JUNE 2025 | V1.0

THE PRODUCTIVITY BENEFITS OF HIGH-VALUE, LOW-CARBON INVESTMENT

The Transition Accelerator
L'Accélérateur de transition

About The Transition Accelerator

The Transition Accelerator drives projects, partnerships, and strategies to ensure Canada is competitive in a carbon-neutral world. We're harnessing the global shift towards clean growth to secure permanent jobs, abundant energy, and strong regional economies across the country.

We work with 300+ partner organizations to build out pathways to a prosperous low-carbon economy and avoid costly dead-ends along the way. By connecting systems-level thinking with real-world analysis, we're enabling a more affordable, competitive, and resilient future for all Canadians.

Learn more at **transitionaccelerator.ca**.

About the author

Travis Southin, PhD, Future Economy Lead, The Transition Accelerator

Travis Southin has deep expertise on the role of innovation and industrial policy in facilitating the transition to a low-carbon economy, with a particular focus on scaling Canadian cleantech firms. Prior to joining The Transition Accelerator, he provided analysis and policy recommendations for the Net-Zero Advisory Body.

Cite this document:

Southin T., (June 2025). The Productivity Benefits of High-Value, Low-Carbon Investment. The Transition Accelerator. Version 1.0

Table of Contents

1. The Takeaway

Adding value to our natural resources can help address Canada's productivity crisis

- Strategic industrial policy can help scale innovative firms into leaders in low-carbon technologies—such as **mass timber, sustainable aviation fuel**, and **EV batteries**—opening new markets for Canadian wood, biomass, and critical minerals. This builds economic **resiliency**, especially in the face of U.S. threats to Canadian economic sovereignty.

THE PROBLEM:

Business as usual won't solve the productivity crisis

- **Canada's productivity crisis is real and long-running.** Low labour and multifactor productivity are jeopardizing Canadian living standards.
- **Oil and gas is impacting overall productivity.** Declining labour productivity and low multifactor productivity in this sector weighs on national figures.
- **Canada struggles to scale up innovative firms.** Without enough high-growth scale-ups, productivity stagnates.

THE OPPORTUNITY:

Scale technology firms in value-added natural resources

- **Look to clean technologies.** Clean technology firms outperform in **R&D spending and export growth**—key factors for productivity growth. The three examples below show how scaling innovative firms in low-carbon, value-added resource technologies can boost R&D and productivity throughout the supply chain.
- **Three key opportunity areas:**
    1. Mass Timber Construction Materials: Converting wood into innovative, **prefabricated construction materials** can decarbonize buildings while reducing costs and construction timelines. This could raise productivity and R&D in forestry, wood product manufacturing[1], and construction—typically below-average sectors for these metrics.

2. **Sustainable Aviation Fuel:**
   Transforming forestry, agriculture and municipal waste into **sustainable jet fuel** can add value to these feedstocks while decarbonizing aviation. This could raise productivity and R&D in below-average sectors for these metrics, such as forestry, while improving already-strong performers such as chemical manufacturing.

3. **Electric Vehicles & Batteries:**
   Converting minerals and metals into **next-generation battery technologies** for EVs can help decarbonize transportation while mitigating threats to downstream auto assembly, potentially reversing declining productivity in upstream sectors like non-ferrous metal production and processing (except aluminum), and downstream sectors like transportation equipment manufacturing.

THE APPROACH:

Strategic Industrial Policy

- **Scaling domestic champions through industrial policy will boost productivity, increase R&D, drive exports, and help the Canadian economy decarbonize.**

  Core industrial policy actions include:

  1. **Setting clear targets** based on production quantities, market share, and/or technological performance benchmarks.
  2. **Creating public-private coordination mechanisms** to facilitate information flows.
  3. **Aligning the policy mix** of demand- and supply-side supports to meet the needs of innovative firms as they scale.

THE CONCLUSION

Industrial policy should support innovation in the extraction and value-added processing and manufacturing stages clean technology value chains. This should reinforce backward linkages (e.g., mining machinery & techniques) and forward linkages (e.g., processing and manufacturing) between resource extraction, manufacturing, and end use.

2. The Problem: Business as usual won't solve the productivity crisis

Canada's productivity crisis is real and long-running

President Trump's tariffs on Canadian goods have spurred a long overdue national conversation on the dangers of having a structurally dependent trade relationship.[2] The crisis has mainly prompted calls for necessary actions like diversifying trading partners and dismantling interprovincial trade barriers. However, with few exceptions,[3] Canadians have shied away from the equally pressing conversation of the need to diversify *what* we export.

Adding value to our natural resources by transforming them into innovative products will bolster resiliency by making Canadian prosperity less reliant on raw commodity prices and easy access to the American market. Instead, growing expertise in exports of innovative products and services will help Canada command higher prices and unlock demand from customers further afield.

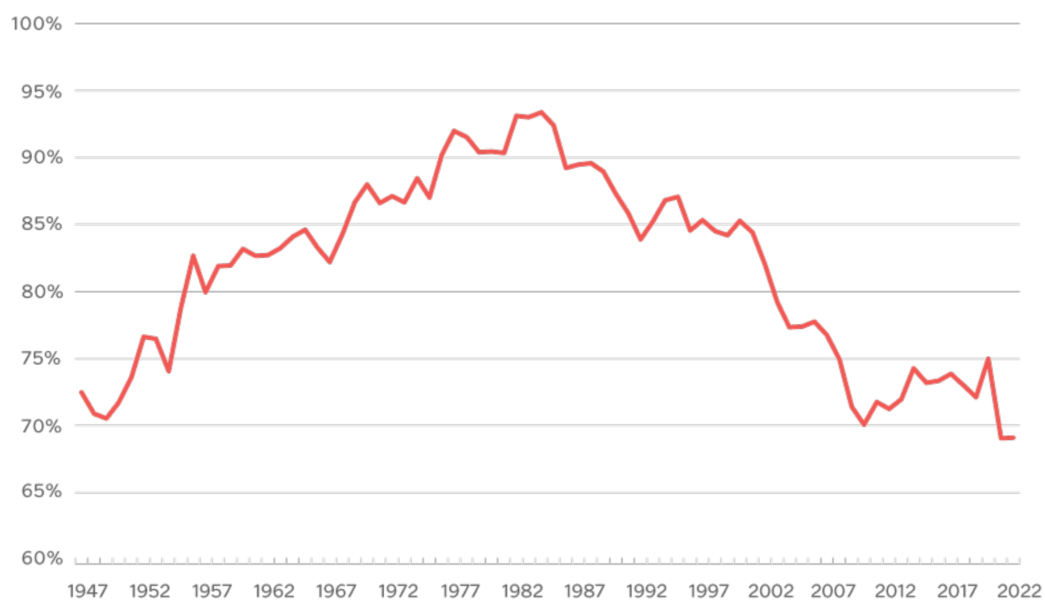
Natural resource exports represent 58 percent of the value of Canada's total merchandise exports.[4] Of this, the United States is by far the largest export destination (78 percent of natural resource exports).[5] Many of these exports are relatively unprocessed products with minimal value-added, such as crude oil (18.6 percent of total exports, 91 percent to the US) and sawn wood (1.2 percent of total exports, 84 percent to the US).[6] Similarly, exports of minerals and metals (21 percent of total exports, 56 percent to the US) are predominantly focused on primary products versus fabricated products.[7]

In short, bolstering our economic autonomy means we need to rapidly do two things that have historically been very un-Canadian—add value to our natural resources and link them with downstream domestic manufacturing. This will help grow high-value-added exports to lessen Canada's structural dependency on shipping raw commodities to the United States.

Securing economic resilience requires Canada to finally fix its long-standing productivity crisis. Decades of declining labour productivity (real gross domestic product per hour worked) and multifactor productivity (gains in real gross domestic product that cannot be attributed to changes in labour and capital inputs) are jeopardizing the living standards of Canadians. Labour productivity growth in the business sector in Canada started to decline in 2000, from 2.3 percent per year in the period from 1991 to 2000[8] to 1.0 percent per year in the period from 2000 to 2015.[9] Canada's productivity slowdown has persisted through the post-covid period.[10]

Labour productivity has fallen to less than 70 percent of US levels, the lowest since 1947.[11] Canada now ranks 17th of 19 advanced country peers, above only New Zealand and Japan.[12]

Falling back: Declining productivity relative to the US has erased Canada's post-war gains



Source: Centre for the Study of Living Standards[13]

Since 2000, labour productivity in Canada has increased at an average annual rate of 0.8 percent, less than half of the US rate of 1.9 percent.[14] Recent data shows a negative growth rate, placing Canada below the OECD average.

Canada also performs poorly in multifactor productivity (MFP), also called total factor productivity (TFP), which "reflects the overall efficiency with which labour and capital inputs are used together in the production process."[15] MFP represents the portion of GDP growth that cannot be explained by changes in labour quality (educational attainment and skills development) and capital intensity (physical capital per worker). Put another way, "if labour and capital inputs remained unchanged between two periods, any changes in output would reflect changes in MFP."[16]

> "When we unpack the [MFP] black box, we see that the contribution it makes comes partly from management—and mostly from innovation."
>
> —*Dan Breznitz*

This means that changes in MFP reflect the amount of growth in output attributed to management practices, brand names, organizational change, general knowledge, network effects, spillovers from production factors, adjustment costs, economies of scale, the effects of imperfect competition and measurement errors.

