Economic Impacts of Advanced Air Mobility

New Air Mobility Options Will Benefit Greater Vancouver, Creating Jobs & Energizing GDP Growth

AAM White Paper Series Part 2
November 16, 2020

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Vision of Canadian Advanced Air Mobility (CAAM)

CAAM intends to facilitate development of airspace above Canada's cities and exurban areas, delivering advanced mobility options and benefits to society, especially residents, businesses, disadvantaged and remote communities, Indigenous peoples, and emergency responders. The VISION for Advanced Air Mobility will be to deliver equitable, inclusive, resilient, intermodal, and accessible elements with Zero Emission Aircraft. A centralized strategy is planned, nationally and regionally, with the inclusion of stakeholders across government, industry, academia, and the investment community.

About This Paper

This paper is about the economic benefits derived for Greater Vancouver and British Columbia from new mobility options, making use of the underutilized airspace above metropolitan areas. How will residents benefit through creation of jobs and increased economic prosperity? How will local governments benefit from increased tax revenue? What will the expected "ripple effect" of increased economic activity be?

Authorship

Several companies and individuals are responsible for the research and preparation of this document. Researched and prepared by NEXA Advisors LLC, the team included transportation economists and experts in aerospace transportation systems, supported by Crown Consulting Inc. Thanks go to authors Eleanor Herman, Phillip Dyment, Chase Leeby, Benjamin Merran, and Thomas Edwards.

Acknowledgement of Statistics Canada Team

The authors relied heavily on analytical tools and expertise provided by Statistics Canada. The Canadian System of Macroeconomic Accounts, made use of here, provides a conceptually integrated statistical framework for studying the state and behavior of the Canadian economy, coast to coast and by province.

Sponsors

This paper was sponsored by the Canadian Advanced Air Mobility (CAAM) Consortium, a non-profit effort bringing together partners across government, academia, industry, and local communities, to lay the foundation for Advanced Air Mobility in Canada, seeking to maximize public benefits for all.

Deep Appreciation

We express our deep appreciation to Teara Fraser, Owner and Lead Executive Officer of Iskwew Air; Duncan Kennedy, co-founder and managing director of Indigenext, and the dozen individuals they brought together to discuss what Advanced Air Mobility will mean for Indigenous communities. We also thank Jeff Ward, Founder and CEO of Animikii, for his insights into Indigenous technology.

Acknowledgement of Ancestral Territories

We respectfully acknowledge that this work is taking place on the unceded and traditional ancestral territories of the Coast Salish Peoples of the Skwxwú7mesh (Squamish), xʷəθkwəy̓əm (Musqueam), kwikwəƛ̓əm (Kikwetlem), q̓ic̓əy̓ (Katzie), Kwantlen and Semyome (Semiahmoo) Nations.

Note on Currencies

All currency amounts in this paper are expressed in Canadian dollars.

On the Cover

AeroG LLC 10-12 Passenger "Air Metro" all-electric eVTOL Concept Vehicle (compliments of AeroG LLC).

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Executive Summary

Advanced Air Mobility—the use of smaller, quiet, fast and safe electric aircraft (Figure 1)—is coming to Vancouver. Innovation-driven advances—such as lithium ion batteries, lightweight composites, electric-motors, hydrogen fuel cells, intelligent systems to fly and manage these vehicles, and other new technologies—are making possible revolutionary new electric vertical takeoff and landing (eVTOL) aircraft that will greatly expand the mobility of people and goods not conveniently served by surface transportation. Analysis performed by companies such as Goldman Sachs, Morgan Stanley[1] and NEXA Advisors/UAM Geomatics[2] forecast a $1.9 trillion market opportunity, with much of this business flowing into the metropolitan areas eager to adopt this new mobility option.

> ***"We're focused very much on R and D (research and development) investment in Canada. It's about good-quality jobs, it's about the long-term success of the company and the sector ... We want a strong, vibrant aerospace sector in Canada, and that is a priority for this government.***
>
> *The Honourable Navedeep Bains, Minister of Innovation, Science and Industry, Government of Canada*

While a dozen cities around the world—Seoul, Munich, Los Angeles, and Dubai, for instance—are the vanguard of AAM implementation, Vancouver may well be the first in North America to embrace this new form of aviation. The societal benefits that eVTOL aircraft bring to Vancouver will be numerous and are outlined in some detail in Part 1 of this series, our October 2020 White Paper: *Advanced Air Mobility Comes to Vancouver: Exciting New Mobility Options for Residents, Businesses, Indigenous Peoples, and Emergency Responders*. This paper, Part 2, focuses on the economic benefits of AAM, and what it means for aviation and aerospace jobs, new businesses, and economic vitality for Greater Vancouver, smaller towns, and First Nation communities tied to the general region.

Figure 1 - Bell NEXUS five-passenger eVTOL, under development in Quebec.

The Canadian Advanced Air Mobility (CAAM) Consortium commissioned this study to better understand how AAM activities will impact the Greater Vancouver economy. NEXA has produced "input-output" type economic impact assessments (EIA) in the past for both U.S. and Canadian projects. However, the scope of this EIA, requiring access to data of national scale and spanning dozens of interlinked industries, broke norms. As referenced in Footnote 2, the business case for AAM in Vancouver identified over $2 billion in direct spending over a twenty-year period. Working from these figures—the "inputs"—to ascertain the economic results—the "outputs"—we collaborated with

[1] https://irei.com/news/morgan-stanley-flying-care-preparing-takeoff/

[2] *Urban Air Mobility: Economics and Global Markets 2020-2040.* www.nexa-uam.com

Statistics Canada, the federal agency tasked with producing data to help better understand Canada, its population, resources, and economy. Statistics Canada has created industry multipliers and specialized models to derive accurate Canada-specific economic projections for jobs, GDP, government revenues, and other benefits. In this way, Statistics Canada was an invaluable partner in the production of this assessment.

This study gives the direct, indirect, and induced economic effects of AAM over the next twenty years. Direct effects include the direct hiring of employees and revenue generation of sales. Indirect effects are the benefits to the supply chain of a company or government agency. Induced effects are those consumer expenditures resulting from direct and indirect effects.

The direct, indirect, and induced jobs and incremental GDP outputs are presented in Figure 2. A "Full-time Equivalent" (FTE) job is a full-time job for one year. We found that, driven by 20-year spending for Advanced Air Mobility services within its four most critical supply chains, the direct, indirect, and induced benefits are significant:

Benefit Category (2021-2040)	Full-time Equivalent Jobs	Incremental Gross Domestic Product – Basic Prices ($'000)
Direct Benefits:	9,188	$ 1,056,167
Indirect Benefits:	4,247	$ 556,463
Induced Benefits:	3,532	$ 555,782
Total	16,967	$ 2,168,411

Figure 2 - Economic impacts of AAM for Greater Vancouver including spill-over into other regions of Canada (2020-2040)

Today, according to industry records, British Columbia's private aerospace sector employs over 9,000 full-time jobs. As shown in Figure 2, the new AAM-driven job estimates can improve this number materially by 2040. These new jobs represent highly paid skilled, technical and, in some cases, scientific labor categories. Over 2,000 permanent jobs are thus forecasted.

NEXA also examined four catalytic benefits—that is, those "spin-off" effects on other industries considered incremental to the quantified impacts of Figure 2. Our findings are:

1. **Trans-Border Trade**: Increased north-south trade along the Cascadia Corridor.
2. **Indigenous community empowerment**: Improved environmental, economic, and social benefits.
3. **University Research and STEM Education**: Acceleration in STEM and private funding driving increased educational opportunities.
4. **Hydrogen Sector Acceleration**: Quickened development and demand for alternative clean power sources, supporting B.C.'s new hydrogen sector.

> ***"Pre-COVID-19, the air transport industry generated a total of 87.7 million jobs globally through direct, indirect, induced and catalytic impacts."***
>
> *The Air Transport Action Group, Geneva, Switzerland, September 2020*

In NEXA's opinion, catalytic impacts could more than double the FTE forecast in Figure 2.

The AAM sector, an important new outgrowth of the world's aerospace industry, can help transform the Vancouver economy, spinning out thousands of new and high-paying jobs on the strength of billions of dollars of incremental revenue activity. In turn, the ability of Vancouver to lead North America in this

sustainable arena will deliver first mover advantages—attracting investment and top talent—to benefit local industries, the public, Indigenous communities, and public responders.

Over the initial two to three-year period, AAM is expected to generate some 320 permanent jobs for the Greater Vancouver region. This gain will be directed from capital expenditures to plan, construct, and begin operating the new infrastructure to support commencement of AAM. A significant fact is that private capital markets can be tapped through partnerships with public and private sector stakeholders, with infrastructure investors (generally Canadian pension funds) committing to funding the requirements. Additionally, regional helicopter operators will begin to invest in new eVTOL fleets, training pilots to operate the new vehicles for the benefit of communities needing alternative forms of advanced air mobility.

> ***"Using the FTE projection of 16,967 direct, indirect and induced jobs over the forecast period, a market growth accelerator of 11.4 percent yields over 2,000 permanent, full-time jobs for the Vancouver region."***
>
> *Michael Dyment, Managing Partner, NEXA Advisors, November 5, 2020*

Over time the FTE projection will lead to over 2,000 permanent jobs supporting this new sector for the Greater Vancouver region. These new positions, involving specialized skills in aerospace engineering, advanced technologies, power systems, pilots, air traffic controllers, and air transport support to name a few, will be well-paying and highly prized job opportunities.

Finally, the consortium formed to organize AAM's launch throughout Greater Vancouver is already bound together by strong commitments to ensure equal access to these new eVTOL mobility services. The region can lead Canada through introduction of revolutionary new aviation technologies that will reduce greenhouse gas emissions, improve transportation system efficiency, promote public health and safety, create jobs and revenue, and improve equitable access to opportunities for all residents—particularly low income groups, seniors, youth, people with disabilities, and other vulnerable population groups.

Introduction and Economic Impact Study Methodology

At the heart of any healthy urban economy is a convenient, accessible, environmentally clean transportation system that allows the improved mobility of people, goods, and services. Mobility solutions take people to work, shopping, recreation, and other places that support the economy and improve their quality of life. Several urban-related societal as well as infrastructure factors are advancing the development of Advanced Air Mobility. One is the increasing congestion of the world's metropolitan areas driven by population growth and rural-to-urban migration. According to the United Nations, in 2018 some 55% of the world's population lived in urban areas, a figure that is expected to increase to 68% by 2050. The Vancouver metro area—hemmed in by water and mountains, and already built out—is forecast to grow from its 2016 base population of 2,570,000 to 3,600,000 by the year 2050.[3] Increased congestion strains emergency response resources, adversely impacts quality of life, and limits the vitality of the local economy.

> ***"B.C.'s aerospace sector is the third largest in Canada. It has more than 200 companies, generates a total of $2.4 billion in revenue annually and directly employs nearly 9,000 people."***
>
> *British Columbia: Innovative, Responsive. Trade and Invest British Columbia, 2018*

According to a 2015 CD Howe Institute study, the cost of lost efficiency and productivity due to traffic congestion in the Metro Vancouver area is between $500 million and $1.2 billion annually.[4] Widening roads and freeway corridors and building more bridges is not only cost-prohibitive but also flies in the face of Vancouver's Transportation 2040 plan, which aims for the majority of trips on foot, bike, and transit, eliminating dependence on fossil fuels through adoption of zero-emission hydrogen and electric power, and offering its citizens and visitors the cleanest air of any major city in the world.

With its growing population, built-out land, and hemmed-in geography, Vancouver's transportation network will require continued and creative improvements in the years to come. AAM holds the promise of substantial economic benefits for the Vancouver area, and not just in terms of reducing congestion as part of a seamless, multi-modal transportation system. Its implementation will require entirely new products and services that rely on investment and development, which in turn will spur economic growth. AAM will create skilled and highly paid jobs, attract global industrial and commercial players, bring in new tax revenues, boost tourism, and improve the ecosystem for institutes of higher learning. Importantly, improved mobility options brought about by AAM and the

Figure 3 - Alaka'i Skai four-passenger hydrogen-powered eVTOL aircraft.

[3] http://www.metrovancouver.org/services/regional-planning/PlanningPublications/OverviewofMetroVancouversMethodsinProjectingRegionalGrowth.pdf

[4] Tackling Traffic: The Economic Cost of Congestion in Metro Vancouver, 2019, C.D. Howe Institute.

jobs they create will greatly benefit Indigenous communities. Last but not least, environmental monitoring and emergency services will dramatically benefit.

This paper lays out the methodology of our economic analysis. It also explores the economic effects—jobs and GDP impact—of the four supply chains required to make AAM a reality. We examine how the region could undertake the manufacturing of aircraft, build the required air traffic management systems and ground infrastructure such as vertiports for landing and takeoff, and ensure safe flight operations. Figure 4 provides the roadmap that this analysis follows.

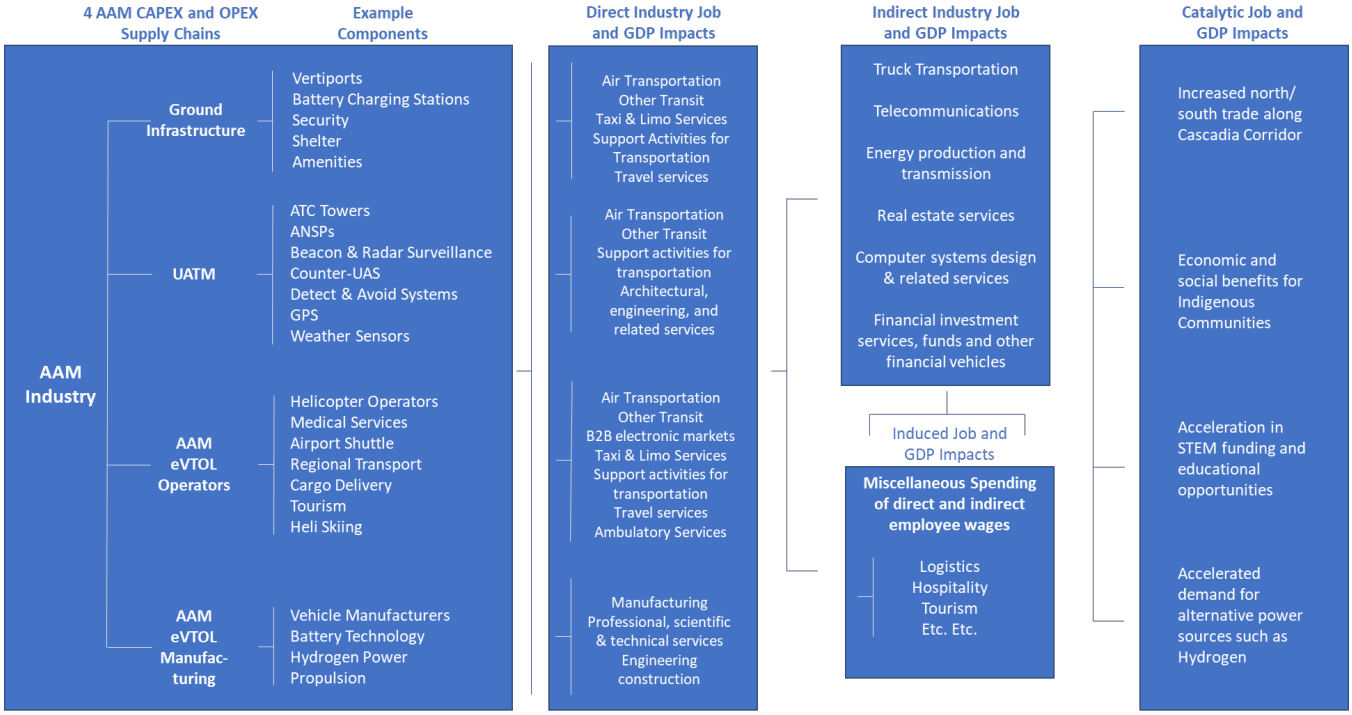

Figure 4 - Advanced Air Mobility industry jobs and GDP impacts are derived through an econometric analysis using AAM industry business case tools and Statistics Canada input/output tools.

In the sections below, we walk readers through the components and concepts illustrated in Figure 4, beginning with a crisp definition of the four supply chains that need to come together to secure a long-term, viable, and profitable Advanced Air Mobility ecosystem. Direct, indirect, and induced job and GDP impacts will be quantified. Lastly, a select number of catalytic benefits will be reviewed for their AAM sector benefits.

What is Advanced Air Mobility?

Advanced Air Mobility refers to a wide variety of aircraft, both large and small, piloted and unpiloted, VTOL (vertical take-off and landing) and STOL (short take-off and landing), hybrid-electric, all-electric or other advanced propulsion (such as hydrogen fuel cells), intra-urban and regional, passenger and cargo vehicles. For the purposes of this study, however, we will only examine the economic impact of VTOL passenger aircraft. Those powered by batteries or hybrid electric systems are called eVTOL (electric VTOL) aircraft. At some point in the future, hydrogen fuel cells may also come into play, fueling hVTOL aircraft. While batteries currently limit flight times and require long charging times in between flights, fuel cells—such as those that will be used in aircraft being developed by Alaka'i, VEA Aviation, AeroG, and ZeroAvia—could offer the benefit of long-range flight capabilities as well as fast refueling.

