
Evaluation of Genome British Columbia

June 12, 2015

Prepared for:

Genome British Columbia

Prepared by:

Dennis Rank and Associates

Jointly with

The Evidence Network

AUTHORS

This document was prepared by:

Dennis Rank
Senior Partner
Dennis Rank and Associates
4037 West 20th Ave.
Vancouver, BC
Canada
V6S 1G6
Tel. 604-224-4607
Fax. 604-224-4606
E-mail: adrank@telus.net

Brian Barge
President and CEO
The Evidence Network
334 Coleridge Dr.
Waterloo, ON
Canada
www.theevidencenetwork.com
Tel: 226.647.1220
Cell: 519.591.8361
E-mail: barge@theevidencenetwork.com

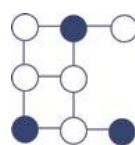
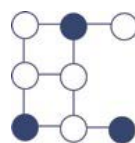
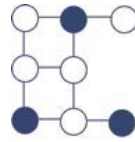


TABLE OF CONTENTS

| | | |
|----------|---|-----------|
| 1 | Introduction | 14 |
| 1.1 | The study..... | 14 |
| 2 | Study Issues and Methodologies | 16 |
| 2.1 | Study issues | 16 |
| 2.2 | Overview of methodologies | 17 |
| 2.3 | Data from Genome BC performance metrics and recent performance reports | 17 |
| 2.4 | BC-specific bibliometric data from the 2014 Genome Canada evaluation | 18 |
| 2.5 | Interviews with key stakeholders | 19 |
| 2.6 | TEN/DRA surveys | 19 |
| 2.6.1 | Survey design..... | 19 |
| 2.6.2 | Survey response rates | 21 |
| 2.6.3 | Analysis of open-ended comments | 21 |
| 3 | Findings on Support for Strategic research | 23 |
| 3.1 | Fostering excellent genomics science..... | 23 |
| 3.1.1 | Productivity..... | 23 |
| 3.1.2 | Excellence | 26 |
| 3.1.3 | Impacts on the capabilities and performance of researchers | 27 |
| 3.1.4 | Impacts on the capabilities and performance of Industry | 30 |
| 3.1.5 | Impacts on the capabilities and performance of non-profits | 32 |
| 3.2 | Addressing areas of strategic importance for BC and Canada..... | 34 |
| 3.2.1 | Support for important strategic R&D in BC..... | 35 |
| 3.2.2 | Support for centres of excellence and platforms | 37 |
| 3.2.3 | Are there any programmatic gaps? | 37 |
| 3.3 | Improving BC's "life sciences" brand..... | 38 |
| 3.3.1 | Is BC becoming an early adopter of –omics? | 38 |
| 3.3.2 | Attraction of top scientists and technologists..... | 38 |
| 3.3.3 | Improving BC's core genomics capabilities | 39 |
| 3.4 | Fostering multidisciplinary science | 39 |
| 3.5 | Possible improvements to support of strategic R&D..... | 40 |
| 4 | Findings on Leveraging | 43 |
| 4.1 | Attraction of funding from national and international organizations through partnerships & collaborations | 43 |
| 4.1.1 | Generating collaborations | 43 |
| 4.1.2 | Number of collaborations | 44 |
| 4.1.3 | Leveraging | 46 |



| | | |
|--------------------|--|-----------|
| 5 | <i>Findings on GE³LS</i> | 48 |
| 5.1 | Fostering GE³LS in Genome Canada and Genome BC projects | 48 |
| 5.1.1 | Genome BC activities | 48 |
| 5.2 | Honest broker role | 50 |
| 5.3 | Impacts on the GE³LS capabilities of researchers, companies, and non-profits | 50 |
| 5.4 | Public communications, outreach, and specialized education | 50 |
| 6 | <i>Findings on Socio-Economic Benefits</i> | 53 |
| 6.1 | Regional economic impacts | 53 |
| 6.1.1 | Economic impact “ripples” | 53 |
| 6.1.2 | Job creation | 53 |
| 6.2 | Fostering practical development of commercial and industrial socio-economic benefits | 54 |
| 6.2.1 | Programmatic support | 54 |
| 6.2.2 | Impacts on firms “advanced” | 55 |
| 6.2.3 | Impacts on firms surveyed | 56 |
| 6.3 | Possible improvements to generating socio-economic benefits | 56 |
| 7 | <i>Conclusions</i> | 59 |
| 7.1 | Achievements to date | 59 |
| 7.2 | Implications for the future | 59 |
| | | |
| Appendix A: | Relevance Of Existing Data To The Evaluation Issues | |
| Appendix B: | Interview Guide | |
| Appendix C: | Interview Respondents | |
| Appendix D: | Details on Firms “Advanced” | |



EXECUTIVE SUMMARY

1. The Study

This evaluation study provides an independent review of the achievements of Genome BC against its goals, as required under Genome BC's by-laws and its Funding Agreement with Genome Canada (GC). The study team investigated Genome BC's achievements against its formal objectives as set out in its by-laws and most recent 2010-2015 Strategic Plan, reviewed its progress vis-à-vis recommendations from the most recent (2009) evaluation, and developed recommendations.

2. Methodologies

Key methodologies included: (1) Review of data from Genome BC performance metrics; (2) review recent performance reporting to the BC Ministry of Technology, Innovation and Citizens' Services; (3) review of BC-specific bibliometric data mined from the 2013-2014 evaluation of Genome Canada; (4) review of findings from an independent economic impacts report conducted in 2014; (5) Interviews with 26 key stakeholders representing leaders within the academic, government, and Non-profit communities who were highly familiar with Genome BC; (6) Surveys of Genome BC researchers (207 respondents; 41% response rate), industry partners (23 respondents; 61% response rate), and non-profit partners (44 respondents; 46% response rate) regarding Genome BC's impact on their resources, capabilities, and long-term performance.

3. Findings on Support for Strategic Research

Productivity. From its inception through April of 2015, GBC scientists have contributed to 1,602 journal publications, 4,462 presentations, and 124 other types of publications (e.g., books, chapters, and conference proceedings). Over 30 publications have been cited 100 or more times, and over 60 publications have been made in top journals such as Nature, the Journal of Biological Chemistry and the New England Journal of Medicine. Genome BC scientists have significantly exceeded what might reasonably be expected on the basis of per capita contributions: BC has won 28% of Genome Canada project funding and 38% of Genome Canada platform funding, while having only 13% of Canada's population.

Further, bibliometric analysis shows that Canada's share of the world output genomics-related slowly climbed from ~4% in 1981 to ~4.5-5.0% recently. Within this, BC's production has nearly doubled on a proportional basis, having climbed from ~8-10% of Canadian productivity in 1981 to about 16% recently, with a clear spike about 2004 (roughly when GBC impacts would be expected). Notable to the study team is that prior to GBC there were large annual swings in BC's share of Canadian productivity; post-GBC the share is much more constant. It is possible that this "smoothing out" of the curve implies a more programmatic genomics focus as opposed to more variable numbers of one-off projects annually prior to creation of Genome BC.

Scientific excellence. Bibliometric analysis shows that the Average of Relative Citations (ARC) for both Canadian and BC researchers has climbed since Genome Canada and Genome BC were formed. However, the ARC for BC researchers has climbed higher (and perhaps slightly faster) than ARC for Canadian genomics researchers in general. By 2011, BC genomics papers were being cited 40-60% more than the average paper world-wide, and notably more often than the average Canadian genomics paper, a very significant finding.

Researchers' capabilities and performance. Genome BC provides extensive support to research teams during the application phase for Genome Canada (and sometimes other) funding support. This usually involves numerous reviews of draft Letters of Intent and full applications by Genome BC staff and

a team of external experts with expertise relevant to each given LOI and/or application. Considerable flexibility and competence are also by key stakeholders in their approaches to doing so.

The study's surveys of researchers found that the highest impacts on researchers' capabilities are related to changing research practices, designing research projects, and identifying and implementing important strategic research topics. This is important as it directly relates to Genome BC's goals of changing how genomics research is planned and conducted to ensure the incorporation of strategic socio-economic goals. This finding strongly suggests that the BC research ecosystem is being influenced. There are lower impacts on the ability to, for example, influence national and international research agendas, not surprising as so many factors come into play there. The influence on GE3LS capabilities has also not been as intense, but is still moderate. In general impacts on researchers' strategic direction and capabilities were greater than impacts related to improvements to researcher's projects, performance of research, and researcher's alliances and networks. Overall, these findings underpin the fact that GBC has had somewhat greater impact on 'core-to-academic' measures, compared to practical, outward-looking, translation measures. (The study team notes that this is a common pattern across other similar research support organizations – improvements to performance rely upon first improving resources and capabilities, and so impacts on the latter are typically stronger. It does, however, point to the continuing importance of Genome BC's attempts to strengthen capabilities, and of communicating this fact to funders.)

For researchers, some of the lowest impacts related to impacts on protecting IP and translating or commercializing research results. This finding is perhaps somewhat surprising, given Genome BC's extensive efforts in this area, but may be related to fact that many Project Leaders are already on the "translation bandwagon", and so there has been somewhat less impact for them.

Industry's capabilities and performance. The survey found that the three highest barriers to company growth were market-related or internal company capabilities: lack of internal knowledge, resources, or capabilities; challenging competitive environment; and lack of access to capital. The first of these is a factor that Genome BC addresses strongly, while access to capital is not quite so actively pursued. Conversely, among the lowest barriers to growth reported by the companies were ones that Genome BC also addresses: lack of access to latest research and top researchers, and lack of access to partner/cooperation networks. This finding suggests that Genome BC has been successful in providing firms with access to these factors.

The five highest impacts of Genome BC on the business performance of companies are on their R&D investments, innovation, time to market, market valuation, and investments received. Conversely, the three lowest impacts were on revenues, employment, and patent applications. These findings are consistent with the early stage development of most practical applications now under development; e.g., many of the firms involved are start-ups, for which ability to obtain investments and decrease time to market are critical challenges. Overall, it appears that Genome BC is meeting a need of companies by enabling improvement to their technical capabilities and technology development, consistent with companies rating 'Lack of access to latest research and top researchers' low in terms of being a barrier to growth. Thus Genome BC appears to be in a strong position to foster translation to a greater degree, while addressing other company barriers to growth, mainly non-technical related support.

Non-profits' capabilities and performance. "Non-profits" here includes both government partners and other non-governmental organizations (NGOs) such as healthcare research organizations. The survey found that two of the highest barriers to success identified by non-profits were market-related or internal organizational capabilities: lack of internal knowledge, resources, or capabilities; and lack of access to capital. Among the lowest barriers to success reported by non-profits (as for companies) is lack of access to latest research and top researchers. And again, as for companies, because these barriers are the ones that Genome BC addresses, this may be an indication that Genome BC is succeeding spectacularly. However, Genome BC would be well-advised to ensure its programs are aligned with the needs of non-

profits. Also of interest is that two of the other four highest barriers to growth were analogous to “time to market” for companies: slow time to achieve practical applications; and regulatory approval. This is a clear indication that the non-profits are likely to be motivated and influential in fostering Genome BC’s translation agenda, including support to companies bringing genomics-based products to the non-profit “market”.

Non-profit survey respondents attributed the greatest average impact to Genome BC on their technical capabilities, research linkages, and practical translation and applications capabilities, but lower impacts on time to translation or application, and exploiting GE3LS knowledge. The former factors are understandable and important, while the last two factors may represent an opportunity for improvement in programming, especially across the wider community.

Focus on important strategic areas. Genome BC conducts numerous activities to identify and support strategic R&D. This first includes extensive consultation with other key organizations in BC and across Canada, including other Genome Centres; universities; and other regional research support organizations such as the BC Cancer Agency, Research Centre, and Michael Smith Centre for Genome Science; the Michael Smith Foundation for Health Research; and the BC Child and Family Research Institute. During support to teams preparing proposals, not just scientific objectives are addressed, but also those related to creating significant socio-economic benefits in areas of strategic importance, including specific mechanisms that are likely to allow these to come to fruition. Most LOIs and full applications go through numerous iterations and refinements to ensure these strategic elements are fully addressed, and (if successful) the Genome BC management teams review both scientific and commercialization or other translation progress against specific milestones and deliverables. Further, Genome BC has either led or participated in creation of Genome Sector Strategies focused on specific genomics-enabled strategic goals and partnerships in the areas of health, energy and mining, the environment, forests and forestry, fisheries and aquaculture, and agriculture. These involve both the research and end-user communities in industry and/or government and Non-profits, as appropriate.

Key stakeholders were almost unanimously very positive in their regard for Genome BC’s actions in bringing `omics to the forefront as a topic of discussion within BC research communities, and a routine and accepted part of research across many sectors. Comments such as “hats off to them”, “their impact has been incredible”, and “a terrific organization” were common. Respondents recognized the fine line that the Corporation must walk in balancing the differing needs of different sectors and actors in the innovation chain. Further, respondents commented that, for the most part Genome BC has struck an excellent balance between support for discovery research and for more applied translational work, and between benefits for the private sector and for the public sector.

Key stakeholders often commented on the importance of the people being brought into their organization and into BC more generally, both in research and in industrial positions. This was usually originally through individuals hired by project funding, but who usually remained long-term in their job positions. Some also mentioned that these individuals are becoming resources for many organizations in the Province, although this aspect may benefit from more explicit attention.

One point here, however, is of interest for future planning: while the opportunities afforded by a revolution in personalized medicine are widely anticipated to be tremendous, several respondents commented that impacts in other sectors – and especially natural resources – could be equally significant, and potentially quicker to bring to fruition.

4. Findings on Collaborations and Leveraging

Collaborations. Genome BC is well regarded by key stakeholders as to how they identify collaborations at both the project and major initiative level, and support their success. Respondents also commented that the Corporation does a good job of going beyond the Lower Mainland in these efforts.

Since 2001, Genome BC has supported a total of 189 Genome Canada and Genome BC projects, involving 532 individual project leaders, co-leaders, and co-applicants across 10 BC research institutions. (This represents an average of 2.8 senior researchers per project.) More recently over the 2010-2015 period (i.e., during the period of the most recent Strategic Plan), Genome BC supported 207 project leaders and 378 co-leaders and co-applicants, for a total of 532 individuals. In addition, over 300 research organizations in at least 26 countries have been involved, at government, university, and industry organizations.

Leveraging. As of March 31, 2015, Genome BC has invested roughly \$713M in R&D and technology development projects, as compared to its direct Genome Canada funding of \$277M.

Further, performance data suggest that an additional ~\$617M has been leveraged by Genome BC scientists. This “additional leveraging” figure is still to be fully validated, but represents follow-on, non-Genome Canada funds that is believed to have been brought into BC for R&D, training, and translation activities subsequent to the Genome BC projects. However, the specific linkages to the earlier work (including attribution and incrementality) are not well known at present, but are expected to be validated by the end of 2015.

5. Findings on GE³LS

Genome BC actions. Genome BC works extensively with project applicants to ensure that relevant GE³LS aspects are identified, addressed, and described within LOIs and full research applications, and manages successful project milestones and deliverables to help ensure these are addressed during the research. The success of BC researchers in winning Genome Canada funding is a strong indicator that the organization is effective in these efforts – most researchers and stakeholders believe that, all other aspects being equal, it is the GE³LS component that is the “make or break” criterion for success in these Competitions.

Integration of GE³LS. Key stakeholders noted that GE³LS is now better integrated than in the past (partly because of the more strategic and applied nature of the projects), and is being done effectively. While stakeholders noted that economic aspects receive far greater attention than other types of GE³LS concerns (e.g., ethical, legal, environmental, and broad societal), there were no concerns voiced over this fact by key stakeholders. (A partial exception is that Genome BC is seen to be putting some increasing focus on various trade and/or regulatory concerns such as trade barriers, international treaty issues, opportunities to use genomics-enabled quality certifications for export opportunities).

Personal observation by a member of the study team demonstrated that these efforts are intensive, well-resourced, and valued by the research teams. However, these observations also suggest that there is still considerable way to go amongst the research community re. fully understanding the importance of addressing GE³LS, and especially of how to effectively translate research findings into practical outcomes. Further, there are some indirect lines of evidence that suggest that the increased focus on using GE³LS research to ensure commercial benefits may be coming at the expense of appropriate “honest broker” attention to potential societal benefits and concerns.

Honest broker role. The interview program found that Genome BC is widely seen as an honest broker with respect to GE³LS issues to the public, government, and academic research teams; although see the comment immediately above.

Impact on GE³LS capabilities of researchers, partners, and non-profits. Genome BC has had a moderate to high impact on the GE³LS capabilities of researchers, and a moderate impact on the GE³LS capabilities of both companies and non-profits. However, neither companies nor, surprisingly, government organizations and non-profits rated their internal GE³LS capabilities very highly in the survey. One key stakeholder commented that it was difficult to find enough top people in the field within BC or even Canada, and going abroad might be welcomed.

Public communication, outreach, and education. The Corporation maintains a very active public communications and outreach function, with staff dedicated to this function. Their activities and outputs are far too many and varied to mention here, but are detailed in the main text.

6. Findings on Socio-Economic Impacts

Programmatic support. Genome BC conducts activities related to development of LOIs and proposals and the project management mechanisms that identify concrete practical applications, and develop teams and mechanisms to help ensure they are developed. This especially happens within Genome Canada programs with translation goals, such as the User Partnership Program (UPP) and the Genomic Applications Partnership Program (GAPP). Genome BC has also itself offered a number of programs to directly support commercial and industrial product and service development in new and/or existing firms.