MFP growth can be thought of as the effect of innovation. Innovation scholar Dan Breznitz notes that "when we unpack the TFP [MFP] black box, we see that the contribution it makes comes partly from management—and mostly from innovation."[17] Breznitz laments Canada's low MFP growth since 2000. Low performance was particularly stark from 2000 to 2008, when MFP growth was actually negative.[18] The Centre for the Study of Living Standards echoes this sentiment, finding that "most of the post-2000 slowdown in productivity growth can be explained by a collapse in multifactor productivity growth."[19] Canada's modest MFP growth from 2015 to 2022 ranks it 10th in the OECD for growth during that period.[20]

The OECD's long-term projections show that Canada would see the slowest growth in real GDP per capita of any advanced economy from 2020-2060.[21] This projected outcome stems from Canada's poor productivity performance in recent years, notwithstanding the boost from demographics via immigration. Much of the lag on productivity is attributable to the period after 2014, where business labour productivity growth was 0.7 percent per year on average.[22] This was exacerbated by oil price declines, which impacted the output per hour (labour productivity) of Canada's oil and gas sector.[23]

Wage growth has slowed in parallel to lagging labour productivity. This is because the ability to continue to pay higher wages over time depends on the ability to generate more output per hour worked. Indeed, average weekly earnings have increased only 1.6 percent between January 2015 and January 2024, adjusted for inflation.[24] The Business Council of Canada notes that this is "a considerable change from a growth rate of more than 1.5 percent per year that Canadian workers enjoyed over the previous two decades."[25] Going forward, securing Canada's prosperity in a geopolitically unstable world demands that we finally address the productivity crisis. This means applying innovation to rapidly expand value-added exports.[26]

Oil and gas is impacting overall productivity

While Canada's oil and gas sector continues to have the highest labour productivity ($400 real value added per hour worked in 2023 compared to $59 for the total business sector), it has been steadily decreasing (34 percent decrease from 1998-2023 compared to a 31 percent increase in the total business sector).[27]

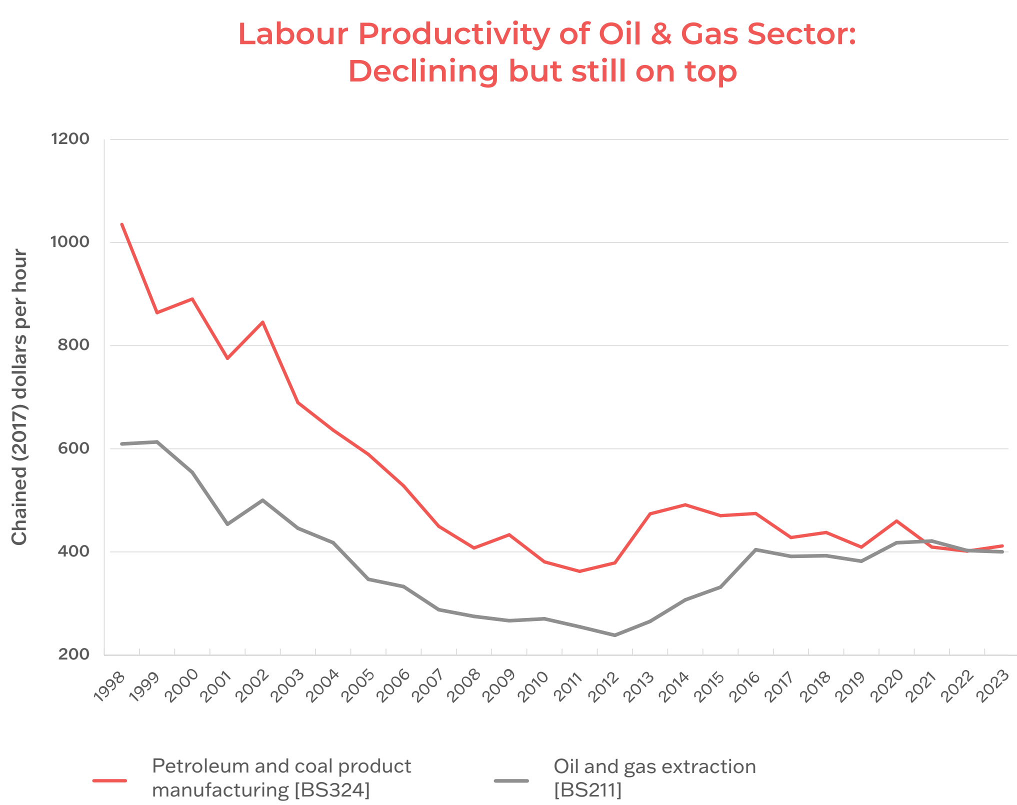


Table: 36-10-0480-01 (formerly CANSIM 383-0033).[28]

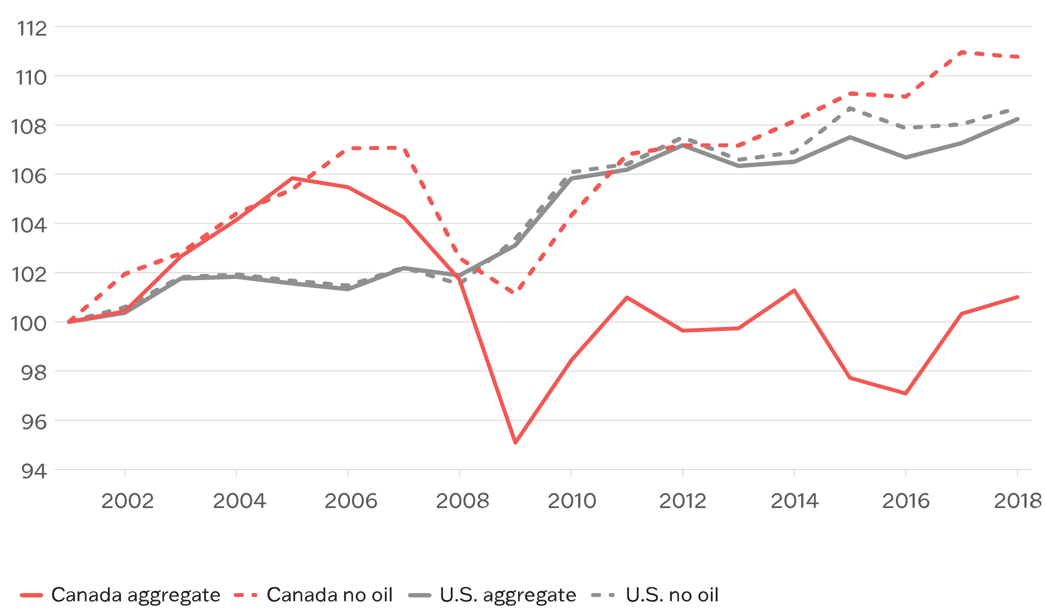
This decrease is partially due to the fact that the oil sands are less productive than traditional oil sources, needing more capital to produce oil. The period of 1995-2015 saw the proportion of Canadian capital invested in the oil sector double from 15 percent to more than 30 percent, coinciding with an oil price boom and the commercialization of oil sands technology.[29] This far outpaced the modest growth in the sector's share of Canada's economic output during the same period.[30, 31]

Current analyses of Canadian productivity overemphasize labour productivity, and hence the importance of the oil and gas sector. Generally, labour productivity has been used in discussions about productivity. However, this doesn't tell the whole story. Labour productivity in a given sector is very much dependent on its relative capital intensiveness. To understand differences, interactions and dynamics between sectors, it is important look at estimates of multifactor productivity, though even this has methodological limitations.[32] The important point is that it is inappropriate—and likely misleading—to base economic strategy thinking exclusively on sectoral labour productivity.

Indeed, analysis by McMaster University researchers has shown that removing oil from MFP calculations boosts Canada's performance in the period 2001 to 2018 from 0.06 percent growth per year to a healthier 0.6 percent, a similar rate to that of the United States (0.47 percent if oil is included, 0.49 percent if oil is excluded).

Remove oil and gas from the equation and Canada's multifactor productivity keeps up with the US

Multifactor Productivity, Index, 2001 = 100



Source: The Globe and Mail & McMaster University[33]

The authors find that higher oil prices made capital-intensive sources of oil (like the oil sands) viable to extract on a commercial scale. However, the greater input required per barrel of oil slowed MFP growth. Similarly, the Bank of Canada summarizes the long-run oil and gas drag on productivity growth as follows: "in the run-up to the 2014 decline in commodity prices, investments were geared toward increasing production as opposed to making extraction processes more efficient... Because of these factors, we assume that the decline in TFP [MFP] will continue in the 2020s."[34]

In short, productivity growth (which matters in the long run for living standards) has been impacted down by low MFP in the oil and gas sector.[35] This is not to deny the importance of the sector's contribution to Canadian prosperity. However, Canada's challenge going forward will be to bolster long-term, sustainable prosperity by augmenting oil wealth through specialization in highly productive industries. This means growing sectors and technologies characterized by high MFP, where innovation leads to more efficient conversion of labour and capital into increased output. Often this will take the form of maximizing the value-added to our natural resources. For example, the next section explores three such R&D growth opportunities: mass timber buildings, sustainable aviation fuel, and electric vehicles.

Canada struggles to scale up innovative firms

Scale-up firms—firms that experience 20 percent revenue growth for three years—are the unsung hero of productivity gains. Scale-ups are rare: only one in 100 companies meet the definition of a scale-up.[36] However, scale-up firms are highly productive: productivity growth levels (six percent) are significantly higher than non-scale-ups.[37] Finally, scale-up firms generate outsized economic impact, generating 20 times the revenue and 5-10 times the employment of non-scale-ups.[38]

Unfortunately, Canada has a poor record of creating scale-ups. ISED's target in 2017's Innovation and Skills Plan was to "double the number of high growth firms in Canada from 14,000 to 28,000 by 2025."[39] Unfortunately, progress towards this goal has been dismal: in 2022, Canada had 17,930 high-growth enterprises by revenue (firms with 20 percent growth for three years).[40]

Relatedly, Canada's SME-heavy economic structure struggles to produce the "frontier firms" (the five percent of companies with the highest productivity levels in their sectors) that have driven global productivity growth over the last 20 years. Indeed, Statistics Canada identifies firm size as a contributor to the growing Canada-US productivity gap, noting that Canada has a larger share of small and medium-sized enterprises (SMEs) than the United States, but that SMEs in Canada are less productive."[41]

An OECD study on frontier firms versus laggard firms saw 3.5 percent growth per year globally, but SME's saw 0.5 percent.[42] Widening the gap over the last 20 years, productivity at the frontier has grown by more than half in manufacturing and more than two-thirds in services between 2003 and 2020, on average across countries and industries. Over the same period the productivity of laggards has grown by less than five percent.

