ADDITIVE MANUFACTURING IN CANADA:

THE IMPENDING TALENT PARADIGM

ICTC CTIC

Information and Communications Technology Council

Conseil des technologies de l'information et des communications

RESEARCH BY:

The Information and Communications Technology Council (ICTC)

FUNDING PROVIDED BY:

The Government of Canada’s Sectoral Initiatives Program

Canada

PREFACE

ICTC's trusted labour market research provides critical economic and labour market insights to inform innovative workforce and skills solutions, as well as practical policy advice. Together, these drive the development of a more prosperous Canadian workforce and industry in a global digital economy.

This report was made possible with the support of Employment and Social Development Canada.

The authors of this report made all reasonable efforts to ensure accuracy and fair reflection of the diverse perspectives gathered during their consultations. The opinions and interpretations in this publication are those of the authors and do not necessarily reflect those of the Government of Canada.

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ACKNOWLEDGEMENTS

This report was made possible by the valuable contributions of various stakeholders both inside and outside of ICTC. Special thanks to the Advisory Committee members, whose input and insight proved extremely valuable. Specifically, we would like to acknowledge the following individuals:

Dušan Kuzma, KUZMA Industrial Group
Farzad Rayegani, Sheridan College
Francois Gingras, The Centre de recherche industrielle du Québec (CRIQ)
Hossein Ahari, George Brown College
James Janeteas, Cimetrix Solutions Inc.
Keith Doyle, Emily Carr University of Art + Design
Mark Kirby, Renishaw (Canada) Limited
Martin Lavoie, Canada Makes
Marv Fiebig, PTooling
Michelle Chretien, Xerox
Norman Holesh, Additive Metal Manufacturing Inc.
Shaun Thorson, Skills/Compétences Canada
Tharwat Fouad, Anubis 3D Mfg.
Vesna Cota, Tyco Electronics
Warren Strome, Revolution 3D Printers

Finally, a special thanks to all our key informant interviewees for their insights and feedback and to all those who helped in reviewing drafts of this report to ensure its accuracy and relevance to the field of Additive Manufacturing in Canada.

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ACRONYMS

3D
3-Dimensional

AI
Artificial intelligence

AM
Additive Manufacturing

CAGR
Compound Annual Growth Rate

GDP
Gross Domestic Product

ICT
Information and Communications Technology

IoT
Internet of Things

LFS
Labour Force Survey

LMI
Labour Market Information

NOC
National Occupational Classification

SME
Small - and medium enterprises

STEM
Science, technology, engineering and mathematics

FOREWORD

Approximately 25 years ago I was introduced to 3D printing and like many at that time, had my doubts on whether 3D printing would have any impact on product development or manufacturing. Coming from a traditional background in manufacturing I felt that you cannot compare or compete with traditional forms of manufacturing such as injection moulding, CNC machining or metal stamping. My opinion changed over time and In 1999 I purchased my first 3D printer, from Stratasys to support our product development services. 3D Printing technology has progressed significantly over the years improving on both the cost and quality fronts. 3D printing was invaluable then and as it is now. The overall impact on one's business, leveraging 3D printing is too profound to overlook. Saving time, money and producing a feature rich products on time is critical for any company's overall success. Rapid prototyping has been a game-changing innovation for designers, engineers, manufacturers since its introduction over two decades ago.

In my experience the rate of adoption of 3D printing in manufacturing is not directly affected by the lack of talent or skilled trades. In many cases 3D printing has not been positioned correctly and or implemented properly. Leading companies to conclude 3D printing has no place in manufacturing. Additive manufacturing must be positioned and treated as an alternative to traditional manufacturing methods rather than a replacement technology. Advancements in materials that offer better mechanical properties will play a pivotal role in inspiring further adoption within the manufacturing sector.

Keeping all things in perspective, adoption of 3D printing in Canada, has been strong as industry and academic institutions are implementing 3D printing at steady rate. Community colleges are establishing TAC's Technology Access Centres (TAC's) making the capabilities and know how available to SME's in a no risk environment. This is important as I find we are a risk adverse society and when you layer on manufacturing which is also conservative, there is a reluctance to try something new. For manufacturers to adopt additive manufacturing the upside has to be significant. It cannot be as good or slightly better as the associated gains are not worth the risk. To address this challenge, Institutions are engaging and supporting SME's with teams comprised of professors, students and industry partners. These initiatives are important and contribute to removing any associated risk and at the same time provide real world experience for the students.

The skills gap we are experiencing is real. Unfortunately, there is no quick fix to the problem. There are a number of identified areas in this report that require addressing and in doing so we may over time have impactful solutions. Academics are working hard to address how they can support industries through Program Advisory Committees. The role of the committee is to ensure programs are current and relevant to industry. I am a member of many PAC's comprised of members from various industries. Our role is to ensure we identify the current and future industry trends, shifts in the skills and knowledge graduates need to meet employer requirements. It's interesting that one common request from industry, irrespective of the program, is the need to focus on soft skills as a priority. We also advise on the need for new programs and participate in their development. Program Advisory Committee members are key liaisons between the College and industry and between the College and the community.

In closing it's important to get involved and be part of the solution. It will take some time before the workforce with the appropriate skills are ready to make an impact. At the same time you cannot afford to wait. You have to control your fate and implement your own in-house programs to support your business needs. Invest in your people, create your own solution, build to win.

James Janeteas
President and CEO of Cimetrix Solutions Inc.

EXECUTIVE SUMMARY

Additive Manufacturing (AM) is renowned for its revolutionary effect on manufacturing processes across industries, but any business looking to make the leap and capitalize on this potential must first retain the high-skill workers needed for AM production techniques and equipment.

Overview of the Canadian manufacturing industry

- Manufacturing is the largest industry in Canada, making up 9% of total employment and 61% of exports.
- The manufacturing workforce has a high concentration of older employees, and is predominantly male.

The state of AM globally and in Canada

- AM is revolutionizing the manufacturing industry, growing worldwide by 25.9% CAGR to $5.165 billion in 2015.
- Globally, 25% of manufacturers are currently implementing AM technology for prototyping only, 10% use AM for proto¬typing and production of final parts, and 1% use AM for final parts production only.
- In Canada, only 1.6% of all enterprises across all industries have used AM for plastics, 0.8% have used AM for metals and 3D printing for metals; and only 0.6% have used AM in other applications.

Disruptive effect of AM on labour markets

- Fewer conventional manufacturing and production jobs; more architecture and engineering jobs.
- Fewer monotonous, low-skill tasks involved in manufacturing jobs; more high-skill tasks requiring digital literacy.
- Shortage of high-skilled labourer, and more so for companies working with metal than with plastic.

Recommendations

Engagement of youth: Industry should develop and expand programs like EIC 3D Mini Summer Camps as early as age 8.

Strengthening applied digital skills for youth: The provinces in consultation with industry should develop and integrate programs like ASDT into the K-12 curriculum.

Leveraging Canada's diverse talent: Policy makers, academia and industry should develop learning opportunities to attract under-represented groups.

Attracting globally trained skilled workers: Government should consult with industry and update the labour market information for manufacturing jobs so that immigration and workforce development staff have better information about emerging occupations. Federal policy-makers should promptly re-evaluate the Express Entry program to ensure it achieves its objective of facilitating the path to permanent residence for individuals possessing skills that are in demand.

Collaboration on training and curricula: Industry and academic institutions should directly collaborate on developing nationally certified curriculum and training programs for AM, based on the evolving real-life job requirements and skills demand. Post-secondary institutions should offer AM programs that combine aspects of both technical and business degrees to meet the technical and soft commercial skills required by AM positions.