Economic impact “ripples”. An modified input-output analysis of regional economic impacts found that Genome BC had to date resulted in: (1) Total direct, indirect, and induced outputs of \$1.658B; and (2) Total direct, indirect, and induced GDP impacts of \$1.454B.

Although these figures are based on the ripple effect of investments in the economy, not the success of the R&D, such input-output analyses are very commonly done for R&D programs, research institutions, and Big Science programs, and so provide a useful benchmark for analysis.

Job creation. There are several ways to estimate job creation: (1) The input-output analysis discussed above estimated that about 21,000 FTE jobs were created. These represent the regional job “ripples” through direct spending and indirect re-spending. (2) Another way to estimate FTE jobs is to divide the R&D expenditures for human resources by average estimated wages and salaries. By this measure, Genome BC and its related projects/platforms created 5,930 “direct” FTE jobs – that is, this is how many FTE positions were directly supported through R&D projects. (3) Neither type of metric captures job creation in the sense of new, incremental, long-term, and sustainable jobs in the bioeconomy – e.g., job in start-ups, spin-offs, and expansions of existing firms that will continue into the future even after all project funding ends. It is possible, but challenging, to measure such job creation, but it is not possible to extrapolate such effects from existing data.

Intellectual property (IP). As of March 2015, intellectual property (IP) protection within projects managed by Genome BC has resulted in: 21 licenses; 478 patent applications (including Patent Cooperation Treaty applications, provisional, non-provisional, etc.); and 31 patents issued.

Impacts on firms “advanced”. Through March 2015, Genome BC had “advanced” 33 firms. “Advancing” means provision of a variety of support that includes grants directly related to strategic opportunities and/or commercialization assistance, helping identify and protect IP, assistance in finding investment funding, etc., up to and including support for creating start-ups. According to Genome BC performance data, as of March 31, 2015, these firms:

- Have raised approximately \$200M in private financing and other funds;
- Have secured over \$1B in co-investment deals with major genomics industry partners such as Genentech, Teva Pharmaceuticals and Illumina;
- Offer over 30 products and services;
- Currently have ~359 employees (this is down slightly from recent figures, as some firms have failed or been sold in the meantime); and
- Have unknown total revenues at present.

Possible improvements to generating socio-economic benefits. There is an opportunity for Genome BC to more rigorously screen potential projects for their likely success at generating socio-economic impacts, and more proactively search for translation opportunities where they have not yet done so. This would be instead of relying so heavily on their current willingness to “never say no” to research teams, in the hope of spreading the message as widely as possible to the academic community as to the need for practical commercialization and translation, and to the industry, government, and Non-profit community as to the potential benefits of genomics approaches.

Within this, more focus on natural resource targets could pay large dividends; some of these would be in the form of revenues, but likely more would be in the form of cost savings and increased sustainability.

Other possibilities include bringing a world-renowned Champion to BC, and to add more sector-specific content expertise to its business development staff.

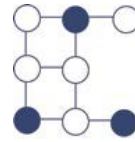
7. Conclusions

Achievements to date. These findings indicate strong performance by Genome BC on all fronts: fostering excellent science in areas of strategic importance for BC and Canada, leveraging significant non-Genome Canada funding, integrating GE3LS into genomics research, and providing a rich environment in which socio-economic benefits can be created. Although it is too early for many concrete practical impacts to have come to fruition – much less to estimate impacts to “the bottom line” – many firms, government organizations, and Non-profits are working actively to this end. Especially important are the findings showing that Genome BC fosters significant improvements to the underlying resources and capabilities of its academic, industry, government, and non-profit communities – these capabilities are critical precursors to the innovation process.

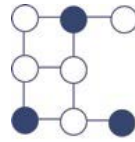
The Corporation has highly regarded programs and staff, and is considered to be creative, proactive, and highly flexible in responding to opportunities. It has carved out a valuable niche in fostering the best proposals, teams, and collaborations appropriate to individual research topics, and has not neglected either researchers or research topics of importance outside the Lower Mainland or those that require cross-disciplinary or cross-sectoral approaches. Its goal of attempting to strike a fine balance between creating private vs. public good socio-economic impacts is appreciated by the community, even if this balance may need some refinement in future (see below).

Implications for the future. These results suggest one possible significant realignment of Genome BC’s strategy, plus a number of more modest changes:

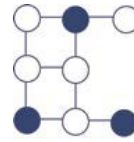
- The most significant change implied here is to adopt a more rigorous – perhaps even more ruthless – approach to project support, only fostering projects and major initiatives that have a strong chance of both scientific and commercial/translation success, brought forward by teams that are already very strong in all required elements: science, GE3LS, commercialization, societal translation. This would be a significant shift from the current “Never say no” approach.
- Ensure all sectors identified by Genome BC in its strategic plan are targeted for support, broadening program emphasis, which has been primarily been directed towards healthcare and forestry. Recognizing that while the benefits of personalized medicine will undoubtedly be huge, they are still a very long ways off, while cost savings and increased sustainability in other sectors could be made more immediately.
- Increase programs and actions offering “people support”, including fostering knock-on impacts from the mobility of highly talented people.
- Simplify the current confusing and ever-changing program architecture and requirements



- Develop better metrics and measurement techniques to measure both commercial and non-commercial impacts.
- Deliberately foster improvements to the GE³LS capabilities of government and Non-profits.
- Reduce red tape in the application, monitoring, financial accountability, and reporting processes.
- Ensure that there are no hidden GE³LS problems related to over-emphasis of this component on commercialization and/or translation, vs. ethical honest broker investigation of potential societal concerns, or related to lack of emphasis on generating non-commercial but important societal benefits.



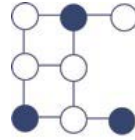
1 INTRODUCTION



1 INTRODUCTION

1.1 THE STUDY

The intent of this evaluation study was to provide an independent review of the achievements of Genome BC against its goals, as required under Genome BC's by-laws and its Funding Agreement with Genome Canada (GC). Specifically, the study team investigated Genome BC's achievements against its formal objectives as set out in its by-laws and most recent 2010-2015 Strategic Plan, reviewed its progress vis-à-vis recommendations from the most recent (2009) evaluation, and developed recommendations for the future, with special emphasis on Genome BC's capacity to make progress against the current draft of its 2015-2020 Strategic Plan.



2 STUDY METHODOLOGIES

2 STUDY ISSUES AND METHODOLOGIES

2.1 STUDY ISSUES

The Genome BC By-laws lay out the types of retrospective evaluation issues that should be addressed every five years. The By-Laws state that evaluation should focus on Genome BC's scientific operations and accomplishments and the socio-economic benefits (SEBs) to BC and Canada, but also including efforts related to GE³LS, public communications and outreach, commercialization and corporate development. Second, the By-Laws note that evaluations should take into account the Corporation's strategic plans, implying that its most recent Strategic Plan, that of 2010-2015, should be another basis for formulating retrospective evaluation issues.

The evaluation issues for this study were therefore cast as a combination of formal goals found in the By-Laws and explicit goals found in the Strategic Plan:

Strategic Research:

1. To what extent has Genome BC succeeded in fostering excellent genomics science?
2. To what extent is this science in areas of strategic importance for BC and Canada?
3. To what extent has Genome BC improved BC's "life sciences brand", nationally and internationally?
4. To what extent Genome BC fostered multidisciplinary science, e.g., wherein genomics is integrated with traditional biology, nanotechnology, and information technology?

Leveraging:

5. To what extent has Genome BC attracted investment funding from national and international organizations, e.g., through research investment partnerships?

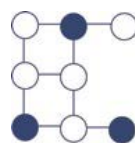
GE³LS:

6. To what extent does Genome foster integration of GE³LS concerns in Genome Canada and/or GBC projects, and what impacts have resulted?
7. To what extent do public communications, outreach, and specialized education efforts¹ succeed in explaining genomics and GE³LS issues, opportunities, potential concerns, and mitigating strategies (i.e., acting as "honest broker re. social license)?

Socio-economic benefits (SEBs):

8. To what extent has Genome BC fostered practical development of commercial and industrial SEBs?

¹ For example, to industry decision-makers and government regulators and physicians, medical students and nurses, and healthcare administrators.



2.2 OVERVIEW OF METHODOLOGIES

There were two major study components. One component mainly focused on the retrospective analysis of achievements against Genome BC's formal goals, while a second component involved analysis of retrospective achievements related to development of core capabilities, as well as factors that will influence prospective thinking such as how these improvements to capabilities then translate (or not) to improvements in performance; e.g., how have improvements to researchers' capabilities in areas such as ability to engage in new research practices or ability to identify strategically relevant research, lead to improvements in performance such as changes to publication records, patenting, or receipt of awards? (Much more detail is presented in the Findings sections.) Work conducted during the study's Design Phase showed that a significant amount of information already existed relevant to the retrospective analysis, including recent summary reports on achievements prepared for other purposes, which could be leveraged for the current study and thus allowed more detailed information to be collected within the more prospective component.

| Data source | Mainly retrospective | Both retrospective and prospective |
|---|----------------------|------------------------------------|
| Data from Genome BC performance metrics, and from recent roll-up reports on performance | ✓ | |
| BC-specific bibliometric data from recent evaluation of Genome Canada | ✓ | |
| Interviews of key stakeholders | ✓ | ✓ |
| Surveys of Genome BC researchers | ✓ | ✓ |
| Surveys of companies involved with Genome BC | ✓ | ✓ |
| Surveys of Non-profits involved with Genome BC | ✓ | ✓ |

2.3 DATA FROM GENOME BC PERFORMANCE METRICS AND RECENT PERFORMANCE REPORTS

Recent roll-up reports on Genome BC achievements were reviewed, mainly:

- The recent impacts report prepared by Genome BC for the BC Ministry of Technology, Innovation and Citizens' Services.² This report provided considerable detail on scientific and SEB achievements, as well as more limited information on performance in developing collaborations, training of highly qualified personnel (HQP), and job creation, derived from Genome BC's extensive performance measurement system.

² Genome BC, January 31, 2014. *Research Impacts Genome British Columbia*.

- The 2014 Science-Metrix evaluation of Genome Canada³ included bibliometric analyses of Genome Canada-funded researchers. Genome BC separately requested customized analyses from Science-Metrix for BC researchers alone, from which selected information was relevant to the current study. (It was not possible to obtain BC-specific data for the stakeholder and researcher surveys that were conducted; the ability to provide regional findings back to the Centres might be considered by Genome Canada for future studies.)
- The independent economic impacts study⁴ conducted in 2014, which used input-output methods to assess Genome BC's direct, indirect, and induced economic impacts on the BC economy, including impacts associated with additional investments brought to BC by Genome BC-supported research projects.

A detailed matrix was developed to assess where the data in these sources were reasonably comprehensive vis-à-vis the evaluation issues, vs. areas where additional information was required. This matrix is provided in Appendix A. Where the existing data solidly reflected evaluation issues, they were updated where possible according to the latest performance data collected by Genome BC; i.e., as of April 2015. However, the assessment showed that existing reports are least informative related to GE³LS, "people factors" such as attraction and retention, interdisciplinarity, province-wide effects (e.g., BC's "life sciences province" reputation), and collaborations. These factors were therefore explicitly discussed in the interview program with key stakeholders addressed in section 2.5.

2.4 BC-SPECIFIC BIBLIOMETRIC DATA FROM THE 2014 GENOME CANADA EVALUATION

BC-specific bibliometric data were provided over the period 1981-2011 for analyses such as

- Trends over time in genomics publications from BC and Canadian researchers, as absolute numbers and as share of world output;
- Trends over time in the specialization index (SI)⁵ of British Columbia and Canada in Genomics papers;
- Trends over time in the Average of Relative Citations (ARC)⁶ of British Columbia and Canada in Genomics papers;
- Data showing SI and ARC for genomics publications in each Canadian province, prior to the creation of Genome Canada and Genome BC (1996-2003) and following their creation (2004-2011)

³ Science-Metrix, December 20, 2013. [Revised February 2014]. *Genome Canada Five Year Evaluation Technical Report – Bibliometrics and collaboration network analysis*.

⁴ MNP LLP, March, 2014. *Genome BC Economic and Social Impact Analysis FINAL REPORT*.

⁵ SI is a measure of relative focus of publications in a particular field, compared to the world average. If SI > 1.0, then the share of publications in genomics, compared to the total publications in all fields, is higher than the world average.

⁶ ARC is a measure of how important a given journal publication is, as indicated by how often it is cited. An ARC > 1.0 for a defined set of publications means these publications are cited more often than the publications in that field world-wide.

2.5 INTERVIEWS WITH KEY STAKEHOLDERS

A total of 54 individuals were nominated as potential respondents in the interview program. These represented leaders with the academic, government, and Non-profit communities who were highly familiar with Genome BC either through participation in strategic analysis (e.g., on the Genome BC Board, or through major collaborations), or through participation in individual research projects (either as part of the research team, or as end-users, or usually both). A total of 36 people were selected for the interview program, mainly on the basis of representing an external viewpoint of Genome BC, rather than (for example) the perspective of university researchers who have been involved in Genome BC and/or Genome Canada research projects. (Such researchers were surveyed in the activity discussed in section 2.6.) A total of 26 of these individuals were interviewed, using the interview guide found in Appendix B. Only two individuals declined to participate in the interviews because of other commitments; the others could not be reached.

A list of interview respondents is found in Appendix C.

2.6 TEN/DRA SURVEYS

2.6.1 SURVEY DESIGN

The Evidence Network (TEN) has successfully and widely employed a similar survey instrument for analysis of capability improvements for researchers and industry resulting from the actions of S&T support organizations such as Genome BC. These surveys first separately address:

- The degree to which stakeholders have engaged with GBC, its programs, or managed projects, since TEN's previous work has identified this factor as of having considerable influence on impacts.
- The impact GBC has in improving the capabilities of stakeholders. This is the most critical section of the survey because, in the case of GBC stakeholders, the impacts on company, researcher, health system or other non-commercial impacts" performance take a long time to occur. Thus, having precursors or proxies to longer term impacts are critical to identifying Genome BC's possible impact on capabilities – if there are no precursors, it is very unlikely that there will be actual impacts.
- Longer-term improvements to performance that are attributed to GBC, asked in two parts:
 - The first part of each question identified the change in performance of the stakeholder or organization since engaging with GBC; and
 - The second part of the question identified the impact of GBC in creating that change, thus identifying the "treatment effect" of GBC on the stakeholders that have worked with it.

This instrument was customized to the current study by TEN and Dennis Rank and Associates (DRA) in several ways:

- Separate instruments were developed for the differing types of capabilities likely to be important to three key groups: academic researchers, industry end-users, and government and other Non-

profits.⁷ This was done using separate working logic models for each of these groups. The logic models then served to identify survey questions that were consistent with the overall operations or services provided by GBC, and the impact expected as a consequence of GBC's work with each stakeholder group.

- This type of survey had not previously been used for Non-profits. However, a review of the logic and of Genome BC activities with Non-profits showed that relevant Non-profit capabilities for the most part mirrored similar capabilities for industry, and appropriate questions and examples could be developed.
- Nor had this type of survey previously been applied to S&T support organizations that have any type of GE³LS mandate.⁸ Unique questions were developed for this aspect:
 - As for the other “capability” questions, we separately asked about the impact of Genome BC on various explicit types of GE³LS capability that might be relevant to each respondent group, and separately asked about the impact of Genome BC on the respondent's ability to exploit this capability for practical ends.
 - For analytic purposes, we also asked respondents to rate themselves in terms of how sophisticated their organizations were in terms of ability to exploit GE³LS knowledge.
- For researchers and companies, we asked about how the GE³LS components helped them do their research, and/or helped them apply the results in practical ways;
- For all stakeholders (but mainly external ones), we asked to what extent Genome BC provided capabilities and innovations related to creating non-commercial socio-economic benefits related to GE³LS, such as those in healthcare, the environment, regulatory regimes, etc., including its “honest broker” role.

⁷ Non-profits” other than government organizations include, for example disease-specific research and patient support organizations, international innovation support organizations, and industry advocacy groups.) Throughout the text we use “Non-profit” to include government organizations when discussing survey results, as they were not separated out in the analysis. Where quotes from respondents are provided, however, we note if they were from government organizations.

⁸ By “S&T support organization” we mean so-called “fourth pillar” organizations that do not conduct research themselves, but provide linkages among academic, industrial, and government and other non-profit end-users, as well as (in some cases) linkages to R&D funding opportunities, and (as for Genome BC) various kinds of management, oversight, and translation functions. Thus their primary roles are as a facilitator of strategic collaborations, a hub for research interactions, and a mechanism to ensure the most efficient and effective practical translation.



2.6.2 SURVEY RESPONSE RATES

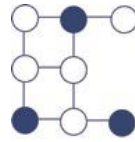
Exhibit 2.1 shows the response rates for researcher, industry, and Non-profit communities, as well as the average time for respondents to complete each survey.

Exhibit 2.1 – Survey response rates

| Target Groups Surveyed | Number of Respondents | Response Rate (%) | Average Time to Complete (min) |
|------------------------|-----------------------|-------------------|--------------------------------|
| Researchers | 207 | 41 | 10 |
| Companies | 23 | 61 | 15 |
| NGOs | 44 | 46 | 14 |

2.6.3 ANALYSIS OF OPEN-ENDED COMMENTS

Content analysis was done of a sample of open-ended comments made in these surveys. These comments were on a very wide variety of topics, but this analysis showed that positive comments outnumbered negative comments by about five to one, and very positive comments outweighed very negative comments by about 18 to one.



