side effects by releasing the drugs only at the target site.

Category	Emerging Technology	Brief Description
Nanotechnology	Superior Implants	Nanometer scale modifications to implant surfaces improve implant durability and biocompatibility.
Nanotechnology	Imprint Lithography	With imprint lithography, patterns are copied many times by impressing a pattern into a polymeric layer. The mold is produced with an electron beam or other next generation lithography technique.
Nanotechnology	Molecular Motors	Molecular motors and devices can manipulate molecules one at a time. They convert chemical energy into mechanical work to perform tasks such as molecular assembly, fine sifting, low-energy-consumption computing and semiconductor quality control.
Nanotechnology	Nanoelectronics	Nanoelectronics are nanometer scale electronic components such as transistors, diodes, relays, and logic gates from organic molecules, carbon nanotubes, and semiconductor nanowires.
Nanotechnology	Quantum Dots	Quantum dots are semiconductor nanocrystals. They absorb photons of all energies above the threshold of the band gap but the wavelength of the light emitted depends on the dot's size.
Nanotechnology	Scanning Probes	Scanning probes are nanotechnology tools that permit users to visualize and manipulate items at the nanoscale and to detect single molecules. They can also be used to push individual atoms and molecules into position to assemble nanometer-scale structures.
Nanotechnology	Self-Assembling Materials	Self-assembling materials are materials that assemble themselves into small nanostructures from raw components in a controlled environment.
Nanotechnology	Materials Enhancement	Nanotechnology materials enhancement technologies consist of nanocrystalline particles that are incorporated into other materials to provide new characteristics, such as to produce tougher ceramics and transparent sunblocks to block infrared and UV.
Nanotechnology	Soft Lithography	Soft lithography can make large numbers of small structures in soft materials. It is much cheaper than conventional lithography and works on curved as well as flat surfaces.
Robotics	Multi-legged Robots	Multi-legged robots can navigate rough terrain where wheeled robots cannot, and are more stable than two-legged robots.
Robotics	Two-legged Locomotion	Two legged locomotion is the ability for robots

Category	Emerging Technology	Brief Description
		to stand and walk on two feet without losing balance.
Robotics	Machine Vision	Machine vision is real-time 3D sensing for computers and machines.
Transportation	Homogenous-Charge Compression-Ignition (HCCI) Engine	HCCI engines are a type of engine that produces low combustion temperatures, meaning that the engine produces only small quantities of nitrogen oxides and soot, and operates at a higher fuel efficiency than gasoline engines.
Transportation	Telematics	Telematics is the convergence of GPS, voice recognition, and wireless technologies to provide safety, entertainment, and navigation services to cars and other motor vehicles.
Transportation	Supercavitating Propulsion	Supercavitation propulsion forms a single bubble that surrounds an underwater object or vessel almost completely. This minimizes contact between the vessel's surface and water and drastically reduces drag, allowing it to travel at much higher speeds.
Transportation	Personalized Public Transportation	Personalized public transportation is a technology field that aims to control individual cars remotely, coordinating and optimizing traffic through the road system.
Transportation	Intelligent Transportation Systems (ITS)	ITS is the integration of a broad range of communications, information, control, and electronics technologies into vehicles and transportation infrastructure. These technologies help monitor and manage traffic flow, reduce congestion, and provide alternate routes to travelers.
Transportation	Hybrid Vehicle Technology	Hybrid vehicle technologies are the electrical, mechanical, and computer components required to produce hybrid vehicles. Hybrid vehicles use a combination of an internal combustion engine and electric motors to improve fuel efficiency and reduce emissions without sacrificing the vehicles' range.
Transportation	Fuel efficient supersonic jet engines	A fuel efficient jet engine capable of producing enough thrust to allow supersonic flight that also minimizes takeoff emissions and noise levels.

Appendix D: People Involved in the Emerging Technology Research Project

Premier's Technology Council

Honourable Gordon Campbell, Chair

Paul Lee, Co-Chair

Jim Mutter, President

William Koty, Member

Derek Chee, Staff Researcher

Tia Tjandisaka, Staff Researcher

Emerging Technology Advisory Committee

Aaron Cruikshank

Chris Dennis

Michael DeSandoli, Creo

Geoffrey Hansen, Rocket Builders

Victor Jones

Dr. Steve Lund, UBC

David Roughley.

Student from the Sauder School of Business at UBC

James Chang

Kyle Clapham

Indranil Guha

Devin Redlich

Brendon Wilson

Former Science and Innovation Council of BC

Jim Reichert, President

Venie Dettmers, Research Analyst

Arnel Lim, Co-op Student Researcher

Thought Leaders in Business and Academia

Lorne MacGregor

Michael Goldberg

Rodger Lea

David Vogt

Mark MaWhinney

Tim Walzak

Don Rix

John McEwen

Linda Thorstadt

Brent Holliday

Morley Lipsett

Adam Holbrook

Norm Toms

Paul Hastings

Barry Jinks

Victor Ling

Wal Van Lierop

Indira Samarasekera