The recent federal budget 2017 welcomed measures to address digital skills development and access to global talent, among many others. Investment in human capital development will yield strong dividends for Canada in the coming years.

1. INTRODUCTION

In 2017, we find ourselves in the budding stages of the Fourth Industrial Revolution. From mechanized production to mass production to automated production; the next phase (known as Industry 4.0) marries digitization and data exchange to manufacturing technologies. Artificial intelligence (AI), advanced robotics, the Internet of Things (IoT), cloud computing, and Additive Manufacturing (AM) are driving disruptive innovation and are expected to bring a significant change to the Canadian economy and business landscape.

AM or three-dimensional (3D) printing is one of the pillars of Industry 4.0. AM technology emerged in the '80s but has only taken a foothold in the majority of industries in the last decade. Additive Manufacturing is defined as the process of joining materials to fabricate objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies.[1]

AM is a revolutionary technology that is being recognized for its advantages by different industry players. With quickly evolving techniques, applications and new printed materials available, AM has moved from a tool used for prototyping to an instrument that can produce advanced products beyond the limits of traditional manufacturing.

The adoption of AM by firms produces various economic benefits. It lowers production costs, improves production efficiency, and contributes to revenue generation for Canadian organizations and businesses. However, a firm's ability to capitalize on these benefits depends critically on their ability to locate, attract and retain labour with the right set of skills to support this new technology.

Technological advances often drive demand for new skills, requiring an innovative and adaptable workforce. The rise in adoption of digital technologies across all industries has increased the demand for highly skilled talent and has left businesses with recruitment challenges.

In light of these developments in the technology sector, ICTC aims to study and explore:

- the state of AM globally and the adoption level by industry in Canada
- challenges the AM sector is facing moving forward
- disruptive effect of AM on jobs
- talent shortage and factors contributing to the talent shortage
- occupations related to AM
- supply and demand of skills required to meet industry requirements
- solutions to attract and retain talent

The evidence-based recommendations in this report are intended to inform policymakers, industry and educators about the labour market impact of AM development across Canada, the state of the talent supply and demand, and how best to tailor their strategies to engage, attract and retain more people. The overarching goal is to place Canada in a position to meet its digital talent requirements to be innovative and competitive in the global digital economy.

2. METHODOLOGY & FRAMEWORK

ICTC's evidence-gathering methodology combines both quantitative and qualitative research approaches to accurately extract, analyze, and report on both publicly available and proprietary data. In developing the study, ICTC employed a mixed approach that included:

- a literature review of academic, industry and public policy research
- key informant interviews (KIIs) with 20 industry, association and academic representatives in volved in AM
- insights and inputs from a 15-member Advisory Group
- economic analysis
- analysis of occupations related to AM

ICTC conducted KIIs with industry leaders representing companies in Canada's Additive Manufacturing (AM) sector, academia and related associations. Companies were selected through Innovation, Science and Economic Development Canada database as well as through primary research conducted by ICTC. An Advisory Committee comprised of executives of the AM companies, academia and associations was engaged in the discussion of the AM sector's prospects and challenges. The committee then provided key recommendations intended to strengthen the AM sector as well as validate research findings.

3. OVERVIEW OF THE CANADIAN MANUFACTURING INDUSTRY

Manufacturing is a major sector in the Canadian economy. It is the largest industry in Canada and the source of 61% of Canada's exports.[2] In 2016, Canada's manufacturing industry contributed C$174 billion or 10% to Canada's GDP.[3] From 2012-2016, the five-year compound annual growth rate (CAGR) of revenue produced by the manufacturing industry totaled 1.2%.

According to the Canadian Manufacturers and Exporters, the transformation currently taking place in Canadian manufacturing is often overlooked. Too often, government policies aimed at spurring innovation and economic development disregard the manufacturing industry, despite the fact that manufacturing drives research and innovation.[4] Manufacturers are developing new technologies, services and products in a wide range of critical sectors including aerospace, defense, automotive, and healthcare.

The manufacturing industry is transforming and shifting away from traditional modes of production, and with these changes bring new opportunities and challenges to businesses and policymakers. AM is one of the disruptive technologies currently revolutionizing the manufacturing industry. It is predicted that in five years, the manufacturing industry will look substantially different than it does today.[5] Rapid technological advancements are poised to unsettle many sectors of the economy, and Canadian businesses are ill-prepared for this change.[6] According to the interviews conducted for this report, demand for highly skilled technology workers is forecasted to rise steadily for the next five years as Canadian businesses adopt new advanced technologies, including AM.

Snapshot of the Canadian Manufacturing Workforce

With 1.69 million employees, the manufacturing industry comprised 9% of the total employed people in Canada in 2016. This figure is slightly down from the 1.73 million people that were employed in 2013. Meanwhile, unemployment in the manufacturing sector remained relatively steady at around 5% from 2013-2016, which is two percentage points lower than the national unemployment average (Figure 1).

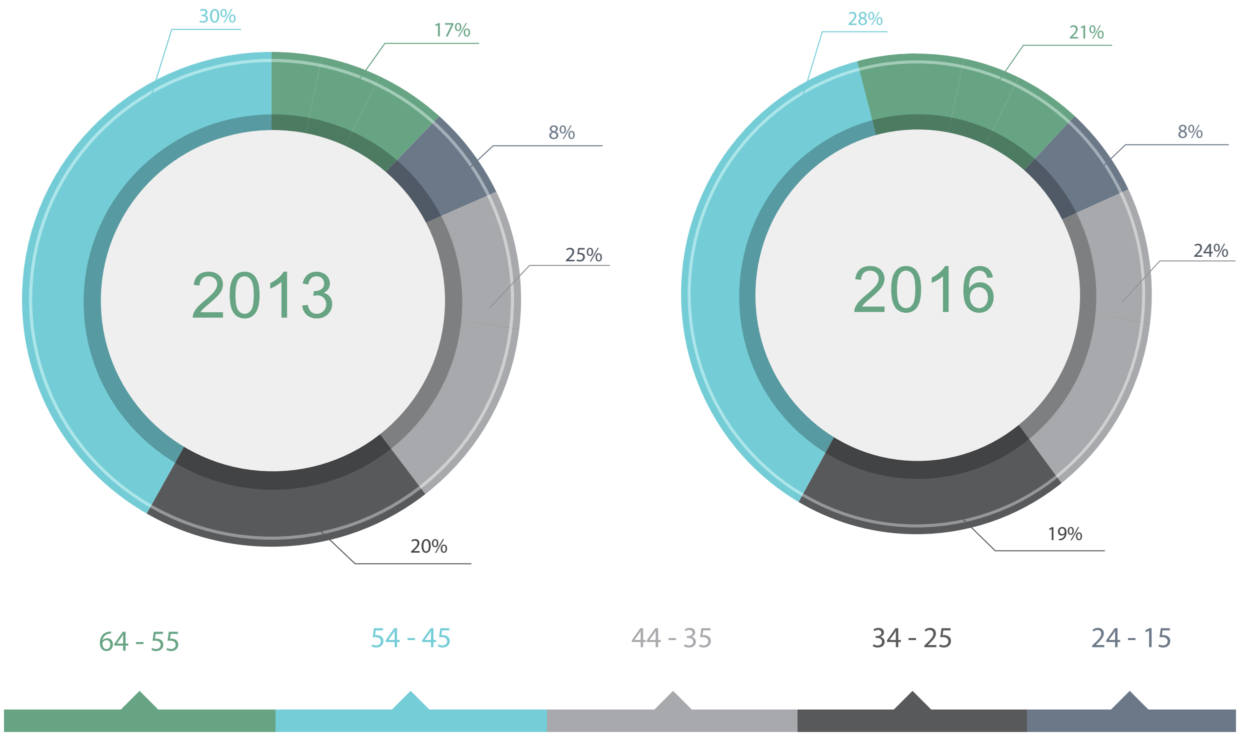
Figure 1. Employment in the Manufacturing Industry, 2013 to 2016

Source: ICTC; Statistics Canada Labour Force Survey, 2013 to 2016.