3 FINDINGS ON SUPPORT FOR STRATEGIC RESEARCH

3 FINDINGS ON SUPPORT FOR STRATEGIC RESEARCH

3.1 FOSTERING EXCELLENT GENOMICS SCIENCE

Data on the excellence of Genome BC-fostered science⁹ come mainly from three sources: specific actions taken by Genome BC to support excellence science in important strategic areas, the Genome BC performance measurement system, and bibliometric analysis. Several key stakeholders also commented on this point. All data sources show strong performance.

3.1.1 PRODUCTIVITY

From its inception through April of 2015, GBC scientists have contributed to 1,602 journal publications, 4,462 presentations, and 124 other types of publications (e.g., books, chapters, and conference proceedings). Over 30 publications have been cited 100 or more times, and over 60 publications have been made in top journals such as Nature, the Journal of Biological Chemistry and the New England Journal of Medicine. BC has had over 30% of Genome Canada-supported research publications.

Genome BC actions. Some of this success rests upon the extensive support that Genome BC provides to research teams during the application phase for Genome Canada (and sometimes other) funding support. This support usually involves numerous reviews of draft Letters of Intent and full applications by Genome BC staff and a team of external experts with expertise relevant to each given LOI and/or application. Considerable flexibility and competence are also seen amongst the staff in their approaches to doing so.

GBC takes a great interest in helping their talented researchers to be successful, putting a lot of resources behind them. And [key staff member] really pushes people in a good way, and has helped us and other researchers to improve their proposals. This attracts a disproportionate amount of funding to BC. I have great respect for this, and for [their] leadership and having the end goal of commercialization in mind, and driving the researchers. – Company

When GBC caught wind of [his initiative], they contacted me to find out more about it, and asked if they could help with some funding. I was impressed that they did their homework and knew about the [proposal ahead of time]. –Non-profit

GBC is of course instrumental for projects that are in their early stages of development. In the past 10 years they have benefitted from their strategic funding of so-to-speak “crazy” ideas that were turned down by GC and NIH, but were ultimately extremely successful. This was through recognizing the high opportunities, not necessarily through being less risk-averse. - Academic/Non-profit

By and large GBC has been very strong, identifying the right people, and working with them to move things along. So as an organization they’ve been very successful. When an idea is brought forward, they push it along a bit and achieve success. They bring experts along to assist in this.

⁹ In this report we explicitly *include* the social sciences and humanities (SSH) under “science”. In our experience, however, many researchers and stakeholders (including those in SSH fields) take “science” to mean things like genomics, biomedical investigation, and bioinformatics; i.e., *excluding* the SSH fields. This bias may occasionally show in the quotes provided, and we have not attempted to refine the respondents’ language.

Increasingly they've engaged more strategically across the province, bringing in government and researchers. - Academic

Of note is that the experts address all of Genome Canada's goals for a given Competition; e.g., not just scientific objectives, but also those related to creating significant socio-economic benefits in areas of strategic importance, including specific mechanisms that are likely to allow these to come to fruition. Most LOIs and full applications go through numerous iterations and refinements to ensure the strategic elements are fully addressed, and (if successful) the Genome BC management teams review both scientific and commercialization or other translation progress against specific milestones and deliverables. Similar actions are taken for programs offered by Genome BC independent of Genome Canada competitions, and the bulk of these programs are strategic or translational in focus. Finally, other important strategic initiatives with genomic components are assisted during their formative stages; e.g., the business plan for the iTarget Autism initiative associated with the Pacific Autism Family Center (PAFC), even if they do not directly depend on Genome Canada or Genome BC programmatic support.

It's a funny organization in that they're a group of high achieving scientists, yet they are practical and sensible, and truly get things done in an efficient and effective way. I have great respect for senior management and the scientists at Genome BC. They aren't just well intentioned, they actually execute what they intend. I interact with Boards all the time, and can honestly say that these guys have astonishing capabilities. – Company

The programs have been compelling, and the Genome BC staff have been very helpful in proposal development; plus it was iterative as the proposal evolved. A real back-and forth, clarifications, etc. In a constructive way, not a tedious one. A fairly unique experience in his experience. – Academic

First, let me say I'm tremendously grateful for Genome BC's support - your investments have made it possible for us to do fantastic things, and the non-financial support you offer, particularly around getting a proposal into the best possible shape, is something that's propagated across all aspects of my research life, not just those funded by Genome BC. – Researcher.

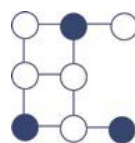
The only complaints made in this arena were that sometimes there was perhaps too much feedback, involving a lot of last minute changes and revisions, and occasional overly rigid approaches to project development.

You've done the nurturing, it's up to the team to deliver the baby. – Academic

They've been a reasonably good collaborator. . . . but they can be somewhat rigid in how they deal with [things like providing operating funds to organizations which have none of their own, or deciding on a research agenda in advance of the leaders agreeing]. We had to work somewhat harder than expected, but in the end they delivered in spades. – Non-profit

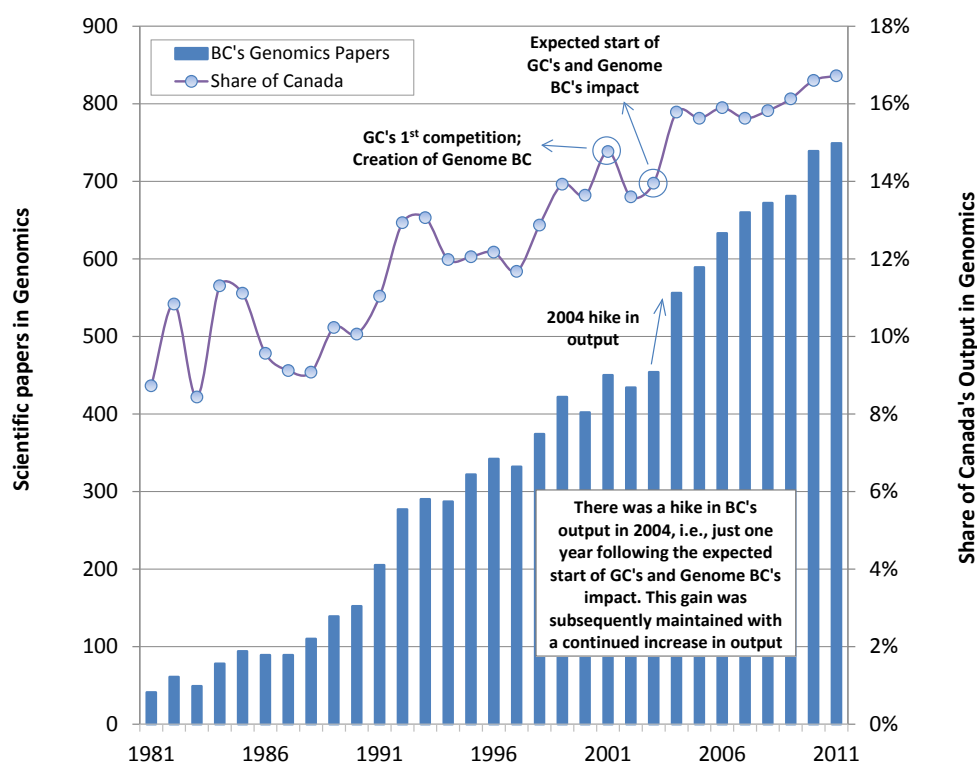
Bibliometric data. BC-specific bibliometric analyses¹⁰ were conducted recently by Science-Metrix, under contract to Genome BC. The analysis was based on a variety of scenarios, with different assumptions about how Canada's scientific productivity would have grown with vs. without Genome Canada support, and with some analyses of the time prior to Genome Canada's creation, vs. afterwards. These findings suggest that Genome Canada and Genome BC had a significant effect on the number and quality of genomics publications (as measured by ARC), but not directly on interest in doing such research (as measured by SI). Some excerpts from these analyses are discussed here. Bibliometric analysis shows

¹⁰ Although SSH fields were not specifically mentioned in this customized analysis, the original analysis done for Genome Canada did include SSH fields through reference to relevant Thomson Reuters' Web of Science databases: the *Social Sciences Citation Index*TM, and the *Arts & Humanities Citation Index*TM



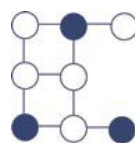
that Canada's share of the world output in genomics-related publications slowly climbed from ~4% in 1981 to ~4.5-5.0% recently. Within this, Exhibit 3.1 shows that BC's production has nearly doubled on a proportional basis, having climbed from ~8-10% of Canadian productivity in 1981 to about 16% recently, with a clear spike about 2004 (roughly when GBC impacts would be expected¹¹). Notable to the study team is that prior to GBC there were large annual swings in BC's share of Canadian productivity; post-GBC the share is much more constant. It is possible that this "smoothing out" of the curve implies a more programmatic genomics focus as opposed to more variable numbers of one-off projects annually prior to creation of Genome BC.

Exhibit 3.1 – Canadian and BC publications in genomics



Source: Science-Metrix analysis for Genome BC

¹¹ Genome Canada's first Competition was in 2001.

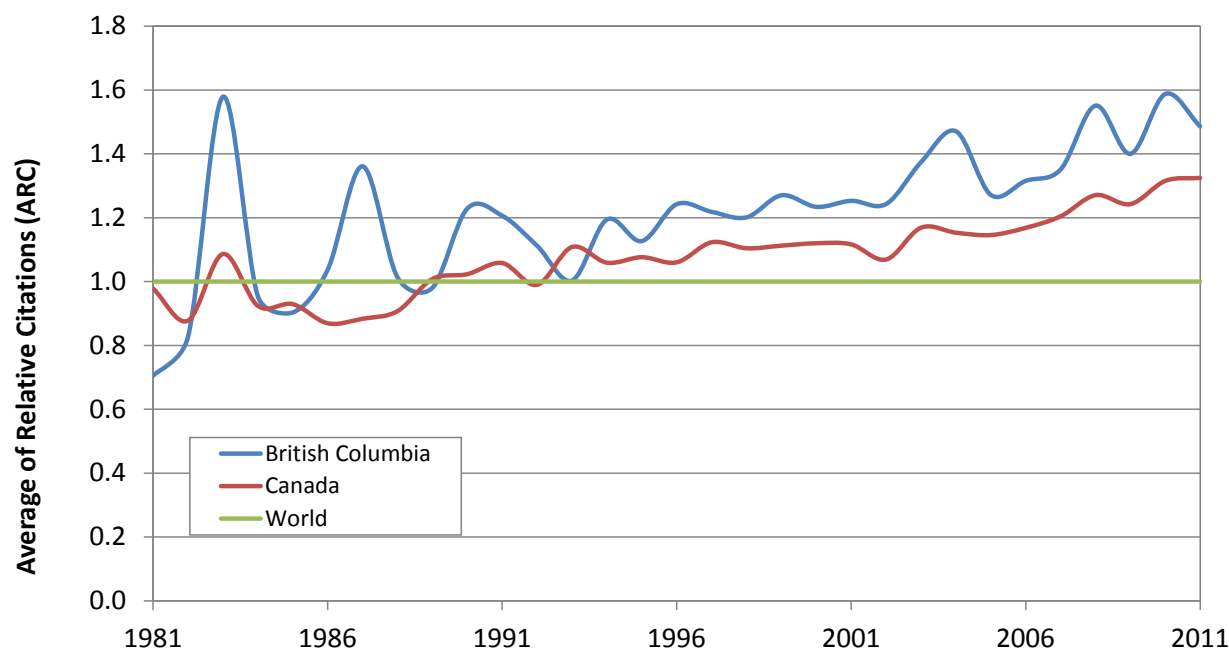


3.1.2 EXCELLENCE

Success in national competitions. Genome BC scientists have significantly exceeded what might reasonably be expected on the basis of per capita contributions: BC has won 28% of Genome Canada project funding and 38% of Genome Canada platform funding, while having only 13% of Canada's population.

Bibliometric data. The Science-Metrix analysis conducted for Genome BC shows that the Average of Relative Citations (ARC) for both Canadian and BC researchers has climbed since Genome Canada and Genome BC were formed. However, the ARC for BC researchers has climbed higher (and perhaps slightly faster) than ARC for Canadian genomics researchers in general, as can be seen in Exhibit 3.2. By 2011, BC genomics papers were being cited 40-60% more than the average paper world-wide, and notably more often than the average Canadian genomics paper, a very significant finding.

Exhibit 3.2 – Average of Relative Citations for Canadian and BC genomics publications



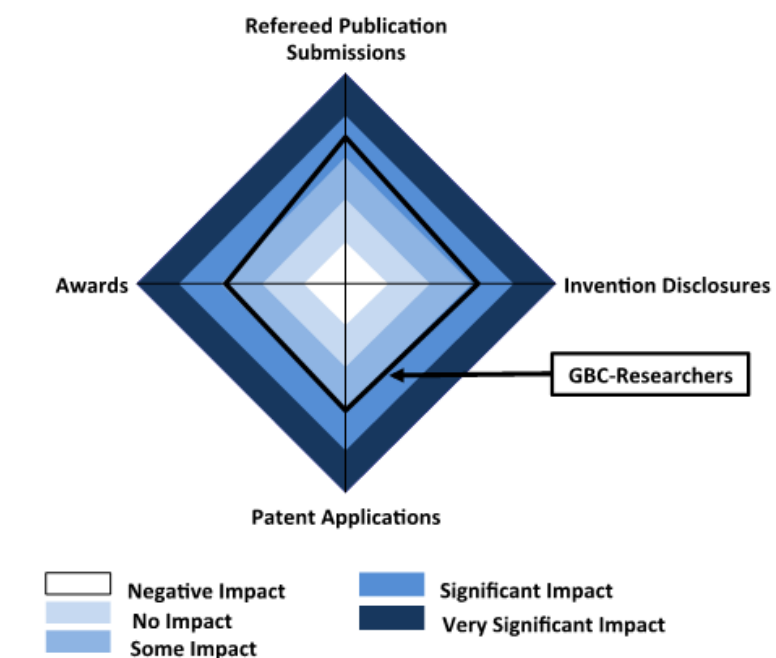
Source: Science-Metrix analysis for Genome BC

3.1.3 IMPACTS ON THE CAPABILITIES AND PERFORMANCE OF RESEARCHERS

The TEN/DRA survey specifically investigated how Genome BC has affected the capabilities of researchers, industry, and Non-profits. Details are found separately in the report on strategic implications¹², while in sections 3.2.3, 3.2.4, and 3.2.5 we note highlights.

Impact on research performance. Exhibit 3.3 shows survey results related to Genome BC's impacts on research performance measures. Reading clockwise, the average impacts range from the middle of the 'significant impact' range for refereed publication submissions to the high end of the 'some impact' range for the Invention disclosures, Patent applications, and Awards measures.

Exhibit 3.3 – Average Impact of Genome BC on Research Performance



Impact on resources and capabilities – strategic directions. Reading clockwise in Exhibit 3.4, the highest impacts on researchers' capabilities are related to changing research practices, designing research projects, and identifying and implementing important strategic research topics.

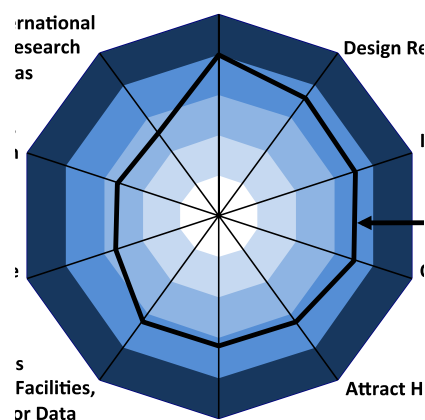
- This is important as it directly relates to Genome BC's goals of changing how genomics research is planned and conducted to ensure the incorporation of strategic socio-economic goals. This finding strongly suggests that the BC research ecosystem is being influenced.

¹² Dennis Rank and Associates and The Evidence Network, May 20, 2015. *Op cit*, has summary findings, while the Companion reports show details for researchers, industry, and Non-profits.



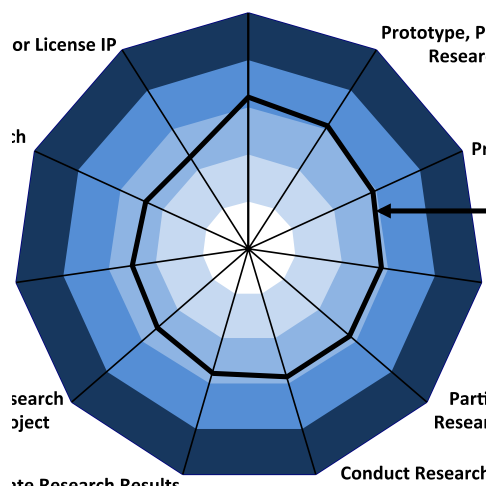
- There are lower impacts on the ability to, for example, influence national and international research agendas, not surprising as so many factors come into play there. The influence on GE³LS capabilities has also not been as intense, but is still moderate.

Exhibit 3.4— Average Impact of Genome BC on Researchers' Strategic Direction Resources and Capabilities



Impact on resources and capabilities – project performance. Exhibit 3.5 shows survey results related to project performance. Again reading clockwise from the highest impacts at the top, these range from the low end of the 'significant impact' rating on the ability to participate in national research networks or projects, down to modest impacts on the ability to identify, protect, or license IP, although there is no clear pattern to the distribution.

