Who Are Ontario’s Highly Qualified Personnel?

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# Table of Contents

Introduction 1

HQP Skills and Occupations 2

**Part 1: In Search of Highly Qualified Personnel** 7

Size and Breakdown 7

Salary 8

Education 10

Cities 13

Industries 16

**Part 2: Who are Highly Qualified Personnel?** 18

Women are underrepresented, and receive lower salaries in HQP occupations 19

For the past 10 years, growing participation in HQP occupations has primarily been driven by an older male cohort 21

Immigrant and visible minority diversity among HQP is high, but some groups are underrepresented and earnings are not equal 21

Conclusion 26

Appendix A: Defining Highly Qualified Personnel 27

Appendix B: Decomposing Demographic Changes 35
High performance computing has been an essential tool for numerical simulation and large datasets since the mid-1960s, when it was used to predict weather systems. Today, its use has grown across a wide variety of research fields including quantum mechanics, weather forecasting, climate research, oil and gas exploration, molecular modeling and many more. With social media and the “internet of things” gathering more and more information quickly and cheaply, datasets have also been growing at a tremendous rate in the social sciences. As a result, high performance computing is becoming an increasingly important tool for fields such as economics, psychology, and sociology.

Advanced research computing (ARC) is an umbrella that includes high performance computing as well as other services and resources that contribute to advanced research such as skilled labour, data storage and management, and networking and visualization. In Ontario, Compute Ontario promotes and supports ARC resources across universities, colleges, hospitals, industry, and government. These computational resources are being used for important research — for example, the newly launched Niagara supercomputing system is conducting unprecedented modelling of how oceans operate and change. In Ontario, ARC has also played a key role in cancer research; at the Princess Margaret Cancer Research lab, it has been applied to work on mapping cancer markers.

To enable wider use of ARC, Compute Ontario and its partners, are seeking to attract and develop talent with the skills and knowledge to use ARC to advance research, as well as skilled individuals who can support these researchers. In this context, we refer to this type of talent as highly qualified personnel (HQP). Working with R.A. Malatest & Associates Ltd.—an independent research organization and provincial advisory committee, Compute Ontario conducted its first study on HQP in 2017–18. This report defined HQP as people with the ability to use software tools and techniques to solve a problem as well as an understanding of the concepts to be researched. Using this definition, we use this report to map and identify the HQP talent that is important to the ARC industry in Ontario.

This report was commissioned by Compute Ontario and builds on its existing efforts to recruit ARC talent and promote ARC resources. It draws on the methodology developed by the Brookfield Institute for Innovation + Entrepreneurship in its report *Who Are Canada’s Tech Workers?* to zero in on one specific population of tech workers using an adapted definition that reflects Compute Ontario’s interest in HQP.
DEFINING HIGHLY QUALIFIED PERSONNEL

Highly Qualified Personnel (HQP): People with both the ability to use software tools and techniques to solve a problem and an understanding of the concepts to be researched.

To map and identify HQP, we must first define them. Our methodology describes the talent that is best positioned to take advantage of ARC resources. According to Malatest’s study, it is not enough for a person to be an expert in a particular field in which ARC is used. At the same time, only knowing the technical aspects of how to leverage supercomputers without deep domain knowledge is also insufficient. As shown in Figure 1, HQP in this context must be those people with both the technical expertise to navigate advanced computing and the specific domain knowledge to be able to apply it to a particular research question. To best capture those individuals at the intersection of these skill and knowledge sets, we build from the methodology developed for our 2019 report, Who are Canada’s Tech Workers.

HQP SKILLS AND OCCUPATIONS

To reach our HQP occupations definition, we analyzed the skills involved in different occupations. We linked the US Bureau of Labour Statistics’ (BLS) O*NET database1 to Canada’s National Occupational Classification (NOC) to guide our selection of the two skill and knowledge sets described above. We identified digital skills based on existing methodology applied in Who are Canada’s Tech Workers and selected fields of domain knowledge that reflected in a significant part of users of Compute Ontario’s computing resources and training programs. As shown in Figure 2, research disciplines with the highest use of computing resources are engineering, chemistry, biochemistry, and physics. The disciplines that are currently utilizing the most training resources are medicine, biology, physics, and engineering as shown in Figure 3. While use of ARC may expand in other fields, this report focuses on fields where ARC use is already relatively high, signalling that those with expertise in these fields may be more prepared to apply ARC in their work.