Looking deeper into the demographic makeup of Canada's manufacturing workforce, a couple of key trends stand out. First, the manufacturing workforce has a higher concentration of older employees. Workers between 55 and 65 years old make up 21% of the total manufacturing workforce, compared to only 16.6% of Canadian workforce overall. Second, the manufacturing workforce is getting older. In 2013, 17% or 293,000 manufacturing workers were between 55 and 65 years of age, while in 2016, 21% or 343,000 manufacturing workers were between the ages of 55 and 65.

Another noteworthy trend pertains to workers between 15 and 34 years of age. This group makes up 27% of the manufacturing workforce, compared to 35% of the total Canadian workforce in 2016. This younger group of manufacturing workers is slowly declining. Workers aged 15 to 34 years made up 28% of the manufacturing workforce in 2013 and declined to 27% in 2016 (Figure 2).

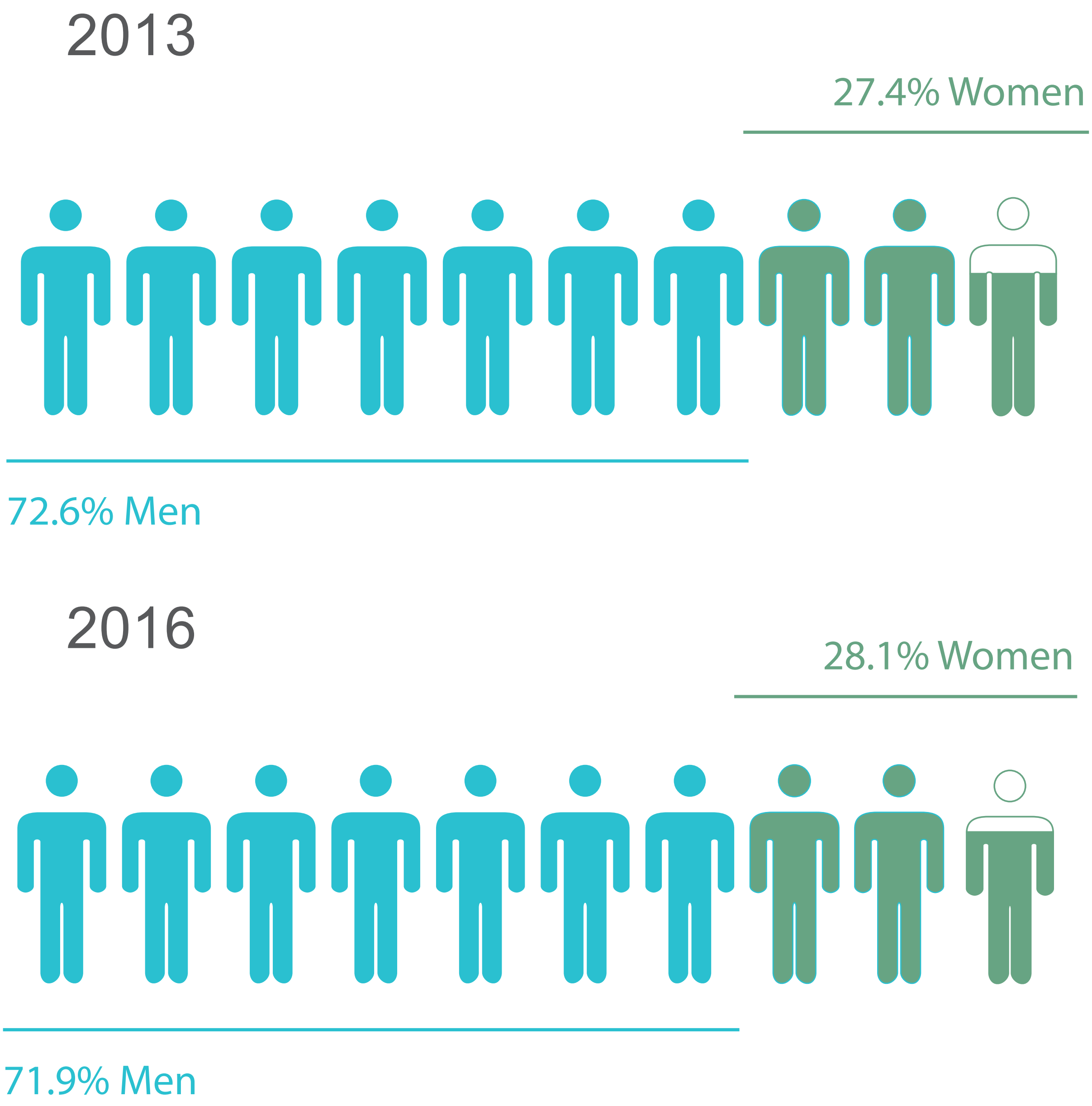
Figure 2. Share of Employment Manufacturing Professionals by Age, 2013 vs 2016



Source: ICTC; Statistics Canada Labour Force Survey, 2013 to 2016.

Women in general are under-represented in the Canadian manufacturing sector. The industry remains male-dominated where men represented almost three-quarters (71.9%) of the total number of manufacturing workers in Canada in 2016. The percentage of women in the manufacturing sector is increasing, having grown from 27.4% in 2013 to 28.1% in 2016 (Figure 3). Women in manufacturing still have a long way to go, however, before reaching the 2016 national employment average of 48%.

Figure 3. Share of Employment Manufacturing Professionals by Gender, 2013 vs 2016



Source: ICTC; Statistics Canada Labour Force Survey, 2013 to 2016.

4. THE STATE OF ADDITIVE MANUFACTURING GLOBALLY

AM is rapidly developing. According to the Wohlers 2016 report, the AM sector (consisting of all AM products and services worldwide) grew by 25.9% CAGR to $5.165 billion in 2015.[7] According to Gartner, the AM global market will reach $17.7 billion by 2020.[8]

There are two main AM markets. The more mature of the two is the consumer market for 3D printers, which has seen its growth rate slowing over the last several years. However, according to Gartner research the number of 3D printers in use worldwide is expected to grow significantly from 62,000 in 2013 to 2.5 million in 2018.[9] The younger market is the industrial 3D printer market. This newer AM market is the driving force behind 3D printer growth and is forecasted to grow significantly in the next five to ten years with the advent of new technological and materials development as well as increased industry adoption, especially in metal AM.

According to the PWC global survey from 2014, 25% of manufacturers are currently implementing AM technology for prototyping; 10% use it for prototyping and production of final parts and 1% use the technology for final parts production only.[10] As technology continues to evolve, more manufacturers will make the shift towards AM for prototyping and the production of final parts.

Industries using Additive Manufacturing

AM is widely used by several industries including healthcare, automotive, aerospace and defense, architecture, consumer products and retail, food and others. As technologies improve and the range of available materials expands (e.g., plastics, ceramics, metals, glass), AM will become even more important for these industries.