> ***"It's time to look at [Advanced Air Mobility]. The address-able market is $1.5 trillion in our base case by 2040. Logistics is leading the way."***
>
> *Morgan Stanley Research, December 2018.*

AAM has until recently been known as UAM, or Urban Air Mobility, given its intended uses over heavily congested cities. However, eVTOL aircraft will also be utilized outside of urban areas, delivering supplies to and transporting passengers throughout remote communities, for instance, or providing regional transport between airports 80-250 km apart. Therefore, the name AAM has been adopted to reflect greater inclusivity of its many uses near and far, which is especially true for British Columbia.

Greater Vancouver Advanced Air Mobility Use Cases

AAM will have numerous uses moving people. This analysis, discussed thoroughly in the AAM White Paper Series Part I, focuses on six:

- **Airport Shuttle Services:** Tying city centers to airports and one metropolitan airport to another.
- **On-Demand Air Taxi:** A network of small electric aircraft hailed by mobile app to land at the passenger's nearest vertiport and delivering the passenger to the vertiport nearest their ultimate destination.
- **Regional Transport Services:** Many city pairs are located too close for a convenient commercial flight but too far for a convenient drive (Vancouver and Seattle, for example). Longer-range eVTOL aircraft will focus on transporting passengers between such city pairs.

Figure 5 – Conceptual TriFan eVTOL Medevac configuration designed by XTI Corp. for Helijet of Vancouver.

- **Medical and Emergency Operations and Services:** eVTOL aircraft in development (Figure 5) are likely to require only one minute to prepare for take-off as opposed to the 10-13 minutes required by some helicopters, thereby reaching critically ill and injured people much more quickly.
- **Business Aviation:** The world's top executives use business aircraft for time management, building enterprise value, and retaining top talent. Yet they, too, get stuck in traffic on the way to the airport. eVTOL aircraft will fly top executives from corporate headquarters to their business aircraft or to their final destinations if within a couple of hundred kms.
- **Air Metro:** The air metro concept of AAM resembles current public transit options such as subways and buses, with pre-determined routes, regular schedules, and set stops in high traffic areas throughout Greater Vancouver. This use case deploys larger eVTOLs, such as the AeroG platform (on the cover of this paper), moving perhaps 10 to 12 or more passengers at a time. An air metro use would take residents from distant passenger stations in a remote suburb to a TransLink Skytrain station closer into the city, or perhaps directly into the airport or downtown.

Small Unpiloted Aerial Systems (sUAS) Use Cases

A number of use cases for sUAS vehicles (sometimes known as drones), generally of limited range and under control through visual line of sight, are detailed in Part I, the White Paper. These are:

- **Wildlife Tracking and Monitoring:** page 47.
- **Coastline Monitoring and Conservation:** page 48.
- **Fishery Monitoring and Compliance:** page 50.
- **Rapid-Fire Dispatch:** page 51.
- **Wildfire Response:** page 53.
- **Retail Goods and Food Delivery:** page 54.

> ***"The final frontier in 'mobility-by-air' remains urban centers, long captive to surface transportation, especially cars, buses and mass rail transit."***
>
> *Michael Dyment, Managing Partner, NEXA Capital Partners.*

This paper, Part II, does not analyze economic impacts of these drone and UAS use cases; however, we will produce an econometric study of drone and UAS applications in the future. The remainder of this report lays out the AAM passenger impacts only.

AAM Challenges and Opportunities

As with any great technological leap forward, especially one that will impact the lives of so many people, AAM must overcome numerous barriers before it can be implemented in a community. In short, it must be safe; it must be financed; it must break even in the near future; and it must be accepted by the public. These requirements have been thoroughly discussed in the White Paper, which examines safety, regulations, capital formation, infrastructure needs, privacy issues, and environmental impacts such as noise.

Opportunities also abound. Vancouver's geography is a key factor in its early utilization of AAM. A distinctive combination of factors—many bodies of water, mountains, and the capital of British

> ***"According to a [recent] poll, 85 percent of Canadians feel that it is important for Canada to invest in its domestic aerospace industry."***
>
> *Aerospace Industries Association of Canada, July 2020*

Columbia, Victoria, located on nearby Vancouver Island—creates increasing congestion, presents challenges to convenient mobility solutions, and positions the city to become an excellent early user of AAM. Additional factors strongly favoring the Greater Vancouver region include:

- Diversified, green, knowledge economy. Several sectors are attracting global talent, corporations, and investment to Vancouver, which is fast becoming the new foundation of the knowledge economy. For example, the city is the third greenest in the world[5] and has long recognized the economic opportunity and global imperative of driving green. Also, Vancouver's economic diversity ranges from leadership in traditional resource industries to social enterprise, technology, aerospace, and digital entertainment.
- A vibrant aerospace sector. Vancouver is the location of more than a dozen AAM projects involving large aerospace companies, universities, and both the federal and provincial governments.
- A strong in situ base of scientific and technical know-how. Vancouver has a network of educational institutions that provide a deep pool of highly skilled talent. For instance, the University of British Columbia is a global center for research and is consistently ranked as one of the top 20 public universities in the world.

Figure 6 - Local aerospace expertise is abundant in B.C.

[5] According to the 2016 Global Green Economy Index, behind only Copenhagen and Stockholm.

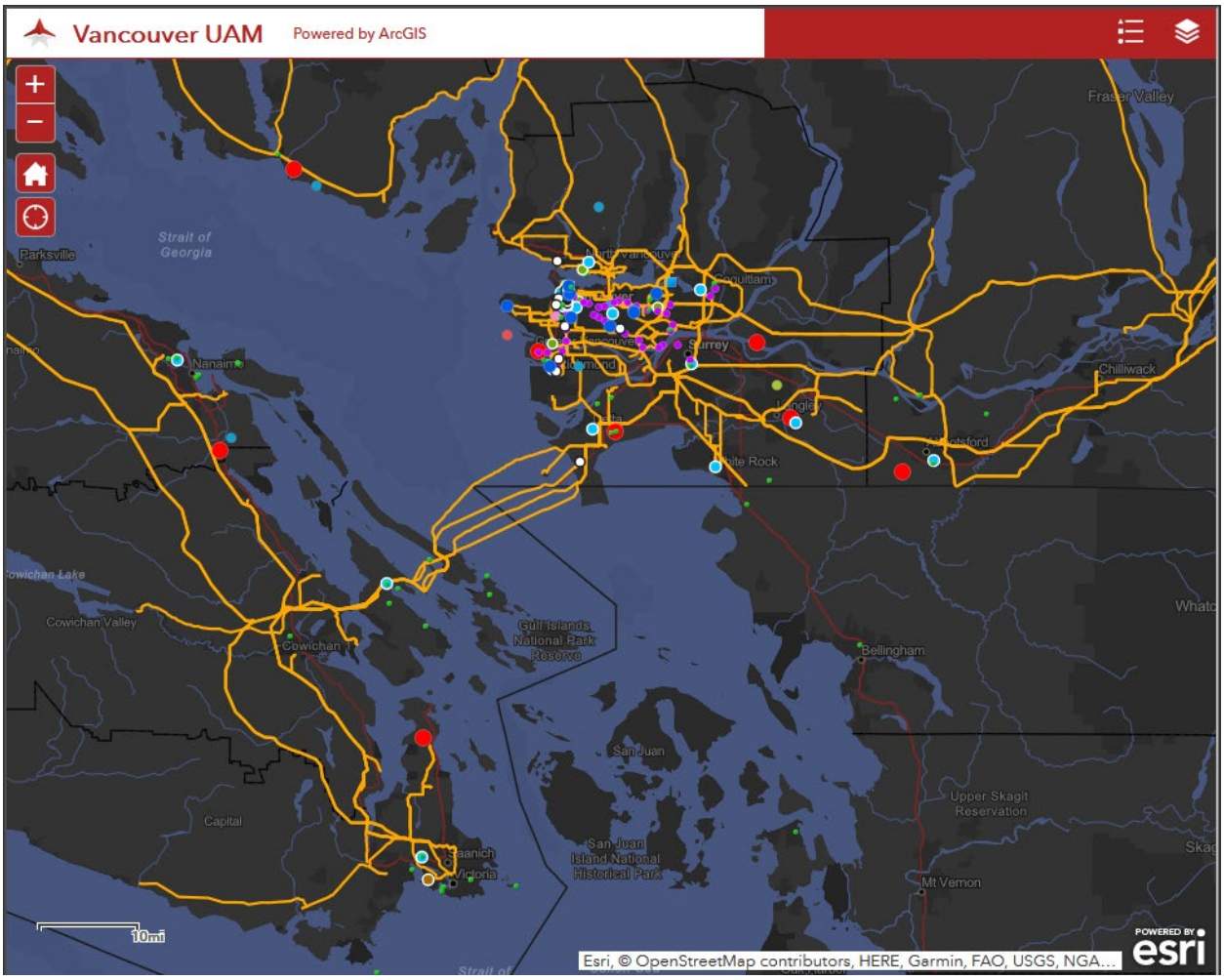

Figure 7 - Greater Vancouver, including parts of Vancouver Island, with important features that aid in AAM planning such as major transportation routes, hospitals, corporate headquarters, helipads, and airports..

- Vancouver's innovation economy. The city has been voted the number one Job-Creating Economy in Canada; the Most Diverse Economy in Canada[6]; the number two Startup Ecosystem in Canada[7]; and the "Number One Cleantech Cluster" in Canada.[8]
- Long experience with and public acceptance of helicopters and sea planes. The active Air Operators maintain licensed AOCs (Air Operator Certificates) and ferry several hundred thousand passengers annually. They have the experience, infrastructure, and regulatory licenses to easily transition to eVTOL aircraft using their current offshore flight corridors—channeling noise and visual disturbances away from populated areas.
- 54 existing helipads. Many of these could be remediated at reasonable cost as vertiports with battery recharging stations and passenger amenities.

[6] Conference Board of Canada. www.conferenceboard.ca

[7] By Startup Genome. https://startupgenome.com

[8] The Global Cleantech Cluster Association.

- Twelve airports.
- 15 hospital centers. Seven are equipped with helipads. These would benefit from drone delivery of supplies and eVTOL Medevac rescue operations.

> ***"The simplification of the technology, combined with the sophistication that can be pushed into the software, has completely changed the landscape of what you can do with these flying vehicles."***
>
> *Eric Allison, Uber Elevate*

The Business of Advanced Air Mobility: Economic Inputs

How does AAM translate into societal benefits, environmental advantages, jobs, and economic growth? This section provides an explanation of the key drivers of such outcomes. The estimated capital and operational inflows and outflows for the Greater Vancouver area are quantified.

Relevant Supply Chains

Bringing Advanced Air Mobility into operational status will require four supply chains to assemble and operate this new transportation system. As shown in Figure 4 on page 9, these begin with AAM ground infrastructure needed to provision landing facilities. The world is actually well-populated with heliports; however, fewer than half are in locations convenient to maximize AAM applications. Ground infrastructure will require expansion into network configurations, with each node, or vertiport, carefully located and built to ensure passenger convenience and value (Figure 8).

Figure 8 - Uber Elevate proposes that rooftop modifications to parking facilities in urban areas can be made cost effectively.

The second AAM supply chain is that of air traffic management, known as RTM (Remote Traffic Management), which ensures safe airspace coexistence for commercial and general aviation, drones, and AAM aircraft. Finding the right RTM solutions on a city-by-city basis will be necessary to unlock full market potential and requires increased collaboration and planning among all stakeholders. NAV CANADA is responsible for managing Canada's airspace and, as an observer of the Canadian Advanced Air Mobility Consortium, will assist in developing the air traffic management portion of the AAM ecosystem.

The remaining two supply chains—eVTOL aircraft manufacturing and the aircraft operators that will fly them—will be fully discussed in the sections below. The ecosystem needs to provide excellent services to passengers at affordable prices at a point where the sector finds equilibrium, thereby becoming and remaining profitable. By definition, this equilibrium is achieved when each of the four supply chains can reach and exceed cash flow profitability.

The NEXA Advisors/UAM Geomatics business analysis tools illustrated in Figure 9 have been developed and used to assess city-by-city AAM feasibility, and Vancouver is one of 75 urban areas studied for this exacting and comparative analysis. A key goal is for each of the four supply chains shown (the "City PPP Model", the "AAM Operating Model", the "RTM Model", and the "AAM eVTOL Supply Chain") to achieve a measure of commercial success.

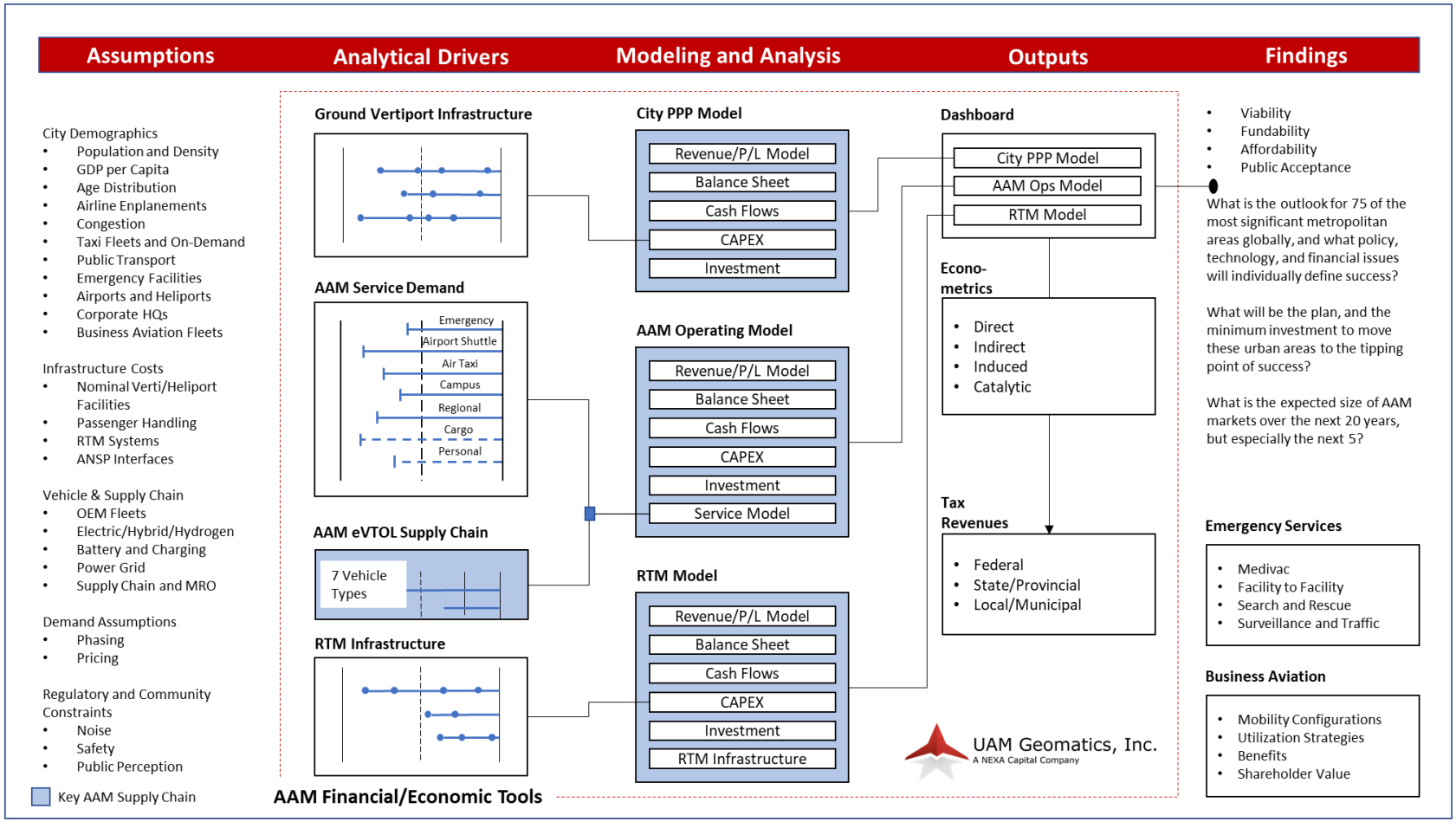

Figure 9 – NEXA Advisors/UAM Geomatics financial and economic tools analyze the four supply chains to assess AAM business viability, city by city. Vancouver is one of the 75 cities analyzed.