Exhibit 3.5 – Average Impact of Genome BC on Researchers’ Project and Research Performance Resources and Capabilities



Note that five of the 10 measures of impact on researchers’ strategic direction and capabilities seen in Exhibit 3.3 were greater than all eleven metrics related to improvements to researcher’s projects, performance of research, and researcher’s alliances and networks, as seen in Exhibit 3.4. Overall, these findings (shown in detail separately in the Researcher Companion Report) underpin the fact that GBC has had somewhat greater impact on ‘core-to-academic’ measures, compared to practical, outward-looking, translation measures.

- The study team notes that this is a common pattern across other similar research support organizations – improvements to performance rely upon first improving resources and capabilities, and so impacts on the latter are typically stronger. It does, however, point to the continuing importance of Genome BC’s attempts to strengthen capabilities, and of communicating this fact to funders.

In Exhibit 3.4 some of the three lowest impacts were related to impacts on protecting IP and translating or commercializing research results.

- This finding is perhaps somewhat surprising, given Genome BC’s extensive efforts in this area. It may be related to fact that many Project Leaders (in the experience of Rank of our study team) are already very active in translation, and so there has been somewhat less impact for them.

Engagement of researchers with Genome BC. Researchers can interact with Genome BC in one or many different ways, ranging from simple management of project funds to extensive liaison around project strategy, design, execution, and translation. Of considerable interest is that analysis of the survey results shows that increased engagement leads to higher impacts:

- Researchers receiving both financial and non-financial support from GBC report greater impact of GBC than researchers receiving only financial or non-financial support;
- The impact attributed by researchers to GBC increases with increasing financial support;
- There is a trend for researchers who used non-financial support or platform facilities to a greater degree to report greater impact; and
- While average impacts attributed to Genome BC or Genome BC/Genome Canada Programs show considerable variability, we found that researchers who accessed Genome BC programs attributed greater impact to Genome BC than those who accessed Genome Canada programs through Genome BC – this may again point to the importance of close liaison, including face-to-face interactions.

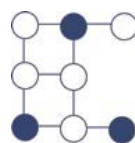
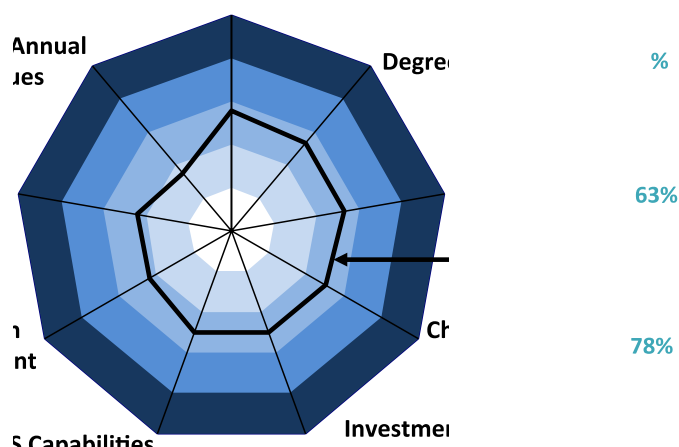
Overall, these findings point to Genome BC having a strong and incremental impact on capabilities and performance.

3.1.4 IMPACTS ON THE CAPABILITIES AND PERFORMANCE OF INDUSTRY

Main barriers to growth facing companies. As context for this section, if Genome BC is not addressing important barriers to commercial growth, then its programming is unlikely to well serve this sector.

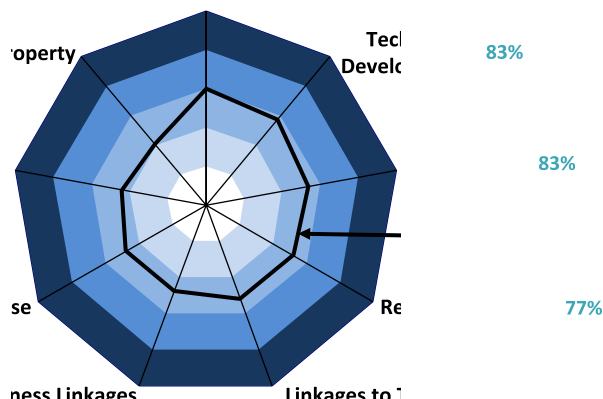
- The survey found that the three highest barriers to company growth were market-related or internal company capabilities: lack of internal knowledge, resources, or capabilities; challenging competitive environment; and lack of access to capital. The first of these is a factor that Genome BC addresses strongly, while access to capital is not quite so actively pursued (while implicit in parts of how Genome BC attempts to help “advance” start-ups).
- Conversely, among the lowest barriers to growth reported by the companies were ones that Genome BC also addresses: lack of access to latest research and top researchers, and lack of access to partner/cooperation networks. This finding suggests that Genome BC has been successful in providing firms with access to these factors.

Impact on company performance. Exhibit 3.6 shows that the five highest impacts of Genome BC on the business performance of companies are on their R&D investments, innovation, time to market, market valuation, and investments received. Conversely, the three lowest impacts were on revenues, employment, and patent applications. These findings are consistent with the early stage development of most practical applications now under development; e.g., many of the firms involved are start-ups, for which ability to obtain investments and decrease time to market are critical challenges.


Exhibit 3.6 – Average Impact of Genome BC on Company Performance


Impact on company resources and capabilities. Genome BC achieves the impacts on company performance described above by helping to improve companies' resources and capabilities through its various support services, platform facilities, and programs available to companies. The impacts on respondent companies are shown in Exhibit 3.7, and show that technical capabilities are rated the highest, but linkages to researchers, talent, and businesses also rate moderately high. Not surprisingly, companies' capabilities around IP have not been affected much, as the study team assumes most are already quite familiar with IP complexities.

- It appears that Genome BC is meeting a need of companies by enabling improvement to their technical capabilities and technology development, consistent with companies rating 'Lack of access to latest research and top researchers' low in terms of being a barrier to growth.
- Thus Genome BC appears to be in a strong position to foster translation to a greater degree, while addressing other company barriers to growth, mainly non-technical related support.
- Of interest is that promotion opportunities for companies to improve their visibility or business opportunities are rated reasonably high, and may point to the potential for more "seal of approval" or "BC Branding" activities.

Exhibit 3.7 – Average Impact of Genome BC on Companies' Resources and Capabilities


Engagement of companies with Genome BC. The surveys found that few companies used the Genome BC non-financial support initiatives (e.g., partnership or networking, proposal development, business or commercialization advice), or Genome BC's platform facilities. However, companies that did use such non-financial support services with greater intensity reported greater average impact on improvements to their resources and capabilities, as well as on improvements to their company performance.

- This points both to Genome BC's success in meeting company needs, and potential opportunities for higher engagement in future.

3.1.5 IMPACTS ON THE CAPABILITIES AND PERFORMANCE OF NON-PROFITS

Main barriers to success facing non-profits. As for companies, ideally Genome BC would address significant barriers facing Non-profits in achieving their mission and goals through innovation. The survey found that:

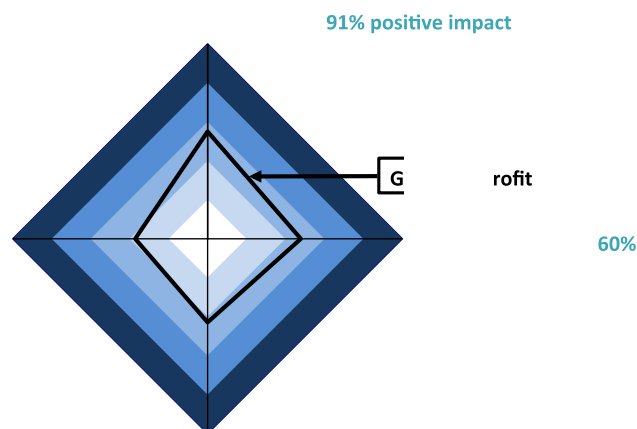
- Two of the highest barriers to success identified by non-profits were market-related or internal organizational capabilities: lack of internal knowledge, resources, or capabilities; and lack of access to capital;
- Among the lowest barriers to growth reported by non-profits (as for companies) is lack of access to latest research and top researchers. And again, as for companies, because these barriers are the ones that Genome BC addresses, this may be an indication that Genome BC is succeeding spectacularly.

However, Genome BC would be well-advised to ensure its programs are aligned with the needs of non-profits.

- Also of interest is that two of the other four highest barriers to growth were analogous to “time to market” for companies: slow time to achieve practical applications; and regulatory approval. This is a clear indication that the non-profits are likely to be motivated and influential in fostering Genome BC’s translation agenda, including support to companies bringing genomics-based products to the non-profit “market”.

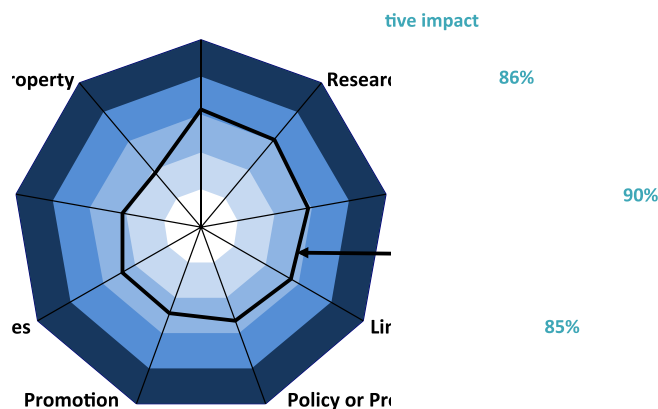
Impact on non-profit organizational performance. As seen in Exhibit 3.8, Genome BC’s highest impacts on the performance of non-profits are on their innovation and R&D investments, while the two lowest impacts were on time to translation or application, and exploiting GE³LS knowledge. The first two factors are understandable and important, while the last two factors may represent an opportunity for improvement in programming.

Exhibit 3.8 – Average Impact of Genome BC on non-profit Organizational Performance



Impact on non-profit resources and capabilities. Exhibit 3.9 shows that non-profit survey respondents attributed the greatest average impact to Genome BC on their technical capabilities, research linkages, and practical translation and applications capabilities.

Exhibit 3.9 - Average Impact of Genome BC on Non-Profit Organizations' Resources and Capabilities



Thus it appears that Genome BC is meeting a need of non-profits by enabling improvement to their technical capabilities, which is consistent with non-profits rating 'Lack of access to latest research and top researchers' low in terms of being a barrier to growth. As well, with relatively high impacts on non-profit's research linkages, Genome BC is playing an important role in making sure genomics advances are available for the benefit of non-profits' members and the wider community.

Engagement of non-profits with Genome BC. The results here are similar to those for companies. Non-profits that used the Genome BC non-financial support services (e.g., partnership or networking, proposal development, application and translation advice) with greater intensity attributed greater average impact on improvements to their resources and capabilities, as well as on improvements to their company performance. Further, non-profits that used Genome BC and Genome Canada programs with greater intensity attributed greater average impact on improvements to their resources and capabilities, as well as on improvements to their organizational performance.

- This again points both to Genome BC's success in meeting non-profit needs, and potential opportunities for higher engagement in future.

3.2 ADDRESSING AREAS OF STRATEGIC IMPORTANCE FOR BC AND CANADA

To what extent is this research in areas of strategic importance to BC and Canada? There are several lines of evidence: actions taken by Genome BC, data from the key stakeholder interviews, the survey data, and (a more minor source) bibliometric analysis. All indicate that Genome BC has a strong focus on

identifying and supporting important strategic research, although these data also suggest some refinements in focus for the future may be required.

3.2.1 SUPPORT FOR IMPORTANT STRATEGIC R&D IN BC

Data from program review and key stakeholders. The organization conducts numerous activities to identify and support strategic R&D. This first includes extensive consultation with other key organizations in BC and across Canada, including other Genome Centres; universities; and other regional research support organizations such as the BC Cancer Agency, Research Centre, and Michael Smith Centre for Genome Science; the Michael Smith Foundation for Health Research; and the BC Child and Family Research Institute.

Straight up: YES. Genome BC has been a huge champion to get various sector groups aware of -omics applications. They are strong supporters of the -omics approach. – Government

This has been a really important role for Genome BC, they're huge if we look at their role in the past 10 years relative to the research of Canada and the world. So they're earned their accolades. – Academic

It's clear that genomics has transformed medicine. Genome BC has been the institutional mechanisms to assist the research community and healthcare community to begin to introduce genomics into healthcare service delivery. Without them, BC would be much farther behind. BC is now a leader in Canada, if not internationally. – Non-profit

Genome BC has been a major change agent for life science research in BC and Canada. Personally, GBC has also enabled me to become involved in genomics research at a level that would otherwise have been impossible. In addition, the experience of working with GBC/GC provided a wealth of learning opportunities and opened doors to research directions that I had never envisioned before. I am very grateful for all of this, as are my trainees. - Researcher

Second, Genome BC has either led or participated in creation of Genome Sector Strategies focused on specific genomics-enabled strategic goals and partnerships in the areas of health, energy and mining, the environment, forests and forestry, fisheries and aquaculture, and agriculture. These involve both the research and end-user communities in industry and/or government and Non-profits, as appropriate. And as noted earlier, the organization explicitly identifies and helps refine commercial and non-commercial translation targets within individual research applications to Genome Canada and other funding sources.

In general Genome BC is seen by key stakeholders as doing a very good job in addressing the needs of different sectors, identifying and supporting important research themes.

As an organization, hats off to them. They have to wear many hats to cover all the ground. – Government

Their impact has been incredible. . . They've done a number of things very well, a re-birth of genomics in BC after the nation had more or less pulled out of it. - Company

A terrific organization. Within the components of the life sciences environment in BC, Genome BC is really one of the leaders, and in some aspects really the dominant leader (as compared, e.g., to university-based organizations, they are a co-leader). - Non-profit

Our Team's research Project is led by Genome Québec. Genome BC has nevertheless contributed significantly for the work performed in BC and contributes in co-funding as well as provides an infrastructure for that part of the work (BC Cancer Centre). - Researcher

Respondents recognized the fine line that the Corporation must walk in balancing these differing needs. Further, respondents commented that, for the most part Genome BC has struck an excellent balance

between support for discovery research and for more applied translational work, and between benefits for the private sector and for the public sector.

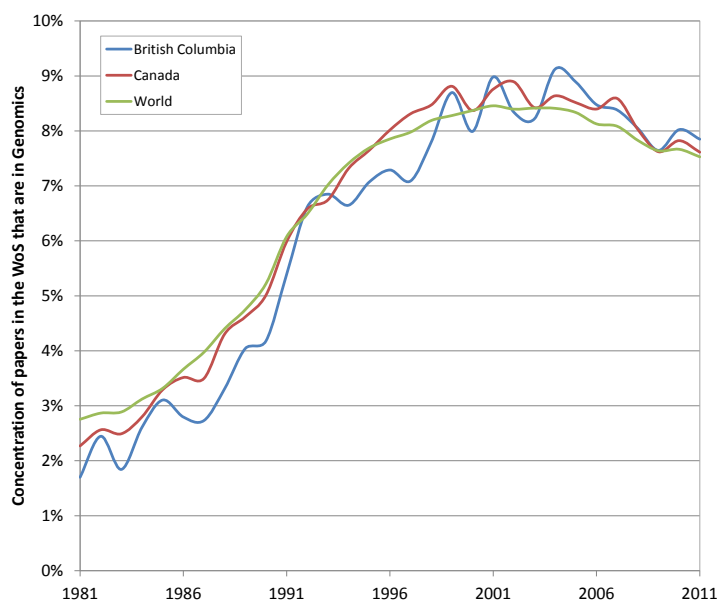
Often [private sector] employees are punished even for succeeding – a success is seen as just barely adequate, it's just doing your job. Any unforeseen event and you just get pounded. So for profits are driven by different kinds of market expectations than Genome BC. By contrast, Genome BC tries to thread that very difficult needle of mixing government money with private money, and make some money along the way. – Company

One point here, however, is of interest for future planning:

- While of course most respondents would prefer *their* sector more attended to, there was some feeling that health had perhaps received more than its due.¹³ While the opportunities afforded by a revolution in personalized medicine are widely anticipated to be tremendous, several respondents commented that impacts in other sectors – and especially natural resources – could be equally significant, and potentially quicker to bring to fruition.

Bibliometric data. To the extent that genomics is being focused on more strongly by BC scientists, this can be seen as an indirect indicator of strategic focus, given that many Genome Canada, and most Genome BC, projects have some applied translational focus as their end goals. First, remember that interest in genomics world-wide has increased tremendously, as seen in Exhibit 3.1, so there is a strong basic strategic impact. The Specialization Index (SI) analysis shows this even more clearly, as seen in Exhibit 3.10. However, the exhibit also shows that this interest was somewhat lower in BC than world-wide prior to the creation of Genome BC, while subsequent to Genome BC's creation and Genome Canada's first Competition in 2001 the SI has increased to the world level, and perhaps slightly above it.

Exhibit 3.10 – Specialization Index for Canadian and BC genomics publications



Source: Science-Metrix analysis for Genome BC

¹³ Not, of course, by respondents in the health sector.