- **Aerospace and defense.** Leading aerospace companies are integrating AM into their produc tion. AM allows for 'tool less' production which is cheaper (no set-up and tooling costs), faster, lighter (intelligent lightweight structures combine high strength with a weight reduction), less wasteful and more environmentally friendly (less raw material, less energy, less fuel and less carbon dioxide). In 2016, GE in partnership with Snecma (SAFRAN) introduced 3D-printed parts for its CFM LEAP aircraft engine that included 19 3D-printed fuel nozzles designed to last five times longer than traditionally made components, were lighter in weight, and had a simpler design (the number of parts used to make the nozzle was reduced from 18 to 1).[11] Aerospace company Airbus (Defence and Space) uses AM for the production of satellite parts. AM technology enabled them to reduce the cost of production, weight, improve temperature resistance, and reduce the production time.[12]

- **Healthcare.** Metal and plastic AM are widely used in healthcare to great effect. With the ability to accurately produce complex features, metal 3D printing is highly suited for the production of medical and dental devices in cobalt chrome and titanium. AM became part of mainstream medical practice to produce body replacement parts, implants, casts etc. 3D bio-printing is a phenomena that changed the health industry by turning a manual, labour-intensive industry into an automated one that allows production of customized replacement parts for the human body, such as bones, cartilage and muscle.

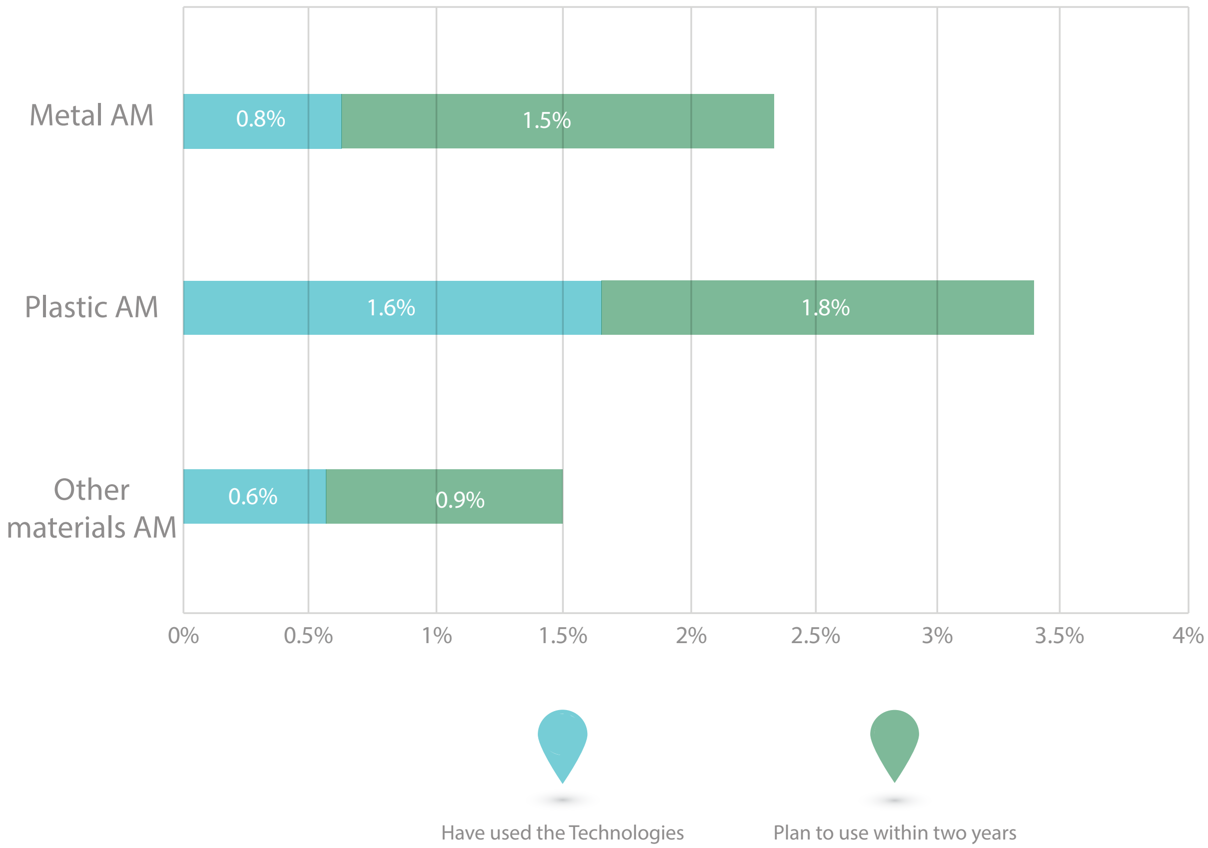
- **Automotive.** AM allows the production of high-end, weight-optimized, highly-customized car components that help to reduce the complexity of design and significantly improve the efficiency of production and operations. Local Motors has created a car made of 75% 3D-printed parts consisting of 80% ABS plastic and 20% carbon fiber. Local Motors aims to produce a car made of 90% 3D-printed parts in the not too distant future. Traditionally, cars are made from thousands of parts but in the case of Local Motors they managed to only use a few dozen.[13] Other automotive companies such as Ford, BMW, Audi, Honda are also exploring ways to use AM technology. In 2017 Ford Motor Company is testing 3D printing of light-weight, large-scale one-piece auto parts.[14]

- **Consumer products and retail.** AM allows the manufacturers to refine the mass production concept from one-size-fits-all to customized products on a mass manufacturing scale. Companies like Normal are exploring new potential applications like customizable earphones in 48 hours. Footwear companies such as Nike, Feetz, New Balance and United Nude are also exploring ways to customize running shoes. In 2016, Adidas joined the AM trend crafting its first pair of running shoes. Futurecraft sneaker features an engineered 3D web structure with dense zones in high force areas and less dense zones in low force areas that allows an optimum level of performance. The technology used avoids the typical process of gluing or stitching and the benefits include greater elasticity, compliancy and support.[15]

5. THE STATE OF ADDITIVE MANUFACTURING IN CANADA

The adoption level of AM in Canada is currently very low. According to a Statistics Canada survey conducted in 2014, only 1.6% of all Canadian enterprises across all industries have used AM including rapid prototyping for plastics and 3D printing for plastics; while only 0.8% have used AM including rapid prototyping for metals and 3D printing for metals; and only 0.6% have used other AM materials.[16]