For the purpose of this analysis, Vancouver's four critical supply chains all succeeded in achieving this success, in turn attracting outside capital to fund each phase of the launch

Pillar	Year	2021-2025	2026-2030	2031-2035	2036-2040	SUM	Pillar Totals
Ground Infrastructure	Ground Infrastructure OPEX	$7,080,538	$15,668,063	$45,839,785	$52,095,751	$120,684,137	$181,388,465
	Ground Infrastructure CAPEX	$13,877,663	$14,769,977	$29,602,682	$2,454,005	$60,704,328	
RTM	RTM Cost OPEX	$3,154,325	$3,797,741	$12,641,869	$26,506,853	$46,100,788	$77,868,401
	RTM Cost CAPEX	$5,282,482	$9,824,189	$8,364,717	$8,296,225	$31,767,613	
AAM Operators	Operator Use Case Revenues	$91,103,282	$207,172,611	$377,773,838	$471,264,943	$1,147,314,673	$1,576,356,945
	MedEvac/EMT Services BC	$80,751,593	$80,865,721	$134,262,161	$133,162,797	$429,042,272	
Vehicles	Vehicle Acquisitions	$33,047,009	$73,037,381	$77,677,583	$66,415,124	$250,177,098	$250,177,098
Vancouver Grand Total		$234,296,893	$405,135,683	$686,162,635	$760,195,698	$2,085,790,909	$2,085,790,909
	Percent of Total	11.2%	19.4%	32.9%	36.4%	100%	

Figure 10 - Greater Vancouver revenue, OPEX and CAPEX analysis, generating monetary inputs used to drive Statistics Canada input/output tool.

Figure 10 shows the extensive analysis provided by the financial and economic tools used in the NEXA Advisors/UAM Geomatics Urban Air Mobility study, produced in five-year increments of 20-year revenue and capital investment estimates for Greater Vancouver. These financial estimates fall into three categories:

- **CAPEX** – Those capital expenditures funds used to acquire, upgrade, and maintain physical assets such as property, plants, buildings, and specialized facilities, technology, or equipment.
- **OPEX** – Costs that a business incurs through normal business operations. Operating expenses include rent, equipment, inventory costs, marketing, payroll, insurance, step costs, and funds allocated for research and development.
- **Vehicles** – Fleet acquisition and maintenance costs to acquire and operate sufficient eVTOL aircraft to sustain the use cases identified.

Supply Chain 1: Provisioning Extensive AAM Ground Infrastructure

The easiest way to create AAM vertiports is to remodel existing heliports. The basic elements of a heliport are clear approach/departure paths, a clear area for ground maneuvers, final approach and takeoff area (FATO), touchdown and liftoff area (TLOF), safety area, and a wind cone. This existing infrastructure can be updated for eVTOL aircraft by adding battery recharging stations and fuel stations for hybrid aircraft, as well as perimeter security, shelters, and other amenities. Given the need to recharge batteries, the region's power grid becomes an essential factor in determining vertiport locations.

Globally, many cities have heliports that are rarely or no longer used. Helicopters are often seen as a nuisance by local communities due to their noise. Given the lower noise signature of eVTOLs, it is likely that some of the unused or underutilized heliports—particularly those near hospitals—may be renovated to utilize the new aircraft.

Integrating an eVTOL aviation network with the existing system of public transportation modes requires detailed planning and analysis. With the objective of implementing the greenest, most cost-effective, and commuter-friendly transit system possible, planners must consider the needs of all users when locating vertiports to enable practical end-to-end solutions for passengers. Metro Vancouver has 54 heliports, including at all 12 airports, and at seven of the 15 hospital centers. The NEXA Advisors/UAM Geomatics Urban Air Mobility Study projected that by 2040 Greater Vancouver would need twelve new

vertiports and possibly one multiport (landing area for multiple aircraft), strategically placed throughout the metro region, in addition to those presently at airports and hospitals.

RTM Ground Infrastructure Components (CAPEX and OPEX)	
• Network design studies • Environmental study • Airspace flight design 3D visualization studies • Concession agreements • Secure project financing • Purchase or lease land • Construction permitting • Architectural and engineering • Site preparation • Site construction • Foundation modifications • Platforms • Egress, walkways • Elevators	• Passenger shelters • Lighting systems • CNS systems (ILS, beacons, etc.) • IT and security systems • Perimeter systems • Parking • Power grid updates • Transport Canada (etc.) permitting and certification • Recharging capability and systems • Fire suppression systems • Aeronautical chart preparation • Operators, maintenance staff and related workforce

Figure 11 - Selected ground infrastructure cost elements.

While the technology is available to upgrade heliports to vertiports, Transport Canada has not yet finalized standards. These regulations may be dependent on the types of aircraft selected, their footprint, weight, and electric or hydrogen charging requirements.

What are the cost elements one must include in CAPEX and OPEX estimates? A list is provided in Figure 11. These elements have been forecasted for Vancouver's infrastructure improvements using specific intrinsic cost data unique to the City and its metropolitan region, such as land cost, labor cost, and so forth.

While certain aspects of vertiports remain to be determined, it is safe to say that the development of infrastructure to support an eVTOL network has significant cost advantages over heavy-infrastructure approaches such as roads, light rail lines, bridges, and tunnels. Compared to the billions of dollars required to extend lines, for instance, the estimate for the 12 new vertiports projected to operate in Greater Vancouver by 2040 (a mix of remediating existing heliports and building new ones) is in the range of $70 million total.

> ***"Airbus is working on different concepts for urban air mobility and is actively engaging with cities and other stakeholders."***
>
> *Vassilis Agouridas, Airbus Mobility*

Supply Chain 2: RTM Safely Managing AAM Air Traffic Flows

An air traffic management system ensures the safe and efficient movement of aircraft. Airplanes and helicopters are guided through the airspace by air traffic controllers. Drones and eVTOL passenger aircraft must also be safely and efficiently managed. It is likely that the first passenger use cases will rely on NAV CANADA's existing system of air traffic controllers: those eVTOL aircraft replacing and/or complementing existing aircraft operations such as Medevac and helicopter operators.

But the many new uses and routes of eVTOLs—both passenger vehicles and drones—would add hundreds, perhaps thousands of movements to the system each day, overloading the area's air traffic management capabilities.

RTM ATC Infrastructure Components (CAPEX and OPEX)	
• RTM interoperability standards and drone/eVTOL agreements. • RTM one-time facilities planning • Site/network optimization study • Systems specifications • Power grid studies • Cyber security architecture studies • Physical security architecture • Facilities (offices) rental costs • Automation Systems and Stations • Flight Decision Support Tools • Computers and Equipment	• Flight Plan and Flight Operations Database • SCADA for Systems and Networks • Power Grid and Backup Systems • Network Design and Site Selection Studies • Weather Information Systems - Areal • Micro Weather Detection Sensors • Beacon Navigation Nodes • Resilient Communications Nodes • High Density Radar

Figure 12 – Selected RTM Cost Elements.

Advanced Air Mobility will need its own air traffic management system working in conjunction with the current system. Human controllers in a new local RTM facility may become airspace managers, focused on supervising automated systems and aircraft operations, ensuring safety and, at all times, security. At such a facility, a single controller could supervise many more aircraft movements than working in an airport ATC tower. A simple explanation is that aircraft will operate in layers of altitude (Figure 13), with drones at the lowest level, eVTOL aircraft in the middle, and traditional aircraft at the highest, though they must also be guided through layers during take-off and landing. Of note is that NAV CANADA already maintains a downtown Vancouver air traffic control tower overlooking Vancouver Harbour. For more detailed information on RTM, refer to page 29 in the White Paper.

"British Columbia's aerospace sector is globally recognized for excellence in delivering highly specialized products and services, supported by a network of education institutions that provide a deep pool of highly skilled talent.

--Trade and Invest British Columbia 2018

Costs to implement RTM capabilities are reflected in Figure 12. While ensuring safe vehicle separation using fully staffed facilities, the costs for Vancouver identified in Figure 10 are affordable when considering their amortization over a period of decades.

According to the NEXA Advisors/UAM Geomatics study, the estimated cumulative cost for Metro Vancouver Advanced Air Mobility Air Traffic Management systems and operations will start at around $80 million. This amount includes the need for a fully staffed Network Operations Center or NOC, within the city's boundary. The NOC would be overseen by NAV CANADA.

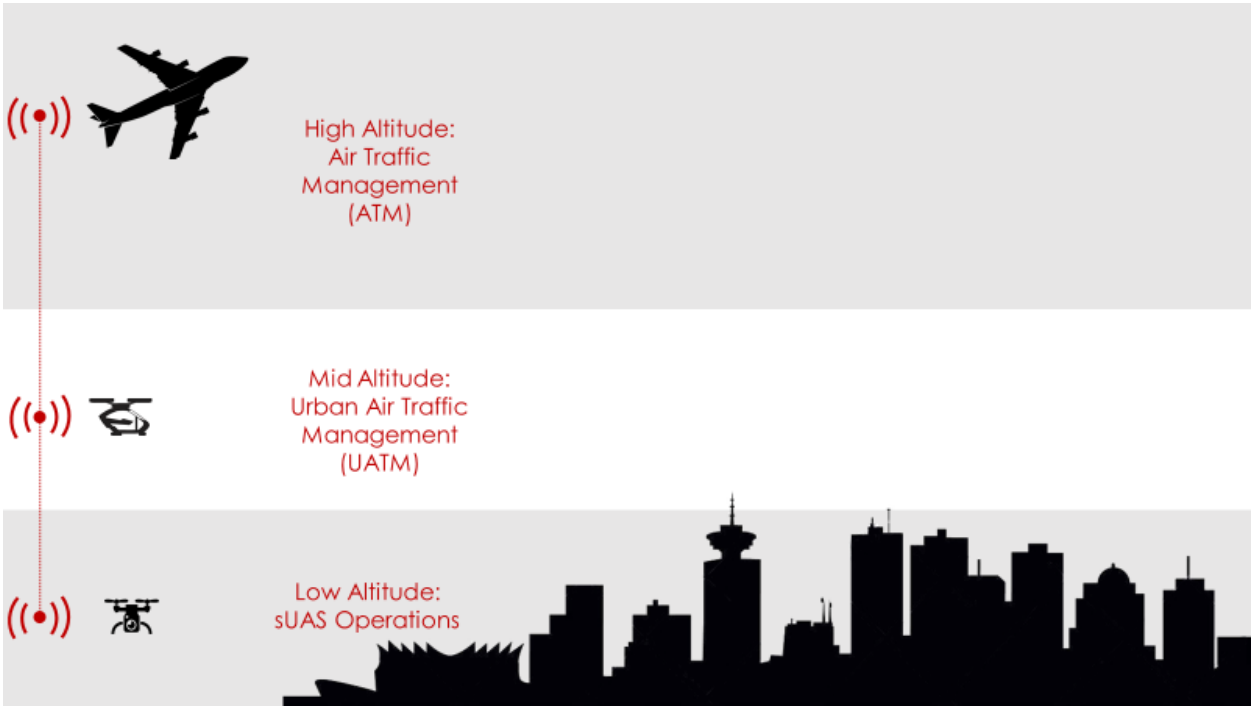

Figure 13 – Simplification of concepts for layering airspace above metropolitan areas.

Advanced Air Mobility must, within a few years, become economically viable to pay off investors as well as to pay recurring costs such as equipment maintenance and upgrades, and employee salaries, and maintain public safety and convenience.

Supply Chain 3: Advanced Air Mobility Operators

Current operators of helicopters are today's vanguard for eVTOL services. Charter helicopter companies in Vancouver, the most familiar being Helijet (Figure 14), have excellent longstanding safety records, trained pilots, weather dispatching expertise and systems, and quality and safety programs. They are also familiar with the regulations, terrain, and locations of the heliports and airports in the region. As an industry, their current services are scheduled operations (e.g. Vancouver Harbour to Victoria), and more, including medical/emergency services, airport shuttle services, regional transport, cargo delivery, tourism, and heli-skiing.

Figure 14 - Helijet currently provides scheduled airline services, air taxi and Medevac services, to British Columbia residents.

Drone operators can be independent individuals, small companies, and large players such as Amazon, FedEx, Air Canada and DHL. Their missions are diversified, and range from healthcare (isotope delivery, vaccine delivery, COVID test kits,

blood transport) to package delivery, agricultural purposes, bridge inspection, and other useful applications.

Supply Chain 4: Advanced Air Mobility eVTOL Aircraft

Several eVTOL prototypes around the world are either in or nearing advanced stages of development and operational trials of one kind or another. Designs vary widely in terms of number of passengers, number of rotors, and distance traveled before recharging.

Even those developers furthest along have not released certain details about their aircraft, but we believe they will be lighter, quieter (Figure 15), and more flexible than helicopters. Medevac eVTOLs, for instance, will be able to land safely in a smaller area, a great bonus when emergency rescue personnel need to reach a critically injured person on a congested road.

> ***"British Columbia companies serve major aircraft manufacturers such as Boeing, Lockheed Martin, and Bombardier. The province is home to pioneering research and development on aerospace composite materials and structures."***
>
> *--Trade and Invest British Columbia 2018.*

Nearly all eVTOL aircraft currently in development are designed to be piloted, at least initially. The next two decades will see increasing use of automation and autonomy performing many functions traditionally performed by humans. Automation and autonomy offer the opportunity to reduce workload and enhance safety for critical aviation functions.

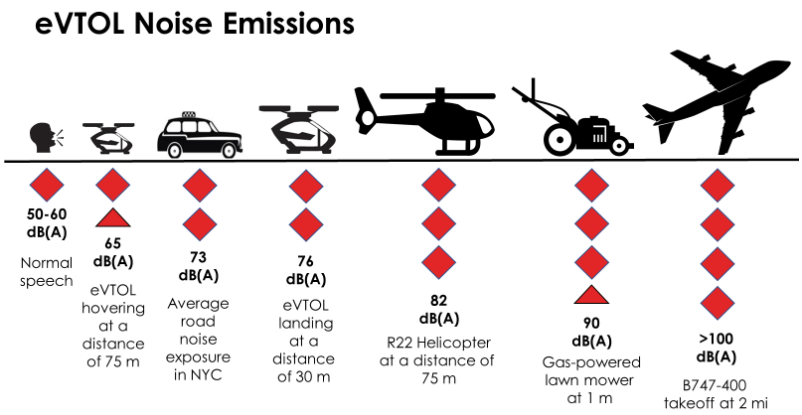

Figure 15 - eVTOL noise will be a key determinant of public acceptance.

Aircraft noise is a key determinant defining success and acceptance of eVTOLs that will operate in areas of higher population density at low altitudes. Smaller eVTOL aircraft are expected to fall well within current noise guidelines, and noise-reducing technologies hold promise for larger aircraft to be good neighbors as well.

Estimated AAM Passenger Demand for Vancouver

Analysis of the major use cases' passenger demand first required separation into price-elastic (sensitive to price) and price-inelastic (less sensitive to price) forecasts. Clearly, on-demand air taxi, airport shuttle, air metro, and regional air transport services are highly price sensitive, while business aviation and Medevac are not. Many factors are considered as well, including the ability of urban residents to afford such services. For these demand forecasts to be realistic, the analysis made use of ten factors—a method uniformly applied to the 75-city study undertaken by NEXA Advisors/UAM Geomatics earlier in 2020. These factors (Figure 16), adjusted to Greater Vancouver's unique demographics, estimate that by 2040, the peak forecast year, some 680,000 passengers are expected to travel using new eVTOL services annually.

Factor	Demand Input	Description
1	Airport O/D Traffic	The Airport O/D input weighted cities according to the level of originating and departing passenger traffic. The total commercial passenger "Enplanement" traffic was gathered for all active airports within the wider city metro areas. A tier was then found for each city to determine how much of the passenger traffic was originating to or departing from the city, eliminating connecting traffic.
2	Mobility Substitutes	The Mobility Substitutes input ranked a city's willingness to accept a new AAM transportation option. The rank was derived from five scores, all weighted accordingly, including on-demand taxi cost, public transport cost, vehicle ownership cost, electricity and gas cost. The higher the cost (except for electricity), the better the city scored for the new UAM services.
3	Per Capita GDP	The per capita GDP (PPP) input weighted cities according to the most up-to-date gross domestic product (PPP) of each city.
4	Distances and Congestion	The Distances and Congestion input weighted cities according to average traveling distances. The rank was derived from ranking the distance from the main airport to the city center, and the total area of the city itself. The higher the congestion, the greater weight this factor played.
5	CIMI Human Capital Indicator	The CIMI Human Capital input weighted cities according to the human capital indicator of the IESE Cities in Motion Index (CIMI), 2019. The CIMI comparatively analyzed 174 different cities. The human capital score was derived from 10 different factors, including higher education levels of the population, available universities, and per capita expenditure on education.
6	Population Density	The Population Density input weighted cities according to their density and proximity to city employment areas. The gravity model determined how likely the factor was able to influence UAM demand.
7	Liveability	The Liveability input ranked cities according to its liveability, focusing on disposable income. The costs of living in each city was derived from Expatistan.com, and then inversed. That rank was combined with the average monthly net salary (after tax) of each city, and the two scores were averaged together. The higher the salary and the lower the cost of living, the higher the cities were ranked for AAM usage.
8	Fortune 1000 Presence	The Fortune Global 1000 Corporations input weighted cities according to commercial business environment. To determine the importance of this factor on passenger demand, we identified the total count, total enterprise value, and total employees of Fortune Global 1000 company headquarters. The three scores were ranked and averaged to influence AAM usage.
9	Business Aviation Activity	The Business Aviation arrivals/departures input weighted cities according to their business aircraft arrivals and departures. The data was derived from multiple sources and databases. Business aviation fleets were considered through JETNETS registrations.
10	Existing Heliports	The Existing Heliports input weighted cities according to their sunk investment in heliport infrastructure. The best available data for heliports is considerably inaccurate, so our proprietary data and research tools were developed and used to increase the accuracy.