Figure 1: Defining HQP

1 O*NET is an occupational database maintained by North Carolina’s Department of Commerce under sponsorship from the US Department of Labour’s Employment & Training Administration (ETA). O*NET provides authoritative occupational information for the US, including the skills and knowledge required for an occupation, the specific tasks performed, and the tools & technologies used. O*NET is the largest and most detailed database of its kind, and tracks almost 1,000 occupational groups. In recent years, prominent research in labour economics, particularly on the automation of labour, has used O*NET’s data on occupational tasks extensively.
Figure 2: CPU Usage by Research Discipline

Figure 3: Relative Percentage of the Attendance in SciNet Training by Researchers from Different Fields
**Table 1:**
*Skill Sets*

<table>
<thead>
<tr>
<th>Digital Skills</th>
<th>Domain Knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer skills and knowledge required to both use software tools and techniques and apply them to solve a problem.</td>
<td>Specific knowledge of the concepts to be researched and the implications of findings.</td>
</tr>
<tr>
<td>1. Programming</td>
<td>1. Physics</td>
</tr>
<tr>
<td>2. Interacting with Computers</td>
<td>2. Chemistry</td>
</tr>
<tr>
<td></td>
<td>4. Engineering and Technology</td>
</tr>
</tbody>
</table>

We identified HQP to be workers in occupations that require mastery in at least one digital skill and at least one area of domain knowledge. Specifically, if an occupation had a high score in at least one digital skill and at least one area of domain knowledge, it received a higher “HQP score”. HQP occupations are those with a composite ranking in the top 4%. This cutoff choice was based on two priorities that are in tension with one another; our definition should be stringent enough that we select only those occupations that truly fall within our skill and knowledge set requirement, but lenient enough that we have a set that describes the population of interest. When this constraint was relaxed, the total number of HQP identified did not change significantly. See Appendix A for more information on methodology, skill choice, and cutoff choice.
Figure 4: Defining HQP Occupations

Based on PCA, network analysis of O*NET skills, knowledge and activities, and Compute Ontario consultation 3 items are selected as “Digital Skills”, and 4 are selected as “Domain Knowledges”

Each NOC is given an ordinal rank in each of the skills. Those ranks are then aggregated to give an ordinal “Digital Score” and “Domain Score”. Finally Those to scores are aggregated into a “HQP Score”

Occupations with a HQP score below a cut-off were excluded.

Glossary of Statistics Canada’s demographic concepts for this report

This report relies on a series of statistical definitions from Statistics Canada’s 2016 Census Dictionary.

**Working Individuals:** Working individuals are people who worked for any amount of time during the reference year (2015), even if only for a few hours.

**Sex:** According to Statistics Canada’s 2016 Census Dictionary definition, sex refers to “whether a person is [biologically] male or female”. The 2016 Canadian Census collected data regarding a respondent’s sex, but not their gender, which may not correspond.

Statistics Canada recently updated its sex and gender variables. Under the new definitions, “sex” refers to “sex assigned at birth” which is typically “based on a person’s reproductive system and other physical characteristics.” Gender, on the other hand, refers to “the gender that a person internally feels (‘gender identity’ along the gender spectrum) and/or the gender a person publicly expresses (‘gender expression’).”

We recognize that there are important differences in meaning between the terms “sex” and “gender,” as well as “female/male” and “woman/man”; however, in this report we use these terms interchangeably given that this distinction was not made in Statistics Canada’s last Census, which is the primary data source for this report.

**Age:** Age refers to the age of a person at their last birthday (or relative to a specified, well-
Visible Minority: Under Statistics Canada’s definition, visible minority refers to “whether a person belongs to a visible minority group as defined by the Employment Equity Act and, if so, the visible minority group to which the person belongs. The Employment Equity Act defines visible minorities as ‘persons, other than Aboriginal peoples, who are non-Caucasian in race or non-White in colour.’ Categories in the visible minority variable include South Asian, Chinese, Black, Filipino, Latin American, Arab, Southeast Asian, West Asian, Korean, Japanese, Visible minority, n.i.e. (‘n.i.e.’ means ‘not included elsewhere’), Multiple visible minorities and Not a visible minority.”

Unfortunately, due to data limitations, we were unable to examine other critical intersections such as HQP who identify as LGBTQ+ or as having a disability.

Concepts calculated and examined

Participation in HQP occupations: The share of a demographic group that works in a HQP occupation. For instance, if there were 100 male workers in Ontario and 8 of those workers worked in a HQP occupation, the participation rate for male workers would be 8%.

Share of HQP: The share of HQP that belong to a specific demographic. For instance, if there were 100 HQP workers in Ontario and 20 of them were women, we would say women workers made up a 20% share of HQP.

Pay in HQP occupations: The weighted average of pay in HQP occupations for the considered demographic groups, where the weight placed on each occupation is the number of people employed in that occupation.

Pay in non-HQP: The weighted average of pay in non-HQP occupations for the considered demographic group, where the weight placed on each occupation is the number of people employed in that occupation.
Comparing HQP to tech workers broadly

**Education**: HQP are highly educated with 72% of HQP having at least a bachelor’s degree compared to 58% of tech workers. This difference is partially explained by the majority of HQP being engineers who legally need a bachelor’s degree to operate. Furthermore many other HQP occupations require at least a bachelor’s degree, while a number of the tech worker occupations might not.

**Industries**: HQP are much more concentrated than tech workers. This is largely due to the fact that HQP in ARC are a specific subset of tech workers focused on research and technology development.

In this first section, we provide an overview of Ontario’s HQP, including: how many there are, what they earn, what level of education they have, which cities they live in, and the industries they work in.