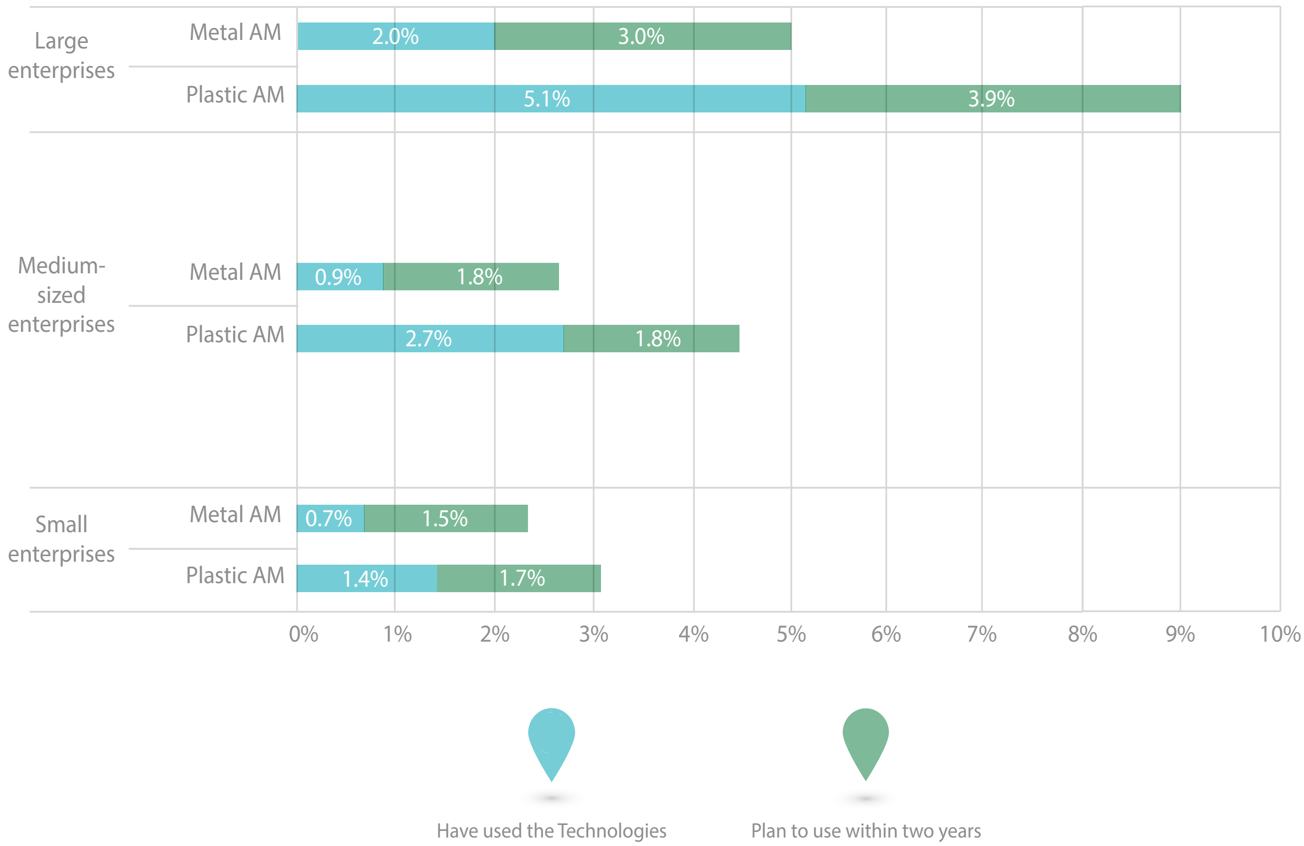
Figure 4. Adoption Level of AM by Canadian Companies, 2014



Source: Statistics Canada Survey of Advanced Technology, 2014.

The adoption level of AM in Canada is higher in large enterprises than their small and medium counterparts. Specifically, 5.1% of large enterprises (250+ employees) reported using plastic AM, compared to 2.7% among medium enterprises (100-249 employees), and 1.4% of small enterprises (10-99 employees). Only 2% of large enterprises reported using metal AM, compared to 0.9% and 0.7% of medium and small enterprises respectively. The adoption level of AM in Canada is expected to increase in the near future. According to survey data, the total adoption level of AM buy large Canadian companies is expected to increase over the next two years by 3.9% for companies who use plastic AM and by 3% for companies who use metal AM.

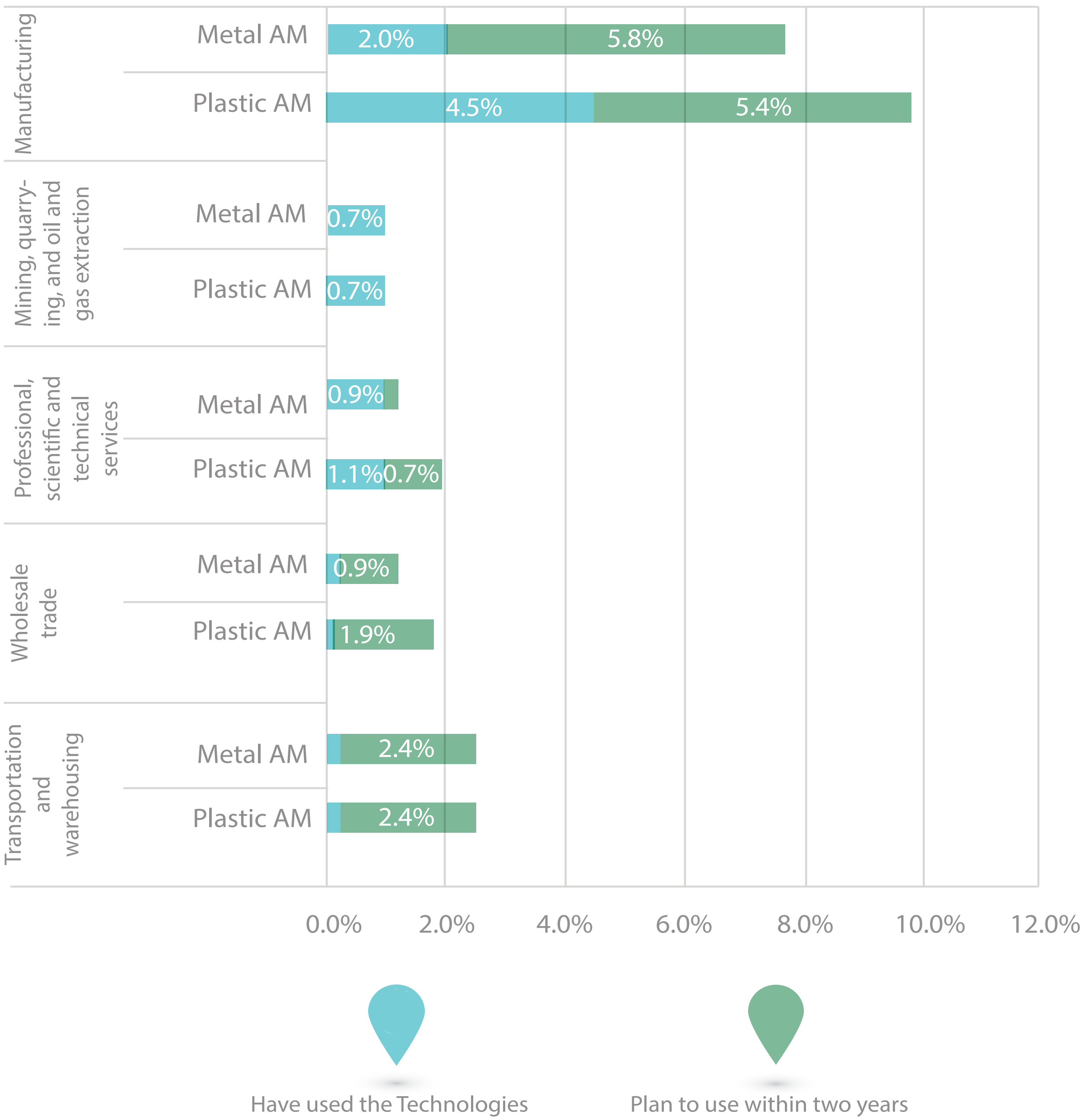
Figure 5. Adoption Level of AM by Canadian Companies by Enterprise Size, 2014



Source: Statistics Canada Survey of Advanced Technology, 2014.

AM is used in various industries in Canada with the manufacturing industry being the leading adopter. 4.5% of companies have used plastic AM and 5.4% of companies plan to use plastic additive manufacturing within the next two years. This represents an average annual growth rate of 60%. The adoption level of metal AM is lower in the manufacturing industry, but it is expected to also accelerate over the next two years. 2% of companies have used metal AM and 5.8% of companies plan to use metal additive manufacturing in the next two years. This represents an even more impressive annual growth rate of 145%.