Figure 16 - Factors applied to Vancouver demographic analysis of future AAM demand.

Advanced Air Mobility Economic Outputs: Jobs and GDP

> ***"The master-economist must possess a rare combination of gifts .... He must be mathematician, historian, statesman, philosopher—in some degree. He must study the present in the light of the past for the purposes of the future. No part of man's nature or his institutions must be entirely outside his regard. He must be purposeful and disinterested in a simultaneous mood, as aloof and incorruptible as an artist, yet sometimes as near to earth as a politician."***
>
> *John Maynard Keynes*

To undertake a 20-year economic impact assessment of Advanced Air Mobility for the Greater Vancouver area, CAAM and NEXA retained the services of Statistics Canada to combine the work of the NEXA data with the input/output modeling capacity of Statistics Canada. The combination depicts the most accurate possible impact assessment of the benefits AAM will deliver specifically to the Greater Vancouver region. The results of the study give insight into not only the city of Vancouver and British Columbia as a whole but include rippling effects for the rest of Canada. The results may be analyzed and carefully considered by policy planners, such as the Vancouver Economic Commission and the Western Economic Diversification group, as well as municipal and provincial governments interested in job creation and general economic growth. These results make it somewhat easier to mobilize Vancouver's resources to act on the AAM opportunity and support goals of a safer, more mobile, publicly affordable, and greener city.

In economics, an input/output model is a quantitative methodology that represents the interdependencies between different branches of a national economy or of regional economies. The Statistics Canada input/output model depicts inter-industry relationships, showing how output from one industrial sector may become an input to another industrial sector. In the inter-industry matrix, column entries typically represent inputs to an industrial sector, while row entries represent outputs from a given sector. This format shows how dependent each sector is on every other sector, both as a customer of outputs from other sectors and as a supplier of inputs.

Econometric and input-output models contain assumptions; after all, if every variable were known, we would have a list of facts and not a forecast. The most important assumption derived from NEXA's business forecast for Vancouver includes the insertion of an "inflection point," the introduction of highly automated flight systems requiring less human intervention. For example, an emerging view of AAM over the next 20 years is that cockpit automation will be necessary to improve the integrity and thus the safety of this new market sector. Automation should eliminate

Figure 17 - Vancouver International Airport (YVR) will become a significant node when Advanced Air Mobility comes online. In 2019, YVR handled 26.4 million travelers.

pilot error, enforce sense-and-avoid rules, and safely separate all vehicles, including eVTOLs and drones. Automation will reduce the cost of operations, as well as the demand for human operators. The cost structure of the entire industry will be dramatically impacted in synchronization with the expansion of vehicle and airspace capacity. The economic impact assessment in this report accounts for the inflection point, as reflected in the charts examined below. This is done through the input phase, whereby the NEXA model factors in automation and its impact on the overall AAM business case.

> ***"We could solve all our problems if only we were the efficient, rational human beings of standard economic theory and had politicians willing to think in the long-term interest of their people rather than their own."***
>
> *Jeremy Grantham, Inventor of Market Bubble Theory*

Statistics Canada's input-output model also comes with certain assumptions and limitations. It does not take into account economies of scale, constraint capacities, technological change, externalities, or price changes. It is, however, easily assumed that technologies improve over time, and that growing firms and industries experience the benefits scale, which reduce, as a proportion, fixed operational costs. Prices are predicted to fall, and productivity generally improve. Other assumptions in the model include fixed consumption behaviors and a fixed share of expenditure relative to income.

Economic Impact – Study Definitions and Methods Used

EIAs assess the impact of an "exogenous shock"—economic activity that stimulates growth—exploring its impact on a number of indicators such as job creation, GDP growth, and revenues. Some of these indicators will be further evaluated at three levels of analysis: direct, indirect, and induced effect. Direct effects calculate the economic value that a business or industry generates by its own means through direct hiring of its own employees, revenue generation from sales, and the portion of its business activity that contributes to national GDP. Statistics Canada states the following: "The direct effect on the output of an industry is a one-dollar change in output to meet the change of one dollar in final demand. Associated with this change, there will also be direct effects on GDP, jobs, and imports." Indirect effects gauge the economic impact that results from demand created by a particular company/industry for products and services from companies that support that business's activities (i.e. supply chain companies).

Statistics Canada classifies indirect effects as follows: "Indirect effects measure the changes due to inter-industry purchases as they respond to the new demands of the directly affected industries. This includes all the chain reaction of output up the production stream since each of the products purchased will require, in turn, the production of various inputs." Finally, there's the induced effect, which measures the economic impact on the broader economy resulting from demand created by employees of the company/industry in question (direct component) and its supporting businesses (indirect component). Statistics Canada defines induced effects as follows: "Induced effects measure the changes in the production of goods and services in response to consumer expenditures induced by households' incomes (i.e., wages) generated by the production of the direct and indirect requirements."

In this instance, the direct effect of a $2.2 billion (page 6) AAM multi-industry exogenous shock to Vancouver over 20 years will produce a number of direct AAM jobs, revenues, and expenditures that will further produce inter-industry demand (indirect impact). Additionally, the induced impact will capture unrelated excess economic activity (e.g., consumer spending in the general economy from increased income provided by AAM). Based on the EIA numbers, we go one step farther in identifying AAM's

catalytic effects on the city of Vancouver and the surrounding region. Growth in AAM will improve trade between West Coast communities along the Cascadia corridor, facilitate economic reconciliation for Indigenous peoples, accelerate investments in science and technology, and boost the role of Vancouver's hydrogen programs and pull-through for the AAM sector. These effects are discussed as an extension to the EIA.

Figure 18 provides a flow diagram of this study's method. The model requires a dollar value shock as an input in the input/output model. NEXA used its 20-year city estimate of $2.2 billion, categorized into four NEXA-defined supply chains, to distribute as shocks to Vancouver's economy. Although the shock

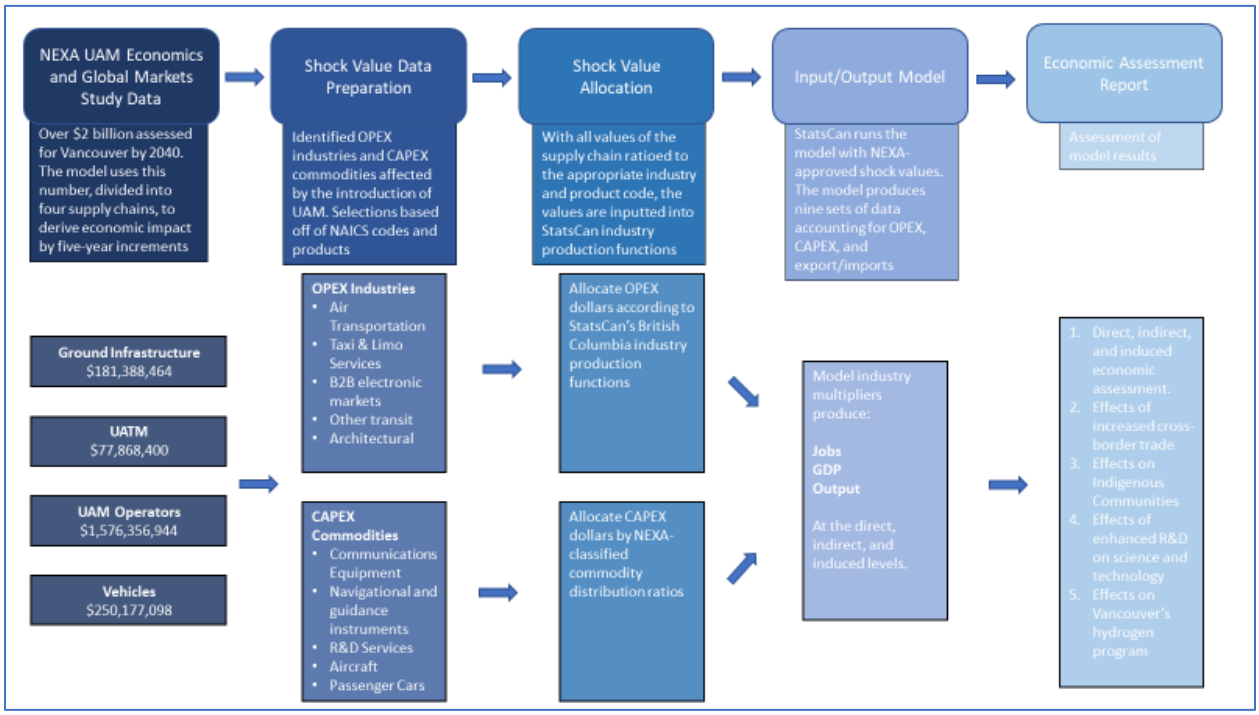

Figure 18 - Shock value allocation flow model.

was forecasted to occur with growing impact over 20 years, due to financial constraints associated with infrastructure construction schedules, the shock was distributed over 20 years. The four supply chains were further disintermediated and segmented by the type of cost-operational (OPEX) or capital expenditure (CAPEX). Statistics Canada provided their North American Industry Classification System (NAICS) codes applicable to the Province of British Columbia. We identified the appropriate and relevant industries and their associated products to distribute the OPEX and CAPEX values. The examples of OPEX industries and CAPEX commodities listed in Figure 18 are just some of the selections NEXA determined were most relevant to the four supply chains. For OPEX, we distributed over $1.7 billion across eight industries, including those such as air transportation and architectural, engineering, and related services. For CAPEX, we distributed over $92 million across commodity classifications. These include: communications equipment, research and development services, and aircraft. In this study, the vehicles or aircraft component, which can be understood to mean aircraft and aircraft component purchases, is considered a capital expense.

The CAPEX commodity dollars were applied to the commodity distribution ratios (e.g., communication engineering construction—a Stats Canada CAPEX commodity—took in 15% of the total CAPEX dollar distribution), resulting in a final shock value. Next, the OPEX industry values were applied to Statistics Canada's production functions associated with each of the selected industries, applying NEXA's OPEX inputs to Stats Canada's industry ratios (e.g., Statistics Canada's function for the architectural, engineering, and related services industry estimates that office administrative services account for 2.43% of total output). Once these final shock values were determined, Statistics Canada ran the numbers through their model, producing outputs in the form of estimated impacts to GDP, jobs, and other economic indicators.

> ***"With a population of over 2.2 million and a GDP of over $90B, Metro Vancouver ranks 64th among city-regional economies in size, but much higher in livability, entrepreneur-ship and 'greenness.'"***
>
> *Vancouver Economic Development Commission, March 2020*

Economic Impact – GDP Growth

GDP, or Gross Domestic Product, is defined as the total value of all domestic final goods and services produced within a specified period. According to the City of Vancouver factsheet #1.5, GDP for Metro Vancouver was $135 billion in 2017. The introduction of AAM to Vancouver over 20 years would generate nearly $2 billion more to the local and provincial economy, an additional 1.4% increase to GDP.

As shown in Figure 19, British Columbia would expect incremental GDP growth of $200 million within the first five years of AAM service. As service expands, the value of AAM increases, finally topping at an additional $732 million in GDP between 2036 and 2040. While the economic shock targets Vancouver, the supply chains that would support the development of AAM bring in inputs from various economic centers throughout the rest of Canada. For our purposes, the focus of the economic impact remains within the Province of British Columbia, although GDP is forecasted to increase for the remainder of Canada as a whole as a result. The rest of Canada (i.e., Canada, except B.C. in Figure 19) would see nearly $360 million in GDP growth, bringing the total impact for the country at well over $2 billion for the entire 20 years. We can assume that the introduction of AAM to Vancouver will serve as a catalyst for introduction into the rest of Canada. Toronto, for example, is another prime city that is expected to follow Vancouver's direction, making the GDP impact on the country significantly higher.

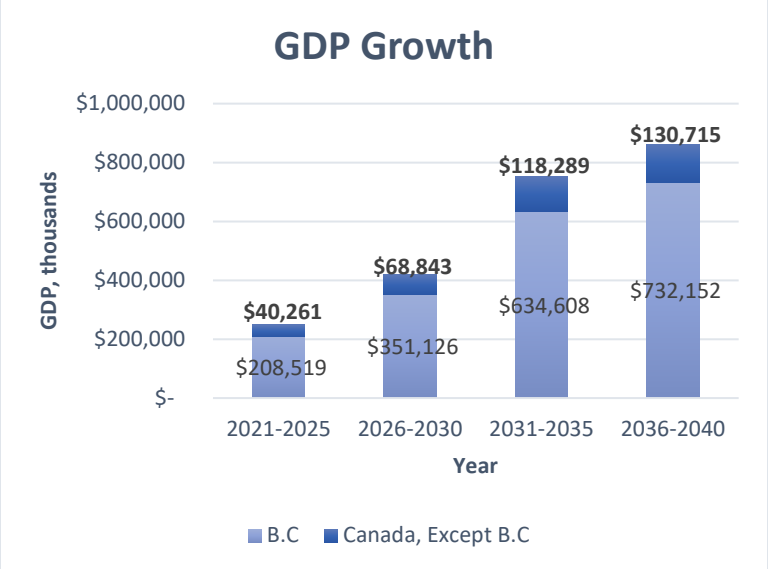

Figure 19 - GDP growth for both British Columbia and the rest of Canada, assuming introduction of AAM infrastructure and services within several years.

Economic Impact – Jobs

Jobs were calculated in full-time equivalence. Statistics Canada describes these as jobs that "include only employee jobs that are converted to full-time equivalence based on the overall average full-time hours worked in either the business or government sectors." For example,

if in 2021 there are an estimated 8,000 weekly hours (40 hours equating to full-time employment) of employment in a sector, that translates to two hundred FTEs in the sector. For AAM, the total forecasted number of sustained FTEs for the 20-year period is estimated at 16,967 workers. Figure 20 shows the job forecast for each five-year time period, with the bars in dark blue representing cumulative jobs gained. As a note, this job count includes the activity spurred by AAM at the direct, indirect, and induced levels. Careful examination of the 2036-2040 period reflects about 1,107 permanent full-time jobs in AAM accruing to the Greater Vancouver region.

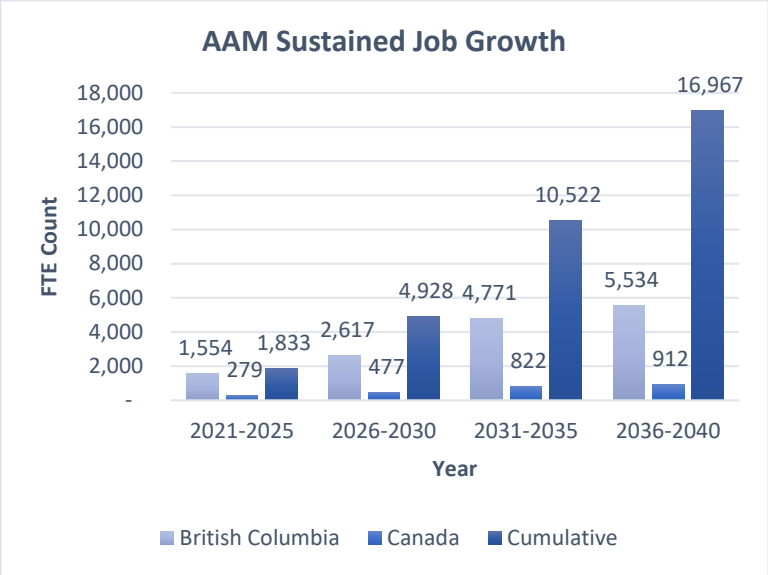

Figure 20 - Sustained job growth: B.C. and outside B.C. in Canada.

Figure 21 shows the level breakdown for British Columbia only. Direct jobs, which are those jobs that come from the direct expenditure by AAM businesses, contain the largest portion of the total job count within each period. The total number of direct jobs over the twenty-year period is estimated at 9,059 positions. Indirect jobs, which are those that support the demand of the direct jobs, estimate at 2,923 jobs. Finally, the induced effect accounts for 2,494 jobs. Across the twenty-year time period, the five OPEX industries with the greatest job gains include, in descending order: 1) transportation; 2) retail trade; 3) finance; insurance; real estate; rental, leasing and holding companies, 4) professional, scientific, and technical services, and finally 5) accommodation and food services.

