JOBS FOR TODAY

CANADA'S BUILDING TRADES & THE NET-ZERO TRANSITION

CBTU
CANADA'S BUILDING TRADES UNIONS

Centre for Civic Governance

September 2025

By Tyee Bridge and Jim Stanford

Jobs for Today is a report from Green Jobs BC, a project of the Centre for Civic Governance (formerly Columbia Institute).

This report extends and updates research first published in *Jobs for Tomorrow* by Tyee Bridge and Richard Gilbert (Columbia Institute, 2017).

Research team: Tyee Bridge, John Calvert, Isabella Johnson, Lee Loftus, Jim Stanford

Reviewed by: John Calvert, Melissa Gregerson, Isabella Johnson, Lee Loftus and Kevin Millsip

Project advisory: Canada's Building Trade Unions (CBTU), John Calvert, Lee Loftus and Kevin Millsip

Our thanks to BC Society for Policy Solutions, Charley Beresford, Ryder Bergerud, Centre for Civic Governance, Melissa Gregerson, Marc Lee and Vancity Credit Union

Commissioned by Canada Climate Literacy Research Inc. DBA Climate Industry Research Team (CIRT)

Graphic design by Creatrix Design Group

Cover photos: Niloo/Shutterstock.com, Jordi C./Shutterstock.com, David Dodge/Flickr

ISBN 978-0-9781918-9-4

Additional copies of this publication may be downloaded from the Centre for Civic Governance website at www.ccg.eco/research/jobs-for-today.

Centre for Civic Governance
Suite 440 - 789 West Pender Street
Vancouver, B.C., V6C 1H2, Canada
info@ccg.eco
www.ccg.eco

CBTU CANADA'S BUILDING TRADES UNIONS

Centre for Civic Governance

UNITED STEELWORKERS USW LOCAL 2009 LANGLEY

CONTENTS

PHOTO TOMMY LEI SUN/SHUTTERSTOCK

1

HIGHLIGHTS

The Canadian and global economies are rapidly transitioning toward renewable energy sources, moving away from burning fossil fuels (coal, oil, and natural gas).

This transition is occurring for both environmental and economic reasons:

- Fossil fuel combustion causes damaging increases in global temperatures due to the release of carbon dioxide, methane, and other greenhouse gases.
- Thanks to new technology, renewable energy sources are now cheaper than fossil fuels.
- New energy conservation techniques that reduce the amount of energy needed to heat buildings and power vehicles are also reducing fossil fuel demand.

Canada and most other countries in the world have committed to reach 'net-zero' by 2050 – by which time most uses of fossil fuels will be phased out, offset by other activities that remove carbon from the atmosphere and help slow dangerous overheating of the earth caused by fossil fuel combustion.

Canada's construction industry has an important role to play in the transition to a net-zero economy. Enormous capital investments and construction will be required to expand renewable energy production, build accompanying infrastructure (like transmission lines, batteries, and public transit), and achieve better energy efficiency (in buildings and other structures), creating increased demand for unionized skilled construction workers and an unprecedented opportunity for good, well-paying jobs for building trades workers. Meeting this need will require strong government commitment and investment in workforce training, as well as the need to ensure that high labour standards are in place.

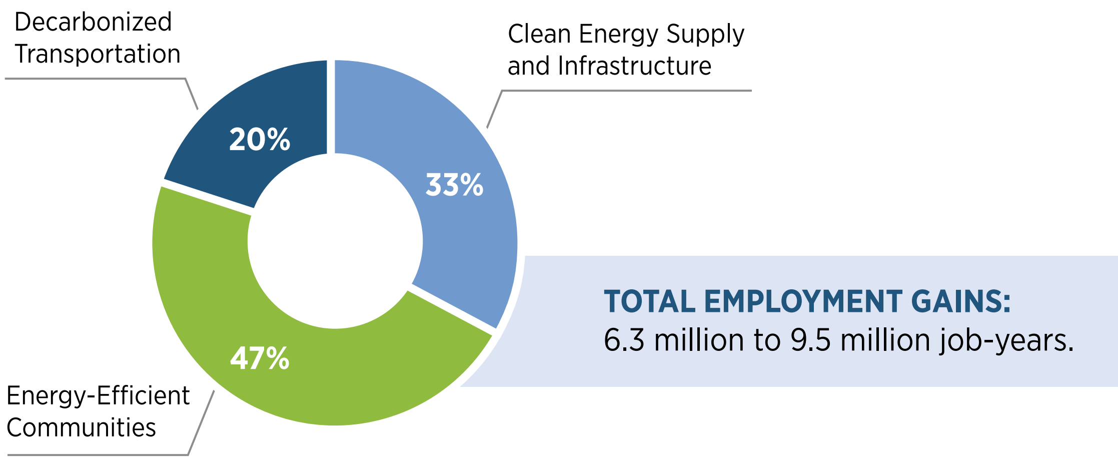
FIGURE 1
Investments Required to Achieve Net-Zero in Canada by 2050