Global frontier firms are defined as "the five percent of companies with the highest productivity levels within each two-digit industry across countries. Further OECD evidence also shows a productivity divergence in individual countries, i.e. rising productivity gaps between productivity leaders and the least productive firms operating in the same country and industry."[43]

The structure of Canada's economy is more skewed towards smaller SMEs over large frontier firms than many of its peers. OECD chief economist Álvaro Santos Pereira cited this study to emphasize the point that "Canada does not have enough frontier firms."[44] Canada's decline in labour productivity after 2000 was caused by a decline in productivity growth in both frontier firms (defined as the top 10 percent of the most productive firms in an industry) and—mainly—non-frontier firms (defined as all other firms).[45] The decline in labour productivity growth of non-frontier firms after 2000 "accounted for 2.95 percentage points, or 90 percent, of a 3.21-percentage-point decline in aggregate labour productivity growth between the periods of 1991 to 2000 and 2000 to 2015."[46]

Where should policymakers look to support the growth of more scale-ups? The rest of this report describes the opportunity to grow innovative firms into leading suppliers of the technologies that will be in demand as the world decarbonizes, such as mass timber building materials, sustainable aviation fuel, and electric vehicles/batteries.

3. The Opportunity: Scale technology firms in value-added natural resources

Look to clean technologies

Productivity scholars have noted the potential productivity-enhancing benefits of the shift to a low-carbon economy.[47] Similarly, the IEA forecasts that its Net-Zero Emissions by 2050 (NZE) scenario would require global annual investment in clean energy rising from US$1.8 trillion in 2023 to US$4.3 trillion in 2030.[48] Scaling domestic champions to become leading global suppliers of clean technologies will position Canada to benefit from this global demand.

> "Innovating is the act of applying ideas to develop and offer new or improved products and services in any stage of production and in each and every sector of the economy... It is here that we truly and tragically fail."
>
> *—Dan Breznitz*

Canada's environmental and clean technology sector has been identified as having the potential to drive future productivity growth.[49] Environmental and clean technology is defined as "any good or service designed with the primary purpose of contributing to remediating or preventing any type of environmental damage or any good or service whose primary purpose is not environmental protection but that is less polluting or more resource-efficient than equivalent normal products that furnish a similar utility."[50]

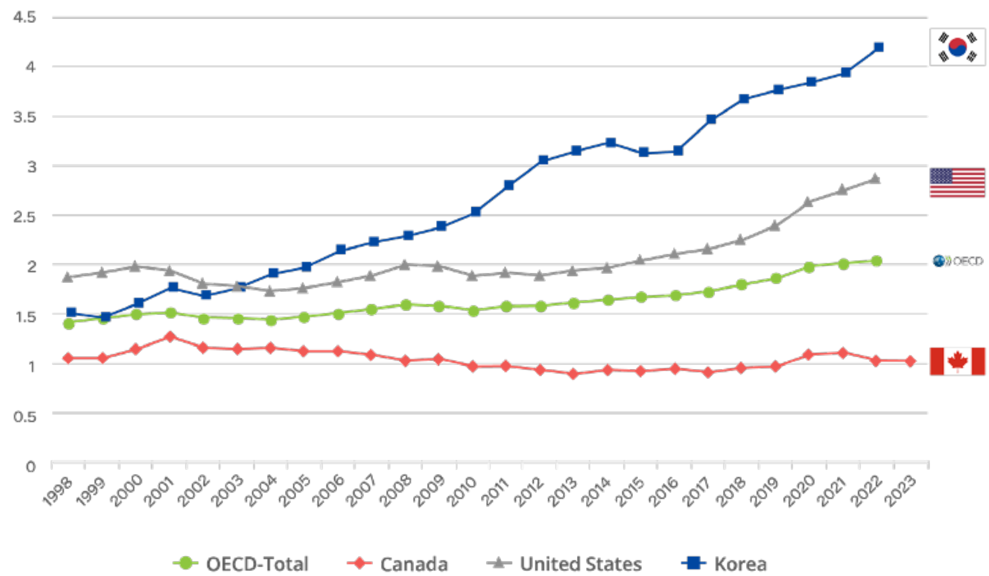
Firms in the environmental and clean technology sector excel at turning innovation investments into productivity gains. Specifically, analysis of firms supported by the Canadian government's suite of Business Innovation and Growth Support (BIGS) finds that this sector is generating above-average productivity growth compared to firms in other sectors programs in 2016-2023.[51]

Today's investment in R&D creates tomorrow's innovations and productivity gains. Hence, expenditure on R&D by both businesses and the public sector serves as a signal of where productivity-boosting innovation is likely to occur in the coming years. Importantly, innovation is one of the main drivers of TFP growth. Sadly, innovation has long been the Achilles heel of the Canadian economy. Dan Breznitz summarizes the problem as follows: "Inventing is the act of coming up with a novel idea, and Canada is pretty good at that. Innovating is the act of applying ideas to develop and offer new or improved products and services in any stage of production and in each and every sector of the economy... It is here that we truly and tragically fail."[52]

Statistics Canada has echoed these concerns, noting that Canada's business-sector R&D spending as a share of GDP is the second lowest in the G7 next to Italy.[53] As the following figure from the OECD illustrates, the gap in what Canadian businesses spend on R&D compared to their global competitors is steadily widening over time:

Canadian businesses are falling behind global competitors on R&D investment

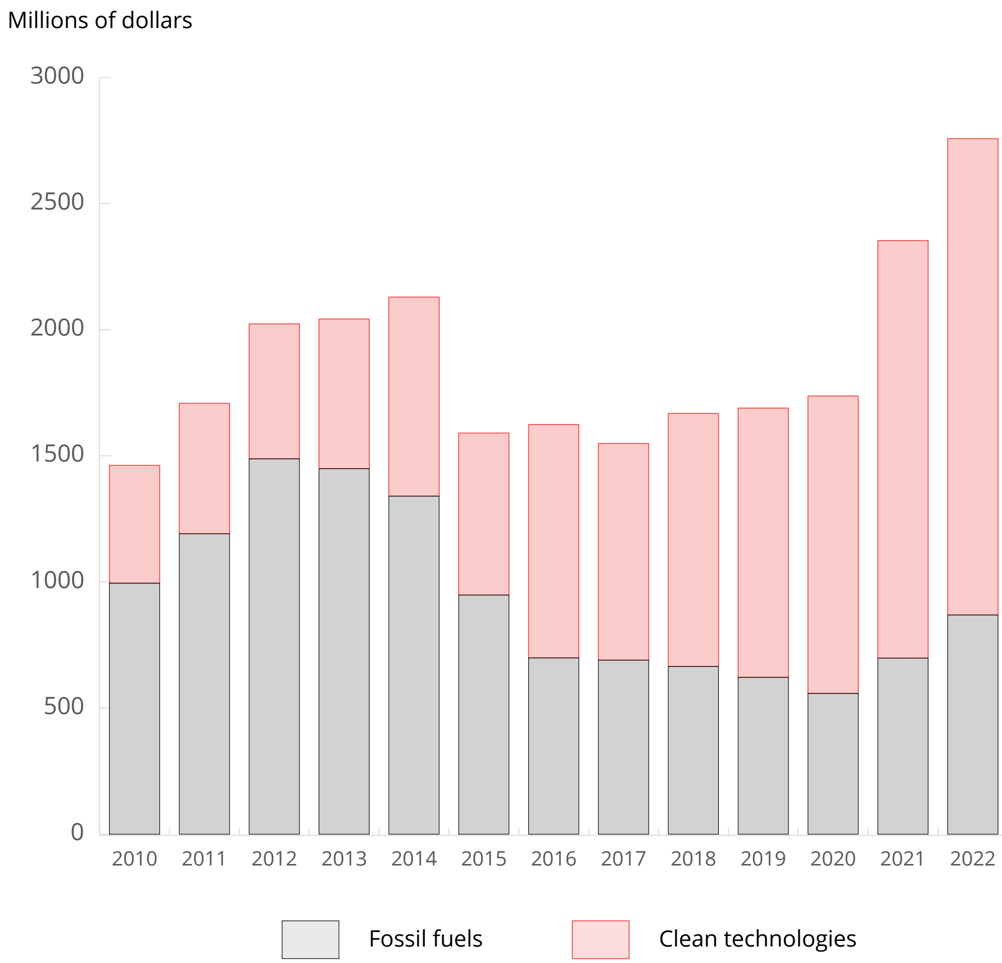
Business Expenditure on R&D as percent of GDP



Source: OECD[54]

In contrast to the overall economy, business R&D spending has grown continuously in clean technologies (energy efficiency, nuclear fission and fusion, hydrogen and fuel cells, electric power, renewable energy resources, and other energy-related technology).