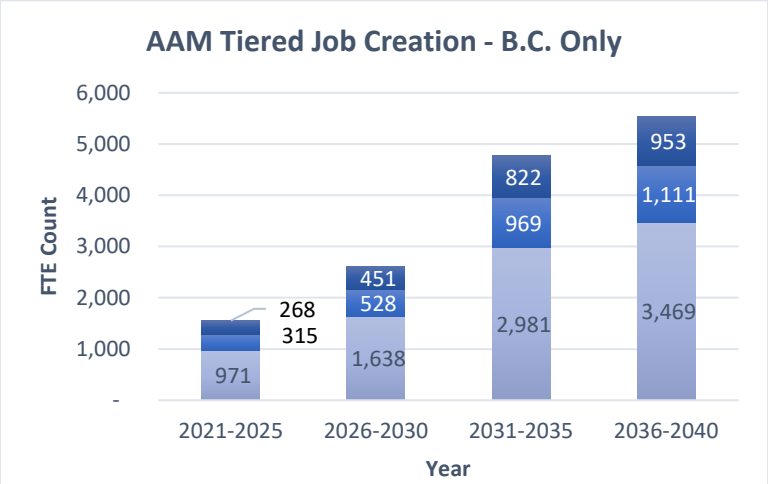

Figure 21 - Direct, Indirect and Induced job creation due to introduction of AAM industries and services.

In the last period in the forecast (2036-2040), transportation and warehousing would account for nearly 64% (or about 3,541 jobs) of all jobs created during the period, while the accommodation and food services industry would account for roughly 4% of the gains (or about 221 jobs). There are 21 other industries in British Columbia that would see job growth as well.

Figure 22 shows the total sustained jobs gained from AAM operational expenditures (OPEX) and capital expenditures (CAPEX), excluding aircraft manufacturing. CAPEX are those purchases needed for day-to-day business operations, such as computers, buildings, and more. They are typically one-time purchases, if not renewed over the course of its capital depreciation. On the other hand, OPEX in AAM will be variable and increasing over time as

the scale of AAM operations increases. Figure 22 illustrates the gap in job activity between capital and operations. The total CAPEX jobs over twenty years is 489, while the total for OPEX is 15,838 full-time equivalent jobs.

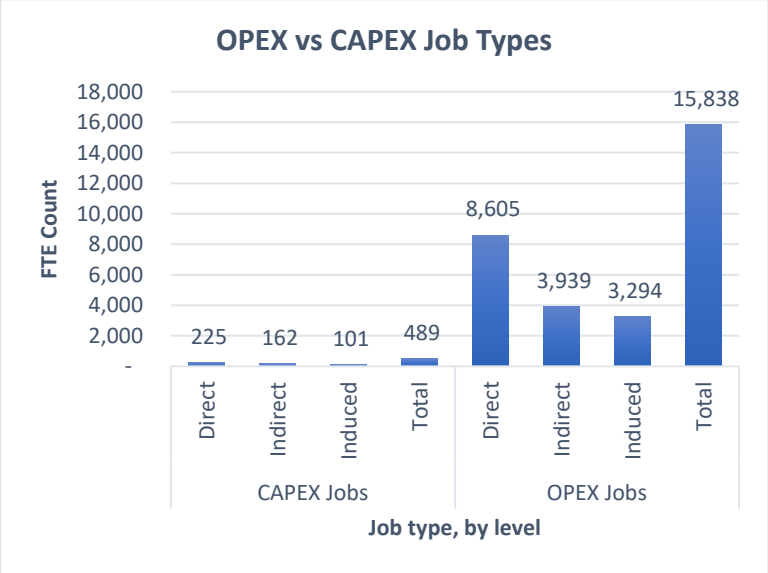

Figure 22 - Jobs by CAPEX and OPEX expenditure category.

The final component to the job forecast—eVTOL aircraft production—serves to illustrate the potential for Vancouver and the greater region to supply AAM aircraft. According to the Statistics Canada estimate, assuming the exclusive domestic production (i.e., no imports) of aircraft, AAM is estimated to achieve hundreds of new and permanent manufacturing jobs.

Figure 23 shows these direct job gains in each period specifically toward the manufacturing of purpose-built eVTOL aircraft. While Vancouver does not currently host eVTOL manufacturing, the assumption is that the growing attraction of Vancouver as a business case for existing eVTOL developers would attract existing Vancouver-based aerospace companies to license, design, and produce the region's needs within the area. The manufacturing job count is the product of that assumption.

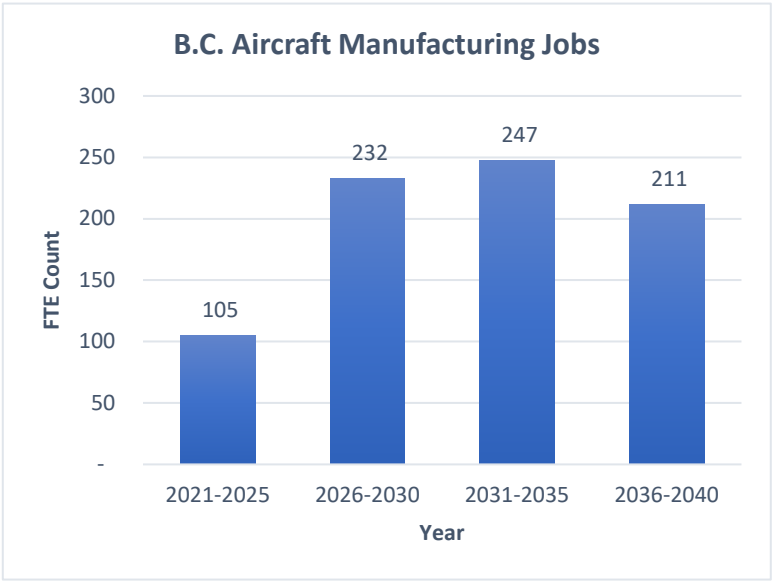

Figure 23 – Manufacturing jobs created by domestic eVTOL production

Economic Impact – Tax Revenues

Another important factor is expected incremental government revenues, which will generally translate into additional government expenditures. The model captures revenue forecasts at the municipal, provincial, and federal level. According to Figure 24, over 20 years the Province of British Columbia would receive a cumulative $167 million in new tax revenues from income and value-added sales tax activities. Total federal revenues equal $34.38 million, while total provincial and municipal revenues equal $92.562 and $40.1 million, respectively.

> ***"The aviation sector supports British Columbians in their everyday lives, as well as attracting investments and enabling our resources, tourism, and knowledge-based industries to thrive."***
>
> *--B.C. Provincial Government's Aviation Strategy*

Total tax revenues generated by British Columbia's AAM industry for each period increase over time as the industry continues its expansion: the first period generates over $18 million, the second period generates $31 million, the third period generates $55 million, and the last period generates $62 million. Unsurprisingly, for each period, the largest contribution is generated at the provincial level.

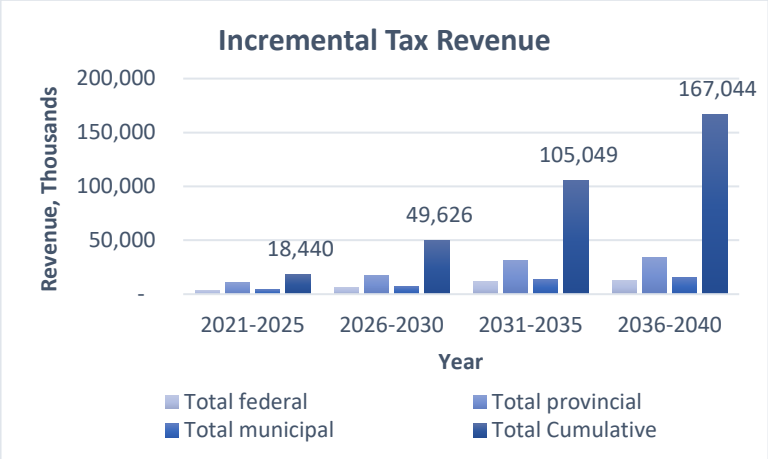

Figure 24 – Incremental tax revenues produced by the new AAM industry sector and related services.

Catalytic Economic Impacts

Economic catalytic impacts are commonly studied when assessing air transport systems, and Advanced Air Mobility is no exception. By definition, an "economic catalyst" is an entity that has (a) two or more groups of customers; (b) who need each other in some way; but (c) can't capture the value from their mutual attraction on their own; and (d) rely on the catalyst to facilitate value-reactions between them. For-profit businesses, joint ventures, cooperatives, standard-setting bodies, and governments operate catalysts.[9] Modern economists claim that, in air transport, catalytic effects are even greater than the direct and indirect effects.[10] In air transport, for example, catalytic impacts arise from:

> ***"An economic catalyst is an entrepreneur [or enterprise] that precipitates a fundamental change in business or technology."***
>
> *Definition of Economic Catalyst*

- Connectivity and interaction benefits
- Tourism benefits and costs
- Imperfect competition and market power in air transport
- Aviation time savings and the value of time
- Agglomeration
- Competition specialization and trade

We have chosen four catalytic impacts worthy of consideration as Advanced Air Mobility becomes established within the Greater Vancouver area.

Catalytic Impact 1 - Accelerated International Trade Along the Cascadia Corridor

Introducing Advanced Air Mobility services between close metropolitan areas should have a catalytic multiplying effect, as the dramatically improved mobility of people, goods, and services will show. Removing the border—via air mobility—will have the impact of moving Vancouver and Seattle many kilometers closer to each other (by automobile, the distance is 231 kilometers, as in Figure 25). By adding together traffic congestion and delays at a border crossing, the mission typically takes 3-4 hours, one way. In an AAM aircraft, however, the trip might take as little as 35 minutes.

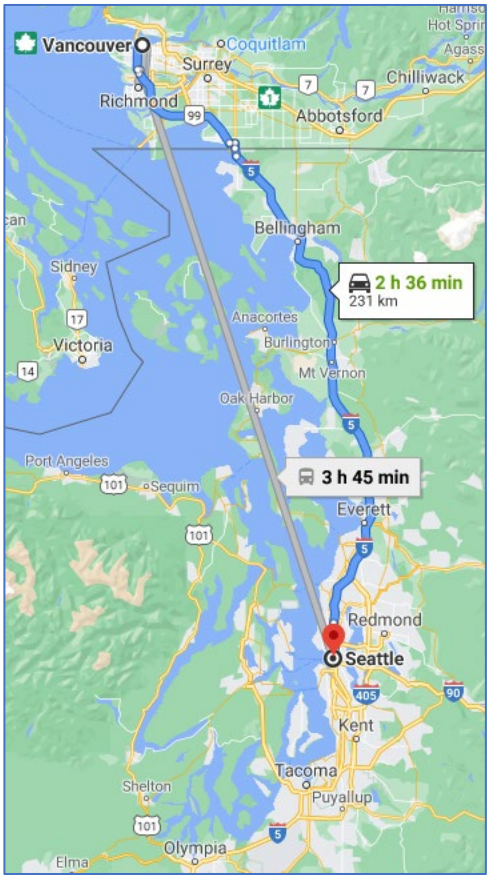

Figure 25 – The Cascadia Corridor and unimpeded driving times by car and public transit.

The Cascadia Corridor is a historically amorphous idea whose main goal involves the shrinking of geography and the breakdown of political boundaries to form an integrated, sustainably developed, regional economy. The geographic scope of the Cascadia region has stretched from Alaska, cutting through B.C., and traveling down to Portland, Oregon. But since 2008, the Cascadia region has been

[9] https://en.wikipedia.org/wiki/Economic_catalyst

[10] Peter Forsyth et al, Wider Economic Benefits of Air Transport. Southern Cross University & Monash University, June 2016

more narrowly defined as a corridor stretching the "megalopolis" along Highway 99/I-5 north from the Whistler ski resort through Vancouver, through Seattle Washington, to Portland, Oregon.[11] The goal for Cascadia is to harmonize the economies of these major cities and surrounding areas.

Three factors promote sustainable development: housing, transportation, and environmental stewardship. Today, these issues of sustainable growth and development dominate urban development policy, and AAM is poised to bring solutions and support growth along this corridor.

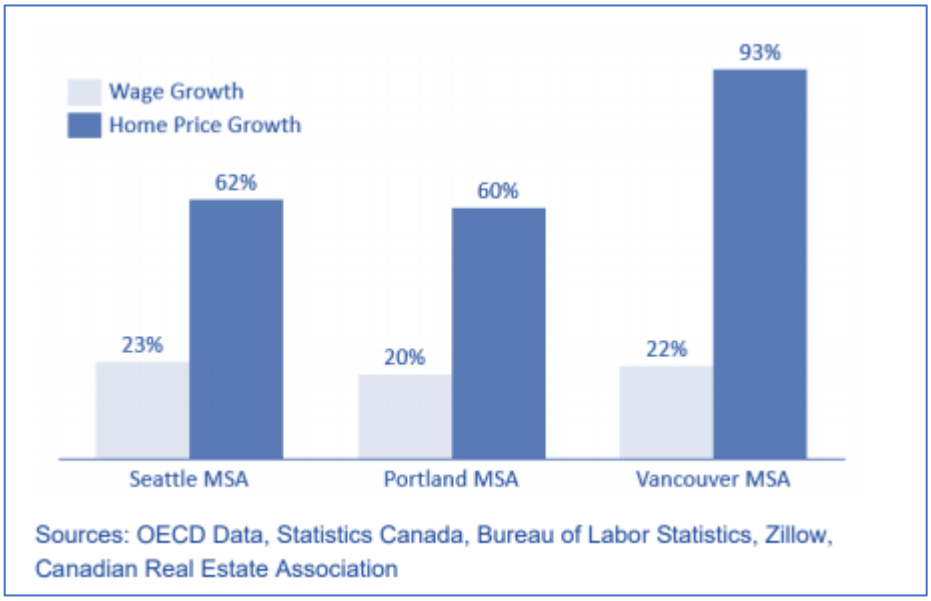

Figure 23 – While wage growth across the three Metropolitan Statistical Areas (MSAs) are roughly equivalent, home price growth is not. Vancouver leads the way in dramatic differences.

Fifty percent of Cascadia residents are housing-cost-burdened; this means that they are spending more than 40% of their income on housing. The average monthly housing cost across the corridor is 44% of median income.[12]

Figure 26 (from Washington State Department of Transportation) shows the different rates of growth between wages and home prices during years 2010-2018. Clearly, each of the three major cities in the corridor is experiencing massive price acceleration in housing payments relative to income, and Vancouver leads the way, with a 71 percent gap between wage growth and home price growth. This is not a sustainable growth trend. The major reason for this spike in housing costs is due to increasing population growth, contrasted with limited land use and land capacity. There simply isn't enough close-in land space to accommodate the rising population in these cities.

> ***"Now home to over 9 million people, Cascadia has become synonymous with our natural beauty and spirit of innovation. Our people, companies, and culture are one of a kind, attracting over 1.68 million people since 2005."***
>
> *Cascadia Vision 2050*

The key to sustainable growth is the development of new and improved transportation infrastructure supporting greater mobility options. Spurred by population growth and limited capacity for urban sprawl, the city inhabitants are losing more and more time in congested traffic. According to Cascadia Vision 2050, "The average commuter in the mega-region spends 11.1 days per year commuting, an increase of 18% since 2011. Witness the rise of 'mega-commuters' – those commuting more than 90 minutes each way." According to the report, Portland and Seattle both saw 70-80% growth in long distance (mega-) commuters from 2010 to 2017. This equates to $10 billion of lost productivity per year.[12]

[11] https://cedar.wwu.edu/cgi/viewcontent.cgi?article=1115&context=bpri_publications

[12] https://21652974-25d8-4ff1-bbc0-8687c8ec1f64.filesusr.com/ugd/e29733_0a5c30de454c4a5a9e682cd5a5681803.pdf

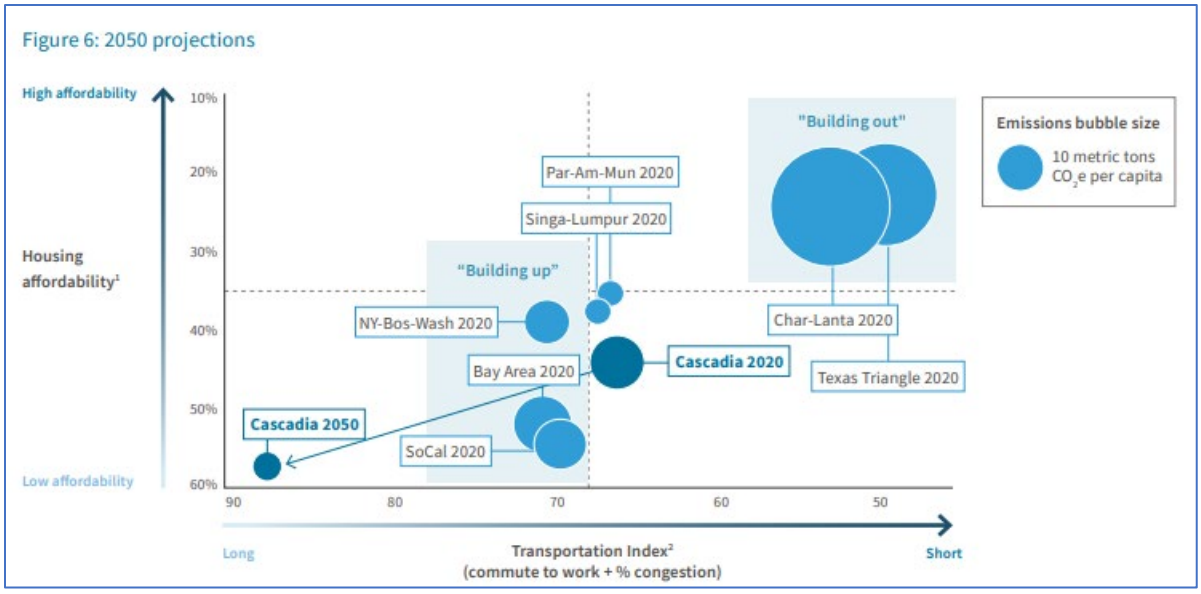

Figure 27 – Projected indices of drive times for Cascadia and correlation to housing costs.