- **200,000** new MW of non-emitting generation capacity (hydro, wind, solar, nuclear, geothermal).
- **50,000 km** of new and expanded transmission lines.
- Adoption of **advanced energy-efficient** techniques and materials throughout ICI construction.
- Energy-saving retrofits on all existing ICI structures over **25 years**.
- **Almost $50 billion** cumulative investment in district energy systems.
- Installation of **3.9 million** electric vehicle chargers.
- **$180 billion** cumulative investment in public transit infrastructure.
- **$50 billion+** investment in 1 to 3 high speed rail systems.

Source: Estimates as described in text (summarized in Table 19, p.68).

The energy transition will result in massive increases in new capital spending by governments, businesses, and consumers in coming decades, as hundreds of billions of dollars will be required for new construction associated with the energy transition. Those investments will create millions of job-years of work for the full range of building and construction trades, and unprecedented opportunities for unionized skilled trades workers.

FIGURE 2
Employment Gains from Net-Zero Investments (million job-years by 2050)



Source: Calculations from published sources as described in text (summarized in Table 19, p.68).

This report estimates that between 6.3 and 9.5 million additional job-years of construction work will be required by 2050 to meet Canada's net-zero goals across all the investments unleashed by the energy transition: building renewable energy facilities, building energy and transportation infrastructure, and constructing and retrofitting energy-efficient buildings. That is equivalent to between 235,000 and 350,000 new jobs, on average, over the next 25 years – increasing current construction employment in Canada by 20%-30%. Almost half of those new jobs will be in the ICI construction sector, one-third in renewable energy projects, and the remaining one-fifth in transportation infrastructure (Figure 2). In addition, another 60-90,000 new ongoing jobs will be created in operations and maintenance roles, many of those also filled by skilled trades workers.

In short, building and construction workers in Canada are entering a period of unprecedented opportunity and prosperity. The historic investments associated with the energy transition, along with other drivers of new work (like Canada's growing population), will reinforce that positive employment outlook. Work will be abundant. Unionized skilled trade workers will be in strong demand.

While the *quantity* of construction work required for the energy transition is very encouraging, parallel efforts will also be required to ensure that the *quality* of that work is top-notch. The shift to renewable energy and sustainable infrastructure will require a highly skilled workforce to ensure a smooth, efficient and effective transition. Governments, employers, and unions need to move quickly to expand training, apprenticeship, and Red Seal programs. New skills will be required for many of these investments: like working with new generations of electrical technology in renewable energy projects, and advanced energy-saving materials and building techniques in the ICI sector. Strong labour standards will also need to accompany publicly supported investments, including union representation, prevailing wages policies, and apprenticeship requirements.

The economic boost from massive investments in renewable energy, transportation infrastructure, and energy-efficient buildings will provide a badly-needed boost to Canadian economic growth and job-creation, at a moment when U.S. President Donald Trump's aggressive tariff policies have created major uncertainty in other parts of the economy. Investments associated with the energy transition are focused on meeting Canada's domestic energy, building, and transportation needs. They are thus less exposed to harmful U.S. trade actions than many other sectors. The economic uncertainty arising from Trump's policies can be moderated by accelerating these investments in Canadian energy security and sustainability.