Clean technology R&D growth is outpacing fossil fuels
Energy-related research and development expenditures by businesses



Source: Statistics Canada Tables 27-10-0347-01 (2014 to 2022) and 27-10-0103-01 (2010 to 2013).[55]

However, the top individual energy technology for business expenditure on R&D continues to be fossil fuels, as clean technologies is an aggregate of many individual technologies. Canadian business spending on energy R&D is still more skewed towards fossil fuels than global peers. For example, IEA data on energy R&D spending by listed companies between 2015-2022 ranks oil and gas third behind automotive and electricity generation, supply and networks.[56] Similarly, fossil fuels have represented a shrinking share of government RD&D funding globally.[57]

Analyzing the sectoral breakdown of R&D investment reveals that the natural-resource-heavy structure of Canada's economy contributes to its overall R&D underperformance compared to its peers. Specifically, University of Saskatchewan innovation scholar Peter Phillips notes that a large portion of Canada's R&D gap is owed to the fact that, compared to its peers, the Canadian economy is more concentrated in the low-R&D sectors of agriculture, forestry, fishing, mining, energy, and related supporting sectors, rather than R&D-intensive sectors like computer hardware and software, pharmaceuticals, automobiles, and aerospace.[58] However, a silver lining is that Canadian firms in these traditionally low-R&D sectors actually spend more on R&D than their international peers in the same sectors.[59]

The clean technology sector also outperforms the general economy in export growth, which is often a key element in becoming more productive.[60] For example, the labour productivity of exporters was 13 percent higher on average than that of non-exporters in Canada's manufacturing sector from 1974 to 2010.[61] While Canada runs trade surpluses in agriculture, timber, minerals, and oil and gas, it "performs poorly in technologically advanced industries."[62]

Exports of clean technology and environmental products have increased by 109 percent from 2012 to 2023, accounting for 2.8 percent of Canada's total exports in 2023.[63] This growth outpaces the 72 percent increase in total economy exports over the same period.[64] Clean technology SMEs are highly export intensive, generating an average of 10 percent of their sales from exports compared to only 5.0 percent for all Canadian SMEs.[65]

Finally, clean technology SMEs also have a higher tendency to export goods compared to all SMEs in Canada. Out of all clean technology SMEs that exported, nearly half (49 percent) reported exporting goods only (compared to 38 percent in all sectors), and 33 percent reported exporting both goods and services, while just 18 percent reported exporting only services (compared to 45 percent in all sectors).[66]

Going forward, Canada should build on its clean technology strength, supporting a cohort of scale-up firms whose innovative products and services will be in high demand as the world reduces its emissions in the coming decades. The next section explores illustrative examples. Technologies like mass timber construction present an opportunity for high-technology, high value-added exports of both goods (modular prefab building materials) and services (engineering and architectural consulting).

Three key opportunity areas

The clean energy transformation presents an opportunity for Canada to add value to natural resources through innovation. Examining real world examples of low- and non-emitting R&D opportunities helps to clarify how Canada can scale innovative firms into highly productive exporters capable of exploiting global demand for key technologies along the pathway to net zero. Research by The Transition Accelerator canvased existing studies of Canada's opportunities to identify seven consensus areas that will experience growing demand in a carbon-neutral economy:[67]

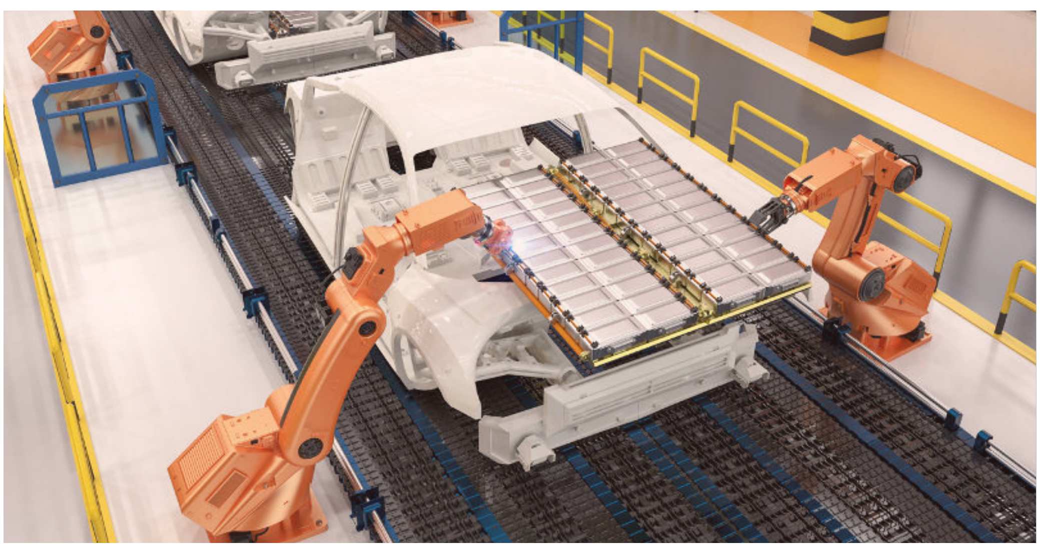
- EVs and the battery supply chain
- Carbon capture, utilisation, and storage
- Hydrogen
- Biofuels
- Value-added agriculture (e.g., alternative proteins)
- Value-added forestry (e.g., mass timber)
- Critical minerals

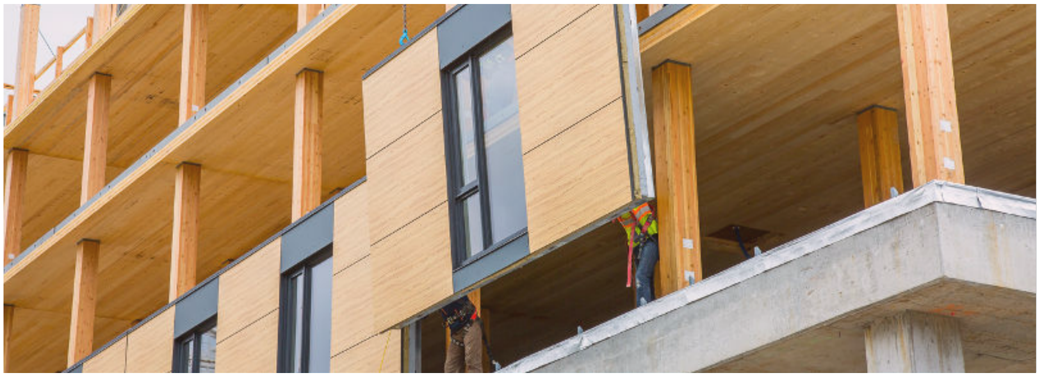
Subsequent research by The Transition Accelerator noted that Canada's natural resource endowment positions it to capture segments of global supply chains, provided that strategic industrial policies cultivate advanced production and innovation capabilities.[68] The following section analyzes three opportunity areas where The Transition Accelerator has convened industry leaders to co-create technology roadmaps:

- Mass timber (The Forest Products Association of Canada and the Canadian Wood Council's *Mass Timber Roadmap*)[69]
- Sustainable aviation fuel (The Canadian Council for Sustainable Aviation Fuels' *C-SAF Roadmap*),[70] and
- Electric vehicles and batteries (Accelerate's *Canadian Battery Innovation Roadmap*,[71] the Battery Metals Association of Canada's *Roadmap for Canada's Battery Value Chain*)[72]

Solving the productivity crisis will certainly require more than achieving success in these three areas alone. However, they serve as illustrative examples of the type of value-added natural resource opportunities Canada should be focusing on.

Specializing in high value-added products such as mass timber, SAF, and electric vehicles will likely raise the output per hour worked (labour productivity) and R&D investment in their primary sectors: wood product manufacturing (mass timber), chemical manufacturing (SAF), and transportation equipment manufacturing (EVs/batteries). Productivity and R&D gains are also likely for sectors adjacent to the primary sector, both upstream and downstream in the supply chain.





Mass Timber Construction Materials: Adding value to lumber to build housing more efficiently

Mass timber construction materials present a growth opportunity for high-value-added wood products that will help decarbonize the building sector. Mass timber lowers embodied carbon emissions in mid-rise buildings by replacing concrete and steel emissions while providing long-term carbon storage. Mass timber comprises a set of relatively mature technologies that have been successfully deployed at scale for decades. Mass timber panels, particularly cross-laminated timber, create opportunities to accelerate construction of multi-unit residential structures at lower cost due to prefabrication and onsite assembly of modular buildings.[73]

The current global mass timber market (as of 2023) is estimated to be $1.6-2.3 billion, with the Canadian share of that estimated at $379 million.[74] This corresponds to about 20 percent of a central estimate of the global market. Projected annual growth rates for the mass timber sector both in North America and globally are 13-14 percent, through 2030, representing an increase of approximately 150 percent.

Canada has the most certified forests in the world (158 million ha). However, currently mass timber, at 200,000 to 300,000 m3 per year, accounts for less than one percent of Canada's wood supply (softwood and hardwood), and only 1-2 percent of North America's softwood lumber production (as of 2021).[75] There are at least 23 operating or potential mass timber manufacturing facilities in North America—of which seven are in Canada (AB, BC, MB, ON, QC).

Mass timber can raise the wood product manufacturing sector's increasing-but-still-mid-tier labour productivity performance (increased 85 percent from 2000-2023 compared to 22 percent increase in total business sector, $60 output per hour in 2023 compared to $59 for the total business sector).[76] Lower productivity sectors such as forestry and logging (increased 85 percent from 2000-2023 compared to 22 percent increase in total business sector, $51 output per hour compared to $59 for the total business sector) can benefit as upstream feedstock suppliers to higher value mass timber building materials.[77] Similarly, downstream sectors like construction whose productivity is low[78] ($49 output per hour in 2023 compared to $59 for the total business sector) and declining (decreased 5.4 percent from 2000-2023 compared to 22 percent increase in total business sector) can expect productivity gains, such as reducing the construction time for buildings by at least 25 percent using mass timber.[79] Finaly, mass timber innovation can boost low R&D performance in the forestry & logging sector (increased 17 percent from 2015-2024 compared to an 83 percent increase for all industries, ranked 28/28 in absolute R&D spending in 2024), wood product manufacturing (increased 158 percent from 2014-2024 compared to an 81 percent increase for all industries, ranked 17/28 in absolute R&D spending in 2024), and construction (increased 106 percent from 2014-2024 compared to an 81 percent increase for all industries, ranked 13/28 in absolute R&D spending in 2024).[80]

Canada has a strong research base in mass timber. The National Research Council of Canada partnered with the Canadian Wood Council and a range of public and private organizations to mount a series of fire safety demonstration tests on mass timber to demonstrate its fire resilience compared to alternative materials.[81] The University of Toronto's Mass Timber Institute aims to help position Canada as a global leader in sustainable mass timber research, education, development, and export by leveraging relationships between educators, researchers, industry, and Indigenous groups on applied research and development in the following priority areas: sustainable mass timber supply chains in Canada, building science, and constructability.[82]