The forecast for the Cascadia region's livability, by transportation index and affordability, is at best precarious. According to Figure 27, by 2050, the Cascadia region's medium monthly payment for housing is expected to increase from roughly 45% in 2020 to nearly 60% in 2050. Meanwhile, the median commute is expected to increase from less than 70 minutes to almost 90.

Finally, the last piece to sustainable growth is the environment. Today, transportation is the largest contributor of greenhouse gas emissions in Cascadia; cars in the mega-region contribute 4.1 million metric tons of CO2 each year. The Cascadia Innovation Corridor group intends for the region to meet its 2050 Paris Climate Accord target: a reduction in emissions by 80%, reducing the current 66 million metric tons of annual emissions to 14 million metric tons. Once again, AAM is poised to take the lead in reducing emissions for the region as a system of transportation supplemental to and integral for a multi-modal transport system.

> ***"The challenges that lie ahead of us are substantial, but ours is a mega-region poised to tackle them. If we are willing to come together and act boldly and with urgency, there is no doubt that Cascadia can become an example to the world by preserving this place and way of life we all hold dear."***
>
> *Chris Gregoire and Greg D'Avignon, Co-Chairs of Cascadia Innovation Corridor*

Trade Within Cascadia is Natural

Housing, transportation, and environmental concerns are identified as the issues that most bind Cascadia together. But it's not just these issues that connect these cities and the region; it is their similar and symbiotic economic portfolios as well.

The following is a list of facts illustrating the innate economic linkages between British Columbia and Washington State[13]:

[13] https://bcbc.com/dist/assets/publications/west-coast-wonders-b-c-washington-cross-border-synergies-and-connections/BC-Washington_Linkages_FINAL.pdf

- British Columbia and Washington state are connected by 13 ports of entry dotted along the B.C.-Washington border. Four of these land crossings are part of the Cascadia corridor.
- Electrical transmission lines connect the two jurisdictions, permitting electricity to flow across the shared border.
- Air services by helicopter—downtown Vancouver to downtown Seattle—have been provided by Helijet Inc. for several decades.
- Further enhancing transportation connections, a floatplane route from downtown Vancouver to downtown Seattle was recently established to service the growing number of business travelers.
- Fully 90% of all northbound truck crossings are destined for the lower mainland. Going south, nearly 60% of all trucks crossing into Washington are destined for Whatcom County or the Puget Sound region.
- Robust growth in respective technology sectors, along with transportation and logistics.
- Washington exports more to B.C. than it does to all other provinces combined.
- If British Columbia is treated as an independent country, it is Washington state's third largest export market, after China and "all other states" (conversely, $6.5 billion, or 30% of all U.S.-bound exports went to Washington State).

FIG. 3: THE MOST IMPORTANT ECONOMIC SECTORS IN SEATTLE AND VANCOUVER, BC

	SEATTLE	VANCOUVER, BC
1	Business Services	Business Services
2	Aerospace Vehicles and Defense	Distribution and Electronic Commerce
3	Distribution and Electronic Commerce	Education and Knowledge Creation
4	Information Technology and Analytical Instruments	Hospitality and Tourism
5	Hospitality and Tourism	Financial Services
6	Education and Knowledge Creation	Transportation and Logistics
7	Transportation and Logistics	Marketing Design and Publishing
8	Marketing, Design, and Publishing	Wood Products
9	Financial Services	Information Technology and Analytical Instruments
10	Insurance Services	Communications Equipment and Services

TABLE IS BASED ON EMPLOYMENT DATA. SOURCES: CLUSTERMAPPING.US; COMPETEPROSPER.CA

Figure 28 – Comparative economic sectors in Seattle and Vancouver

Figure 28 above compares the ten most important economic sectors of Greater Seattle and Greater Vancouver.[14] They share eight out of the top ten sectors, with most matching very closely in rank. This suggests that the skills of each city's workforce are particularly similar; the market for the two cities are reasonably well aligned.

[14] https://cedar.wwu.edu/cgi/viewcontent.cgi?article=1115&context=bpri_publications

And with the introduction of AAM in Vancouver, there is an opportunity for Seattle's second largest sector – Aerospace Vehicles and Defense – to become a competitive mega-sector inclusive of Vancouver. This would make the two cities economically virtually identical.

> ***"The increases in traffic congestion and mega-commuters have also taken an environmental toll. Today, transportation is the largest contributor of greenhouse gas emissions in Cascadia. Single-occupancy vehicles in our mega-region contribute 4.1 million metric tons of CO2 each year."***
>
> *Cascadia Innovation Corridor*

Giving credence to this market match are many global firms such as Amazon, Microsoft, and Weyerhaeuser. Their headquarters are in Seattle, and they have major satellite offices in Vancouver to leverage the locally skilled workers, industry linkages, and international markets.

The Role of AAM

AAM will play a significant role as the bridge that connects these mega-cities to accelerate transactions and by this boost to trade widen job catch basins and improve all three sustainable Cascadia Corridor development goals: housing, transportation, and environmental stewardship. With AAM, some trips that take hours today can be completed in roughly 35 minutes. AAM will better connect the executives and skilled professionals of Seattle with Vancouver. It will connect the industries and businesses of Bellevue with Vancouver. And it will connect the residents of Tacoma with Vancouver. The list goes on, but the idea is that each of these cities has its own labor force and mix of economic needs. Under current conditions, a resident of Tacoma would find employment prospects limited within roughly fifty miles of their city. This means a potential mismatch in employment, resulting in economic inefficiencies.

An essential element of sustainable economic growth is improving livability, and once again the major problem is the inability of residents to afford to live where they work. AAM is the solution to this as well. AAM can connect cities large and small with the installation of new and more convenient vertiports. These would serve as terminal linkages between cities in the corridor, connecting residents a hundred miles away to opportunities they could not otherwise access. In this way, AAM allows mega-cities such as Vancouver space to breathe, decongesting the streets and improving air quality. At the same time, residents of traditionally small to mid-sized or rural cities would bring home larger incomes and stimulate local economic growth within the Cascadia Corridor.

Essentially, AAM creates a highly efficient mobility bridge that improves the flow of people, goods, and services, redistributing from oversaturated markets to underserved markets and populations. This is the catalytic impact of improved mobility desired by governments and policymakers. Improvements in cross-border trade, helped by production improvements within the Cascadia region itself, can produce thousands of new jobs over time, in a catalytic manner brought about by dramatically improved north-south mobility.

Catalytic Impact 2 - Unique Benefits for Indigenous Peoples

The statistics in this report refer to the entire Province of British Columbia as a whole and are not broken out into particular groups or geographic areas. However, there is one group we wanted to give special consideration with regards to economic opportunities created by Advanced Air Mobility: Indigenous Peoples. There are 637 First Nations on what is now known as Canada—some 203 of them in British Columbia—as well as two culturally distinct Indigenous groups, the Inuit and the Métis. These groups have distinct worldviews, cultural practices, spiritual beliefs, and languages. In the 2016 Census, 270,585 people identified as Indigenous out of 4.5 million people living in the Province.[15]

> ***"Advanced Air Mobility is an extraordinary opportunity for Reconciliation through Innovation. Indigenous entrepreneurs and First Nations are ready to take a leadership position in this opportunity for British Columbia to build back better."***
>
> *Duncan Kennedy, co-founder and managing director of Indigenext, supporting Indigenous entrepreneurship and opportunities for youth.*

The reason for this special focus is that historical inequities of colonization have resulted in substantial economic gaps between Indigenous and non-Indigenous people, particularly for Indigenous people on reserve, and it is crucial to work to close this gap at every opportunity. A meaningful engagement on the part of government would support ongoing national efforts at reconciliation. The *2019 Indigenous Economic Progress Report*, written by the National Indigenous Economic Development Board, states that in Canada the median income for non-Indigenous men ($41,230) is nearly three times the income for First Nations men on reserve ($14,580). (Median income for Indigenous women on reserve is slightly higher than that of men.) Overall, Indigenous unemployment rates remain more than twice as high as non-Indigenous unemployment rates.[16] Many Indigenous communities in British Columbia—such as Kingcome Inlet (Gwayi) and Gilford (Gywasdums), which have been continuously inhabited for more than 10,000 years, have difficulty in creating jobs and keeping youth in their communities. As a result, youth unemployment rates over 50% are the realities in some communities.[17]

Figure 29 - Indigenous cultures thousands of years old attract tourists from all over the world.

Indigenous economic development has the potential to boost Canada's economic growth by $27.7 billion annually, according to a 2016 report published by the National Aboriginal Economic Development

[15] https://www12.statcan.gc.ca/census-recensement/2016/as-sa/fogs-spg/Facts-PR-Eng.cfm?TOPIC=9&LANG=Eng&GK=PR&GC=59

[16] The National Indigenous Economic Board. The Indigenous Economic Progress Report 2019.

[17] The National Indigenous Economic Board. The Indigenous Economic Progress Report 2019.

Board.[18] Indigenous youth, in particular, will drive economic activity as the Indigenous population is growing at four times the rate of the non-Indigenous. In 2016, the median age in years for the Indigenous population was 29.1 and 41.3 for the non-Indigenous population. Indeed, as the aging non-Indigenous population enters retirement, there are not enough non-Indigenous youth to fill the growing labor shortfall, which in 2019 was more than 500,000 jobs across Canada, according to Statistics Canada.

The employment of Indigenous youth can offset the resulting economic limitations. Youth, in general, are fascinated by and far more comfortable with new technologies. The advent of AAM in Indigenous communities would inspire youth, increase STEM (Science, Technology, Engineering, and Math) education, and create good-paying technology jobs, enabling youth to remain on their traditional lands should they choose to do so, and contribute substantially to local economic activity. Social aspects of AAM and Indigenous people are discussed on p. 39 of Part 1 of this Series, but suffice it to say that government efforts to employ Indigenous people in the new field of Advanced Air Mobility would not only serve its own economic interests, it would go towards fulfilling its responsibility for reconciliation of historic injustices and help Indigenous communities to prosper and thrive.

> ***"The question isn't how the technology can serve Indigenous people, but how can Indigenous people serve the technology? Given the social issues involved, can we speed up the approval processes and regulations to benefit in the near future both socially and economically from this technology?"***
>
> *Ray Gerow, President of Eagle Spirit Community Solutions, West Vancouver*

Animikii, based in Victoria, is a digital agency that drives social innovation through Indigenous technology (Figure 30). Founder and CEO Jeff Ward sees a bright future for Indigenous people working in the tech industry. "Indigenous people have been scientists, inventors, technologists, and innovators for thousands of years," he said. "There are some tens of thousands of unfilled tech jobs in Canada, and Indigenous Peoples are the fastest growing demographic." Ward explained that his company operates as a social enterprise, empowering people to leverage technology as a way to move away from resource-based economies.

Figure 30 - Animikii Indigenous Technology. Animikii is a digital agency that drives social innovation through Indigenous technology.

Accessible and efficient road networks and transportation systems play a key role in the functioning of any contemporary economy. Convenient transportation promotes the sale of goods and services and increases jobs and revenues. Many Indigenous communities in remote areas experience transportation inequalities as their needs have not been prioritized by government. Currently,

[18] National Aboriginal Economic Development Board (2016). Reconciliation: Growing Canada's Economy by $27.7B, http://naedb-cndea.com/reports/naedb_report_reconcilation_27_7_billion.pdf

Figure 31 - Iskwew Air, owned and operated by Teara Fraser, is an Indigenous woman-owned airline serving remote B.C. communities from Vancouver.

transportation—by aircraft or water—is time-consuming and expensive, and goods—whether food, personal items, or building materials—extremely expensive.

Yet the building of roads and runways—where possible in remote areas—might also destroy habitat, trees, migration patterns, and wildlife. The Indigenous worldview is more complex than that of the non-Indigenous. Harmony and balance of all things is vital: people, animals, insects, fish, birds, plants, water, land, and air must thrive together. Clean, green Advanced Air Mobility, while not destroying habitat, would bring some noise, though likely significantly less than that of helicopters.

"From an Indigenous perspective, we don't typically look at economic impact on its own," said as Teara Fraser, Owner and Lead Executive Officer of Iskwew Air, Canada's first Indigenous woman-owned airline, which serves Indigenous communities and operates out of Vancouver International Airport (Figure 31). "We look at the wellness of the whole and the impact of something through an ecological, social, equitable lens and ask how this serves the whole."

"Iskwew" (pronounced ISS-KWAY-YO) is the Cree word for woman. Teara Fraser, a Métis woman whose ancestral language is Cree, has a nickname for the eight-passen-ger-seat aircraft, calling it the Sweet-grass Warrior. She ultimately sees the resilience and might of women and Indigenous peoples benefitting the aviation industry. "Including and amplifying the diverse, important, talented and much-needed voices in aviation, we can see a future of innovation, of abundance and of economic prosperity," she said.

The implementation of AAM in Indigenous communities—especially those that are remote and under-served—would have extensive economic effects. The first would be the direct employment of aircraft operators, pilots, maintenance staff, those who load and unload cargo, those who maintain the vertiports, and the associated office personnel.

Easier and more cost-effective transportation of supplies would incentivize the opening of new shops, which would hire personnel. In paying less for basic items, residents would have more money to spend elsewhere, creating a ripple effect of economic prosperity throughout the community.

Housing in many remote communities is extremely crowded due to the extraordinary expense of transporting building materials. Lower transportation costs would result in the construction of more houses and businesses, creating construction jobs.

eVTOL aircraft would boost the Indigenous cultural tourism industry, which in 2016, according to Indigenous Tourism B.C., sustained more than 7,400 direct full-time jobs at 401 Indigenous tourism businesses, from guided adventures to a variety of cultural experiences, and generated more than $705 million in GDP. Though the advent of COVID-19 has sharply reduced tourism, it is expected to rebound

quickly once the virus has abated. It is likely that transportation in eVTOL aircraft would increase the number of visitors to Indigenous tourism areas, resulting in the construction and operation of hotels, restaurants, shops, and the opening of supporting businesses. Overall, the range of jobs created by eVTOL aircraft could be great—from service and hospitality employment, to construction, architecture, small business ownership, hotel and restaurant management, piloting, and aircraft maintenance.

Indigenous people such as Teara Fraser, whose company Iskwew Air is already certified by Transport Canada to carry passengers, would likely own and operate the eVTOL aircraft. The hotels, retail shops, construction firms, hunting and fishing lodges, and other businesses owned by Indigenous people would remain mindful of the need to balance increased economic abundance with the Indigenous worldview.

Catalytic Impact 3 - Boost for Academic Science and Technology Programs

An industry that will be a key early benefactor of investment in AAM/UAS will be the network of higher-level learning institutions.

A strong technology sector is the backbone of any modern society. Highly skilled science and technology jobs are responsible for transforming cities such as Tokyo, Seoul, and San Francisco into financial powerhouses with economies that dwarf that of many countries. British Columbia and Vancouver have proven to be hotbeds of technological innovations due to their unique positions both geographically and economically. In turn, the technology sector has encouraged many indirect benefits for the economies at a provincial and city level.