**SIZE AND BREAKDOWN**

In 2016, around 201,000 Ontarians were employed in HQP occupations, representing 2.9% of the Ontarian labour force.

Figure 5 shows that of the top 15 HQP occupations in Ontario in 2016, Computer Programmers and Interactive Media Developers and Software Engineers and Designers employ the largest numbers of people, together making up 37.1% of HQP. Other engineering groups (mechanical, civil, etc.) make up another 56.2%, while scientists and researchers make up the remaining 6.7%. Engineering occupations represent the highest proportion of HQP for two reasons. First, choosing engineering occupations is an artifact of our method as engineering occupations tend to require both digital skills and knowledge within the domains of engineering and technology. Secondly, there are greater numbers of engineers in Ontario than there are researchers and scientists.

<table>
<thead>
<tr>
<th>Occupational group</th>
<th>Number of workers</th>
<th>Share of workforce</th>
</tr>
</thead>
<tbody>
<tr>
<td>HQP</td>
<td>201,000</td>
<td>2.9%</td>
</tr>
<tr>
<td>Non-HQP</td>
<td>6,790,000</td>
<td>97.1%</td>
</tr>
</tbody>
</table>

Table 2: Number of HQP
Figure 5: Top 15 HQP Occupations by Employment in Ontario

Source: 2016 Canadian Census, BII+E Analysis

Table 3: HQP Employment Income

<table>
<thead>
<tr>
<th>Occupational group</th>
<th>Employment Income</th>
</tr>
</thead>
<tbody>
<tr>
<td>HQP</td>
<td>$90,000</td>
</tr>
<tr>
<td>Non-HQP</td>
<td>$55,000</td>
</tr>
</tbody>
</table>
In 2016, HQP were paid considerably more than non-HQP. We see in Figure 6 that Geoscientists and Oceanographers, Engineering Managers, and Mining Engineers received the highest pay, earning $135,297, $126,460, and $114,506 per year respectively. Half of the HQP occupations earn roughly $90,000, but there are some that earn significantly less. For instance, Biological Technologists and Technicians earning the least at $41,727.

Figure 6: HQP Occupations by Average Earnings in Ontario

Source: 2016 Canadian Census, BII+E Analysis
HQP have much higher levels of formal education on average than non-HQP. In 2016, the majority of HQP (72%) held at least a bachelor’s degree, 17% had a college or CEGEP diploma, 1.7% had an apprenticeship and/or went to trade school and only 0.16% held no degree or diploma (including a high school diploma). Workers in non-HQP occupations on the other hand, were less likely to hold at least a bachelor’s degree or above (30%), and 38% had either no degree or held a high school diploma. While the portion of HQP that have a postgraduate degree is 18 percentage points higher than non-HQP, one might expect it to be even higher. It is worth noting, however, that as our definition is based on the occupation level, seniority is not taken into account.

**Figure 7:**
Educational Composition of HQP Occupations

![Educational Composition of HQP Occupations](image)

Source: 2016 Canadian Census, BII+E Analysis

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2 Statistics Canada’s definition of HQP is individuals that have a bachelor’s degree, so it is worth noting that our skills based methodology does a fairly good job of capturing that definition as well.
The majority (55.3%) of HQP are educated in Engineering or Engineering Technologies and Engineering Related Fields. This is unsurprising, given that 69% of HQP occupations are in engineering occupations. For a more nuanced look at educational backgrounds, we identified the top seven fields of study based on the most recent degrees held by HQP and unpacked the portion of people in each HQP occupation that studied in one of those fields. Figure 9 shows that while HQP in engineering occupations largely went to school for engineering, 24% did not. The primary reason for this is that many Software Engineers and Designers and Computer Engineers are educated in computer science. Engineering Managers were also fairly varied in their educational backgrounds. The field distributions of other occupations are not entirely surprising; individuals in research and science occupations largely pursued education in their fields. Two notable exceptions are Chemists and Biological Technologists and Technicians, who come from a variety of educational backgrounds.

**Figure 8:**
Educational Backgrounds of HQP Occupations

*Source: 2016 Canadian Census, BII+E Analysis*
Figure 9: Educational Backgrounds of HQP Occupations by NOC

Source: 2016 Canadian Census, Bill+E Analysis
CITIES

Toronto has the highest number of HQP with 106,600, followed by Ottawa–Gatineau with 34,000 and Waterloo Region with 11,200. The cities across Ontario with the highest concentration (proportion of the labour force made up of HQP) were Ottawa–Gatineau with 4.8%, Waterloo Region with 4.0%, Toronto with 3.4%, Carleton Place with 3.3%, and Sarnia with 3.1%. In Figure 11 we show the HQP population in small and medium-sized population centres of Ontario, while the HQP populations are relatively small, in total HQP in non-major urban areas make up 8% of the total number of HQP.

Figure 12 shows the percentage point change in the cities with the highest HQP population. Over 2006 and 2016, there was a significant increase in the Waterloo Region, which grew by 3,290 HQP. In contrast, Ottawa experienced a decrease of 2,140 HQP over the same time period.