Policy has supported Canadian firms to develop advanced capabilities in manufacturing mass timber modular construction materials. Natural Resources Canada's 2021 State of Mass Timber report and associated database documented 750 completed or under-construction mass timber projects from 2007 to 2022 in Canada.[83] Provinces such as Ontario and BC have produced mass timber strategies and investments.[84] For example, the Ontario government invested $3.46 million in Element5, Ontario's first certified manufacturer of cross-laminated timber. The funding will "more than triple the company's production, creating 32 new jobs, increasing revenue by over 300 percent and boosting export sales by nearly 600 percent."[85] Leading firms are expanding operations into modular and prefabricated products. For example, BC-based Kalesnikoff announced that they are expanding their operations to offer more modular, prefabricated mass timber building materials.[86]

Sustainable Aviation Fuel: Adding value to forestry, municipal and farm waste by turning it into clean jet fuel

Converting forestry, agriculture, and municipal waste into sustainable aviation fuel (SAF) can add value to these feedstocks while decarbonizing aviation. This could raise productivity in improving-but-still-laggard sectors, such as forestry and logging (increased 85 percent from 2000-2023 compared to 22 percent increase in total business sector, $51 output per hour compared to $59 for the total business sector) and crop and animal production (increased 91 percent from 2000-2023 compared to 22 percent increase in total business sector, $55 output per hour compared to $59 for the total business sector).[87] This could also raise R&D in forestry and logging (increased 17 percent from 2015-2024 compared to an 83 percent increase for all industries, ranked 28/28 in absolute R&D spending in 2024) and agriculture (except aquaculture) and support activities for crop production and animal production (decreased one percent from 2016-2024 compared to a 76 percent increase for all industries, ranked 18/28 in 2024), while improving already strong performers such as chemical manufacturing (increased 55 percent from 2014-2024 compared to an 81 percent increase for all industries, ranked 4/28 in 2024).[88]

A promising R&D opportunity is producing SAF at scale using the Fischer-Tropsch process to convert syngas from the gasification of biomass waste into hydrocarbons.[89] This emerging technology is currently being demonstrated at scale with support from US subsidies introduced under the Biden administration[90] Fischer-Tropsch is key to both biomass and power-to-liquid pathways to making SAF. In the biomass-to-liquids pathway, SAF is produced from the gasification of forestry waste or municipal solid waste followed by the Fischer-Tropsch process and further refining. Regarding the power-to-liquids pathways, SAF is produced via the combination of CO_2 and low-carbon-intensity hydrogen in the Fischer-Tropsch process followed by further processing and refining.

Canada has established research excellence in SAF. The National Research Council of Canada has research facilities and government scientists working on sustainable aviation.[91] After conducting the world's first civil jet flight powered by 100 percent biofuel in 2012[92], the National Research Council's Flight Research Lab of the Aerospace Research Centre has tested various SAF formulas in contrails and emissions flight research.[93] Academic research centres include Waterloo Institute for Sustainable Aviation and University of Toronto Institute for Aerospace Studies.

Policy has also supported industrial research to advance Fischer-Tropsch to SAF pathways in particular. For example, in 2019, Natural Resources Canada awarded $7 million to Quebec-based Enerkem as the winner of the Sky's the Limit Challenge for its process to produce SAF from forestry and agricultural biomass.[94] Enerkem is also combining its waste gasification technology with Shell's Fischer-Tropsch technology to make SAF from waste materials in Rotterdam.[95] In 2023, the strategic Innovation Fund announced $350 million to support Canada's new Initiative for Sustainable Aviation Technology, which includes a focus area to "transition to alternative fuels."[96] Canada has a large cohort of innovative firms in SAF technology who have organized into the C-SAF.[97] For example, Calgary-based Expander Energy's patented technology converts biomass into "Fossil Free" Low Life Cycle Carbon Intensity synthetic kerosene jet fuel (SynJet®).[98]

Electric Vehicles & Batteries: Adding value to critical minerals by becoming leaders in next-generation battery technology

Bloomberg New Energy Finance projects that the global battery market will grow five times from 1,000GWh/yr in 2024 to over 5,000 in 2035.[99] Canada possesses rich deposits of most of the critical minerals needed for EVs (ex: fifth-largest global nickel producer; some of the largest known rare earth reserves).[100] Bolstering Canadian innovation in next-generation battery technology will help offset some of the risk posed by American tariffs on Canada's EV sector, which is currently skewed towards attracting foreign firms to assemble current-generation technology.

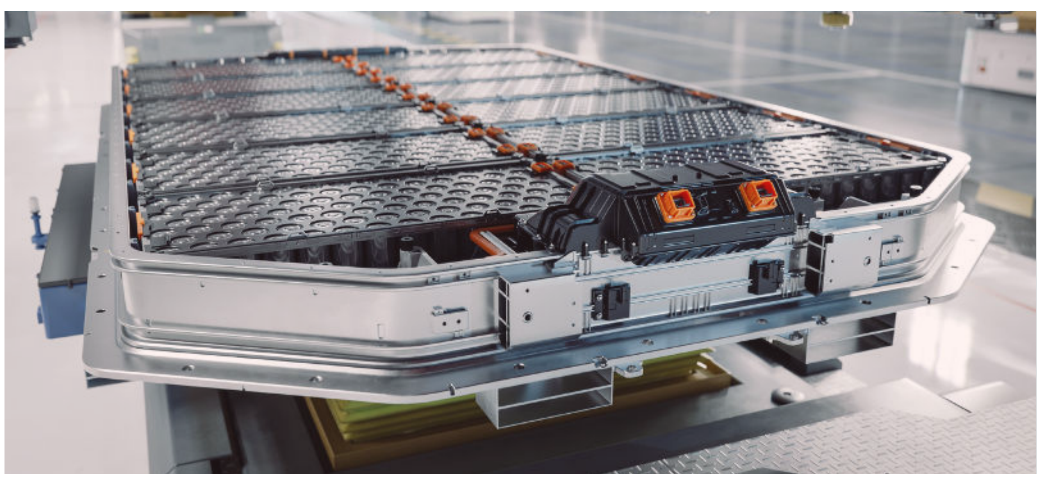
A Canadian target was set in partnership with the Battery Metals Association of Canada, Energy Futures Lab, and Accelerate in *A Roadmap for Canada's Battery* Value Chain: produce 1.3 million electric vehicles in Canada by 2030, as well as the raw materials, processed metals, and batteries for 100 GWh of battery capacity. This would replicate Canada's current 10 percent share of North American automotive manufacturing.[101]

Converting minerals and metals into next-generation battery technologies for electric vehicles could help reverse declining productivity in upstream sectors like non-ferrous metal (except aluminum) production and processing (53 percent decline since 2000 to $84 output per hour in 2023, which is still above the $59 for the total business sector in 2023).[102] Canadian leadership in battery/EV technology could also increase productivity in downstream sectors like motor vehicle manufacturing (seven percent decline since 2000 to $74 output per hour in 2023, which is still above the $59 for the total business sector in 2023) and motor vehicle parts manufacturing (81 percent increase since 2000 to $88 output per hour in 2023, which is above the $59 for the total business sector in 2023).[103] This could also raise R&D in upstream sectors like primary metal manufacturing (declined 33 percent from 2014-2024 compared to an 81 percent increase for all industries, ranked 14/30 in absolute R&D spending in 2024), as well as downstream sectors like motor vehicle, motor vehicle body and trailer and motor vehicle parts manufacturing (increased 328 percent from 2014-2024 compared to an 81 percent increase for all industries, ranked 6/30 in absolute R&D spending in 2024).[104]

Two promising technological frontiers in electric vehicles are solid-state electrolyte batteries, as well as lithium anode batteries with sulfur cathodes. These have been identified as pathways to leapfrog current chemistries dominated by Chinese supply chains. For example, with “lithium-metal sulfur batteries, lithium is the only critical mineral required which reduces material expenses and geopolitical risks.”[105]

Canadian academics from the Universities of Calgary and Waterloo made important breakthroughs in the late 2000s in solid-state batteries and lithium sulfur batteries.[106] Researchers at UBC are continuing to advance solid-state sulfur cathodes as part of the Battery Innovation Research Cluster.[107] Similarly, researchers at the University of Calgary’s Western Canada Battery Consortium and Innovation Hub are advancing both solid-state and lithium sulfur batteries.[108]

Government scientists have also harnessed research infrastructure supported by federal and provincial governments to advance the technologies. For example, National Research Council researchers have tested and improved solid state battery performance using the Canadian Light Source facility in Saskatchewan.[109] Hydro Quebec is also a solid-state battery innovation leader, pioneering ultrathin lithium metal anodes and solid electrolyte polymers.[110]



Policy has also supported industrial research collaborations. For example, Next Generation Manufacturing Canada supported a joint R&D project by Mississauga-based battery maker Electrovaya and Process Research Ortech to scale up pilot manufacturing techniques for solid-state batteries.[111] Building capabilities at scale positions SMEs to benefit as technology suppliers to large foreign manufacturers, such as VW, who announced plans for their St. Thomas, Ontario battery plant to make solid-state batteries.[112]

In sum, the three examples of opportunities for collaborative R&D should be pursued through a whole supply chain approach. This means that innovation ecosystems and regional clusters should be encouraged to form around leading Canadian firms as they continue to scale. This involves identifying and supporting secondary innovation opportunities in upstream and downstream supply chain linkages. For example, innovation in processing feedstocks for SAF (biomass) and critical minerals for electric vehicles can create opportunities to enhance competitiveness in downstream manufacturing, logistics and end-use applications.

Aggregate R&D spending could also be enhanced by added R&D investments in sectors that already have a strong track record, such as chemical manufacturing (such as processing feedstock into SAF), machinery manufacturing (such as CNC machines for mass timber), and transportation equipment manufacturing (for EV components).

In sum, Canada needs to prioritize investment in highly productive sectors that a cleaner global economy depends on. Investments in value-added low-emissions products in mining, sustainable fuels, green chemistry, mass timber, and metal manufacturing will all boost productivity significantly.

4. The Approach: Strategic Industrial Policy

Scaling domestic champions through industrial policy will boost productivity, increase R&D, drive exports, and help the Canadian economy decarbonize

As noted above, the Canadian economy has increasingly been concentrated in sectors with low multifactor productivity (e.g., oil and gas).[113] This means that achieving growth in output per hour worked is primarily outside of our control, determined by raw commodity prices rather than value-added through innovation. The result is decades of low productivity performance.