Of course, we cannot predict with full certainty how specific technologies, timelines, and government policies will evolve over the next quarter-century, as the world moves toward a net-zero economy. But what is certain is that this energy transition will continue and accelerate: both because it is necessary for the environment, and because it makes economic sense.

Building trades workers and their unions will play a leading role in the coming energy transition. Unionized labour is essential to successfully complete these many new investments. And unions will fight to ensure that job quality and compensation is top-notch, thus maximizing the opportunities for building workers, their families, and communities.

Canada and the Global Energy Transition

- Under the Paris Agreement of 2015, 197 nations (including Canada) committed to quickly reduce emissions of CO^2 and other greenhouse gases (GHGs) to try to keep global warming under 2°C.
- Canada then committed further in 2021 to transition its economy to net-zero GHG emissions by 2050. We have been joined in this pledge by 110 other countries (Energy and Climate Intelligence Unit, 2024).
- Total greenhouse gas emissions in Canada have declined by 7% since 2005 (Canadian Climate Institute, 2024), and should fall to 40% below 2005 levels by 2030.


PHOTO SERGEI MISHCHENKO/SHUTTERSTOCK

2

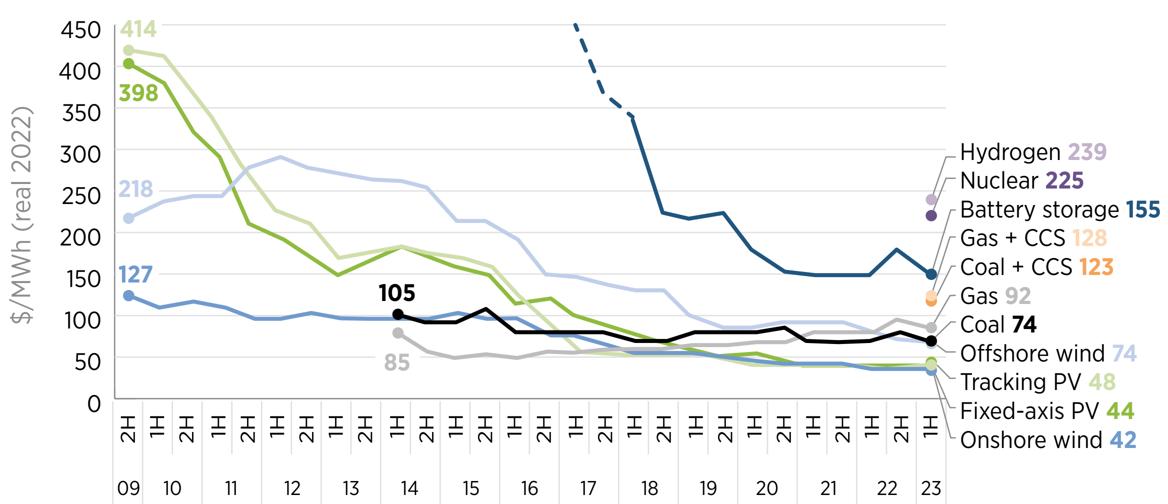
INTRODUCTION

Canada and other countries have entered a historic economic and technological transition toward a net-zero economy. For both environmental and economic reasons, consumers and industries are shifting away from the use of fossil fuels. Carbon-based energy sources (like oil, natural gas, and coal) emit carbon dioxide and other forms of pollution when burned. Concentration of these pollutants in the atmosphere is causing significant increases in worldwide temperatures and altering climate and weather patterns. Extreme weather events are becoming more frequent and more damaging: droughts and floods, record-breaking heat, violent storms, and rising sea levels.

To curtail these damaging and costly consequences, countries around the world – including Canada – have agreed to phase-out most uses of fossil fuels. Most countries (including Canada) have pledged to reach a 'net-zero' economy by 2050, at which point pollution from (small) remaining amounts of fossil fuel consumption would be offset by other activities (such as new forests) that reduce the amount of carbon in the atmosphere. Reaching net zero will require rapid expansion of non-carbon sources of energy (such as hydroelectric, nuclear, wind, solar, and geothermal power), and also more efficient use of energy (so that less energy is required to heat buildings and power vehicles).