3.2.2 SUPPORT FOR CENTRES OF EXCELLENCE AND PLATFORMS

Genome BC has supported several key platforms, including the Michael Smith Genome Sciences Centre (GSC) at the BC Cancer Agency (BCCA), the Genome BC Microarray Platform: Laboratory for Advanced Genome Analysis at the Vancouver Prostate Centre, the University of Victoria - Genome B.C. Proteomics Centre, the UBC Engineering Physics Project Lab, the UBC James Hogg Research Centre, the UBC Okanagan Innovation Centre, and the Joint Engineering Centre (BCCA) at the BC Institute of Technology. Key stakeholders often mentioned the importance of these platforms, as well as industry platforms developed that were facilitated by project funding.

[Genome BC support] has allowed us to set up programs and platforms that we couldn't have done to same degree. – Company

3.2.3 ARE THERE ANY PROGRAMMATIC GAPS?

Stakeholders noted four possible areas for improvement: focusing more strongly on projects that will lead to concrete socio-economic returns in the near-term, increasing the focus on natural resource sectors (including regulatory and international trade implications), simplifying programming, and reducing “red tape”.

The worst thing about Genome BC is the overbearing in-person and paper-based reporting requirements. The budget documents are a mess. The categories are so convoluted, and the processes so demanding, that they can't be done by research administrative assistants. I've spent more time on my reporting requirements for my two Genome BC grants than for my 19 OTHER GRANTS COMBINED in the last four years. This situation is so bad that I now look elsewhere first, and only apply to Genome BC if absolutely necessary. - Researcher

It is a difficult government environment now, it's quite hierarchical and they only want to hear very simple messages. The metrics are often related to accountability, not achievements - Non-profit

. . . perhaps they're underselling the commercialization aspects. It is probably possible for them to get some additional commercial benefit out of the work. I would like to see this because to the extent that public money is used, something beneficial should come back. - Company

One of their big opportunities for long term success is to really think increasingly across the entire bioeconomy, not just the human health. . . the BC economy is driven by other sectors which are suffering in demonstrating value added, e.g., forestry, fisheries and aquaculture. Genome BC should work with the responsible ministries which have explicit demands for growth of sectors, and this has serious implications for their GE³LS mandates. - Academic

I'd like to talk more about pure biodiversity issues, while to date we have targeted fisheries and stocks of tangible economic value. The non-economic species are important, but not as tangible – I'd like to disentangle this environmental side from resource management. But the programs did not allow this kind of component. – Academic

From a risk assessment perspective, applications of genomics in natural resources [and regulatory aspects] will save BC a lot of money. . . . What could Genome BC do better? Having them as Champion reaching out to industry groups would be terrific. This is easier for them than university scientists – academics are very insulated from industry, and regulatory processes for environmental aspects. . . They can be a cornerstone for bringing people together from different disciplines, including social sciences, regulatory (all levels of government), and industry. – Government

Micromanagement is far, far too much, on the reporting – far too much. Financial management is [nitpicky], such as transferring [minor amounts of money] from one budget item to another, and there's far too much reporting. - Academic

The biggest negative has been – and not of their own doing – is the incredible amount of paperwork they have to do for a grant, and do the R&D. – Academic

Genome BC could have a much bigger impact on science if they could simplify their grant application and monitoring processes. At present the vast majority of scientists are, in practice, shut out from applying by the complexity of the process. With few exceptions only those with admin assistance can manage the process. In this day that means only pre-existing teams etc. can do so. There is LOTS of great science that Genome BC is missing. – Researcher

3.3 IMPROVING BC'S "LIFE SCIENCES" BRAND

3.3.1 IS BC BECOMING AN EARLY ADOPTER OF –OMICS?

There are no hard data on this topic, but several key stakeholders commented that Genome BC has had a positive effect here, with –omics research becoming more common and accepted in part because of the Corporation's actions and strategies, and with earlier and more intense interest from the investment community; e.g.,

Absolutely: I'm seeing a trend towards acceptance of genomics – there's not so much of a barrier as before when I started, stakeholders see a really tangible benefit of the technologies and the expertise. When I started, there was a real resistance to it – genomics was seen as too costly, too technical, too reductionist. - Academic

Developing BC's life sciences brand – excellent job! They have worked with [multiple organizations] to support the system and provide resources to develop a more common brand. . . Genome BC is an important part of the BC ecosystem, which is getting better and better at speaking with a common voice, [with multiple organizations] all singing from the same song sheet. . . So this helps make the message to government. – Non-profit

We've had the pleasure of educating investors of how great it is to invest in BC, and they're shocked. You can get a lot done in BC for relatively small money, and BC is great at supporting companies: low burn rate, great interactions with communities, partnerships, etc. – Company

3.3.2 ATTRACTION OF TOP SCIENTISTS AND TECHNOLOGISTS

Key stakeholders often commented on the importance of the people being brought into their organization and into BC more generally, both in research and in industrial positions. This was usually originally through project funding, but usually remaining long-term in their job positions. Some also mentioned that these individuals are becoming resources for many organizations in the Province, although this aspect may benefit from more explicit attention.

Genome BC's program support has been terrific for industry. Without a doubt we have been able to hire people that allowed us to find successes well beyond the [original] project that was funded. I can absolutely confirm that the vast majority we've hired through Genome BC have stayed on afterwards. – Company

Yes, certainly I have benefitted from the Proteomics Centre and Michael Smith Centre being able to attract some of the best people – this has been outstanding. BC has become one of the places to go if you want to learn about genomics. – Government

Is more “people development” needed? Yes, this is an interesting idea. . . The people aspect would definitely interest me. . . This is quite a concern for a number of HQP and it’s a concern of mine. And we need lots of HQP in this technology-heavy domain. So any solid industrial opportunities would be quite attractive. – Academic/Non-profit

There’s an incredible quality of people we can hire here. . . Investors such as Roche can’t believe the quality of the team here . . . A third of the company staff were originally hired through Genome BC funds, so Genome BC trained up the people who formed our company. This company would not exist without Genome BC allowing us to build up a world-class lab and hire these people. It’s the people and it’s also the infrastructure. – Company

3.3.3 IMPROVING BC’S CORE GENOMICS CAPABILITIES

Sections 3.3.1 and 3.3.2 speak to this point as well. Here we note that many Genome BC-supported projects have fostered significant internal capability within the research teams and end-user partners, including industry. This capability has been used to pursue additional topics subsequent to the end of the original project.

The Genome BC programs themselves weren’t commercial successes, but they were definitely enabling to build our core capabilities in terms of bringing people into the company, and these have had impacts much more broadly. And it allowed us to find funding more broadly outside. So the support has contributed to fund raising, and allowing significant advances in several other areas not originally targeted. - Company

3.4 FOSTERING MULTIDISCIPLINARY SCIENCE

There are no direct performance system data on this point, nor were the key stakeholder interviews revealing. However, from the personal experience of the study team [Rank], multiple disciplines and sectors are normally represented within research teams for both Genome Canada and Genome BC projects, and the Genome BC support process to refine LOIs and full applications frequently suggests additional scientific and/or GE³LS disciplines (and expert individuals) that should be included in the research.

Key stakeholders also commented on this point, noting not only multidisciplinary and multisectoral approaches being fostered within individual projects, but knock-on effects subsequent to the projects’ end, through the evolving interests of the participants

Genome BC has been really good at expanding beyond genomics. [We are] really an engineering firm, but now with applications/technologies in genomics, so it’s been really good here. – Company

Yes, their approach has been good for multiple stakeholders using multidisciplinary approaches, they’ve been compelling in that regard and in dealing with community partners and bringing people together. - Academic

I have evolved over the years, largely through [a group] at the Genome Science Centre. I have become more interested in immunology while [the GSC group] has become more interested in genomics, so we now have a unique intersection of fields. I would credit Genome BC with fostering this transition – not all the credit, but certainly some. – Non-profit

I also like the fact that [my organization] has been able to carve a niche and a space for biological sciences in [our non-health sector] that's differentiated from the medical community. - Government

Genome BC's great value for us is as a bridge between conventional life science research and clinical activity and engineering and technology development. Genome BC has supported projects that would be difficult to fund otherwise. This is really a unique area for Genome BC in Canadian funding and I hope this can continue. - Researcher

3.5 POSSIBLE IMPROVEMENTS TO SUPPORT OF STRATEGIC R&D

The main message was to provide even more of the same, through more proactive, intense, and multidimensional, multidisciplinary, and multisectoral avenues. A frequent theme from key stakeholders was an increasing awareness of the commonality of problems, scientific approaches, and technical platforms across widely disparate scientific fields. If Genome BC could act even more strongly as a clearinghouse and one-stop-shopping to point researchers and end-users to resources that might be of interest to them – even in a very different discipline – this would be of great benefit.

When first went to Genome BC they said, "We're not just medicine". I didn't really believe that at the time. But now I see how my medical field overlaps with animals and other problems, but I don't have the opportunity to share with others. The scientific symposium and short talks were great, but perhaps they just need more of this. [The staff members] are to be congratulated. – Academic

But the group doing [this analysis] should have talked to the people in forestry and bowel disease and fish and cattle, etc. But the programs are responsive, so there's a timing problem. If Genome BC could have said, 'We're thinking about getting a [particular analytic machine], who's interested?' it would have been really cool to know who else could do it. So they could be a sort of a clearinghouse for this information – who's doing what, what equipment, etc. – Academic

I would like to see Genome BC promote the development of Genome Centres in 3 to 5 selected hospitals throughout the province. I see this development as essential to implementing personalized or precision medicine into clinical practice. I believe now is the time to adopt genomics within the practice of medicine and BC is the place to do it because of the distributed medical school model and because of Genome BC's influential presence. – Researcher

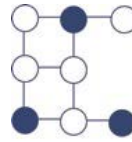
Another area that I feel very important, but underfunded is genomic knowledge dissemination. As it currently stands, large scale-data sets generated with Genome BC funds are largely under-utilized in terms of their potential for knowledge generation. It will be important to engage the broader, non-omics oriented research community to take advantage of the data and results generated [for example through] easy-to-use web portals. . . Only in this way also the non-omics oriented research community can benefit from large-scale projects, and vice versa future systems biology targeted project will benefit largely from the gained functional gene data generated by the non-omics community. - Researcher

And as noted earlier, even stronger targeting on targets likely to yield socio-economic gains is desired by many stakeholders.

The health sector strategic plan is reasonably good, but the four domains may still spread themselves too thin. Some organization like Genome BC needs to do this targeting. . . . they can drill down more easily than [other organizations in the field]. So stay the course, keep on target. – Non-profit

Another frequent theme was the importance of "people support" as a critical factor.

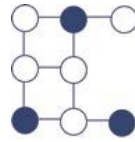
I'm often asked about what can be done to optimize this sector. Without a doubt it's people: knowledge transfer . . . This should be the Provincial and Ministry focus, and bringing in world-class



talent at that [because] building successful companies requires global level talent. The best, best, bang for the buck are the people programs. – Company

Some researchers also commented on this theme:

I really value being able to have done my PhD and postdoc in Vancouver, and then move on to a research/faculty position here. Working alongside a Comp II project, then as part of a Comp III project, then my own projects, has been amazing. I wonder if there's a role for Genome BC in funding a small handful of PhD/Postdoc scholarships to promote home-grown talent? – Researcher



4 FINDINGS ON LEVERAGING

4 FINDINGS ON LEVERAGING

4.1 ATTRACTION OF FUNDING FROM NATIONAL AND INTERNATIONAL ORGANIZATIONS THROUGH PARTNERSHIPS & COLLABORATIONS

4.1.1 GENERATING COLLABORATIONS

Genome BC is well regarded by key stakeholders as to how they identify collaborations at both the project and major initiative level, and support their success. Respondents also commented that the Corporation does a good job of going beyond the Lower Mainland in these efforts.

I'm really impressed with the GBC staff, they reach out, they're fun to talk to, and they're good people to bounce ideas off. Plus they check in with me once in a while to see what's happening. They go out of their way to deal with the Island people, and of course the Proteomics Centre on the Island. – Non-profit

My experience with them overall has been very good. When GBC came forward regarding an opportunity to fund a major research program, it was significant economic and social opportunity, so it was a no-brainer to become involved with. – Company

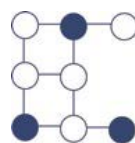
I've been very happy with Genome BC. I've worked with over the years with every Centre in Canada over multiple funding programs – GBC is among the top one or two in terms of ease and quality of working with them. . . They are extremely proactive and facilitative to work with. . . Some [other Centres] never really understood this role, thinking they were funders, not coordinators. – Academic

Their connections are broad and deep, they're known because of the quality of people involved. The community in BC is very tight, people tend to know each other. . . [The CEO] epitomizes this viewpoint, he's a self-effacing and wonderful guy, doing this because he thinks it's important for our society and for science in BC. – Company

Genome BC provides . . . an unparalleled amount of support for developing novel ideas into fundable projects and they help bring together different teams and investigators to network and collaborate on larger team projects. Genome BC also helps fund projects that fall outside the scope of CIHR - such as projects that are too translational for CIHR, but yet not ready for clinical application - such that a hospital or health authority would not consider funding the application yet. – Researcher

One survey respondent complained, however, at the integration of government scientists within projects:

Unfortunately, when a Genome Canada project is funded, the relationship between Genome Centres and co-PIs is not well defined and remains unclear. Although we have invested a lot of money in different Genome Projects, the story is the same. Our scientists are not fully recognized as full participants. This is a real concern. – Government



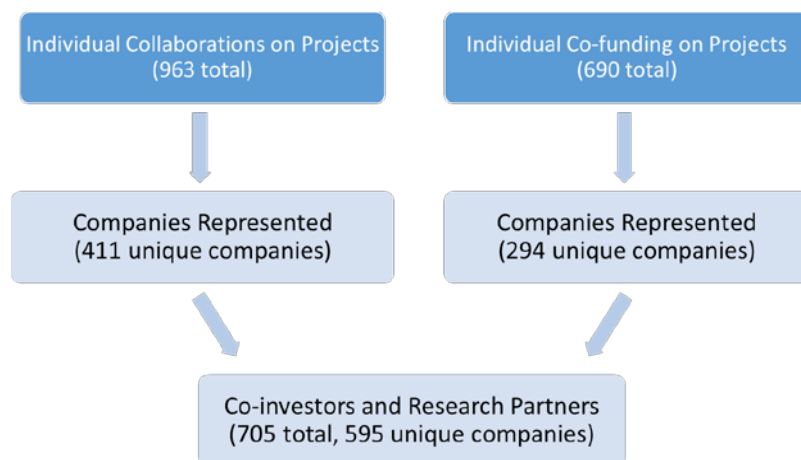
4.1.2 NUMBER OF COLLABORATIONS

At the project level:

- Since 2001, Genome BC has supported a total of 189 Genome Canada and Genome BC projects, involving 532 individual project leaders, co-leaders, and co-applicants across 10 BC research institutions.¹⁴ (This represents an average of 2.8 senior researchers per project.)
- Over the 2010-2015 period (i.e., during the period of the most recent Strategic Plan), Genome BC supported 207 project leaders and 378 co-leaders and co-applicants, for a total of 532 individuals.¹⁵

In addition, over 300 research organizations in at least 26 countries have been involved, at government, university, and industry organizations such as the UK's Wellcome Trust, National Cancer Institute, Karolinska Institute, Scripps Research Institute, Stanford University, University of Oxford, Massachusetts Institute of Technology, Harvard, London School of Economics, UMEA University, European Molecular Biology Laboratory, Australian Wine Research Institute, US Department of Agriculture, Oakridge National Laboratory, Marine Harvest, Glaxosmithkline, and Novartis.¹⁶ These project-level collaborations have frequently involved industrial end-users on the project team, contributing funds, technical and scientific expertise, research resources (e.g., samples, data), or all of these. Exhibit 4.1 shows project collaborations from inception through April, 2015 – there have been an average of 7.2 organizations involved per project.

Exhibit 4.1 – Project level collaborations with end-users



Source of graphic: Mohammed Basham, Genome BC.

¹⁴ Many scientists have been involved with more than one Genome Canada and/or Genome BC project; duplicates are not included in this figure.

¹⁵ Again, not including duplicates within a given category. However, does not add to 585 because inter-group duplicates were removed.

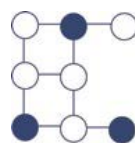
¹⁶ Text adapted from Genome BC, January 31, 2014, *Op cit*.

Of additional interest in Exhibit 4.1 is that many of these industrial collaborators have participated more than once, as seen in the total number of individual collaborations and individual co-funding being higher than the number of unique companies involved. This can be seen as an indirect measure of satisfaction with the interaction with Genome BC. Further, the bulk of firms have participated as both co-funders *and* as research partners. As will be seen below, this has increased the impacts of the participation.