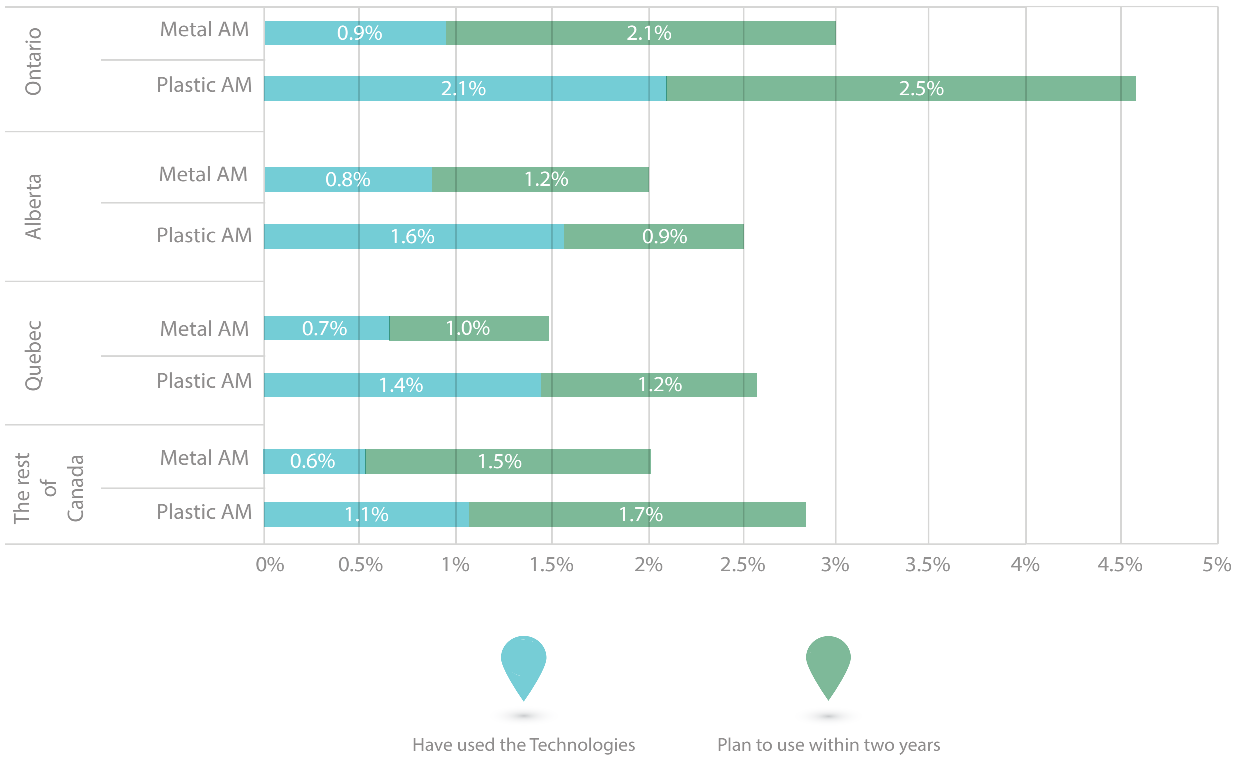
Figure 6. Adoption of AM by Large Enterprises in Canada Across Industries, 2014



Source: Statistics Canada Survey of Advanced Technology, 2014.

Looking at adoption rates of AM across provinces, Ontario, Alberta and Quebec lead in plastic and metal AM. Ontario has the highest level of AM adoption, followed by Alberta and then Quebec based on a Statistics Canada survey conducted in 2014.

Figure 7. Adoption of AM Across Provinces, 2014



Source: Statistics Canada Survey of Advanced Technology, 2014.

Challenges the Sector is Facing Moving Forward

According to the interviews conducted and secondary research, ICTC identified the main issues for Canadian companies utilizing AM. The top challenges faced by these companies include:

- Shortage of highly skilled talent
- Lack of government funding, tax incentive programs for SME
- Lack of awareness, technical literacy
- Technology advertising and promotion
- Limited availability of printable materials
- Limited print quality
- Limited print speed
- A lack of standardization and regulations
- Business application

6. DISRUPTIVE EFFECT OF ADDITIVE MANUFACTURING ON LABOUR

There are competing views about the impact of advanced technologies on the labour market and whether advances in manufacturing will result in an overall increase or decrease in job opportunities. The popular belief is that development of advanced technologies (of which AM is a part) will have a disruptive effect that will reduce jobs and result in a downsizing of the labour market. According to the World Economic Forum "The Future of Jobs" report, advanced technology has a mixed effect on various job families.[17] As such, AM as one of the labour-substituting technologies is expected to decrease employment by an annual growth rate (CAGR) of 3.6% in manufacturing and production roles. Conversely, AM as a resource-efficient sustainable mode of production is expected to increase employment by CAGR of 3.33% in architecture and the engineering job families, supported by a continued and fast-growing need for skilled technicians and specialists to create and manage the technology.

According to the interviews conducted for this report, rather than replacing jobs, AM is altering the make-up of jobs. In other words, advanced technologies like AM reduce the need for monotonous tasks and lower skilled jobs, while increasing demand for high-skilled labour to perform tasks that require digital literacy.

Skills required in Additive Manufacturing

Any economy or industry needs skilled talent in order to innovate and be competitive globally. According to a Canadian Manufacturers & Exporters survey, attracting or retaining skilled labour is the number one challenge for manufacturing companies in Canada.[18] Of those surveyed, 35% state that access to workers with the needed skills is the number one challenge that they face.

The interviewees were questioned about their overall workforce requirement in plastic and metal AM, including recruitment challenges and employee characteristics. The majority of the respondents agreed with the statement that they are currently experiencing and are expecting to continue to experience recruitment challenges to hire skilled labour, and this problem is very severe for companies engaged in metal AM. Jobs related to AM are difficult to recruit for because of the rare blend of skills and experience required. The interviewees stated that they always experience difficulty filling metal AM positions and sometimes they experience difficulty filling plastic AM positions. Primary and secondary research confirms that labour supply in AM is not adequate to meet industry needs. In other words, the AM sector is experiencing a labour market imbalance. Considering that the AM sector is expected to expand both in terms of technology development and industry adoption, the demand for additive manufacturing professionals is expected to significantly increase in the near future, which in turn will create a skills gap in the workforce.

Occupations Related to Additive Manufacturing

ICTC's primary and secondary research identified that the current Canadian workforce is not prepared to meet the demands for skilled labour in additive manufacturing. Recruiting talent in jobs related to AM has proven very difficult because of the rare blend of skills and experience required. According to the primary and secondary research, there are skills gaps in areas such as plastic and especially in metal AM. Areas with skills shortages that are vital to businesses engaged in AM were categorized into eight groups: **engineering, materials, IT, technical, skilled trades, operations, design, applications and commercial.**

Talent with skills in the areas listed above is in high demand. The labour market was already under pressure to find talent with the right blend of technical skills especially in metal AM, but also to find talent that combines technical and soft skills presenting a real recruitment challenge for the sector. According to the interviews conducted, a perfect candidate should have a combination of both technical and soft skills.

In order to analyze the growing demand for AM specialists in detail, ICTC conducted a “mapping exercise”. First, it leveraged the interviews and secondary research conducted and identified specific skills relevant to the AM sector, it then linked these skills to the occupations. Second, certain identified occupations were analyzed using Employment and Social Development Canada’s (ESDC) occupation description and linked to the National Occupations Classification (NOC) codes. The occupations were classified further into four broad groups: management occupations, occupations requiring a university degree, occupations requiring a college education or apprenticeship training, and occupations requiring secondary school and/or occupation-specific training. Due to the different nature and skills required in metal and plastic AM occupations, the occupations were divided into two groups: metal AM and plastic AM. Table 1 and Table 2 summarize the top occupations that have been identified as being in high demand.