Scale-up firms who export are the unsung heroes of productivity growth. They excel in turning R&D investments into innovative, value-added products. This leads to high output per hour worked (labour productivity), as well as efficiency in producing more value with all other inputs to the production process, such as capital (multifactor productivity). Unfortunately, Canada struggles to produce innovative scale-up firms. As such, addressing Canada's productivity crisis requires scaling up innovative firms into global exporters of value-added products that will be increasingly in demand as the world moves to reduce emissions.

Productivity scholars emphasize that achieving productivity growth associated with scaling cleaner technologies requires public intervention to steer innovation and help create new markets.[114] This public action can help overcome market failures currently stifling private low-carbon investment, including achieving economies of scale and capturing the value from R&D investment.[115]

What does scale-up industrial policy look like in practice? The first point is to emphasize that successful industrial policy does not have to be expensive. For example, Taiwan's successful rise to prominence in semiconductor manufacturing cost the government about US$35 million over less than a decade to completely transform its economy.[116] Rather than spending, coordination is the central component of all successful industrial policy. This means focusing on innovative firms in a strategic technology, establishing ongoing dialogue to determine their evolving needs, and continuously mobilizing a wide range of policy tools to support their growth.

Countries like the United States, Japan, and Korea have used industrial policy to help cohorts of innovative firms overcome these barriers as they grow into global leaders in technologies such as electric vehicles and energy storage.[117] For example, the table on the next page from Accelerate's recently published *Canadian Battery Innovation Roadmap (2024)* illustrates how leading countries in battery innovation have industrial policies working to achieve specific targets that deploy policy mixes comprising a wide range of policy instruments, guided by strong information exchange via public-private coordination forums.[118]

China	United States	European Union	South Korea	Japan
SETTING TARGETS				
Production Targets				
• Raise domestic content of core components and materials to 40% by 2020 and 70% by 2025	• Capture 60% of domestic demand by 2030	• Capture 90% of domestic demand (550 GWh) by 2030 • 2030 targets for domestic critical mineral extraction (10%), processing (40%), recycling (25%)	• 40% of global battery market and 20% of materials/parts/equipment market by 2030 • 4x cathode production capacity and triple exports of battery-making equipment the next five years	• 600 GWh (or 20% share of the global battery market) by 2030 • 150GWh domestic production by 2030
Innovation Targets				
• Next-gen battery energy density of 500 Wh/kg by 2025	• Solid-state and Li-metal production cost <60 $/kWh, 500 Wh/kg, cobalt/nickel-free by 2030	• Increase energy density (+60% compared to 2019 values) • Reduce cost by 60% compared to 2019 values • Improve cycle lifetime (at least by a factor of two compared to 2019)	• 800 km single charge by 2026 • Lithium-sulfur batteries commercialized by 2025, solid-state by 2027, and lithium-metal by 2028 • Recycling 100% domestic secondary battery closed-loop by 2030	• Full commercialization of solid-state batteries by 2030
INDUSTRIAL POLICY MIXES AND COORDINATION FORUMS				
Supply Push				
• Joint Venture FDI requirements • R&D investments • Loans for mineral supply chain	• DoE R&D funds • DoE Loan Program • IRA tax credits	• Horizon Europe R&D • European Investment Bank • Important Projects of Common European Interest	• Public-private 'battery alliance' R&D fund • Loans & guarantees for critical minerals • Battery-specific tax credit bonuses	• NEDO R&D consortiums
Demand Pull				
• Transit procurement • Purchase subsidies • EV mandate & credit system	• IRA EV consumer incentive thresholds for domestic supply chains	• Procurement thresholds for domestic supply chains • Fit-for-55 2035 ICE phase out • EU Batteries Regulation	• EV purchase incentive technical eligibility criteria	• EV infrastructure investment
Public-Private Coordination				
• China EV100	• Li-bridge	• European Battery Alliance • InnoEnergy • BATT4EU	• Korean Battery Alliance	• Storage Battery Industry Strategy Council

What should a Canadian version of this approach look like? The core elements for a high-value, low-emission Canadian industrial strategy are rooted in the principles of effective modern industrial policy.[119]

The core elements are:

1. Set bold and clear economic targets to guide strategy in priority opportunity areas

- Canada should create "low-carbon competitiveness goals." "Goals" here means quantitative economic targets that refer to physical actions: improvement, production, and deployment of technologies. "Low-carbon" means indexed to specific emissions reduction targets. "Competitiveness" means benchmarked to a vision of Canada's place in the global supply chains of 2030 and 2050.
- These targets have to represent a strategic play that is premised on the competitive advantages of Canadian resources, firms, and communities.
- Targets must be supported by a clear supply chain strategy that seeks to build economic value in Canada, while identifying export opportunities.
- Use the targets to focus public funds and guide policy design at the sectoral level.

A great starting point for selecting targets are the ones contained in The Transition Accelerator's industry-codesigned roadmaps: The Forest Products Association of Canada and the *Canadian Wood Council's Mass Timber Roadmap (2024)*,[120] The Canadian Council for Sustainable Aviation Fuels' *C-SAF Roadmap (2023)*,[121] Accelerate's *Canadian Battery Innovation Roadmap (2024)*,[122] and the Battery Metals Association of Canada's *Roadmap for Canada's Battery Value Chain (2022)*.[123]

Electric Vehicles	Sustainable Aviation Fuel	Mass Timber
SETTING TARGETS		
• By 2030, Canada produces 1.3 million electric vehicles (10% of NA) as well as the raw materials, processed metals, and batteries for 100 GWh of battery capacity. • By 2035, increase the number of Canadian-owned firms in the battery sector tenfold, contributing to 20% of the North American battery value chain. • By 2035, secure 1,000 patents in battery technology. • By 2035, train and integrate over 10,000 skilled professionals into Canada's battery industry, with at least 500 graduates annually from specialized training programs.	• One billion litres of SAF production by 2030 (10% of all jet fuel use in Canada), achieving a minimum 50% reduction in life cycle greenhouse gas emissions compared to conventional jet fuel, which would represent a reduction of about 1.6 million tonnes of GHG emissions.	• Increase mass timber market value to $1.2 billion by 2030 and double that to $2.4 billion by 2035, with Canada's mass timber sector serving 25 percent of world mass timber market.

2. Create inclusive partnerships to foster strategic collaboration

- Canadian industrial policy needs new forms of collaboration between First Nations, government, industry, finance, universities, and civil society.
- Collaborative forums should not be talking shops but active working groups that set and revise targets, create strategy, seed projects, and identify high priority investments.
- Brokers and independent intermediaries are crucial to the success of collaboration. It is important to empower independent voices that can provide expertise and help to develop projects. An independent agency could be in government, so long as it is insulated from politics and free from bureaucratic routines. Or, it could be from civil society. Or, they could be true public-private partnerships—organizations built for the purpose of catalyzing strategic collaboration in specific technologies.

3. Align the policy mix

With these goals and partnerships established, the final task is to mobilize a whole-of-government industrial policy mix to support innovative Canadian firms to scale up. The ongoing public-private information flows facilitated through the collaborative partnerships are key to ensuring that the wide variety of policy instruments housed in different government departments (and levels of government) are deployed to meet the evolving needs of Canadian firms as they grow.

Too often, Canadian discussions of industrial policy in the context of building a carbon-neutral economy focus only on specific economic development projects (investment attraction for battery factories), specific policy instruments (tax credits for investment in capital and R&D), or specific environmental policy goals (producing clean energy or decarbonizing high-emission sectors). While activities in each of the three domains can generate marginal productivity gains (e.g., deploying foreign technology to more efficiently generate clean energy or decarbonize existing facilities), securing Canadian prosperity in the long term means all of these activities must be pursued in ways that work towards achieving the overarching goal of scaling innovative Canadian firms into large exporters capable of capturing global market share in strategic clean technologies.

Canada's current policy mix focuses primarily on early-stage R&D for cleantech (start-up support), incentivizing large foreign firms to invest in manufacturing plants (investment attraction), and adoption of existing cleantech regardless of whether it is sourced from Canadian or foreign suppliers (decarbonization projects). Supporting start-ups and large-scale adoption without offering scale-up support is a recipe for producing promising Canadian cleantech startups that are acquired by foreign firms to scale up their technology in other countries that offer more generous scale-up support. The irony is that these foreign firms later benefit from Canadian policy supports for cleantech adoption and decarbonization projects once they perfect the Canadian-invented technology to become leading suppliers. This underscores the importance of supporting scale-ups with intellectual property supports so that they can secure freedom to operate in global markets characterized by powerful competitors who seek to entrench their technology leadership via patent thickets.[124]

In contrast, the leading countries discussed above augment start-up and decarbonization project supports with scale-up support. This takes the form of supplying "patient capital" via large loans and grants for first-of-a-kind deployment, using strategic procurement to provide revenue for firms to scale through the commercialization valley-of-death, and offering support services to help firms secure intellectual property and open up markets for their technologies by advocating for them to be embedded in international standard-setting and regulatory bodies. For example, the US Bipartisan Infrastructure Law (BIL) and the Inflation Reduction Act (IRA) committed over US$26 billion to create the Department of Energy's Office of Clean Energy Demonstrations (OCED), addressing the need for first-of-a-kind demonstrations at scale (e.g., the Hydrogen Hubs program).[125] The US is also helping its firms capture early technological leadership at scale in sustainable aviation fuel[126] through loans and loan guarantees from the Department of Energy's Loan Program Office, whose lending capacity was massively increased to approximately US$412 billion by the IRA.[127] These loans were instrumental in supporting American success stories like Tesla through the valley-of-death.[128]

The chart on the next page synthesizes some of the main supply-side and demand-side policy recommendations from The Transition Accelerator's industry co-created roadmaps for electric vehicles, sustainable aviation fuel, and mass timber.