Figure 10:
Concentration of HQP by Cities in Ontario

Source: 2016 Canadian Census, BII+E Analysis
Figure 11:
HQP in Small and Medium Population Centres of Ontario

Source: 2016 Canadian Census, BII+E Analysis
Figure 12:
10 Years Change in HQP Employment for Ontario Cities, 2006–2016

Source: 2016 and 2006 Canadian Census, BII+E Analysis
HQP are highly concentrated in the Professional, Scientific and Technical Services industry. This industry accounts for 42% of all HQP, with the next largest industry being Public Administration at only 7.7%.

For a more nuanced picture of HQP industries, we examined the 4-digit level of industries. The two largest categories are Computer System Design and Related Services and Architectural, Engineering and Related Services with 37,000 and 31,400 individuals respectively. Combined, they make up 81% of the HQP in the Professional, Scientific and Technical Services industry, with Scientific Research and Development Services, and Management, Scientific and Technical Consulting Services constituting another 14.6%. Not only are HQP concentrated in terms of industry, but they are also make up a significant portion of the industries in which they are concentrated. As shown in Figure 14, HQP make up roughly a third of Architectural, Engineering and Related Services, Scientific Research and Development Services, and Computer System Design and Related Services respectively.

Figure 13:
Number of HQP Employed by 4-Digit Industry Group

Source: 2016 Canadian Census, BII+E Analysis
Figure 14:
Share of HQP by 4-Digit Industry Group

Source: 2016 Canadian Census, BII+E Analysis
PART 2: WHO ARE HIGHLY QUALIFIED PERSONNEL?

In this section we examine diversity among HQP, focusing specifically on the earnings and participation of women and visible minority groups.

Comparing HQP to tech workers broadly

The results of our analysis of HQP in Ontario are largely consistent with our analysis of Canada’s tech workers in Who Are Canada’s Tech Workers?; however, there are some striking differences.

Gender pay gap: The gender pay gap for HQP is $16,700 while for tech workers it is $7,300, which reflects a difference of $9,400. This difference is largely explained by the higher level of education among HQP. For tech workers the gender pay gap is $19,600 for those with a bachelor’s degree and there are very few HQP without a bachelor’s degree.

Participation of young women over time: Both HQP and tech workers have seen declines in the participation rate of young women over time, but this change is much starker for HQP.

Relationship between participation and pay for visible minorities: The findings in Who Are Canada’s Tech Workers? demonstrated that there is a somewhat positive relationship between participation of demographic groups (visible minority and sex) and their level of compensation. In the context of HQP this relationship is less present, for example, West Asian men have the second highest participation rate of any group at 9.4%, but are only the 14th (out of 22 groups) in income. On average, West Asian men make $43,300 which is only 43% of what White men who are working as HQP earn.

Additionally, the pay gap for the Black population of HQP is much higher when compared to tech workers. Black tech workers make 90% of their White counterparts’ employment income whereas Black HQP make only 64% compared to their White counterparts.
Women are underrepresented, and receive lower salaries in HQP occupations.

There are serious disparities in participation and earnings between men and women in HQP occupations.

Men are four and a half times more likely than women to be in a HQP occupation, and make up 83% of the HQP. There is also a significant pay gap between men and women employed in HQP occupations, with women earning on average $16,700 less than men as compared to a gap of $14,400 less in non-HQP occupations. Women in HQP occupations are as likely to hold a bachelor’s degree as their male counterparts, but are more likely to hold a postgraduate degree. However, the simple pay gap between women and men in HQP occupations who hold a bachelor’s degree or above is $4,600 higher than the pay gap for those without a bachelor’s degree.

<table>
<thead>
<tr>
<th>Sex</th>
<th># of HQP</th>
<th>Share of HQP Workforce</th>
<th>Participation in HQP Occupations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men</td>
<td>167,500</td>
<td>83%</td>
<td>4.64%</td>
</tr>
<tr>
<td>Women</td>
<td>33,600</td>
<td>17%</td>
<td>1%</td>
</tr>
</tbody>
</table>

Table 5:
Employment Income of Men and Women in HQP Occupations

<table>
<thead>
<tr>
<th>Sex</th>
<th>Pay in HQP occupations</th>
<th>Pay in non-HQP occupations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men</td>
<td>$95,100</td>
<td>$52,600</td>
</tr>
<tr>
<td>Women</td>
<td>$78,000</td>
<td>$40,100</td>
</tr>
</tbody>
</table>

The pay gap we refer to in this report is a “simple pay gap,” which does not control for other potential factors such as experience, education or occupational choice.
Table 6:
Employment Income of Men and Women in HQP Occupations by Education Level

<table>
<thead>
<tr>
<th>Sex</th>
<th>Below bachelor’s degree</th>
<th>Bachelor’s degree and above</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men</td>
<td>$54,700</td>
<td>$96,800</td>
</tr>
<tr>
<td>Women</td>
<td>$39,600</td>
<td>$78,500</td>
</tr>
</tbody>
</table>