At the Corporate level, Genome BC has fostered and/or entered into major collaborations such as¹⁷:

- Genome BC has invested \$22M on behalf of Western Economic Diversification (WD) in 11 contracts;
- Genome BC partnered with the BC Centre for Disease Control (BCCDC) on research projects that include work on Chlamydia, tuberculosis (TB), and H1N1 influenza;
- Genome BC provided funds and expertise to develop the BC life science proposals for the federal Centres of Excellence for Commercialization and Research (CECR) program; BC leads six (27%) of the 22 CECRs;
- The \$55M Bovine Sequencing Project, in which the Genome British Columbia Sequencing platform brought its strength and expertise of full-length cDNA sequencing, resulted in optimized breeding of cattle in BC and around the world;
- Genome BC manages the \$10M Pediatric Medulloblastoma Cancer Genetics Project (led by the BC Cancer Agency), which is a component of the Medulloblastoma Advanced Genomics International Consortium (MAGIC);
- BC leads the international conifer sequencing effort currently underway, along with the USA and Sweden;
- The International Co-operation to Sequence the Genome of the Atlantic Salmon is a \$10M collaboration between Genome BC, the Chilean Economic Development Agency, InnovaChile, Norwegian Research Council, and the Norwegian Fishery and Aquaculture Industry Research Fund;
- CanEuCre is a \$11M collaboration between BC and the European Union to generate new research tools for academia and industry for targeting of specific molecules to the brain for use in neuroscience research and gene therapy; and
- A \$6M BC-Spain Grape Genomics project was a collaboration between Genome BC scientists, Spanish researchers, and the wine industry to gain a better understanding of grapevine genomics and the grape ripening process in order to improve grape quality in both table and wine grapes.

¹⁷ Text adapted from Genome BC, January 31, 2014, *Op cit*.



4.1.3 LEVERAGING

As of March 31, 2015, Genome BC has invested roughly \$713M in R&D and technology development projects, as compared to its direct Genome Canada funding of \$277M; recent running totals are shown in Exhibit 4.2.

Exhibit 4.2 – Running totals of spends in past three years

| Contribution since inception | 2013 (\$M) | 2014 (\$M) | 2015 (\$M)* |
|-----------------------------------|--------------|--------------|--------------|
| Genome BC funding (from Province) | 154 | 162 | 174 |
| Genome Canada | 255 | 269 | 277 |
| Other investment** | 216 | 230 | 262 |
| Subtotal | 625 | 661 | 713 |
| Leveraged Funds*** | 617 | 617 | 617 |
| Total BC-based*** | 1,242 | 1,278 | 1,330 |

* This is not the full 2010-2015 plan as some funds are uncommitted.

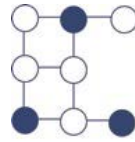
** Mainly project co-funding. Some is from Provincial ministries, but is not included in the main Provincial total as they are project-based.

*** As of December 2013. See text.

Exhibit 4.2 notes that an additional ~\$617M has been leveraged by Genome BC scientists. If this funding is fully dependent upon and attributable to the Genome BC-related work, then roughly \$1.2B has been brought into the Province. However, the “additional leveraging” figure should be considered “soft” for the moment. It is still to be fully validated, representing information collected by Genome BC on follow-on, non-Genome Canada funds brought into BC for R&D, training, and translation activities subsequent to the Genome BC projects.¹⁸ The specific linkages to the earlier work (including attribution and incrementality) are not known at present, and so it could be a significant overestimate of true additional funding leveraged and attributable to participation with Genome BC.¹⁹

¹⁸ This is a new metric collected internally, although not always consistently, from project reports, presentations, interviews, etc. Full validation and updating are expected by the end of 2015.

¹⁹ Alternately, it is possibly an underestimate because of inconsistent data collection.



5 FINDINGS ON GE³LS

5 FINDINGS ON GE³LS

5.1 FOSTERING GE³LS IN GENOME CANADA AND GENOME BC PROJECTS

5.1.1 GENOME BC ACTIVITIES

As noted in section 3.3, Genome BC works extensively with project applicants to ensure that relevant GE³LS aspects are identified, addressed, and described within LOIs and full research applications, and manages successful project milestones and deliverables to help ensure these are addressed during the research. The success of BC researchers in winning Genome Canada funding is a strong indicator that the organization is effective in these efforts – most researchers and stakeholders believe that, all other aspects being equal, it is the GE³LS component that is the “make or break” criterion for success in these Competitions.

Personal observation by a member of the study team demonstrated that these efforts are intensive, well-resourced, and valued by the research teams.

- However, these observations also suggest that there is still considerable way to go amongst the research community re. fully understanding the importance of addressing GE³LS, and especially of how to effectively translate research findings into practical outcomes. This is true even within the clinical community in terms of practical mechanisms needed for translation, even though such practical applications are always the rationale underlying the research.

Key stakeholders noted that GE³LS is now better integrated than in the past (partly because of the more strategic and applied nature of the projects), and is being done effectively.

In the more late stage work they're doing now, it's feasible to do meaningful GE³LS investigations (it's much harder at the discovery stage), so their change in emphasis and success is more related to the late stage work they're now supporting than any significant change in how they're approaching GE³LS. - Academic

Previously I thought GE³LS was a token, tacked on, and not synergistic. But recently this has improved significantly. For example, the [natural resources] project has really started influencing policy. Because of this alone I'm seeing GE³LS in a more positive light. That said, this is a hard thing: you need to bring people together and this is difficult. You can't herd cats but you can move their food! – Academic

I talk to them outside of the project on GE³LS, this is also very impressive, and I like the idea of developing things with communities. It's good to look forward to this, and we will try to copy some of this approach. – Non-profit/Collaborator

The SSH side is a little abstract for me, to be honest. But the applications – more and more people are aware of omics importance, so if industry embraces genomics or DNA, their social outcomes and PR could be much better. So GE³LS could really help here – this could be the economic driver. The compliance side is the stick, but the economics could be the driver. – Government

GE³LS really does get integrated even on a small scale, a lot of back and forth within the proposal development. There's always this push. - Academic

Respondents noted that while early in Genome BC's history there was a strong (probably over-strong) emphasis on ethics, the main focus now is to help research partners agree on explicit socio-economic goals – and especially consideration of economic impacts for BC and Canada – and develop concrete project mechanisms for achieving them.

In the survey component, very few of the respondents commented one way or the other about GE³LS, but there is clearly some feeling, among some researchers, that this component has become more of a “sales component” to ensure commercial or translation success, even in the face of possible societal issues.

. . . Initial interactions with both GE³LS and non-GE³LS staff were excellent, and supportive. After [the GE³LS leader] left, however, our team was progressively pressured by the Science PIs to change our research focus, and other staff that we dealt with offered us no support in our efforts to continue with the research that we had agreed on in the grant application process with the science PIs from UBC. . . We were required to almost completely abandon the work that we had planned and worked towards for 2 years, as we were instructed to become little more than PR flacks for the PI's potential commercialized products. . . Genome BC staff, including the GE³LS coordinator, did nothing to defend our research program against this assault. . . The punchline is that GE³LS projects must have more autonomy from the commercializing ambitions of the science PIs, and that before this happens, GE³LS research is either compromised or continually vulnerable to the whims of the PIs whose work would not have been funded without GE³LS participation. – Researcher

The current GE³LS focus on helping translation is well described by one researcher, who noted that even more SSH integration could be done, especially for public good benefits:

The role of the social sciences still seems to be a mystery to Genome [BC]. At first, it was a hasty add on to the science grants, which were basic R&D in nature. Many of the social science components were focused on ethical questions. Now, it seems that the only research being contemplated is direct commercial applications. Social sciences can do so much more. A social scientist can translate the work of the scientists to the end users and wider communities; find the policy/regulatory implications; engage with the scientists and community to find out what applications are most useful; and look to the longer picture of how innovation in this area can be best managed from a long-term perspective. Scientists don't have time or training to do any of these things, and the current business focus will neglect them in favour of immediate returns. If public monies are funding the research, there should be a public as well as private payoff. We could help you to map these out. – Researcher

However, the survey of researchers suggests that sometimes resourcing is insufficient to do meaningful work:

Since I have led GE³LS teams the reality is that the amount of money allocated is not enough to sustain a research program of any substance. So [to] reach my research target I have to prepare many research grant proposals and I have to train young graduate students. Thus it is not possible to have the same impact as my peers in genomics since they hired only postdoctoral students and were able to make a concentrated effort on their research tasks. I did not have this luxury. - Researcher

Of interest are several points here:

- While key stakeholders noted that other types of GE³LS concerns (e.g., ethical, legal, environmental, and broad societal) are focused on to a considerably lesser degree, there were no concerns voiced over this fact by them. However, at least a small proportion of the SSH research community is far from pleased about this situation. If a significant number of strong SSH scientists now avoid working on genomics R&D because of perceived conflict of interest, or lack of proper integration of their findings within the innovation and translation pipeline, this is a potentially serious but hidden problem.
- A partial exception is that Genome BC is seen to be putting some increasing focus on various trade and/or regulatory concerns (e.g., trade barriers, international treaty issues, opportunities to use genomics-enabled quality certifications for export opportunities). One respondent noted that

the regulatory community is very conservative in some sectors because of fears of an industry backlash if highly sensitive genomics-enabled testing uncovers many more instances of environmental contamination. For example more sensitive detection technologies for trace contaminants in industrial effluent streams might lead to more stringent regulatory regimes. This does not, however, mitigate the potential problem noted immediately above.

5.2 HONEST BROKER ROLE

The interview program found that Genome BC is seen as an honest broker with respect to GE³LS issues to the public, government, and academic research teams.

From the public point of view, they've done a pretty good job being seen as a notable player with a great international reputation. – Academic

In order to unlock healthcare silos of data and make the right connections between genotypic and phenotypic datasets we need a trusted body to take the lead. Genome BC or a spin-off from Genome BC could provide this leadership as a trusted, honest broker capable of interacting with both public and private interests. – Company

Certainly they consult people very well, they represent the community to the province in an advocacy and honest broker role. - Academic

5.3 IMPACTS ON THE GE³LS CAPABILITIES OF RESEARCHERS, COMPANIES, AND NON-PROFITS

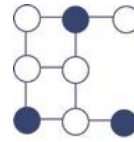
The earlier Exhibits 3.4, 3.6, and 3.8, respectively, show that Genome BC has had a moderate to high impact on the GE³LS capabilities of researchers, a moderate impact on the GE³LS capabilities of companies, and a moderate impact on the GE³LS capabilities of non-profits. Not shown here (but discussed in the Companion reports) is that neither companies nor, surprisingly, government organizations and non-profits rated their internal GE³LS capabilities very highly in the survey. One key stakeholder commented that it was difficult to find enough top people in the field within BC or even Canada, and going abroad might be welcomed.

Genome BC supports GE³LS well, but there's a dearth of front-line leaders in this area within the province. . Although you don't want overemphasize the importance of the GE³LS aspects – the key has to be the genomics focus – perhaps you could bring in top people from outside BC? Yes, this is the message I would bring forward. - Non-profit

5.4 PUBLIC COMMUNICATIONS, OUTREACH, AND SPECIALIZED EDUCATION

Genome BC maintains an active public communications and outreach function, with staff dedicated to this function. On the outreach front:

- The organization routinely provides news releases (33 in 2014 alone) on genomics-related matters involving both Genome BC and other organizations.
- A wide variety of announcements (at least 12 in 2014 and 2015) is made related to matters such as events sponsored by Genome BC and other genomics-focused organizations (e.g., results of Brain Canada's 2013 Multi-Investigator Research Initiative, or the 2015 Personalized Medicine



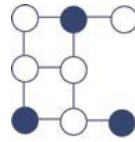
Summit, which was in part sponsored by Genome BC), newly released quarterly newsletters, and new R&D initiatives;

- The “Events” calendar shows over 60 events open to researchers and the general public in 2014 alone.
- Media resources include photo galleries, a dedicated YouTube genomics education channel, and a genomics glossary of scientific and technical terms;²⁰
- Corporate publications include the newsletter, Genome BC’s Strategic Plan, Annual reports, evaluation reports, etc.

Related to genomics education, Genome BC maintains a wide variety of materials and programs aimed at primary and high school students and teachers, many of them easily accessible web-based resources, including:

- Teacher resources such as animations, hands-on activities for students, articles, student work projects;
- Annual Geneskool Camps hosted in university laboratories that provide high school students with week-long exposure to the science and techniques used in molecular biology and practical applications such as those in the clinic;
- Fast Facts, that each year present dozens of recent interesting discoveries and applications of genomics culled from research world-wide;
- Activities such as access to recent Gene Screen BC films on practical and sometimes controversial topics, and puzzles and mysteries for students to solve;
- An education map showing Genome BC’s involvement in cities and regions across BC.
- The Genome BC Foundation, which helps support genomics education conducted by third parties, including educators and industry.

²⁰ Photo Gallery: <https://plus.google.com/photos/115546370797556156090/albums?banner=pwa>;
YouTube Channel: <http://www.youtube.com/genomicseducation>; Glossary:
<http://www.genomebc.ca/education/glossary/>.



6 FINDINGS ON SOCIO-ECONOMIC BENEFITS

6 FINDINGS ON SOCIO-ECONOMIC BENEFITS

6.1 REGIONAL ECONOMIC IMPACTS

6.1.1 ECONOMIC IMPACT “RIPPLES”

A modified input-output analysis²¹ of regional economic impacts found that Genome BC had to date resulted in:

- Total direct, indirect, and induced outputs of \$1.658B; and
- Total direct, indirect, and induced GDP impacts of \$1.454B;

Our study team notes that although these figures are based on the ripple effect of investments in the economy, not the success of the R&D, such input-output analyses are very commonly done for R&D programs, research institutions, and Big Science programs, and so provide a useful benchmark for analysis. This analysis was somewhat expanded over a stock analytic framework (i.e., in which only Genome BC spending on projects, platforms, and Centre operations might be included), in that it also included value-add analysis of some of the follow-on investments obtained by research teams after the projects ended (see also section 4.1.2). Our study team also notes that these post-project impacts were ~75-80% of the initial impacts arising from the projects, indicating significant subsequent interest and investment in the projects' science and/or translation opportunities.²²

6.1.2 JOB CREATION

There are several ways to estimate job creation:

- The input-output analysis discussed in section 6.1.1 estimated that about 21,000 FTE jobs were created. These represent the regional job “ripples” through direct spending and indirect re-spending.
- Another way to estimate FTE jobs is to divide the R&D expenditures for human resources by average estimated wages and salaries. By this measure, Genome BC and its related projects/platforms created 5,930 “direct” FTE jobs – that is, this is how many FTE positions were directly supported through R&D projects.
- Neither type of metric captures job creation in the sense of new, incremental, long-term, and sustainable jobs in the bioeconomy – e.g., job in start-ups, spin-offs, and expansions of existing firms that will continue into the future even after all project funding ends. It is possible, but challenging, to measure such job creation; e.g., a detailed case study program of the firms “advanced” by Genome BC, and discussed below in section 6.2.2 and in Appendix D would illuminate these impacts. It is not possible to extrapolate such effects from existing data.

²¹ MNP LLP, March, 2014. *Op cit.*

²² As noted earlier, however, the data on these follow-on investments are “soft”.

6.2 FOSTERING PRACTICAL DEVELOPMENT OF COMMERCIAL AND INDUSTRIAL SOCIO-ECONOMIC BENEFITS

6.2.1 PROGRAMMATIC SUPPORT

As described earlier, Genome BC conducts activities related to development of LOIs and proposals and the project management mechanisms that identify concrete practical applications, and develop teams and mechanisms to help ensure they are developed. This especially happens within Genome Canada programs with translation goals, such as the Genomic Applications Partnership Program (GAPP).

In addition, Genome BC has itself offered a number of programs to directly support commercial and industrial product and service development in new and/or existing firms. Recently, for example, the Corporation offered three programs that allowed partnerships of academic researchers with industry and other support organizations such as Western Economic Development:

- Partnerships Program;
- Proof-Of-Concept program; and
- Small Business/Technology Transfer Program.
- Plus the Genome BC-specific Strategic Opportunities for Industry.

Within these programs, the Corporation is said to be good at balancing the needs of multiple stakeholders and sectors, and in balancing the needs of science vs. the needs of commercialization and other kinds of translation. They also offer very sound constructive criticism with respect to potential economic payoffs.

I've worked with other federal and regional innovation support organizations], and the best thing about Genome BC was that they offered the most criticism about what we proposed, more so than any other program, being skeptical and acting like venture capitalists. – Company

Genome BC didn't try to bend my program towards genomics. They didn't interfere with the science process, they were very flexible. – Non-profit

It's an excellent collaboration and . . . a complicated partnership, with multiple roles over multiple years, and with multiple federal and provincial responsibilities . . . In that dragon's den process, this was new to us, but useful in helping portray the economics of it, marry it to innovation and marry that to regulatory obligations. This project implicates large trade and environmental issues. . . We got lots of good shepherding from Genome BC in this process; it was well laid out and articulated, plus it leveraged previous work on the discovery side. – Government

Such programs, however, are in continual flux²³; earlier similar programs included the Proof of Concept program, the Applied Genomics Innovation Program, the Applied Genomics Consortium Program, and the Strategic Opportunities for Industry program. Some stakeholders commented that this continual evolution (along with concomitant changes to program criteria, co-funding requirements, etc.) created unnecessary confusion in the community.

Finding matching funding is always challenging, including Genome BC/s own 33/33/33 requirements, and is become increasingly difficult – this should be reviewed. And the criteria keep

²³ As are those of Genome Canada more generally, in which different strategic programs frequently arise, targeting different sectors and/or different types of end-users.

changing re. eligibility of different kinds of co-funding . . . this is tough. But to flip this around, they've been excellent at finding matching initiatives outside Genome BC, e.g., Brain Canada, so it goes both ways. – Academic

If I had my way, they'd have a regular suite of funding programs that were predictable, this would be great. Especially in this province, where there aren't a lot of other sources of funding. – Non-profit

6.2.2 IMPACTS ON FIRMS “ADVANCED”

As of March 2015, intellectual property (IP) protection within projects managed by Genome BC has resulted in:

- 21 licenses;
- 478 patent applications (including Patent Cooperation Treaty applications, provisional, non-provisional, etc.); and
- 31 patents issued.