Electric Vehicles	Sustainable Aviation Fuel	Mass Timber
INDUSTRIAL POLICY MIX		
Supply Push		
• **Structuring EV incentives** to benefit Canadian firms & technologies and support demonstration at scale • **National IP Strategy** with patent pools, education supports, SME financing, fast-track patents for critical technology • **Training programs** that enhance partnerships with educational institutions • **Expand research centers**, establish demonstration facilities, and build out national labs	• **Production incentives** that level playing field with renewable diesel • **Preferred lending rates** for SAF facilities through the Canada Growth Fund or the Canada Infrastructure Bank • **R&D&D support** for ($200 million to $1 billion) first-of-a-kind (FOAK) and early-stage commercial facilities	• **Embodied carbon subsidy** through the Canada Infrastructure Bank, calculated per m2, modelled on the Bank's retrofit program • **Production or investment** tax credit for low carbon intensity building materials • **Low-cost finance**, loan guarantees, grants, and equity stakes
Demand Pull		
• **Streamline regulatory processes** for new battery technologies • **International partnerships** for standards and training • **Develop new standards** for next generation battery materials • **Boost exports** via EDC/GAC supports • **Procurement** of Canadian and next-generation batteries/EVs	• **Contract for differences** to guarantee CFR credit amounts • **Waive carbon tax** on SAF • **Harmonize certification frameworks** and SAF accounting methodologies • **Create a Canadian SAF Registry** (Book & Claim SAF accounting system) • **Procurement** programs of SAF for federal fleets	• **Embodied carbon regulations** and building code changes (ratcheted up over time) to create demand for mass timber • **'Wood first' procurement requirements** to use of mass timber in public-sector buildings

Industrial policy should coordinate supply-side and demand-side policy instruments to incentivize innovation in both natural resource extracting and value-added processing/manufacturing of clean technologies. This calls for a whole-value-chain approach, building technical superiority in all the production steps from resource extraction through to manufacturing. This involves using policy supports to scale up firms in both upstream/backward linkages (e.g., mining, mining machinery & techniques) and downstream/forward linkages (e.g., critical minerals processing and battery manufacturing).[129] Doing so will boost productivity thanks to the innovative, value-added products of a new cohort of Canadian scale-up firms.

5. The Conclusion

This report has presented industrial policy to scale Canadian suppliers of low- and non-emitting technologies as a pathway to achieve the twin goals of decarbonization and productivity-boosting economic competitiveness. Canada can mitigate uncertainty associated with carbon-intensive energy and address the productivity crisis by helping Canadian companies secure technological leadership in value-added products that the world will need as it moves towards carbon neutrality in the coming decades.

This report highlights the importance of analyzing Canada's productivity crisis through the lens of the real economy and differences between sectors. This kind of perspective shows that aggregate numbers can be misleading and can preclude room for discussion of sector-specific policy changes that should augment the more general, across-the-board solutions typically put forward in discussions on how to boost productivity (such as tax incentives, reducing red tape, increasing competition and interprovincial trade, etc).

While framework-level policies would likely be useful, what is also required is to look at sectors that are poised for longer-term growth, and these are dominated by emerging clean energy and materials. Canada has many opportunities to scale these new technologies and sectors by adding value to our natural resources. This will build on our clean technology leadership while generating productivity gains up and down the supply chain. Doing so would also boost regional economic development. For example, critical mineral development has potential to position regions like Greater Sudbury as leading export hubs for innovative hard-rock mining solutions, equipment, and expertise.[130]

Going forward, economic modelling is needed to assess in greater detail what the potential upside benefits could be for investment, productivity and macroeconomic performance from targeted industrial policy initiatives in areas such as EVs, batteries and critical minerals; mass timber and modularized construction; and sustainable aviation fuel.

Endnotes

1 Labour productivity for Wood products manufacturing ($59.6) is slightly above average ($59.1)

2 https://www.cbc.ca/news/politics/trump-tariff-march-4-1.7469928

3 https://irpp.org/research-studies/reducing-canada-vulnerability-to-us-tariffs/; https://www.theglobeandmail.com/business/commentary/article-now-is-the-winter-of-canadas-economic-reckoning/; https://cleanenergycanada.org/report/the-world-next-door/

4 2022 data: https://natural-resources.canada.ca/science-data/data-analysis/10-key-facts-canada-s-natural-resources-2023

5 2022 data: https://natural-resources.canada.ca/science-data/data-analysis/10-key-facts-canada-s-natural-resources-2023

6 2023 data: https://oec.world/en/profile/country/can

7 https://natural-resources.canada.ca/maps-tools-publications/publications/mineral-trade#details-panel1

8 https://www150.statcan.gc.ca/n1/pub/11f0019m/11f0019m2020002-eng.htm

9 https://www150.statcan.gc.ca/n1/pub/11f0019m/11f0019m2020002-eng.htm

10 https://ppforum.ca/policy-speaking/alvaro-santos-pereira/

11 Centre for the Study of Living Standards: https://www.csls.ca/ipm/45/IPM_45_Haun.pdf

12 Centre for the Study of Living Standards: https://www.csls.ca/ipm/45/IPM_45_Haun.pdf

13 Centre for the Study of Living Standards: https://www.csls.ca/ipm/45/IPM_45_Haun.pdf

14 https://www150.statcan.gc.ca/n1/pub/11-631-x/11-631-x2024005-eng.htm

15 https://www.oecd.org/en/data/indicators/multifactor-productivity.html

16 https://www.oecd.org/en/data/indicators/multifactor-productivity.html

17 https://www.theglobeandmail.com/business/commentary/article-how-canadas-middle-class-got-shafted/

18 https://www.theglobeandmail.com/business/commentary/article-how-canadas-middle-class-got-shafted/

19 http://csls.ca/ipm/45/IPM_45_Haun.pdf

20 https://www.oecd.org/en/data/indicators/multifactor-productivity.html?oecdcontrol-00b22b2429-var3=2022

21 https://ppforum.ca/policy-speaking/alvaro-santos-pereira/

22 https://ppforum.ca/policy-speaking/alvaro-santos-pereira/

23 https://ppforum.ca/policy-speaking/alvaro-santos-pereira/

24 https://www.thebusinesscouncil.ca/report/engines-of-growth/

25 https://www.thebusinesscouncil.ca/report/engines-of-growth/

26 https://www150.statcan.gc.ca/n1/pub/11f0019m/11f0019m2020002-eng.htm

27 NOTE: Chained (2017) dollars per hour, Labour productivity is the ratio between real value added and hours worked. Real value added for each industry and each aggregate is constructed from a Fisher chain index. https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=3610048001

28 https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3610048001

29 https://www.theglobeandmail.com/business/commentary/article-canadas-productivity-problem-isnt-that-big-if-we-exclude-oil/

30 https://www.theglobeandmail.com/business/commentary/article-canadas-productivity-problem-isnt-that-big-if-we-exclude-oil/

31 https://www.theglobeandmail.com/business/commentary/article-canadas-productivity-problem-isnt-that-big-if-we-exclude-oil/

32 It is relatively easy to estimate labour productivity—by dividing value added by labour input (workers, or hours). It is much less straightforward to also include an estimate of the amount of capital in production. Thus there are more assumptions made in deriving TFP estimates (through decomposition or econometric techniques). A particular difficulty is including the quality or technological level of capital.

33 Note: 2018 is the latest data the authors used in their Globe and Mail article (https://www.theglobeandmail.com/business/commentary/article-canadas-productivity-problem-isnt-that-big-if-we-exclude-oil/ and their academic article (https://oliverdl.com/files/cje_wp.pdf)

34 https://www.bankofcanada.ca/2024/05/staff-analytical-note-2024-12/

35 This interpretation is also consistent with more recent estimates of MFP from Statistics Canada: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3610020801&pickMembers%5B0%5D=2.1&cubeTimeFrame.startYear=2000&cubeTimeFrame.endYear=2023&referencePeriods=20000101%2C20230101

36 Innovation Policy Lab: https://dais.ca/reports/scale-up-verse/

37 Innovation Policy Lab: https://dais.ca/reports/scale-up-verse/

38 Innovation Policy Lab: https://dais.ca/reports/scale-up-verse/

39 ISED: https://ised-isde.canada.ca/site/innovation-better-canada/en/tracking-progress-and-results-innovation-and-skills-plan

40 Statistics Canada. https://www150.statcan.gc.ca/n1/daily-quotidien/241106/dq241106c-eng.htm

41 https://www150.statcan.gc.ca/n1/pub/11-631-x/11-631-x2024005-eng.htm

42 https://www.oecd.org/en/topics/sub-issues/productivity-and-business-dynamism.html

43 https://www.oecd.org/en/topics/sub-issues/productivity-and-business-dynamism.html

44 https://ppforum.ca/policy-speaking/alvaro-santos-pereira/

45 https://www150.statcan.gc.ca/n1/pub/11f0019m/11f0019m2020002-eng.htm

46 https://www150.statcan.gc.ca/n1/pub/11f0019m/11f0019m2020002-eng.htm

47 https://www.productivity.ac.uk/wp-content/uploads/2021/09/WP009-Productivity-opportunities-and-risks-Transitions-scoping-paper-FINAL.pdf p. 2

48 https://www.iea.org/reports/world-energy-outlook-2023

49 https://www.csls.ca/ipm/45/IPM_45_Barr.pdf

50 This definition is used in Statistics Canada's Survey of Environmental Goods and Services and Environmental and Clean Technology Products Economic Account. This sector does not map directly to NAICS codes; Jiang, K. (2023) "Canada's Environmental and Clean Technology Sector (2021)," Office of the Chief Economist, Global Affairs Canada. https://www.international.gc.ca/trade-commerce/economist-economiste/analysis-analyse/ect-etp.aspx?lang=eng

51 Statistics Canada's BIGS database contains 123 innovation programs delivered by 18 federal Departments, including 15 clean technology programs; Carta, M. and F. Demers (2023) "Analysis on Federal Business Innovation and Growth Support to Clean Technology, 2016 to 2020," Analysis in Brief. Statistics Canada, ISSN 1707-0503, ISBN 978-0-660-49328-2.