Table 1. Top Occupations Related to Metal AM Across All Industries, 2011 to 2016

Occupations related to Metal AM, NOC codes	Employment in 2016	CAGR 2011-2016	Proportion in 2016
Management Occupations			
0211 Engineering managers	1,849	0.8%	2.7%
0911 Manufacturing managers	7,305	0.0%	10.8%
University degree			
2115 Other professional occupations in physical sciences	248	4.1%	0.4%
2132 Mechanical engineers	3,728	-4.6%	5.5%
2133 Electrical and electronics engineers	3,403	-4.3%	5.0%
2141 Industrial and manufacturing engineers	1,511	-0.9%	2.2%
2142 Metallurgical and materials engineers	253	1.0%	0.4%
2173 Software engineers and designers	5,178	6.8%	7.6%
2174 Computer programmers and interactive media developers	15,191	9.0%	22.4%
College education or apprenticeship training			
2232 Mechanical engineering technologists and technicians	2,093	0.6%	3.1%
2233 Industrial engineering and manufacturing technologists and technicians	2,913	8.3%	4.3%
2241 Electrical and electronics engineering technologists and technicians	3,155	-6.9%	4.6%
2252 Industrial designers	1,030	6.8%	1.5%
5241 Graphic designers and illustrators	8,441	8.9%	12.4%
7231 Machinists and machining and tooling inspectors	3,563	-3.3%	5.3%
7232 Tool and die makers	952	-4.8%	1.4%
Secondary school and/or occupation-specific training			
9411 Machine operators, mineral and metal processing	1,053	5.5%	1.6%
9416 Metalworking and forging machine operators	2,151	7.7%	3.2%
9417 Machining tool operators	1,270	6.2%	1.9%
9612 Labourers in metal fabrication	2,575	21.3%	3.8%
Total	**67,860**	**3.2%**	**100.0%**

Table 2. Top Occupations Related to Plastic AM Across All Industries, 2011 to 2016

Occupations related to Metal AM, NOC codes	Employment in 2016	CAGR 2011-2016	Proportion in 2016
Management Occupations			
0211 Engineering managers	1,849	0.8%	3.2%
0911 Manufacturing managers	7,305	0.0%	12.7%
University degree			
2115 Other professional occupations in physical sciences	248	4.1%	0.4%
2132 Mechanical engineers	3,728	-4.6%	6.5%
2133 Electrical and electronics engineers	3,403	-4.3%	5.9%
2141 Industrial and manufacturing engineers	1,511	-0.9%	2.6%
2173 Software engineers and designers	5,178	6.8%	9.0%
2174 Computer programmers and interactive media developers	15,191	9.0%	26.4%
College education or apprenticeship training			
2232 Mechanical engineering technologists and technicians	2,093	0.6%	3.6%
2233 Industrial engineering and manufacturing technologists and technicians	2,913	8.3%	5.1%
2241 Electrical and electronics engineering technologists and technicians	3,155	-6.9%	5.5%
2252 Industrial designers	1,030	6.8%	1.8%
5241 Graphic designers and illustrators	8,441	8.9%	14.7%
Secondary school and/or occupation-specific training			
9535 Plastic products assemblers, finishers and inspectors	1,400	9.9%	2.4%
Total	**57,443**	**3.2%**	**100.0%**

Source for Table 1&2 : Statistics Canada Survey of Advanced Technology, 2014.

The occupations which employ the largest number of employees across all industries in 2016 include: manufacturing managers, computer programmers & interactive media developers and graphic designers & illustrators. Note that some of these occupations have the highest CAGR from 2011-2016. Based on the CAGR column from Table 1 (the occupations related to Metal AM) labourers in metal fabrication, industrial engineering & manufacturing technologists & technicians and industrial designers are the occupations with some of the highest growth rates. Note that some of the occupations with the highest growth rates require only college education/apprenticeship training or are general labourer occupations. The same trend is observed in the occupations related to plastic AM (Table 2). In particular, plastic products assemblers, finishers and inspectors experienced the strongest employment growth rates and are among the occupations most in demand. The above results suggest that Canada's competitive position globally would improve by training more workers for positions in those high growth occupations.

Factors Contributing to the Talent Shortage

A wide range of related factors contribute to the skilled talent shortage in the AM sector. These factors create barriers to the sector's development and future success. The factors were combined into 4 groups:

1. Manufacturing is suffering from an image and perception problem. The overall Canadian work force, women and youth (15-29 years old) in particular have a low interest in working in the manufacturing industry. Manufacturing is competing with other "sexy" industries to attract highly skilled talent and losing the battle. The industry is viewed as not trendy, physically demanding, not very exciting and overall does not appeal to new workers. A career in manufacturing is viewed by many as an option for those who cannot obtain a university degree. Jobs in manu facturing are still associated with a monotonous, assembly-line work style where working con ditions are unappealing. These misconceptions deter youth and women from pursuing a career in the manufacturing industry.

2. The Canadian workforce is becoming more educated. The share of the workforce with a bachelor degree has increased from 18% in 2012 to 20% in 2016, the share with a graduate and/or professional degree rose from 8% to 10% while the share with some postsecondary and postsecondary certificate or diploma decreased from 43% to 42% over the same period.[19] While the Canadian workforce is becoming more educated, the industry is lacking on the technical side in skilled trades like technicians, welders, machine operators etc.

3. Canadian culture has formed a biased opinion that a university education is valued higher than a college or trade school education. Youth are led to believe that smart students should obtain a university degree as it will provide an easy, better career. This is in stark contrast to modern day reality, where skilled workers are paid high wages and in many cases, are in higher demand than university graduates. Interviews conducted identified a lack of skilled tradespeople as a primary barrier and one of the most important to overcome. "We need our secondary education to adopt the idea that trades are not a low ranking degree". (According to the interviews conducted)

4. Aging population. The manufacturing workforce is getting older and aging faster than in other industries. As previously mentioned, in 2013 21% of the manufacturing workforce were 55 to 64 years of age compared to 16.6% in all other industries. The significance of this issue is that the manufacturing industry will have a larger workforce turnover than other industries, which will present greater challenges in finding skilled labour and filling vacant positions over the next 10 years.[20]

5. Weak linkage between academia and industry. When companies were asked whether post-secondary education provides the workforce with the skills that their companies require, the majority of respondents answered negatively. WEF's study highlights that 50% of the subject knowledge acquired during the first year of a four-year technical degree is estimated to be outdated by the time of graduation.[21] According to the interviews conducted, the biggest challenge for educational institutions is to provide students with hands-on experience which aligns with industry needs post-graduation.

7. SOLUTIONS & POLICY RECOMMENDATIONS

Being faced with a talent shortage is not unique to AM and also extends to the other cutting-edge technologies such as advanced robotics, artificial intelligence, internet of things (IoT) and others that have expanded rapidly over the past several years.

Overcoming skills challenges for AM specialists involves active engagement on the part of industry, education and professionals as well. Each has a role to play in closing the gap between high demand and low supply.

Engagement of youth

One of the most important challenges facing the manufacturing industry is its image. The Canadian population generally, and young people particularly, have a misperception about what a career in the manufacturing industry looks like, and that needs to change.

Starting as early as elementary school, students should be exposed to accurate information about what a modern manufacturing job entails, the exciting opportunities available, and the above average wages that can be expected.[22] In today's digital age, manufacturing jobs are high skill and high-tech, and "cleaner" than the outdated perception of manufacturing work would suggest.[23]

Exposing kids to new "cool" technologies like AM that they can use to make things of interest to them is a key to attracting young people to consider a career in manufacturing.

There are a number of international programs that exist to address this challenge that should be adopted nationally. One current example is the U.S. by Englewood Incubation Center (EIC) 3D Mini Summer Camps for children aged 8 to 12, which uses the TinkerCad program. This simple, easy to learn, online 3D design and 3D printing app for kids teaches them to create 3D objects.