Figure 15:
Educational Composition by Sex: HQP Occupations

Source: 2016 Canadian Census, BII+E Analysis
Unfortunately, these findings are not a surprise. As described in Who Are Canada’s Tech Workers? it has long been the case that gender representation and earnings in science, technology, engineering, and mathematics (STEM) occupations are far from equal. A significant body of research suggests that barriers to entering such roles begin early in life for women: influences from families, teachers, role models, and cultural stereotypes can impact the likelihood of women to engage in subjects that set them up for tech roles later in life. There is also evidence pointing to a male-dominated culture in STEM education, and to discrimination in hiring or on the job. These barriers can steer women away from STEM majors and impact their career opportunities and trajectories in occupations that fall under the HQP umbrella. While women have long surpassed men in the attainment of a bachelor’s degree or higher, they remain underrepresented in STEM education programs. These trends impact the labour market in the form of lower participation in science and tech occupations. Previous studies have also highlighted that women tend to be paid less, both within the same occupations and across occupations. Furthermore, the gender pay gap grows as careers progress and salaries increase, resulting in particularly stark differences at the top of the wage distributioniv.

This analysis is drawn from Who Are Canada’s Tech Workers?

From 2006 to 2016, 31,350 more Ontarians started working in an HQP occupation, which corresponds to a change in participation in HQP occupations from 2.6% of the Ontario labour force to 2.9%. It is important to delineate between two forces that drive this change. The first are shifts driven by overall demographic change, which we refer to as the composition effect. For example, if older people were more likely to work in an HQP occupation and the overall population is aging, this demographic change will likely increase participation. The second force driving participation change is the propensity effect is the change from shifting the inclination of a certain demographic group to participate in HQP occupations, we call this the propensity effect. In this case, if Ontario did not experience any demographic change in terms of age and sex, it could have 33,590 more people working in an HQP occupation, implying that the composition effect was negative and small. In Table 7, each age-sex cell shows the portion of the propensity effect (change in participation holding demographic changes constant) that can be explained by that group, as well as the actual percentage change in participation for that group.

Growth of participation in HQP occupations has been driven primarily by older men. Male participation grew by 5.1 percentage points while female participation grew by only 0.3 percentage points. HQP between the ages of 45 and 64 years old accounted for 72% of the propensity effect with 57% being explained by men in that age range. Individuals between the ages of 15 and 24 drive the next largest portion of participation growth, with most of the growth being contributed by men. Notably, however, there has been a 24% decrease in participation of women between the ages of 25–44, accounting for -12% of the propensity effect.

Diversity in Ontario’s HQP occupations is high relative to the Ontario labour market as a whole. However, certain groups are underrepresented and receive less pay.

Visible minorities made up 41% of Ontario’s HQP and were twice as likely to work in HQP occupations compared with non-visible minorities. Those identifying as Chinese, West Asian, Korean,
Who Are Ontario’s Highly Qualified Personnel?

While this figure suggests that on average HQP earn more than non-HQP across gender and visible minority groups, it does not suggest that an individual moving from a non-HQP occupation to a HQP occupation will necessarily experience this pay increase.

Table 7: Participation Changes in HQP Occupations by Sex and Age

<table>
<thead>
<tr>
<th>Sex</th>
<th>Age</th>
<th>15–24 Years</th>
<th>25–34 Years</th>
<th>35–44 Years</th>
<th>45–54 Years</th>
<th>55–64 Years</th>
<th>65–74 Years</th>
<th>Total effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men</td>
<td>20% of effect</td>
<td>8% of effect</td>
<td>38% of effect</td>
<td>19% of effect</td>
<td>3.1% of effect</td>
<td>91%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>58% increase</td>
<td>3.6% increase</td>
<td>24% increase</td>
<td>26% increase</td>
<td>25% increase</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.4% of effect</td>
<td>-7.5% of effect</td>
<td>-4.4% of effect</td>
<td>10% of effect</td>
<td>0.3% of effect</td>
<td>9%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.1% increase</td>
<td>16% decrease</td>
<td>8.3% decrease</td>
<td>35% increase</td>
<td>84% increase</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total effect - Age</td>
<td>25%</td>
<td>-7.1%</td>
<td>3.6%</td>
<td>48%</td>
<td>24%</td>
<td>3.4%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Arab, and South Asian were the most likely to work in HQP occupations out of all visible minority groups. People who identified as Filipino or Black had the lowest participation rates in HQP occupations.

For most visible minority groups in HQP occupations, average pay is much lower than for non-visible minority HQP workers. The average pay across all visible minorities in HQP occupations was $77,100, which is $30,700 more than visible minorities make in non-HQP occupations. However, they make an average of $18,900 less than non-visible minorities in HQP occupations. This pay gap ranges from Latin American and Black HQP who make 64% of White HQP, to Arab HQP who make 48%.

Disparities in pay are even more stark for female HQP belonging to visible minority groups. For the most part, women receive lower compensation than men across all visible minority groups, on average receiving $15,900 less than their male counterparts in HQP occupations. However, White female HQP, who have an average salary of $73,900, do earn more than all visible minority HQP men except those who identify as Chinese.