Through March 2015, Genome BC had “advanced” 33 firms. “Advancing” means provision of a variety of support that includes grants directly related to strategic opportunities and/or commercialization assistance, helping identify and protect IP, assistance in finding investment funding, etc., up to and including support for creating start-ups. As of March 31, 2015, these firms:

- Have raised approximately \$200M in private financing and other funds;²⁴
- Have secured over \$1B in co-investment deals with major genomics industry partners such as Genentech, Teva Pharmaceuticals and Illumina;
- Offer over 30 products and services;
- Currently have ~359 employees (this is down slightly from recent figures, as some firms have failed or been sold in the meantime); and
- Have unknown total revenues at present.²⁵

Further details on the “advanced” firms are found in Appendix D.

²⁴ Genome BC is in the process of updating and validating this figure.

²⁵ These data are still being validated by Genome BC. As many firms are start-ups, these data are often confidential.

6.2.3 IMPACTS ON FIRMS SURVEYED

The survey of industry²⁶ found that:

- The 23 companies that responded to the impact assessment survey attribute \$1.1 million in increased annual revenues to Genome BC, which accounts for 3% of the total change in revenues generated by companies since first engagement.
- These companies attribute \$3.1 million in investments received to Genome BC, which accounts for 5% of the total investments received by companies since first engagement.
- The companies attribute \$28.8 million in increased market valuations to Genome BC, which accounts for 5% of the total change in market valuation achieved by companies since first engagement.
- Companies attribute the creation of 15 jobs to Genome BC, which accounts for 5% of the total increase in employment experienced by companies since first engagement with Genome BC.

As context, the firms surveyed represent a different sample from those “advanced”. Although there is a small degree of overlap, the survey sample contains many large or very large firms, while the “advanced” firms are mainly start-ups. Thus these proportionally smaller impacts for the survey firms are understandable.

6.3 POSSIBLE IMPROVEMENTS TO GENERATING SOCIO-ECONOMIC BENEFITS

As noted earlier in section 3.5, there is an opportunity for Genome BC to more rigorously screen potential projects for their likely success at generating socio-economic impacts, and more proactively search for translation opportunities where they have not yet done so. This would be instead of relying so heavily on their current willingness to “never say no” to research teams, in the hope of spreading the message as widely as possible to the academic community as to the need for practical commercialization and translation, and to the industry, government, and Non-profit community as to the potential benefits of genomics approaches. Within this, more focus on natural resource targets could pay large dividends; some of these would be in the form of revenues, but likely more would be in the form of cost savings and increased sustainability.

I believe proposal calls should be less area focused. . . Even more connection and promotion of entrepreneurship, from idea to small/early-stage startups would be fantastic. Something akin to SBIR grants would be very impactful! - Researcher

Genome BC needs to think very hard and strategically about being able to pick and demonstrate commercial successes – the problem is to migrate to earlier stage genomics based discovery research. So the programs and projects need to be even more translational. This isn't CIHR, so Genome BC needs to show this targeted focus. – Company

Genome BC needs to learn to say no. . . And the strategic relationship has to be looked at at a very high level. . . Plus the MLAs all have to know what's going on in their district. – Company

²⁶ This survey was of a selection of firms that was somewhat larger than only the firms advanced, so this is a somewhat different lens on the situation. For the survey results, the raw numbers are less important than the contribution of Genome BC to the firms.

But although they are pushing on specific targets, they still want to do all things for all people all the time. Genome BC needs to be the first to commit on a target; they need to put their money where mouth is. – Non-profit.

Genome BC is getting better at “walking the walk” for these benefits, and actually getting them applied in the natural resources fields. But compared to, say, human health genomics is still not that widely used. – Government

If you look at comments from politicians who say “We’ve put in \$XX, and there’s been no return”, making this link is extremely important. Genome BC did a good job with coming up with the forest sector targets. Now the other natural resource sectors like mining and oil & gas are really looking at genomics, especially. . . But don’t invite them to your meetings, go to theirs. Perhaps the comment is to be much more proactive – Company

Another comment is that bringing a world-renowned Champion to BC would immediately increase international interest in making investments here.

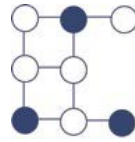
The staff are doing a great job here, but things could always be better: you need an internationally recognized person here in BC. . . Genomics is still young and fresh, and you still needs a spokesperson. . . Should we bring in top people from outside BC? Yes, this is the message I would bring forward. This would be terrific, although Genome BC would have to have the ability to fund outside the province. - Non-profit

Other comments related to the fact that Genome BC does not have content experts doing business development tied to specific sectors.

It would be good to have a staff person to engage the sector, to really get a good idea of what’s going on. Have sector-based experts who both know genomics plus are generalist enough to understand how genomics could deal with practical issues. This is better than having groups get together for a couple of days to ID problems. – Company

Finally, one survey respondent noted that the social sciences aspects were not as well covered within innovation development:

Overall I believe Genome BC is a strong support mechanism for research based in BC. Their grasp of the science is strong, as well and their understanding of the grant application process. Their social science capabilities are a bit more limited, particularly regarding business and innovation issues of concern to industries not in the medical field. – Researcher



7 CONCLUSIONS

7 CONCLUSIONS

7.1 ACHIEVEMENTS TO DATE

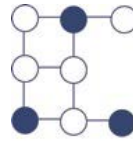
These findings indicate strong performance by Genome BC on all fronts: fostering excellent science in areas of strategic importance for BC and Canada, leveraging significant non-Genome Canada funding, integrating GE³LS into genomics research, and providing a rich environment in which socio-economic benefits can be created. Although it is too early for many concrete practical impacts to have come to fruition – much less to estimate impacts to “the bottom line” – many firms, government organizations, and Non-profits are working actively to this end. Especially important are the findings showing that Genome BC fosters significant improvements to the underlying resources and capabilities of its academic, industry, government, and non-profit communities – these capabilities are critical precursors to the innovation process.

The Corporation has highly regarded programs and staff, and is considered to be creative, proactive, and highly flexible in responding to opportunities. It has carved out a valuable niche in fostering the best proposals, teams, and collaborations appropriate to individual research topics, and has not neglected either researchers or research topics of importance outside the Lower Mainland or those that require cross-disciplinary or cross-sectoral approaches. Its goal of attempting to strike a fine balance between creating private vs. public good socio-economic impacts is appreciated by the community, even if this balance may need some refinement in future (see below).

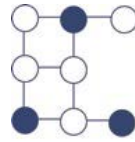
7.2 IMPLICATIONS FOR THE FUTURE

These results suggest one possible significant realignment of Genome BC’s strategy, plus a number of more modest changes. These are discussed in detail in the separate report on implications for strategy, but in short are:

- The most significant change implied here is to adopt a more rigorous – perhaps even more ruthless – approach to project support, only fostering projects and major initiatives that have a strong chance of both scientific and commercial/translation success, brought forward by teams that are already very strong in all required elements: science, GE³LS, commercialization, societal translation. This would be a significant shift from the current “Never say no” approach.
- Ensure all sectors identified by Genome BC in its strategic plan are targeted for support, broadening program emphasis, which has been primarily been directed towards healthcare and forestry. Recognizing that while the benefits of personalized medicine will undoubtedly be huge, they are still a very long ways off, while cost savings and increased sustainability in other sectors could be made more immediately.
- Increase programs and actions offering “people support”, including fostering knock-on impacts from the mobility of highly talented people.
- Simplify the current confusing and ever-changing program architecture and requirements
- Develop better metrics and measurement techniques to measure both commercial and non-commercial impacts.
- Deliberately foster improvements to the GE³LS capabilities of government and Non-profits.
- Reduce red tape in the application, monitoring, financial accountability, and reporting processes.



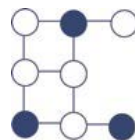
- Ensure that there are no hidden GE³LS problems related to over-emphasis of this component on commercialization and/or translation, vs. ethical honest broker investigation of potential societal concerns, or related to lack of emphasis on generating non-commercial but important societal benefits.



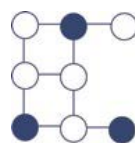
APPENDIX A – RELEVANCE OF EXISTING DATA TO THE EVALUATION ISSUES

Appendix A – Relevance of Existing Data to the Evaluation Issues

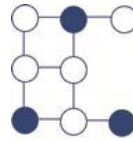
| Genome BC Objectives (paraphrased) | Jan, 2014 “Research Impacts” | Addendum | Other |
|--|---|--|--|
| 1. Initiate research in sectors of importance to the province, focusing on issues that could provide social & economic benefits | | | |
| - RESEARCH | ✓ Pubs (5.2, App C, App D) | ✓ (Extensive publication details) | Genome Canada 2014 BC-specific bibliometric data |
| - APPLICATIONS | ✓ (6.4, 6.5, 6.7) | ✓ (Firms advanced) | |
| - COMMERCIALIZATION | ✓ (6.5, 6.6) | ✓ (Patents, Firms advanced) | |
| - BENEFITS FOR SOCIETY | ✓ (6.1, 6.3) | ✓ (Details on above in Firms Advanced; includes valuation) | |
| - SOCIETAL ACCEPTANCE | | | |
| - Develop research programs to facilitate translation | ✓ (App B) | ✓ (specific programs discussed) | Corporate website |
| - Catalyze and support new entrepreneurial ventures, including companies, service providers and partnerships between academia and industry | ✓ (6.5) | ✓ (Firms advanced, specific programs discussed) | ✓ (e.g., website) |
| - Ensure that B.C.'s brand as the “the life science province” is maintained and recognized both nationally and internationally. | ✓ Pubs (5.2, App C, App D) | | |
| - Reduce commercialization risk by integrating social science and humanities programs (and end-users) into research and publications. | (✓) Discussed briefly (App D) but impact unclear | | |



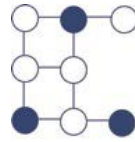
| Genome BC Objectives (paraphrased) | Jan, 2014 “Research Impacts” | Addendum | Other |
|--|--|----------|---|
| <ul style="list-style-type: none"> - Remove barriers to application of genome sciences through education of industry decision-makers and government regulators and physicians, medical students and nurses, and healthcare administrators. | | | |
| 2. Enhanced Capabilities: Genome B.C. will continue to support local scientific centres of excellence with capabilities and infrastructure required for the proposed research activities, as well as develop partnerships with other research groups and industry partners in B.C., Canada and internationally | | | |
| <ul style="list-style-type: none"> - Ensure that B.C. remains an “early adopter” and developer of cutting-edge genome-based technologies and allow for the maintenance and expansion of B.C.’s core competencies. | ✓ (Adoption implicit throughout; although “early adopter” not discussed) | | |
| <ul style="list-style-type: none"> - Catalyze interaction among scientists involved in technology development at the interface between biology, nanotechnology and information technology | ✓ (Interactions implicit throughout; although nanotech not discussed) | | May be obtained from analysis of research applications and/or progress reports? |
| <ul style="list-style-type: none"> - Attract the world’s best scientists and technologists to retain GBC’s technology edge and secure funding for current and future research programs. | ✓ No. of scientists, HQP (5.1), but “attraction” not discussed Funding attracted (5.1) | | Genome Canada 2014 BC-specific bibliometric data |



| Genome BC Objectives (paraphrased) | Jan, 2014 "Research Impacts" | Addendum | Other |
|---|--|---|--|
| - Involve proactively more social sciences and humanities (SSH) researchers into Genome B.C. programs. | | | ✓ Analysis of research applications, knowledge of Rank |
| 3. Leverage: Genome B.C. will attract investment funding from regional, national and international organizations using cost-effective processes, such as partnerships with other research organizations and industry. | | | |
| - Ensure the future competitiveness of B.C. researchers in Genome Canada competitions, with the objective of attracting ~25% of available funds. | ✓ GC and council funding (App C) Total funding attracted (5.1) | ✓ Leveraging of BC funding (Intro, Co-investment profile) | ✓ GC database, Genome Canada 2014 BC-specific bibliometric data |
| - Implement an international strategy by identifying consortia and/or research groups with which Genome B.C. could establish collaborations and leverage funding from other regions of the world. | ✓ (6.8) | ✓ Notable Cdn & Int'l investors (Co-investment profile) | ✓ GC database |
| - Develop strategies to run collaborative research programs with other genome centres in areas that are of common interest. | ✓ (6.8) Sector strategies | | ✓ Sector strategies |



| Genome BC Objectives (paraphrased) | Jan, 2014 “Research Impacts” | Addendum | Other |
|--|---|----------|-----------------------------------|
| <ul style="list-style-type: none"> - incorporate new pathways to ensure success in securing the required funding for its proposed research programs, including: <ul style="list-style-type: none"> o Drive more initiatives that involve direct province-to-province research partnerships. o Lead international initiatives that target countries with similar sectors and compatible expertise. o Investigate and establish strong ties with industry in key strategic areas. | <p>✓</p> <p>Sector strategies (4.0)</p> <p>Collaborations (6.8), though “leadership” and “province-to-province” not discussed</p> | | <p>✓</p> <p>Sector strategies</p> |



APPENDIX B – INTERVIEW GUIDE

Appendix B – Interview Guide

Strategic Research:

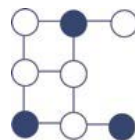
1. To what extent does Genome BC help support important strategic R&D for BC?
 - a) To what extent does Genome BC identify opportunities – and support genomics research – critical to BC and Canadian strategic sectors?
 - b) Has Genome BC helped create centres of excellence and platforms?
 - c) Are there any gaps in Genome BC's range of programs to support this strategic R&D (i.e., from discovery, through strategic, to translation)?
2. To what extent has Genome BC improved BC's "life sciences brand", nationally and internationally?
 - a) Are BC industry, government, and healthcare becoming early adopters of genomics technologies, in part because of Genome BC?
 - b) Has Genome BC helped BC attract and retain the world's best scientists and technologists?
 - c) Has Genome BC helped maintain or expand BC's core genomics capabilities?
3. To what extent has Genome BC fostered multidisciplinary science (e.g., integrating genomics with traditional biology, nanotechnology, and information technology)?
4. Can you suggest how Genome BC could improve the ways it identifies strategic opportunities, or helps support strategic R&D?

Leveraging – Collaboration, consortia, and partnerships:

5. To what extent has Genome BC developed strategic research partnerships with other R&D organizations, to help leverage expertise and resources?
 - a) Regionally?
 - b) With other Genome Centres?
 - c) With other Canadian R&D organizations?
 - d) Internationally?
6. Has Genome BC succeeded in identifying opportunities to lead important R&D initiatives, nationally or internationally?
7. How successfully has Genome BC initiated and conducted collaborative research programs with industry?
8. Can you suggest any improvements to how Genome BC goes about identifying appropriate research collaborations, consortia, and funding sources?

GE³LS – Genomics-related ethical, environmental, economic, legal, and social research:

9. To what extent has Genome been successful at integrating GE³LS concerns in Genome Canada and/or Genome BC projects?
 - a) Has the GE³LS research allowed research findings to be applied in more appropriate and practical ways? (For example, to help remove undue barriers to application, or to reduce commercialization risk?)

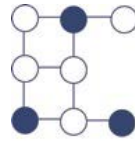


- b) Does the research address important societal outcomes and impacts (i.e., other than commercial ones, such as in health care, the environment, resource or community sustainability).
 - c) To what extent does Genome BC act as an “honest broker” regarding GE³LS issues (i.e., identifying opportunities, and mitigating potential concerns, and explaining genomics and GE³LS issues to industry decision-makers, government regulators, and physicians, medical students and nurses, and healthcare administrators?
10. Can you suggest ways Genome BC could improve the way it addresses GE³LS topics, or uses GE³LS research findings?

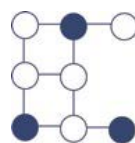
Socio-economic benefits:

11. To what extent has Genome BC fostered practical development of commercial and industrial socio-economic benefits?
- a) What are the key ways Genome BC tries to do so?
 - b) How well does Genome BC help develop partnerships among academic researchers and end-users in industry, government, and Non-profits?
 - c) To what extent has Genome BC catalyzed and/or supported entrepreneurship?
12. To what extent has Genome BC fostered practical development of societal benefits that may not rely on commercialization or corporate development?
- a) What are the key ways Genome BC tries to do so?
 - b) How well does Genome BC help develop partnerships among academic researchers and end-users in healthcare, government, and Non-profits?
13. Can you suggest ways Genome BC could improve the way it attempts to identify and support opportunities to create industrial and societal benefits?

Thank you!