52 https://www.theglobeandmail.com/business/commentary/article-how-canadas-middle-class-got-shafted/

53 Statistics Canada: https://www150.statcan.gc.ca/n1/pub/36-28-0001/2024007/article/00002-eng.htm

54 OECD: https://www.oecd.org/en/data/datasets/science-technology-and-innovation-scoreboard.html

55 https://www150.statcan.gc.ca/n1/daily-quotidien/240919/dq240919b-eng.htm

56 https://www.iea.org/data-and-statistics/charts/spending-on-energy-r-and-d-by-listed-companies-2015-2022

57 https://www.iea.org/data-and-statistics/data-tools/energy-technology-rdd-budgets-data-explorer

58 https://www.theglobeandmail.com/business/commentary/article-despite-its-shortcomings-canada-is-not-an-economic-basket-case/

59 https://www.theglobeandmail.com/business/commentary/article-despite-its-shortcomings-canada-is-not-an-economic-basket-case/

60 Baldwin, J., and Yan, B. (2015). "Empirical Evidence from Canadian Firm-level Data on the Relationship between Trade and Productivity Performance."

61 https://www.edc.ca/en/blog/why-exporters-do-better.html

62 https://www.thebusinesscouncil.ca/report/engines-of-growth/

63 https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=3610064601; https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1210009801&cubeTimeFrame.startYear=2012&cubeTimeFrame.endYear=2023&referencePeriods=20120101%2C20230101

64 https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1210009801&cubeTimeFrame.startYear=2012&cubeTimeFrame.endYear=2023&referencePeriods=20120101%2C20230101

65 Calculations by the Office of the Chief Economist. Note: clean technology is not a part of the North American Industry Classification System but a special aggregation of the survey. 2020 data: https://www.international.gc.ca/trade-commerce/economist-economiste/analysis-analyse/ect-etp.aspx?lang=eng

66 Ibid.

67 Bentley Allan conducted a review of existing studies on Canada's opportunities for NZAB. The results support these sector choices. See: Allan, Bentley et al. 2022. Canada's Future in a Net-Zero World: Securing Canada's Place in the Global Green Economy. https://institute.smartprosperity.ca/publications/CanadasFuture; Canadian Institute for Climate Choices. 2021. Sink or Swim: Transforming Canada's economy for a global low-carbon future. https://climateinstitute.ca/reports/sink-or-swim/; BCG. 2021. Canada Can Lead the World https://www.bcg.com/en-ca/publications/2021/canada-can-lead-in-low-carbon-technology; Duruflé, G., and Carbonneau, L. 2016. Forging a Cleaner and More Innovative Economy in Canada. Sustainable Development Technology Canada and Cycle Capital Management; RBC Economics. 2021. Trading Places: Canada's place in a changing global economy. https://royal-bank-of-canada-2124.docs.contently.com/v/trading-places-canadas-place-in-a-changing-global-economy-pdf; RBC Economics. 2021. The $2 Trillion Transition: Canada's Road to Net Zero. https://thoughtleadership.rbc.com/the-2-trillion-transition/; Canada's Industry Strategy Council. 2020. Restart, Recover, and Reimagine Prosperity for all Canadians: An Ambitious Growth Plan for Building a Digital, Sustainable, and Innovative Economy. https://ised-isde.canada.ca/site/innovation-better-canada/sites/default/files/attachments/00118a_en.pdf

68 https://transitionaccelerator.ca/reports/electrons-rocks-and-brains/

69 https://transitionaccelerator.ca/reports/the-mass-timber-roadmap/

70 https://transitionaccelerator.ca/reports/the-c-saf-roadmap/

71 https://bir.acceleratezev.ca/

72 https://transitionaccelerator.ca/reports/a-roadmap-for-canadas-battery-value-chain/

73 https://transitionaccelerator.ca/reports/the-mass-timber-roadmap/

74 https://transitionaccelerator.ca/reports/the-mass-timber-roadmap/

75 https://transitionaccelerator.ca/reports/the-mass-timber-roadmap/

76 2023 data, Chained (2017) dollars per hour, Labour productivity is the ratio between real value added and hours worked. Real value added for each industry and each aggregate is constructed from a Fisher chain index. https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=3610048001

77 Ibid.

78 Ibid.

79 https://transitionaccelerator.ca/wp-content/uploads/2024/06/MT_Roadmap_Digital_vf.pdf

80 2024 data, Total in-house research and development expenditures, 3 digit NAICS codes, excluding services sectors: https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=2710033301

81 https://firetests.cwc.ca/wp-content/uploads/2022/07/Mass-Timber-Fire-Demonstration-Test-Summary.pdf

82 https://academic.daniels.utoronto.ca/masstimberinstitute/

83 https://natural-resources.canada.ca/our-natural-resources/forests/industry-and-trade/forest-products-applications/mass-timber-construction-canada/23428

84 https://www2.gov.bc.ca/gov/content/industry/construction-industry/mass-timber/mass-timber-action-plan ; https://www.ontario.ca/page/ontarios-forest-sector-strategy

85 https://news.ontario.ca/en/release/1004878/ontario-investing-35-million-in-mass-timber-manufacturer-to-build-more-homes-faster

86 https://www.woodbusiness.ca/kalesnikoff-to-build-new-mass-timber-mill-in-b-c/

87 2023 data, Chained (2017) dollars per hour, Labour productivity is the ratio between real value added and hours worked. Real value added for each industry and each aggregate is constructed from a Fisher chain index. https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=3610048001

88 2024 data, earliest year available used for forestry & agriculture, Total in-house research and development expenditures, 3 digit NAICS codes, excluding services sectors: https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=2710033301

89 https://transitionaccelerator.ca/reports/the-c-saf-roadmap/

90 https://www.energy.gov/eere/bioenergy/synthetic-aviation-fuel-grand-challenge#!divAbstract

91 https://nrc.canada.ca/en/research-development/research-collaboration/sustainable-aviation

92 https://nrc.canada.ca/en/research-development/research-collaboration/video-nrc-flies-worlds-first-civil-jet-powered-100-percent-biofuel

93 https://nrc.canada.ca/en/stories/national-research-council-canada-investigates-aircraft-contrails-sustainable-aviation-fuels

94 https://impact.canada.ca/en/challenges/green-aviation/results

95 https://enerkem.com/newsroom/from-waste-to-chemicals-to-waste-to-jet

96 https://www.canada.ca/en/innovation-science-economic-development/news/2023/06/canada-invests-350-million-in-national-sustainable-aviation-innovation-network.html

97 https://c-saf.ca/category/launch-members/technology/#close

98 https://www.expanderenergy.com/technology-expander-energy/

99 https://bir.acceleratezev.ca/

100 https://canada-us-trade.acceleratezev.ca/

101 https://transitionaccelerator.ca/reports/a-roadmap-for-canadas-battery-value-chain/

102 2023 data, Chained (2017) dollars per hour, Labour productivity is the ratio between real value added and hours worked. Real value added for each industry and each aggregate is constructed from a Fisher chain index. https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=3610048001

103 Ibid.

104 2024 data, Total in-house research and development expenditures, excluding services sectors, 3 digit NAICS codes except for 4 digit for Motor vehicle, motor vehicle body and trailer and motor vehicle parts manufacturing; Aerospace product and parts manufacturing; and All other transportation equipment manufacturing: https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=2710033301

105 https://carnegieendowment.org/research/2024/09/energy-innovation-us-industrial-stature?lang=en&center=russia-eurasia

106 https://bir.acceleratezev.ca/

107 https://battery-innovation.ok.ubc.ca/research/technology-development/

108 https://electricautonomy.ca/ev-supply-chain/batteries/2024-01-15/exclusive-western-canada-battery-lab/

109 https://www.lightsource.ca/public/news/2023-24-q4-jan-march/findings-pave-way-for-longer-lasting-solid-state-batteries.php

110 https://www.hydroquebec.com/ce-transportation-electrification-energy-storage/solid-electrolyte-batteries.html

111 https://ised-isde.canada.ca/site/global-innovation-clusters/en/canadas-cluster-projects

112 https://financialpost.com/commodities/vw-plans-to-make-solid-state-batteries-ontario

113 https://www.theglobeandmail.com/business/commentary/article-canadas-productivity-problem-isnt-that-big-if-we-exclude-oil/

114 https://www.productivity.ac.uk/wp-content/uploads/2021/09/WP009-Productivity-opportunities-and-risks-Transitions-scoping-paper-FINAL.pdf p. 2

115 https://www.productivity.ac.uk/wp-content/uploads/2021/09/WP009-Productivity-opportunities-and-risks-Transitions-scoping-paper-FINAL.pdf p. 2

116 Breznitz, D. (2021). Innovation in real places: Strategies for prosperity in an unforgiving world. Oxford University Press, USA. At p. 81.

117 https://www.isi.fraunhofer.de/en/presse/2024/presseinfo-02-internationale-batteriepolitik-strategien-der-fuehrenden-laender.html

118 https://bir.acceleratezev.ca/

119 https://netzeroindustrialpolicy.ca/reports/taking-a-strategic-approach-to-industrial-transition

120 https://transitionaccelerator.ca/reports/the-mass-timber-roadmap/

121 https://transitionaccelerator.ca/reports/the-c-saf-roadmap/

122 https://bir.acceleratezev.ca/

123 https://transitionaccelerator.ca/reports/a-roadmap-for-canadas-battery-value-chain/

124 https://www.theglobeandmail.com/business/commentary/article-productivity-productivity-why-canada-keeps-talking-about-it-but-sees/

125 https://www.energy.gov/oced/office-clean-energy-demonstrations

126 https://www.canarymedia.com/articles/air-travel/doe-makes-3b-commitment-to-two-sustainable-aviation-fuel-projects

127 https://www.canarymedia.com/articles/air-travel/doe-makes-3b-commitment-to-two-sustainable-aviation-fuel-projects

128 https://www.energy.gov/lpo/tesla

129 https://rabble.ca/economy/staple-theory-50-why-linkages-matter/

130 https://munkschool.utoronto.ca/media/7030/download?inline=/download