Amongst women in HQP occupations, visible minority women earn less than all non-visible minority women. Women who identified as Korean (average salary $25,500), West Asian (average salary $32,400), Arab (average salary $38,500), Filipino (average salary $42,000) and Black (average salary $42,400) earn the least. However, for both men and women across visible minority groups, there is a pay premium for working in HQP occupations that is roughly consistent, and on average 66% higher than the pay received by each group in non-HQP occupations.

All women from visible minority groups participated in HQP occupations at rates lower than men from the same groups. However, while one would expect a correlation between participation and average pay, and there is a weak one of 0.4, we see a number of examples of demographic groups with high participation and low average pay. The starkest examples are West Asian, Arab, and Korean men.

5 While this figure suggests that on average HQP earn more than non-HQP across gender and visible minority groups, it does not suggest that an individual moving from a non-HQP occupation to a HQP occupation will necessarily experience this pay increase.
Figure 16:
Pay Difference between HQP and Non-HQP Occupations by Visible Minority and Sex

Source: 2016 Canadian Census
Note 1: Each point represents a Visible Minority – Sex pair
Note 2: Drawn with 45 Degrees Line
Figure 17:
Pay and Participation by Visible Minority and Sex

Source: 2016 Canadian Census
Note: Each Point Represents a Visible Minority − Sex pair
Context

As with sex-based discrimination in HQP occupations, our findings on race-based discrimination align with our research on tech workers. In *Who Are Canada’s Tech Workers?*, we explained that according to available research, immigrants represent a significant and essential part of STEM occupations and the technology sector, but there are significant barriers faced by certain demographic groups, in particular, Black and Hispanic workers. Studies have shown that underrepresented minority groups are less likely to have strong beliefs in their mathematical abilities and that teachers have lower expectations of Black students, particularly in math subjects. Even when Black and Hispanic students major in STEM degrees, they are less likely than their White and Asian counterparts to pursue a career in technology or science. Research on the topic suggests this is the result of biases in recruiting, negative perceptions of the work culture, and encounters with racism on the job. In a study of individuals who voluntarily left technology occupations, “men of colour” were most likely to leave because of perceived unfairness. Additionally, nearly one quarter of underrepresented men and women of colour who left tech jobs experienced stereotyping at twice the rate of their White and Asian counterparts.

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6 This analysis is drawn from *Who Are Canada’s Tech Workers?*
While HQP do exist across Ontario, they tend to be concentrated in Ontario’s larger cities, in certain industries, and in certain degree programs. Ontario’s population of HQPs are also notably less diverse than the overall population of the province.

To further build awareness about the potential applications of advanced research computing and to recruit new talent into supercomputing, there are clear opportunities for Compute Ontario to focus future efforts on expanding the use of ARC in university programs in engineering, computer science, and scientific disciplines. For current talent, Compute Ontario should focus on the Architectural, Engineering and Related Services, Scientific Research and Development Services and Computer System Design and Related Services industries in Ottawa, Waterloo, and Toronto.

Efforts to build a stronger awareness of HQP and develop talent with the right skills and knowledge to fill HQP roles should also include a focus on fostering greater diversity among those considering the relevant fields of study, as well as those pursuing relevant careers. A lack of diversity in current participation and pay gaps may be holding a large number of Ontarians back from engaging in the types of roles and research that are of interest to Compute Ontario, and may be limiting the diversity of perspectives that inform the shape of this research.
In this appendix, we detail the full methodology we employed, including robustness checks involved in defining HQP. We first identified HQP occupations based on their requisite skills.

We relied on the US Department of Labour’s O*NET database to identify the skill content of different occupations. The O*NET database collects detailed information on 974 occupational groups (as of April 2018). It includes a common taxonomy on important occupational attributes, such as skills, knowledge, and abilities.

Specifically, we crosswalked O*NET occupations to Canada’s 500 National Occupational Categories (NOC) occupations at the 4-digit level (which is the most detailed set of occupations available) and used the resulting skills, knowledge, and work activities to identify whether each 4 digit NOC is considered an HQP occupation.

We identified HQP as individuals with consistent competence in the two following skill and knowledge categories:

1. **Digital Skills**: The ability to both use software tools and techniques and apply them to solve a problem.

2. **Domain-Specific Knowledge**: Specific knowledge in a research field that utilizes high performance computing.