APPENDIX C – INTERVIEW RESPONDENTS



Appendix C – Interview Respondents

Steinar Bergseth
Special Adviser
The Research Council of Norway

Fiona Brinkman
Professor, Department of Molecular Biology and Biochemistry
Head Brinkman Laboratory
Simon Fraser University

Inanc Birol
Bioinformatics Group Leader
Michael Smith Genome Sciences Centre
BC Cancer Agency (BCCA)

Robert Brunham
Director, BC Centre for Disease Control (BCCDC); Head, Vaccine Research Laboratory
Professor Emeritus, Department of Medicine University of British Columbia

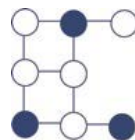
Brendan Byrne (briefly via email)
Vice President - Physician Solutions
Telus Health Physician Solutions

David Castle
Vice President Research
University of Victoria

Martin Dawes
Head, Department of Family Practice
University of British Columbia
Cameron Duff
Executive Director, Plant Health Science
Canadian Food Inspection Agency

Diane T. Finegood
President & CEO
Michael Smith Foundation for Health Research

Roger Foxall
CEO, Lifescience Strategies
Ex-President and CEO, Genome BC



Bettina Hamelin
Director, Research and Development for Western Canada
Pfizer Canada

Pierre Lapointe
FP President & CEO
Innovations

Victor Ling, Genome BC Board member
President & Scientific Director Terry Fox Research Institute (TFRI)
BC Cancer Research Centre

Andre Marzali
Chief Scientific Officer, Boreal Genomics
Director, Engineering Physics, UBC

Robert McMaster
VP Research, Vancouver Coastal Health Authority
Associate Dean Research, Faculty of Medicine, University of British Columbia

Brad Nelson
Director and Distinguished Scientist, Deeley Research Centre
BC Cancer Agency

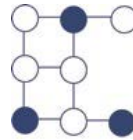
Peter O'Callaghan, Former Genome BC Board member
Senior Partner
Blake, Cassels & Graydon LLP

Rachael Scarth
Director, Associate Vice President Research Operations
University of Victoria

Brian Riddell
President & CEO
Pacific Salmon Foundation

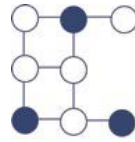
Michael Russello
Assistant Professor
University of British Columbia, Okanagan

Michael Stoehr
A/Manager, Forest Genetics and Coastal Douglas-fir Breeding, Tree Improvement Branch
BC Ministry of Forests

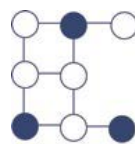


Simon Pimstone
Director, President and CEO
Xenon Pharmaceuticals Inc.

Wyeth Wasserman
Executive Director, Child and Family Research institute
Associate Dean of Research, Department of Medicine, University of British Columbia



APPENDIX D – DETAILS ON FIRMS ADVANCED

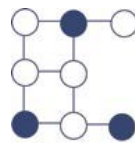


Appendix D – Details on Firms Advanced

A new table is in preparation by Genome BC, in which some of the figures will be validated and updated ; this will likely be ready by the end of 2015.

| Name of Company | Date Created | Number of Jobs | Additional financing/funding raised | Location of Company (past & present) | How company was advanced by Genome BC | Description of products/services | Revenues generated from products/services |
|------------------------------|--------------|----------------|-------------------------------------|--------------------------------------|--|--|---|
| Xenon Pharmaceuticals | 2000 | 70 | \$90M | Burnaby, BC | Company research supported through the Applied Human Health Competition and the Translational Program for Applied Health | The company uses genomic tools to reduce the time for identification and validation of drug targets for unmet medical need. Products Pipeline • Approved product to treat lipoprotein lipase deficiency • Late stage clinical program initiating for a novel pain medicine • Early development stage product for the | In 2012 Xenon entered in co-development and exclusive licensing deal with Teva Pharmaceuticals (\$376 M) and previously had a co-development deal with Genentech (\$646M) |

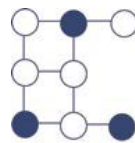
Dennis Rank and Associates



THE EVIDENCE NETWORK
Measuring Innovation Impact

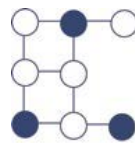
| Name of Company | Date Created | Number of Jobs | Additional financing/funding raised | Location of Company (past & present) | How company was advanced by Genome BC | Description of products/services | Revenues generated from products/services |
|------------------------|--------------|----------------|---|--|---|---|--|
| | | | | | | treatment of anemia | |
| Boreal Genomics | 2009 | 31 | \$26M in venture capital \$9M research funds \$1M industry research | Now based in Los Altos, California with a research and development site in Vancouver, British Columbia | Spin-out of Genome BC Technology Development platform tech. Further funded through the Proof of Concept program | Privately held provider of technology for non-invasive genomic profiling of tumors from blood plasma of cancer patients Products Pipeline • Provides the assay through both service and instrument offerings (OnTarget™ platform) | The company identified a \$450M opportunity in the research market space and a future opportunity in excess of \$1B for patient diagnostic testing |

| Name of Company | Date Created | Number of Jobs | Additional financing/funding raised | Location of Company (past & present) | How company was advanced by Genome BC | Description of products/services | Revenues generated from products/services |
|-----------------------|--------------|----------------|--|--------------------------------------|--|--|--|
| GenoLogics Inc | 2002 | 200 | In 2011, the company announced \$8M in a financing partnership with Illumina | Victoria, BC | Spinout from the UVIC-Genome BC Proteomics Centre (technology platform funded in 2001 onwards) | Simple goal to build a flexible and adaptable Lab Information Management System (LIMS) for the proteomics industry. Products Pipeline: • The LIMS software has been adopted worldwide and a feature now supported by Illumina | Over \$10M |
| MRM Proteomics | 2010 | 7 | \$300K | Vancouver, BC | Spinout from the UVIC-Genome BC Proteomics Centre (technology platform funded in 2001 onwards) Also funded through | The company's core expertise is in the use of high sensitive MRM-MSbased technology platforms for protein biomarker discovery/ | Total Revenues ~\$600K The company anticipates growth as the proteomics market is expected to double from \$4.2 B to \$9B |



| Name of Company | Date Created | Number of Jobs | Additional financing/funding raised | Location of Company (past & present) | How company was advanced by Genome BC | Description of products/services | Revenues generated from products/services |
|------------------------|--------------|------------------------|--|--------------------------------------|---|--|---|
| | | | | | the Proof-of-Concept Program | validation and clinical diagnostics dev. Products Pipeline: • The company is currently selling two kits (PeptiQuant MRM Assay Kits) | by 2017 and the consumables market supporting that growth is expected to be at least as significant |
| Sirius Genomics | 2001 | No longer in operation | Sirius raised \$15M to develop a sepsis companion diagnostic | Vancouver, BC | Funded by GBC through the Strategic Opportunities Fund for Industry (SBIR-like program) | The company was founded to be the leader of companion diagnostics and validation of biomarkers that may play a role in the treatment of sepsis. Although the company is no longer in operation, the principals have moved onto | 0 |

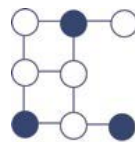
Dennis Rank and Associates



THE EVIDENCE NETWORK
Measuring Innovation Impact

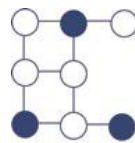
| Name of Company | Date Created | Number of Jobs | Additional financing/funding raised | Location of Company (past & present) | How company was advanced by Genome BC | Description of products/services | Revenues generated from products/services |
|------------------------------|--------------|----------------|--|--------------------------------------|---|--|--|
| | | | | | | other ventures within the community. | |
| Precision Nanosystems | 2010 | 9 | \$1M in seed funding \$4M in non-dilutive funding | Vancouver, BC | Funded through Strategic Opportunities Fund, Technology Development Initiatives fund & the Proof of Concept program | The company is developing a unique delivery system (nanoparticles) for delivering a drug to a specific location, without toxic side effects. Product Pipeline • Proprietary equipment (NanoAssemblr™) and companion Reagent Kits (SUB9KITSTM) | Total Revenue > \$500K Two markets: drug delivery/RNAi therapeutics (est. market size \$3.0B) and research tools/functional genomics (est. market size \$0.7B). |

Dennis Rank and Associates

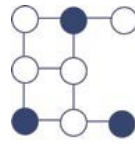


THE EVIDENCE NETWORK
Measuring Innovation Impact

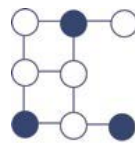
| Name of Company | Date Created | Number of Jobs | Additional financing/funding raised | Location of Company (past & present) | How company was advanced by Genome BC | Description of products/services | Revenues generated from products/services |
|---------------------------------|--------------|----------------|--|--------------------------------------|---|--|---|
| Traumis Surgical Systems | 2011 | 4 | Asset Purchase / Dev. Agreement (>\$3M) with the distribution partner (Synthes Inc). | Vancouver, BC | Research funded through the Technology Development Initiatives fund resulted in the creation of this spin-out company | Traumis specializes in the invention and development of less invasive, radiation-free surgical tools and systems. Products Pipeline: • Novel drilling tool for surgeons | Ready for submission to the FDA |
| Creative Molecules Inc | 2009 | 1 | None known at this time | Vancouver, BC | Spin-out from the University of Victoria-Genome BC Proteomics Centre | Creative Molecules was developed for commercializing reagents for proteomics research (to be likely targets for drugs). Product Pipeline: • One product group (12 reagents) | \$85K |



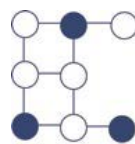
| Name of Company | Date Created | Number of Jobs | Additional financing/funding raised | Location of Company (past & present) | How company was advanced by Genome BC | Description of products/services | Revenues generated from products/services |
|-------------------------------|--------------|----------------|---|--------------------------------------|---|---|--|
| | | | | | | | |
| Indel Therapeutics Inc | 2008 | 10 | \$2.6M in equity financings since 2008 ~\$1.5M in grant funding for research | Vancouver, BC | Spin-off from the Functional Genomics for Emerging Infectious Diseases (PREPARE) Project, initially funded through a Genome Canada Competition II | New platform technology and identification of novel drugs to address the global health crisis caused by antibiotic resistance. Product Pipeline: • New drug targets for the treatment of bacterial and parasitic infections and, potentially, fungal and viral infections | Anticipating the antibiotic market globally is worth \$20-\$30B; the company is focused on developing antibiotic therapies that will have peak annual sales greater than \$250M. |



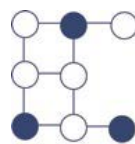
| Name of Company | Date Created | Number of Jobs | Additional financing/funding raised | Location of Company (past & present) | How company was advanced by Genome BC | Description of products/services | Revenues generated from products/services |
|------------------------------------|--------------|----------------|-------------------------------------|--------------------------------------|--|--|---|
| Inimex Pharmaceuticals | 2002 | 30 | Raised \$22M in Series B funding | Burnaby, BC | Company advancement through two national competitions | <p>The company is focused on the development and commercialization of Innate Defense Regulators (IDRs), novel first in class drugs that specifically manage the body's innate defenses without causing inflammation.</p> <p>Products Pipeline:</p> <ul style="list-style-type: none"> • Phase 2-ready lead product (IMX492) | Revenue – \$1.90M |
| DuVax Vaccines and Reagents | 2011 | 1 | \$25K | Victoria, BC | Funded through Genome BC's <i>Proof of Concept</i> program | Develops a platform technology which will be used to produce a line of highly | No data |



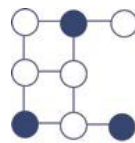
| Name of Company | Date Created | Number of Jobs | Additional financing/funding raised | Location of Company (past & present) | How company was advanced by Genome BC | Description of products/services | Revenues generated from products/services |
|--------------------------|--------------|----------------|--|--------------------------------------|---|--|--|
| | | | | | | protective, safe, and cost effective vaccines and biological reagents | |
| viDA Therapeutics | 2012 | 15 | Closed a \$2.5M equity financing round | Vancouver, BC | Founded with support from GBC's Strategic Opportunities Fund for Industry | viDA Therapeutics is a biopharmaceutical company developing therapeutics for the prevention of chronic tissue injury and promotion. Products Pipeline: • A suite of inhibitors to treat chronic and orphan skin conditions, fibrosis, rheumatoid arthritis, and cardiovascular disease | Pre-clinical development stage. Global hypertrophic scarring market worth ~ \$12B per annum |



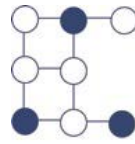
| Name of Company | Date Created | Number of Jobs | Additional financing/funding raised | Location of Company (past & present) | How company was advanced by Genome BC | Description of products/services | Revenues generated from products/services |
|------------------------|--------------|----------------|--|--------------------------------------|---|--|--|
| | | | | | | | |
| Fusion Genomics | 2013 | 6 | Aims to raise \$150,000 to further refine assay and develop new ones in other areas of interest (adult and childhood leukemia and viral-associated cancers). | Vancouver, BC | Research supported through the Proof-of-Concept program created this spin-out company | <p>Fusion genomics is a next generation sequencing assay development company specializing currently in assays for the diagnosis of childhood cancers.</p> <p>Products Pipeline:</p> <ul style="list-style-type: none"> • Assay for the identification of childhood cancers in development | Anticipated market worth \$32M. Future market for virus associated cancers is estimated \$550M |



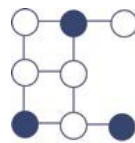
| Name of Company | Date Created | Number of Jobs | Additional financing/funding raised | Location of Company (past & present) | How company was advanced by Genome BC | Description of products/services | Revenues generated from products/services |
|------------------|--------------|----------------|---|--------------------------------------|--|--|---|
| | | | | | | | |
| AbCellera | 2012 | 3 | \$25K in seed financing \$50K funds raised (Expects to close a financing round (\$250k - \$500k) in 2014) | Vancouver, BC | Research advanced through Proof of Concept program | The company will build on its proprietary microfluidic technologies for single cell analysis for the discovery of new antibody molecules for therapeutics, diagnostics and reagents applications. Products Pipeline: <ul style="list-style-type: none"> • Next-generation monoclonal antibody therapeutics in development | Market size for research is ~ \$750M |



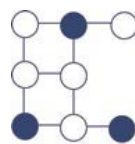
| Name of Company | Date Created | Number of Jobs | Additional financing/funding raised | Location of Company (past & present) | How company was advanced by Genome BC | Description of products/services | Revenues generated from products/services |
|--------------------|--------------|----------------|--|---|--|---|---|
| PREVENT Inc | 2008 | 8 | \$30M from various sources (CECR funding of \$14.95M; \$10.5M of in-kind support from its founding partners) | Saskatoon, SK, with resources in Vancouver, BC, and Halifax, NS | Funded through Genome BC's <i>Proof-of-Concept</i> program | A non-for-profit vaccine development company established as a Centre of Excellence for Commercialization and Research. PREVENT subcontracts late-stage development, scale-up manufacturing, and preclinical and clinical work to service providers. Products Pipeline: • Five in-licensed vaccine candidates | |



| Name of Company | Date Created | Number of Jobs | Additional financing/funding raised | Location of Company (past & present) | How company was advanced by Genome BC | Description of products/services | Revenues generated from products/services |
|---------------------------|--------------|----------------|---|--|--|---|--|
| GenomeDx Biologics | 2008 | 31 | Closed a Series A financing round in 2012 and a Series B financing in 2013 (confidential) | Based in San Diego, California and Vancouver, BC | Funded through Genome BC's <i>Proof-of-Concept</i> program | <p>GenomeDx curates the world's most comprehensive genomic activity database on metastatic prostate cancer and couples it to cloud-based informatics to analyze millions of data points from a patient's tumor.</p> <p>Products Pipeline:</p> <ul style="list-style-type: none"> • Decipher™ (a genomic test that forecasts risk of metastasis in men with prostate cancer). • Other tests in development | The market size for the company's whole pipeline is ~ \$900M |

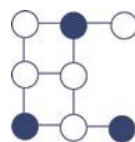


| Name of Company | Date Created | Number of Jobs | Additional financing/funding raised | Location of Company (past & present) | How company was advanced by Genome BC | Description of products/services | Revenues generated from products/services |
|-------------------------|--------------|----------------|---|--------------------------------------|--|---|---|
| Coastal Genomics | 2012 | 4 | ~\$600K in equity financings since it was formed & ~\$1M in grant funding | Burnaby, BC | Funded through GC/GBC work with the GSC's technology development platform. | Coastal Genomics is a privately-owned corporation that intends to commercialize a novel liquid handling automation technology to be marketed as the Ranger automated workstation for improvement of sample preparation for Next-Generation Sequencing | 0 Just launched |
| Target Tape | 2010 | 2 | ~\$1M raised | Vancouver, BC | Funded through GC/GBC work with the GSC's technology development platform | The company is developing new tools for spinal surgery applications that can make a surgeon's work | Potential market size: General surgical aid (spinal, vascular, orthopaedic, thoracic) ~ |



| Name of Company | Date Created | Number of Jobs | Additional financing/funding raised | Location of Company (past & present) | How company was advanced by Genome BC | Description of products/services | Revenues generated from products/services |
|------------------|--------------|----------------|-------------------------------------|--------------------------------------|---|---|---|
| | | | | | | easier, safer, and faster | \$300M |
| Metamixis | 2013 | 1 | Fundraising in progress | Vancouver, BC | Support from the Entrepreneurship Education in Genomics program resulted in this spin-out | Production of small molecules from engineered microbial sources for the pharmaceutical and fine chemical industries | 0 |
| Tait Labs | 2013 | 2 | Fundraising in progress | Vancouver, BC | Support from the Entrepreneurship Education in Genomics program resulted in this spin-out | Manufacturing and sales of MS+TM (Mandarin Skin Plus), a revolutionary health product that aids digestion and promotes gastrointestinal | 0 |

Dennis Rank and Associates



THE EVIDENCE NETWORK
Measuring Innovation Impact

| Name of Company | Date Created | Number of Jobs | Additional financing/funding raised | Location of Company (past & present) | How company was advanced by Genome BC | Description of products/services | Revenues generated from products/services |
|-----------------|--------------|----------------|-------------------------------------|--------------------------------------|---------------------------------------|----------------------------------|---|
| | | | | | | health | |