Recommendation 1: Industry and education systems should be educating the general public on the benefits of choosing a career in manufacturing. Industry, together with education systems should develop programs like the 3D Mini Summer Camp previously mentioned.

Recommendation 2: Creating maker spaces in all school libraries, to provide hands-on experience and promote interaction with the AM technology, allowing them to become a maker and create physical objects out of a digital idea.[24]

Strengthening applied digital skills for youth

To ensure future success in the dynamic and evolving digital ecosystem, Canada needs to nurture a strong talent pipeline for science, technology, engineering and math (STEM)—starting with elementary and secondary education through to post-secondary education and then transitioning into full time employment.[25]

STEM is intricately linked to advanced technologies and provides greater access to post-secondary education programs, which in turn increases the chance for a good career. While many youth understand the importance of STEM, few end up choosing it as a field of study. Problem solving, analytical skills and creativity are the building blocks for innovation. These skills can be integrated into the curriculum in ways that inspire STEM learning while still promoting a balanced education.[26]

British Columbia (BC) is one of the first provinces that introduced Applied Design, Skills, and Technologies (ADST) K-12 curriculum. ADST is an "experiential, hands-on program of learning through design and creation that includes skills and concepts from traditional and indigenous practice; from the existing disciplines of Business Education, Home Economics, Information Technology, and Technology Education; and from new and emerging fields".[27] In this program students develop their ability to design and learn how to apply their skills using appropriate technologies.

Recommendation 1: The provinces in consultation with industry should integrate computer science learning that includes components such as computational thinking, design thinking, coding, and application development into integrated learning from K-12, consistent with ADST program in British Columbia.

Recommendation 2: Educators should provide more information about career paths and occupational roles that require STEM learning.

Leveraging Canada's diverse talent

Canada has a proud tradition of welcoming and celebrating diversity. Canada's digital economy is currently made up of approximately 25% women, 3% Indigenous people, 7% youth and 40% immigrants—suggesting there is room for an even greater diversity of participation.[28] Diverse and inclusive businesses are more productive and innovative, translating into real and significant financial gains for businesses and the economy at large. As talent scarcity increases, leveraging Canada's diverse talent pool will help replace the aging workforce and ensure businesses have the skilled people they need to grow and compete in the global digital economy.[29]

Recommendation: Governments at all levels, as well as post-secondary academic institutions and industry should collaborate on a strategy for improving diversity and inclusion in the Canadian workforce. This group should focus on targeted learning opportunities to attract underrepresented groups. This may include targeted industry-driven awareness and community programs to attract diverse talent into high-demand sectors like AM and targeted scholarships to attract underrepresented groups.

Attracting globally trained skilled workers

Based on interviews, companies engaged in AM prefer to hire local workers. However, as population growth continues to decline, domestic skilled talent will become scarcer. Canada has a strong tradition of welcoming global talent and is a popular destination for immigrants. However, as more countries look to internationally educated professionals to fill impending talent shortages, this will increase the competition Canadian employers will encounter in securing top talent from abroad.[30]

However, there are a number of challenges in efficiently and effectively matching immigrants to jobs commensurate with their experience and skills while also meeting employers' labour demands. Employers in high-demand sectors in the digital economy experience difficulties and delays in getting visas for high-skilled (permanent and temporary) digital talent to come to Canada.[31] Furthermore, companies in new and emerging technology sectors like AM are experiencing difficulties in securing talent because there are few or no National Occupational Classification (NOC) codes to match these jobs to. As a result, these jobs and the potential candidates get overlooked while demand keeps exponentially growing. Overall, these challenges reduce a company's competitiveness in attracting highly educated digital talent from abroad. If Canada is to become a leader in the global digital economy, it must establish an immigration system that efficiently attracts and retains the best global digital talent. It is also crucial that we continue to build and promote Canada's brand as a talent-friendly nation.

Canada is already on the way to making the migration process for high skilled workers more efficient. In March 2017, Canada announced the new Global Talent Stream program to help fill in-demand occupations with global talent for companies that are seeking innovation and growth. The Global Skills Strategy, including the Global Talent Stream of the Temporary Foreign Worker Program, will be launched on June 12, 2017. Some features of the program include the eligibility for workers to have their work permit applications and temporary resident visas processed in 10 business days and dropping the work permit requirement for short-term highly skilled work (for instance, 30 days or less in a 12-month period). In addition to helping Canadian businesses grow and attain the global talent they need quickly, this initiative will identify a global talent list of eligible high-demand occupations through collaboration with stakeholders and labour market experts.[32]

Recommendation 1: Federal and provincial policy-makers should work with industry to update the labour market information (LMI) used by immigration and workforce development staff for assessing the supply of and demand for emerging occupations.

Recommendation 2: Federal policy-makers should promptly re-evaluate the Express Entry program to ensure it achieves its objective of facilitating the path to permanent residence for individuals possessing skills in demand.

Closer relationship between industry and the post-secondary institutions

The education system struggles to keep up with rapidly developing technology, especially in areas like advanced digital technologies. Post-secondary education is already experiencing disruption, and the pace of this disruption will speed up substantially.[33]

Even in cases where course curriculum is updated annually, students are graduating with knowledge that is already outdated. WEF's study highlights that as much as 50% of the subject knowledge acquired during the first year of a four-year technical degree is estimated to be outdated by the time of graduation. [34] While colleges are increasingly focused on short-term, highly practical learning, university students are generally enrolled into traditional four-year bachelor degree programs that do not provide enough practical learning opportunities.

Coordination between industry and post-secondary institutions are critical. That's why it is even more important to improve the communication partnership between post-secondary institutions and industry. The education process should be similar to learning to play the piano: theory should be supported with practice. Students need hands-on experience in order to gain appropriate and up-to-date technical skills.

Recommendation 1: Companies need to work more closely with educators to develop program curricula, address curriculum gaps, and provide adjustments in a timely manner based on the current skills that are in demand. It is critical to develop nationally certified curriculum for AM and have it fine-tuned by industry that will help ensure it is up to date with what is required by the market.

Recommendation 2: Industry must play a more direct role in identifying relevant skills and increasing efficiency in skills training. One of the best ways of doing this is by developing work-integrated learning programs, providing more internship, co-op and placement programs, and apprenticeship programs. Federal and provincial governments should provide support through incentive programs like student wage subsidies.

Importance of commercial/business skills

The According to the interviews conducted, commercial/business skills are as important as technical skills. The ideal candidate should have a combination of an engineering degree, business degree, and customer service experience.

Recommendation : Post-secondary institutions should consider developing educational and training programs that combine aspects of both technical and business degrees, on the assumption that soft commercial skills are as important as technical skills.

These recommendations form part of Canada's National Digital Talent Strategy Digital Talent — Road to 2020 and Beyond, designed to ensure that Canada's current and future workers and entrepreneurs are equipped with the skills and competencies needed to succeed in our increasingly digital and global economy.

8. CONCLUSION

Industry 4.0 combines digitization and data exchange to existing manufacturing technologies. A vital component in this new wave of automation is AM, which is revolutionizing the manufacturing industry and strengthening the whole economy in the process. AM's rapid technological advancement has brought job description changes to the manufacturing sector, and Canada's workforce has struggled to adapt and meet these new demands.

A skills shortage is the top challenge facing Canadian manufacturers interested in adopting AM technology. The problem is compounded by an aging workforce and low entry of new workers to the labour market. Access to top-quality labour with cutting-edge skillsets is critical to Canadian manufacturers looking to adopt AM technology and compete globally.

This report made findings and recommendations intended to assist policymakers, industry and educators to address the challenges facing the AM sector and to encourage AM adoption rates in Canada.

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