7 We crosswalked the NOC to O*Net using a two-stage process. First, we leveraged the existing crosswalks between NOC and ISCO (International Standard Classification of Occupations) and between ISCO and O*Net. From this base-level matching, we manually went through the results and adjusted these matchings, primarily through using job titles associated with each occupational groupings. Most importantly, we followed the principle that every NOC occupation has to have at least one matching O*Net occupation. As we’re interested in Canadian occupations, this allows us to make sure we have all Canadian occupations categorized...
### Table 7: SKW Descriptions

<table>
<thead>
<tr>
<th>SKW</th>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Programming</td>
<td>Digital Skills</td>
<td>Writing computer programs for various purposes.</td>
</tr>
<tr>
<td>Interacting with Computers</td>
<td>Digital Skills</td>
<td>Using computers and computer systems (including hardware and software) to program, write software, set up functions, enter data, or process information.</td>
</tr>
<tr>
<td>Knowledge of Computers and Electronics</td>
<td>Digital Skills</td>
<td>Knowledge of circuit boards, processors, chips, electronic equipment, and computer hardware and software, including applications and programming.</td>
</tr>
<tr>
<td>Biology</td>
<td>Domain Knowledge</td>
<td>Knowledge of plant and animal organisms, their tissues, cells, functions, interdependencies, and interactions with each other and the environment.</td>
</tr>
<tr>
<td>Chemistry</td>
<td>Domain Knowledge</td>
<td>Knowledge of the chemical composition, structure, and properties of substances and of the chemical processes and transformations that they undergo. This includes uses of chemicals and their interactions, danger signs, production techniques, and disposal methods.</td>
</tr>
<tr>
<td>Engineering and Technology</td>
<td>Domain Knowledge</td>
<td>Knowledge of the practical application of engineering science and technology. This includes applying principles, techniques, procedures, and equipment to the design and production of various goods and services.</td>
</tr>
<tr>
<td>Physics</td>
<td>Domain Knowledge</td>
<td>Knowledge and prediction of physical principles, laws, their interrelationships, and applications to understanding fluid, material, and atmospheric dynamics, and mechanical, electrical, atomic and subatomic structures and processes.</td>
</tr>
</tbody>
</table>
The list of skills identified for the _digital skills_ category is the same as the digital skills chosen in _Who are Canada's Tech Workers?_, explained in Appendix A of that report. To identify fields of _domain-specific knowledge_, we looked at the fields that most use Compute Ontario’s resources—specifically those with the highest Central Processing Unit (CPU) usage and those that are the highest users of Compute Ontario’s training resources. Compute Ontario usage data is shown in Figures 17 and 18.

_Figure 18:_

**CPU Usage by Research Discipline**


Note: each box represents 1% of CPU usage.
Figure 19: 
Shifts in Participation by Discipline

Source: November 12, 2018 (SciNet HPC Consortium) Trends in Scientific Computing Training by an HPC Center Ramses van Zon et al
Note: each box represents 1% of training usage
For each of the Skills, Knowledge, and Work Activities categories in O*Net (SKWs), O*NET produces two measures: level (the complexity at which one is required to know the SKW), and importance (how vital the SKW is to an occupation). An SKW’s level is measured on a 1-7 scale, with specific anchor points (unique to each SKW) to delineate the scale. SKW’s importance is measured on a 1–5 scale, with 1 being “not at all important” and 5 being “very important”.

Due to the specificity of the anchor levels attached to each SKW, direct comparison between different SKWs is difficult. Further, even within the same SKW, the difference in skills is not consistent (e.g., the distance between a level 1 and level 2 in the skill “Mathematics” is not the same as the distance between a level 4 and level 5 in the same skill). Therefore, we focus on the ordinal scale (whether one number is more significant than another) rather than the cardinal scale (whether one number larger than another and by how much).

As a result, we first ranked all occupations using each of the SKWs considered, then aggregated the resulting seven rankings into one composite measure. For the individual ranking, we multiplied each SKW’s level and importance. Combining these two measures is O*NET’s recommended way of using them, as it incorporates both the complexity and the importance of a particular SKW to an occupation. However, O*NET also recommends normalizing the two scales before combining them, as the two measures have different ranges. We do not do that here, as we were not interested in cardinal measures. Instead, after multiplying the raw scores, we used them to rank each occupation for each of the seven skills we identified.

We next aggregated each skill ranking into an HQP ranking. We created the HQP ranking in two aggregation steps: first, we created a score for the digital skills category and for the domain-specific knowledge category. We chose an aggregation method that rewards a high rank while not punishing a low rank. Second, we aggregate these two scores into a final HQP ranking. We wanted occupations that have relatively high scores in both the digital skills score and the domain-specific knowledge score, so we chose an aggregation method that punishes low scores. The method we used is detailed below. A harmonic mean is used for the first stage aggregation and a geometric mean is used for the second.

**Harmonic mean**

A harmonic mean is defined as the reciprocal to the arithmetic mean of the reciprocals of the inputs:

\[
\bar{x}_H = \frac{n}{\sum_{i=1}^{n} \frac{1}{x_i}}
\]

In the context of aggregating rankings, harmonic means reward a high rank while not punishing a low rank. Due to the reciprocal calculation, a one rank difference between rank one and two affect the mean as much as a 100 rank difference between rank 100 and rank 200.