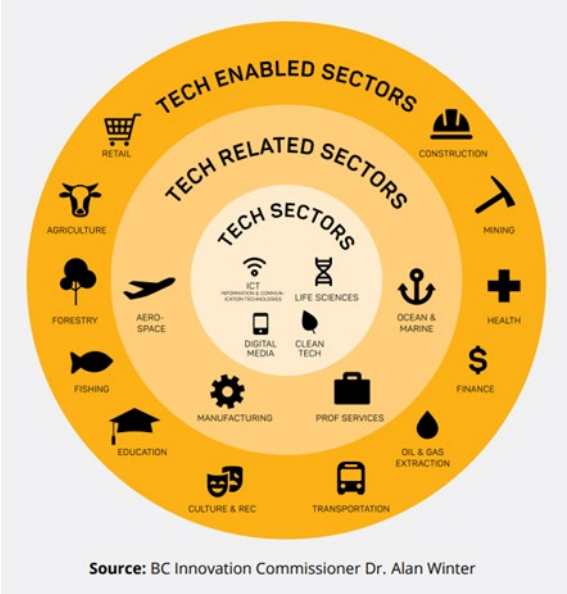

Figure 32 - Relationships between sectors in the innovation value chain. Aerospace, transportation and manufacturing are prominently featured.

The Tech Sector in B.C.

Vancouver and British Columbia take pride in the breadth and depth of their tech industries (Figure 32). This is one of many reasons that have encouraged more than 10,000 tech companies to call B.C. their home. The technology sector directly employs more than 149,000 Canadians in British Columbia and produces 7% of B.C.'s total GDP. B.C. has proven to be an excellent incubator of startups at a global standard. Beating out every other Canadian Province, B.C. has found itself ranked 15th Best Startup Ecosystem in the World in 2017, according to Startup Genome's Global Startup Ecosystem Report. A key aspect of B.C.'s tech success is the well-rounded nature of the ecosystem.

Vancouver is the Canadian gateway to the Pacific and Asia, and has also earned the third spot in the 2019 rankings for best quality of living globally, according to the global consulting firm Mercer.[19] These factors, together with the beautiful setting of mountain vistas and ocean views, combine to nurture the city's current tech-boom.

There are many reasons as to why the tech sector is the best indicator of economic strength. The largest of these is the workforce. High tech jobs require educated and skilled people to fulfill. The people attracted to these positions often relocate from other cities or countries. This is especially true in British Columbia, where KPMG ranked B.C.'s skilled talent pool as one of their three major takeaways in their annual 2018 Technology Report Card. A new cutting-edge industry such as AAM would attract top minds from around the world.

Tech has a profound impact on economies at a deeper level. According to a report by the B.C. Tech Association, for every dollar invested in a B.C. technology program, $14.20 is generated towards the net GDP, and $9.10 in tax will be received by the government. These funds can be reinvested into programs promoting tech again for exponential returns on the original investment.

[19] https://mobilityexchange.mercer.com/Insights/quality-of-living-rankings

AAM as an Education Catalyst with Emphasis on Aerospace and Transportation

AAM has the potential to be a STEM catalyst for Vancouver, thrusting it into the status of a technological "hot" city, a term coined by economist Enrico Moretti to describe cities that are innovation hubs. At this level, the effect of momentum in terms of innovation can be extremely powerful. Within these cities, the anchor companies can see magnified effects on the local economy. These "hot companies" can generate five indirect jobs for every direct job they create. These five jobs are comprised of both skilled and unskilled positions such as teachers, doctors, waiters, or delivery people. This is a key aspect in examining the potential impact of investments in the tech sector. This cycle (Figure 33) becomes a positive feedback loop. With Tech Investment comes direct tech workers. These workers indirectly foster the need for non-tech workers, who improve the quality and capacity of the ecosystem. This, in turn, encourages further investment, and the cycle continues.

> ***"Workers in these [hot] cities make 2-3 times what a worker with the same position would be making elsewhere."***
>
> *Enrico Moretti, Editor-in-chief, Journal of Economic Perspectives*

One catalytic effect that is already apparent and likely to increase is the effect that AAM will have on regional academic institutions. Similar to many emerging technology-driven industries, the drone/AAM sector will require significant amounts of engineering and scientific talent to fuel its growth. An investment in this technology represents an investment in the broader region and the development of an asset base into which institutions such as the University of British Columbia or Simon Frasier University can tap to expose students to experiential learning opportunities in a new, exciting industry. Academic partners can begin to foster a network of talent directly for Vancouver's talent pool and private stakeholders that further invigorates the region economically.

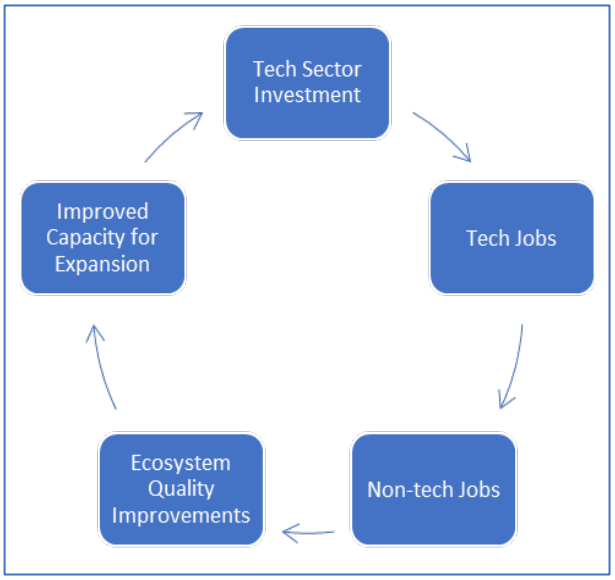

Figure 33 - Cycle of Tech Sector Investment and Benefits

With further investments, high-profile commercial players will be drawn to the region. Another catalytic effect is the potential for collaboration between universities and colleges, businesses, and the easier facilitation for business development and partnerships that could exist in a healthy ecosystem. Not only will closer proximity among businesses spur economic growth in the region, but the actual investments in Vancouver assets that allow for greater mobility of people, goods and services will be a catalyst for growth by allowing easier face-to-face access between stakeholders.

A small sampling of academic areas offered in B.C. higher education campuses that can directly benefit Advanced Air Mobility and drone delivery include, but are not limited to:

- Environmental studies and clean energy engineering
- Transportation and multi-modal systems
- Mechatronics and robotics

- Acoustics and noise mitigation
- Aerodynamics
- Flight control systems
- Composites and advanced materials manufacturing
- Electric propulsion
- Hydrogen energy transformation and fuel cells
- Drone delivery systems and applied engineering programs
- Network design-Big Data analytics

Public Universities and Institutions in British Columbia	Public Colleges in British Columbia
• British Columbia Institute of Technology (Burnaby, Richmond, and Vancouver) • Capilano University (North Vancouver) • Emily Carr University of Art and Design (Vancouver) • Justice Institute of British Columbia (New Westminster) • Kwantlen Polytechnic University (Surrey, Langley, and Richmond) • Nicola Valley Institute of Technology (Merritt) • Royal Roads University (Victoria, Vancouver Island) • Thompson Rivers University (Kamloops) • University of the Fraser Valley (Abbotsford, Chilliwack, Clearbrook, Hope, and Mission) • University of British Columbia (Vancouver and Kelowna) • University of Northern British Columbia (Prince George, Fort St. John, Quesnel, and Terrace) • University of Victoria (Victoria) • Simon Fraser University (Burnaby, Vancouver, and Surrey) • Vancouver Island University (Nanaimo)	• Camosun College (Victoria) • Coast Mountain College (Prince Rupert, Terrace, Smithers, Hazelton, and Haida Gwaii) • College of New Caledonia (Prince George) • College of the Rockies (Cranbrook) • Douglas College (New Westminster and Coquitlam) • Langara College (Vancouver) • North Island College (Campbell River, Comox Valley, Port Alberni, Port Hardy, and Ucluelet) • Northern Lights College (Dawson Creek, Fort St. John, Chetwynd, Fort Nelson) • Okanagan College (Kelowna, Vernon, Penticton, Salmon Arm) • Selkirk College (Castlegar, Nelson, Trail, Grand Forks, Kaslo, and Nakusp) • Vancouver Community College (Vancouver)

Figure 34 – Public universities and colleges throughout B.C.

According to a recent study[20], a 10% increase in a region's number of universities per capita is associated with 0.4% higher future GDP per capita in that region. A positive spillover is seen from universities to geographically close neighboring regions. This catalytic relationship between GDP per capita and universities is not simply driven by the direct expenditures of the university, its staff and students. Part of the effect of universities on economic growth is mediated through an increased supply of human capital and greater innovation.

The emergence of Advanced Air Mobility, the potential "first mover" advantage of the Greater Vancouver region in this sector, and the willingness of the region's well-equipped higher education

[20] *The economic impact of universities: Evidence from across the globe*, Economics of Education Review, Volume 68, February 2019

schools, can justify public as well as private funding programs. A boost in such investment in academic programs will have a serious catalytic effect for the entire region, boosting academic R&D investment.

Catalytic Impact 4 - Acceleration of B.C. Hydrogen Programs

The nascent, but rapidly growing, hydrogen industry could greatly impact British Columbia's economy, as the Province is uniquely situated to become a major hydrogen exporter. With abundant hydroelectric power for clean hydrogen production, proximity to major hydrogen consuming economies, and a long history as the "cradle for fuel cell innovation," B.C. plans to become a global leader in the new hydrogen economy (Figure 35). Vancouver's adoption of AAM can bring early investments to the embryonic hydrogen industry, accelerating the development of the sector while also creating jobs and triggering the expansion of economic activities downstream of the hydrogen industry.

> ***"Government is taking bold action to meet the climate targets set out in our world-leading CleanBC plan. Producing and exporting made-in-B.C. hydrogen power is an exciting opportunity to reduce greenhouse gas emissions, boost our economy and create good clean energy jobs."***
>
> *Hon. Michelle Mungall, B.C. Minister for Energy, July 2019*

Sustainable fuel sources are a chief concern for AAM, and hydrogen power is often presented as a potential option for powering environmentally friendly VTOL aircraft. While the only direct byproduct of hydrogen fuel cell power is water, hydrogen power is not inherently environmentally friendly. Before hydrogen atoms can be used in fuel cells, the hydrogen must be isolated from mixed gas sources, and this process is not always green.

There are three primary categories of hydrogen production (Figure 36). Grey hydrogen refers to hydrogen produced from fossil fuels through methods such as Steam Methane Reforming and Coal Gasification. While these options are the least costly, they produce great amounts of CO2. Blue hydrogen refers to hydrogen produced in the same methods as grey hydrogen, however the CO2 emitted during production is sequestered via carbon capture and storage (CCS). This process is more environmentally friendly, but much more expensive. Green hydrogen is produced with zero emissions using electricity from clean energy sources to electrolyze water and separate the hydrogen atoms from oxygen atoms. Although this process is expensive, green hydrogen produces zero emissions from start to finish.

Figure 35 - First Canadian retail hydrogen station opens in Vancouver, June 2018. The station was a collaboration between Royal Dutch Shell and the Hydrogen Technology and Energy Corporation. HTEC works to promote hydrogen energy and make it available to consumers. The company has partnerships with energy companies Imperial Oil and Shell, as well as automakers Honda, Toyota, and Hyundai.

The pure hydrogen obtained through these methods is then stored, and the energy can be harnessed through either combustion of the hydrogen or through hydrogen fuel cells. Fuel cells convert the chemical energy of hydrogen and oxygen into electricity through a pair of redox reactions. Hydrogen is stripped of its electrons upon entering the fuel cell, and those electrons are forced though a circuit, generating electricity. The positively charged hydrogen atoms then move through the fuel cell to the cathode where they bind with oxygen and the electrons that were sent through the circuit. This produces only water and heat as byproducts, providing completely green electricity.

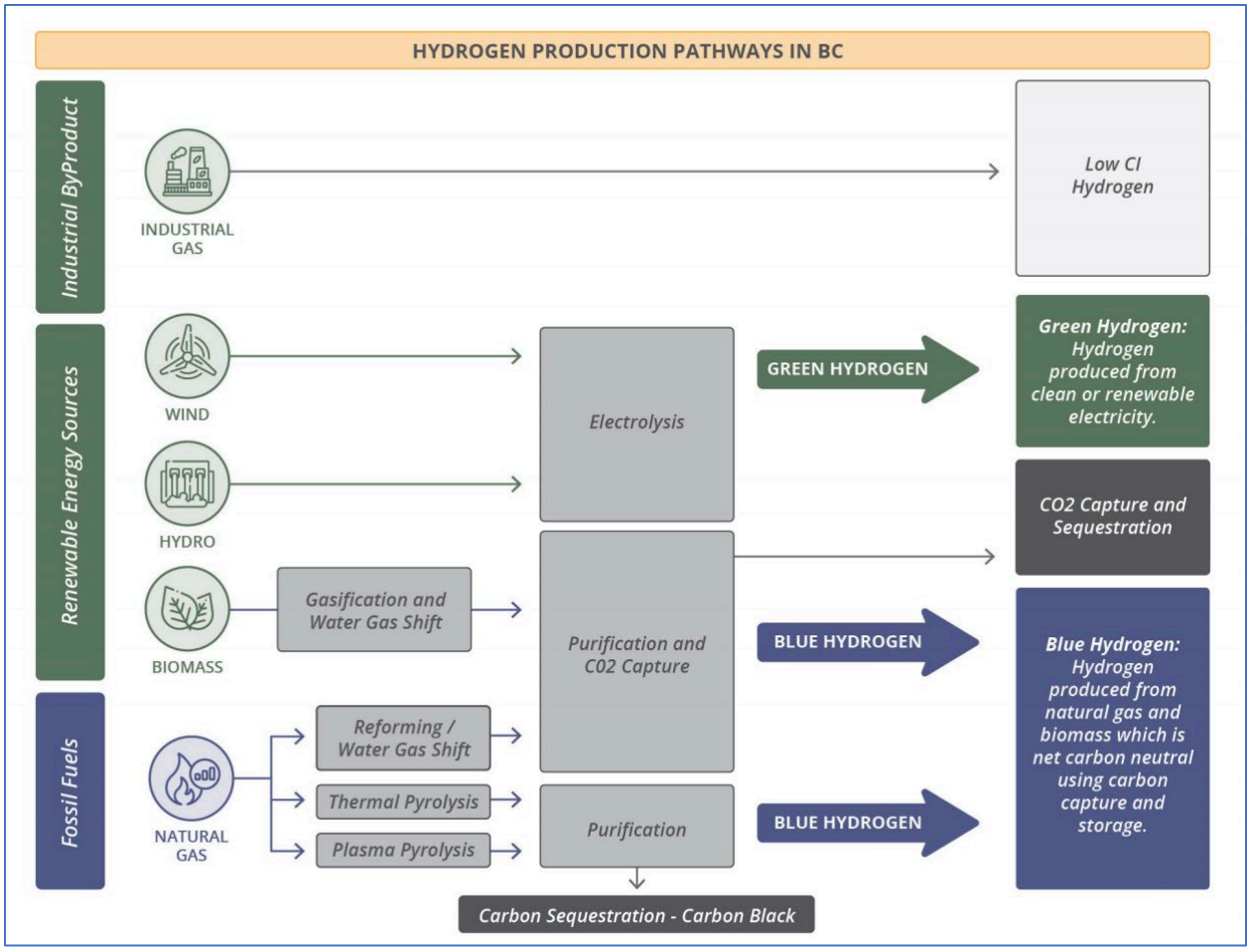

Figure 36 - Pathways to Hydrogen Production in B.C.

Some hVTOL aircraft developers, such as Alaka'i (Figure 37), are designing aircraft powered by hydrogen fuel cells. Alaka'i's proposed design of an hVTOL aircraft, Skai, would feature an impressive maximum payload of 1,000 pounds and a two-hour maximum flight time with a top speed of 185 kph. Cutting-edge hydrogen fuel cells could have certain benefits over batteries that would make them well-suited for regional air mobility, such as improved energy density and higher specific power. While eVTOLs are better suited for urban missions with a 10 to 60-mile range, hydrogen powered VTOL aircraft have the potential to fly further with heavier payloads, making them ideal for regional air mobility operations up to 150 miles away. Forrest Harrington, the Business Development lead for Ballard Unmanned Systems (recently acquired by Honeywell), believes hydrogen can also benefit fixed-wing aircraft operators and passengers. "When we look at fixed-wing vehicles," he said, "they have far more efficient aerodynamics than multirotor aircraft and use less power, which makes them more ideal candidates for fuel cells." Hydrogen is also inherently "Energy Content Rich" (Figure 38).

Figure 37 - Alaka'i Skai four-passenger six-propeller hVTOL.

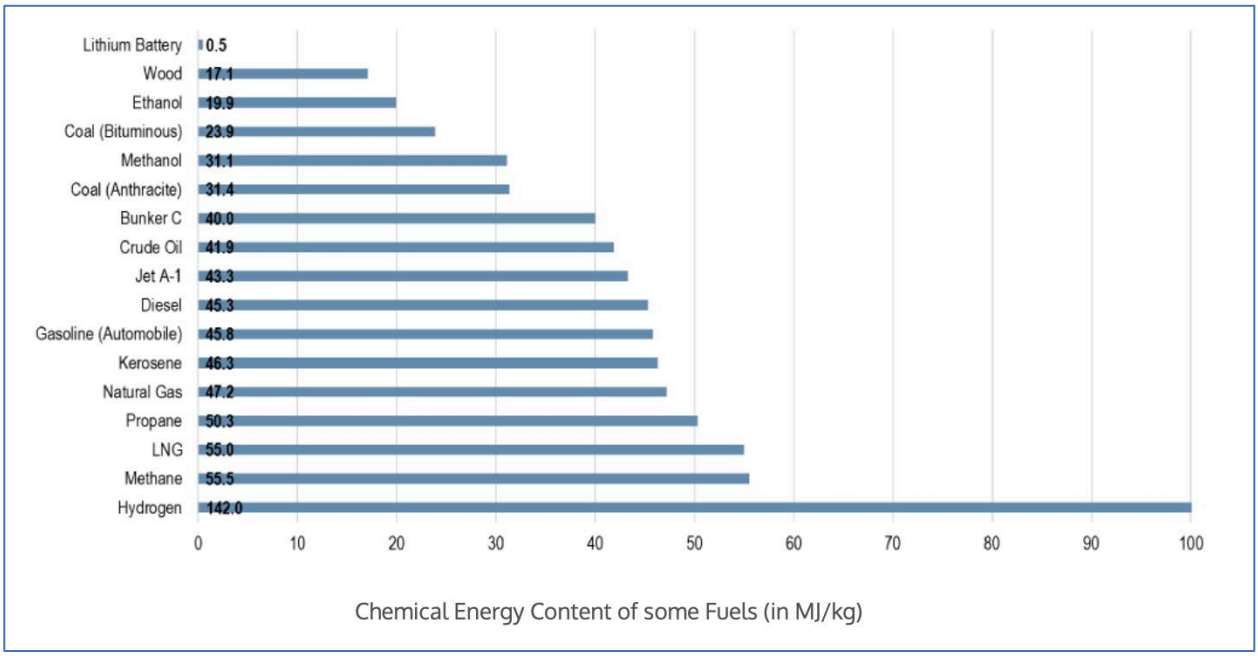

Figure 38 – As indicated, hydrogen energy content leads other fuel sources considering density measures.

British Columbia is uniquely positioned to capitalize on hVTOL for several reasons cited. Aircraft developers focusing on hydrogen as the energy source are already viewing B.C. as their ideal launch location. Hydrogen fuel cell developments are proceeding rapidly around the world.

ZeroAvia, a company focused on developing a zero-emission aviation powertrain, recently made history with the first successful flight of its modified Piper M-Class demonstration airplane powered by hydrogen fuel cells. The six-seater aircraft completed taxi, takeoff, a full pattern circuit, and landing at a research and development facility in Cranfield, England. The company is now focusing on long-range flights, aiming to complete a 250-mile zero-emission flight shortly.

Airbus recently revealed three hydrogen-powered commercial aircraft concepts as part of the company's ZEROe initiative, with the goal of introducing zero-emission aircraft to their fleet by 2035. Unlike ZeroAvia's Piper M Class, Airbus plans to use modified gas turbine engines that will burn liquid hydrogen as fuel, with additional fuel cells to create complementary electrical power for the aircraft.

> ***"I strongly believe that the use of hydrogen – both in synthetic fuels and as a primary power source for commercial aircraft – has the potential to significantly reduce aviation's climate impact."***
>
> *Guillaume Faury, CEO Airbus*

The European Union is quickly mobilizing to claim their stake in the hydrogen economy. According to Faith Birol, executive director of the International Energy Agency, "Hydrogen electrolysers and lithium-ion batteries are on the verge of becoming the decade's breakout technologies. These technologies should play a key role in bolstering Europe's transport and industry as the continent emerges from the crisis and looks to develop new advanced manufacturing for export. If the EU seizes this opportunity, it will give itself a cutting edge on global markets."

Countries such as Germany, Britain, Australia, and Japan have already announced hydrogen strategies, with hundreds of millions of dollars of research and development funds available for clean energy technologies.

> ***"The German hydrogen strategy shows that one of the world's largest fossil gas consumers is preparing for a future without fossil fuels."***
>
> *Felix Heilmann, researcher at climate think tank E3G*

Germany is especially keen to capitalize on the potential economic benefits of hydrogen production and exportation. The German hydrogen strategy aims to ramp up hydrogen production through 2040 through subsidies for producers of green hydrogen and billions in government funding for research and development. Germany plans to first implement hydrogen power in processes where electrification is too difficult or dangerous; industries such as heavy goods transportation, steel production, chemical refining, and aviation. The government has declared the creation of a European hydrogen infrastructure as one of the main priorities of its upcoming EU Council presidency, in the hopes of establishing itself as an export champion in the coming years.

While Europe is steadily advancing its endeavors into hydrogen power, Canada, and more specifically, British Columbia, have been focusing on a turn to hydrogen since the 1970s. Since Geoffrey Ballard (Figure 39), founder of Ballard Power Systems, first set up shop in North Vancouver in 1979, Canada's hydrogen and fuel cell sector has been recognized as a global leader, with B.C. hosting Canada's largest industry cluster.

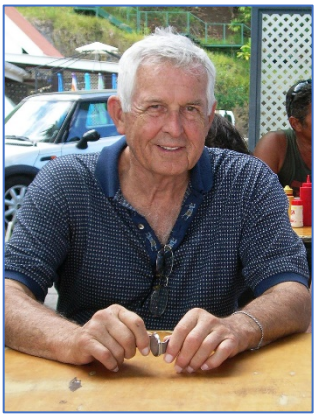

Figure 39 - Geoffrey Ballard (1932 - 2008), Father of the fuel cell industry and long-time Vancouver businessman.

B.C. already has significant advantages over its European competitors in that the Province has abundant natural gas and natural gas infrastructure, which is crucial for isolating and transporting hydrogen, in addition to an abundance of hydroelectricity to produce green hydrogen, an already booming fuel cell tech hub, and proximity to the largest hydrogen markets in Asia and California.

BC Hydro, a provincial Crown corporation under the Ministry of Energy and Mines, is the largest producer of hydroelectricity in British Columbia, with 31 hydroelectric dam facilities throughout the Province. There are also privately-owned hydroelectric dams throughout B.C. More than 90 percent of British Columbia's electricity generation is water-powered, and Canada is already a top global exporter of energy, second to Germany. With abundant hydroelectricity, production of pure hydrogen for fuel cells or combustion can be obtained with substantially less climate consequences, giving the Province and Canada as a whole a distinct advantage over other countries interested in hydrogen production and exportation.

A 2019 B.C. hydrogen study conducted by Zen and the Art of Clean Energy Solutions looked at the potential environmental and economic benefits of a booming hydrogen export industry in B.C., and their findings were impressive (Figure 40). The study argues that the local deployment of hydrogen technology will help maintain a healthy economic cluster in the Province; will help develop technical expertise, job opportunities and intellectual property; and will contribute to the continued growth of the sector by ensuring B.C. maintains a strong competitive advantage, all while encouraging the growth of eco-friendly industries.

> ***"B.C. is well positioned to develop a hydrogen industry for both domestic and export markets with the long-term goal of using the Province's hydroelectricity to produce completely green hydrogen."***
>
> *B.C. Ministry of Energy, Mines, and Petroleum Resources*

Local acceptance and deployment of hydrogen in B.C. will be required for the Province to meet 2030 and 2050 decarbonization goals and emissions reduction commitments. The Province aims to incentivize the use of both Battery Electric Vehicles (BEVs) and Fuel Cell Electric Vehicles (FCEVs), although the B.C. Hydrogen Study believes FCEVs will be better suited to replace medium and heavy-duty vans, buses, and trucks. While the adoption of hydrogen within B.C. can help catalyze the industry as a whole, the

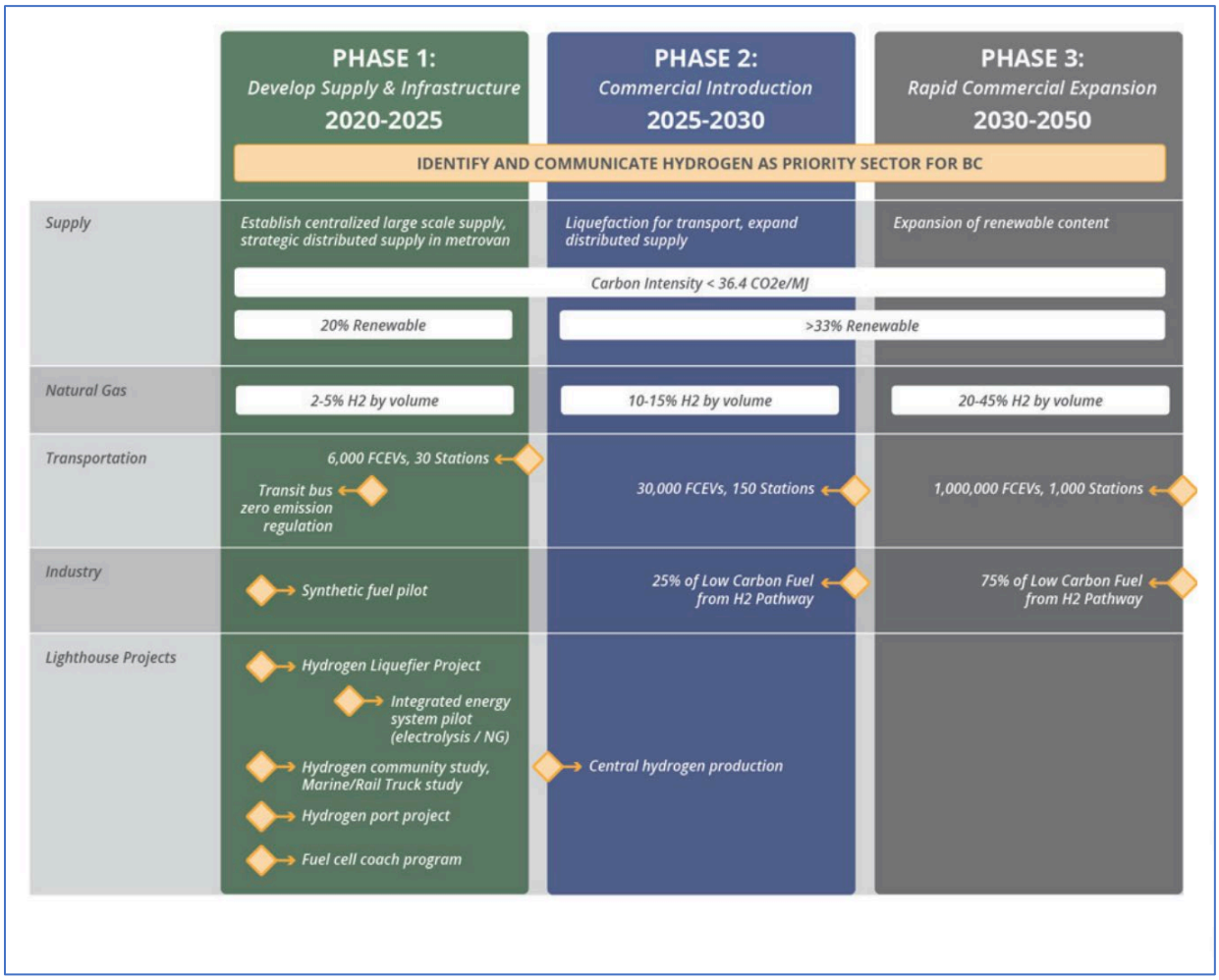

Figure 40 - A 2019 study conducted by Zen and the Clean Art of Energy examined benefits of a B.C. hydrogen industry.

real economic benefits for the Province come with exporting hydrogen to key markets in Asia and the U.S.

British Columbia's economy is heavily dependent on the extraction, consumption, and export of natural resources, and hydrogen fits as a value-added future export resource that can support both local and international decarbonization efforts. B.C.'s coastal access and proximity to leading markets such as China, Japan, South Korea, and California position the Province to become a major exporter of clean hydrogen.

The 2019 B.C. Hydrogen Study projected the aggregate demand in those key markets to reach 100 million tons of hydrogen annually by 2050, under conservative forecast assumptions. If British Columbia were to capture 5% of the market share in those regions, the hydrogen export market could reach $15 billion in annual revenue with significant upside potential. Not only would this bring new export revenue to the Province, but it would also stimulate local employment growth and would likely attract foreign capital investment, bringing great economic opportunities to British Columbia.

> ***"How fitting Canada's first retail hydrogen station opens in Vancouver when the country's first gas station also opened here, 111 years ago. Back then, even with only a few cars on the road, demand for gasoline was increasing and it made sense to build a fueling station to support a growing network of automobiles."***
>
> *Colin Armstrong, CEO, Hydrogen Technology and Energy Corporation*

British Columbia already accounts for over 80% of the Canadian hydrogen and fuel cell sector jobs, and the sector had total revenues of $272 million in 2017. With the introduction of Advanced Air Mobility and the development of hydrogen-powered VTOL aircraft, the hydrogen and fuel cell industries in British Columbia are poised to expand at an exponential rate.

A vibrant urban and regional air mobility industry in Vancouver and the surrounding regions could bring early customers to B.C.'s hydrogen market, fueling investment and innovation in the sector as VTOL aircraft developers turn toward hydrogen fuel cells for longer-range missions. A turn toward hydrogen will be necessary for B.C. to reach its Greenhouse Gas emissions goals for 2030 and 2050, and hVTOL aircraft could help alleviate the dependence on fossil fuels for air transport while simultaneously expanding the hydrogen economy and parallel industries. Embracing hVTOL will have a powerful catalytic impact on the Greater Vancouver region.

Conclusion

This study examined the disruptive effects of six AAM use cases: airport shuttle services, on-demand air taxi, regional transport, medical and emergency operations and services, business aviation, and air metro. It explored the economic stimulus to four Supply Chains: aircraft manufacturers, RTM, vertiports, and operators.

Using the Statistics Canada economic models, we have arrived at several conclusions: that the direct benefits of implementing AAM in British Columbia will create some 9,200 full-time equivalent (FTE) jobs worth more than $1 billion in GDP; that indirect benefits include more than 4,200 indirect FTE jobs worth more than half a billion dollars in GDP, and that 3,500 induced jobs will be generated, also worth more than half a billion dollars in GDP. Together, benefits include nearly 17,000 FTE jobs, more than 2,000 permanent jobs (Figure 41), and more than $2 billion in GDP.

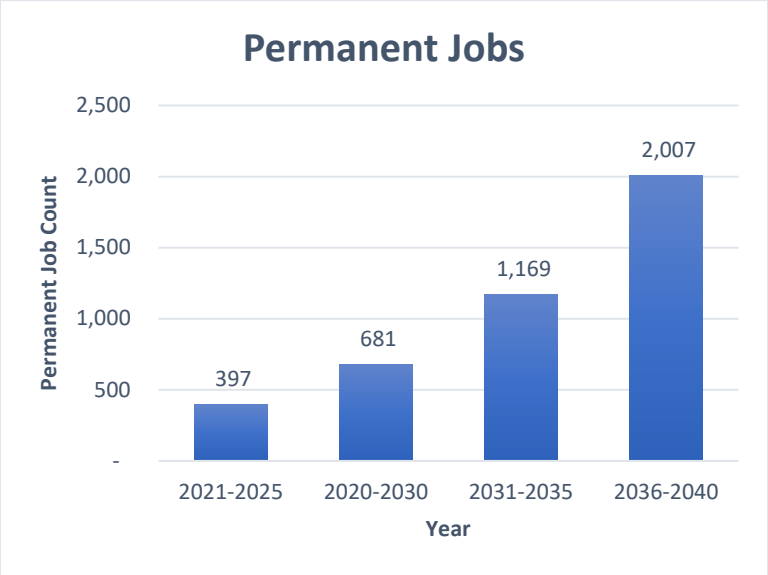

Figure 41 – Permanent jobs created by Advanced Air Mobility.

We also examined four benefitting sectors for their catalytic economic impacts: trans-border trade within the Cascadia Corridor; Indigenous community reconciliation and empowerment; university research and STEM Education, and hydrogen sector acceleration. These alone have the potential to produce thousands of additional permanent jobs for the Greater Vancouver region.

Advanced Air Mobility will be an economic and social disruptor; in other words, it will radically change aviation and transportation in fundamental ways. Simply put, people will begin to do things differently in their daily lives. Other such disruptors include the invention, utilization, and wide public acceptance of the automobile, the airplane, the computer, and the internet. Such disruptions create jobs, tax revenues, and the resulting spending that ripples far and wide across the economy.

In short, Advanced Air Mobility will transform the British Columbia economy with billions of dollars in incremental activity in jobs and revenues. The Metro Vancouver area is poised to lead the way in attracting investment and talent to provide clean, green technology offering new transportation options that will benefit local industries, public responders, government authorities, Indigenous and remote communities, and the public at large.