**Geometric mean**

A geometric mean takes the n-th root after multiplying all of the inputs:

\[
\bar{x}_G = \left( \prod_{i=1}^{n} x_i \right)^{\frac{1}{n}}
\]

In the context of aggregating rankings, geometric means reward particularly high ranks and punish particularly low ranks. The geometric mean is the exponential of the arithmetic mean, and as a result, dramatizes the effect of the arithmetic mean.
HQP OCCUPATIONS IDENTIFIED

Using the outlined methodology, we examined a list of ranked occupations and selected a sensible cut-off based on several criteria. This corresponded to the top 4% of occupations according to their HQP Rank:

1. Mechanical engineers
2. Physicists and astronomers
3. Computer engineers (except software engineers and designers)
4. Aerospace engineers
5. Chemical engineers
6. Metallurgical and materials engineers
7. Electrical and electronics engineers
8. Software engineers and designers
9. Computer programmers and interactive media developers
10. Chemists
11. Engineering managers
12. Geoscientists and oceanographers
13. Civil engineers
14. Meteorologists and climatologists
15. Biological technologists and technicians
16. Petroleum engineers
17. Electrical and electronics engineering technologists and technicians
18. Mining engineers
19. Geological engineers
20. Other professional engineers, n.e.c.

Choosing a cutoff for a continuous measure is a difficult task which requires balancing two goals.

The choice should be stringent enough that we select only those occupations that truly fall within our skill and knowledge definition while also being lenient enough that we have a set that describes the population of interest. We made an informed decision based on three considerations. The first is in understanding the impact on the number of HQP identified by including occupations just outside of the cut-off point; i.e. how sensitive our model is to the next addition. The second is to see if there are natural cut-off points; where there are large score changes from one occupation to the next in rank. It should be noted that due to the ordinal aspect or the skill rankings which the HQP score is built from, this at best is a loose proxy (as the magnitude of the difference in ranking has no clear interpretation). However large jumps may indicate a group that is qualitatively distinct from others. Finally, through consultation with Compute Ontario, we also conducted spot checks to ensure our cut-off didn’t marginally exclude occupations that are identified to be important user groups of high performance computing. For example, Petroleum Engineers, Mining Engineers and Geological Engineers, were between top 3 to 4% of the rankings, all of which are major user groups according to Compute Ontario.

Figure 18 has HQP population on the y axis and the number of occupations selected to be an HQP occupation on the x axis. For example, Mechanical engineers have the highest HQP rank and have a population of 23,465. The next highest, Physicists and Astronomers, adds 1,295, and so on. As is shown there are a few stable sections with large jumps when an occupation with a significant population is added. Our chosen cut-off lies at the end of one such stable section, as including occupations just before this cut-off has an insignificant impact on identified HQP but likely improves the diversity of the occupations identified.

The next occupation, Computer Network Technicians increases the number of identified HQP by 26,700 and received careful deliberation as to
its inclusion. Incidentally, occupations below that occupation have significantly lower ranking than previous occupations. This may indicate that there are features of the occupations before this increase that differentiate them from the occupations that come after.

It should be stressed that any occupational group we choose can never be the full set of those we might consider HQP but this methodology is designed to identify a representative subset and to focus our analysis on individuals who have a high level of skill and knowledge in our categories of interest.

Figure 20: HQP Population Change by Cutoff Variation
Figure 21: HQP Scores of Occupations

HQP Scores of NOCs

Computer network technicians

HQP Score

Occupation Rank

0 10 20 30 40 50

0 25 50 75 100

WHO ARE ONTARIO’S HIGHLY QUALIFIED PERSONNEL?
Who Are Ontario’s Highly Qualified Personnel?

Appendix B: Decomposing Demographic Changes

Following Cortez, Jaimovich, and Siu (2017), we are interested in our ability to decompose change in the share of the population who are employed within HQP occupations into two main effects - changes in demographic population share, and changes demographic-cell level HQP employment propensity. Conceptually, we are trying to understand whether HQP employment among age and sex groups changed due to the demographics changing, or the rate of HQP job participation among each demographic group changing.

For this report, we looked at the change over 10 years, from the Census in 2006 to the Census in 2016, with our demographic cell being a Sex-Age group. This results in 12 demographic cells (2 levels in Sex and 6 levels in age for each 10-year interval starting from 15-24 year olds.) We call the population participation rate at 2016 1 and the population participation rate at 2006 0. By construction:

$$\pi_1 - \pi_0 = \sum_i p_{i1}s_{i1} - \sum_i p_{i0}s_{i0}$$

Where \(p\) is the propensity of a specific demographic cell to be employed within HQP occupations and \(s\) the share of that demographic cell in the overall population. By adding and subtracting terms, we can decompose this initial difference into three components:

$$\pi_1 - \pi_0 = \sum_i \Delta p_{i1}s_{i0} + \sum_i p_{i0}\Delta s_{i1} + \sum_i \Delta p_{i1}\Delta s_{i1}$$

The first term in this equation is the contribution to the overall change in the share of the population due to changes in the propensity for each demographic cell over the considered period, holding the population share of each demographic groups constant. We call this the propensity effect. The second term is the contribution of the overall change in the share of the population due to changes in the share of specific demographic cell in question, holding the propensity constant. We call this the composition effect. The third and final term measures the interaction between these two effects.

Note that in this instance, we’re interested in the distribution of workers in technology occupations, not necessarily changes in unemployment dynamics. As a result, we use the labour force population as the base group, while not distinguishing between working and unemployed people.