On top of the environmental necessity of reducing fossil fuel use, there are now powerful economic motivations, too: technological improvements have reduced the cost of renewable power sources, which are now cheaper than fossil fuel energy. Considering all capital and operating costs, wind and solar power now cost less than coal or gas-fired power, and much less than oil (see Figure 3). Rapid improvements in battery technology are further enhancing this cost advantage; more powerful and affordable batteries will help smooth fluctuations in supply from renewable sources and further reduce the need for fossil fuels. Shifting toward renewable and non-carbon energy sources offers the prospect of cheaper, more reliable, and non-polluting energy abundance. These economic advantages are accelerating the uptake of renewable energy systems, above and beyond the impact of environmental regulations.

FIGURE 3
Levelized Cost of Electricity by Fuel Source, 2009-2023

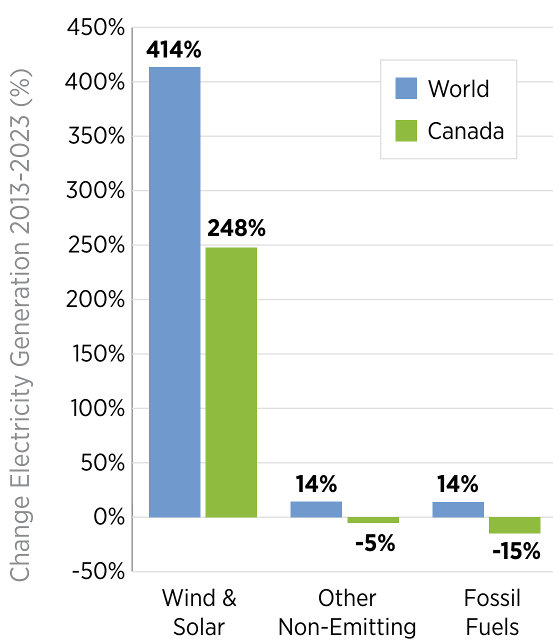


Source: Bloomberg NEF (2023).

For all these reasons, the energy transition is picking up speed, in Canada and around the world. Over the last decade, wind and solar generation grew by over 400% globally, and by almost 250% in Canada (Figure 4). The consumption of fossil fuels, meanwhile, is declining in relative terms (compared to population and economic growth), and will soon start declining in absolute quantities. Emerging market economies, led by China, are investing massively in non-emitting energy sources, both for environmental reasons and because they are now less expensive. Thanks to our abundant resources of renewable energy (including hydroelectric, wind, and solar resources), Canada has immense potential to prosper as this transition continues.

FIGURE 4

Change in Electricity Generation by Source, 2013-2023



Source: Authors' calculations from Ritchie and Rosado (2024) and Canada Energy Regulator (2023).

Specific policies to support this global energy transition have sparked plenty of controversy among Canadians, and building and construction workers have often been caught in the middle of these debates. New fossil fuel projects certainly generate some new job opportunities, and proponents of those projects emphasize their employment effects as they push for project approvals and favourable tax changes. However, the scale of investment and job-creation will be even larger in non-carbon energy projects and energy conservation initiatives. Job prospects for construction workers will not be undermined by the coming energy transition. To the contrary, as documented in this report, employment opportunities for unionized skilled trades workers will be very strong as the energy transition gathers steam.

Enormous inputs of skilled construction labour will also be required to build and maintain the facilities and equipment associated with the energy transition: renewable energy projects, related infrastructure (like transmission lines and batteries), energy efficient buildings, district energy systems, and public transportation. Hence the energy transition will strengthen job opportunities for building and construction trades.

This report outlines the key drivers of construction job-creation that will result from the energy transition in coming years. And it estimates the number of new building and construction jobs arising from each of those categories over the next quarter-century, as Canada works toward net-zero by 2050.

Building Trades and Net-Zero Emissions

The construction industry has a vital role to play in helping Canadians meet their climate goals. Major construction projects will be required to transform and expand Canada's electricity system, build more energy-efficient buildings and communities, and decarbonize Canada's transportation infrastructure:

- Rapid expansion of non-emitting sources of electricity, including hydro, wind, solar, nuclear and geothermal energy.
- Construction of net-zero buildings, energy-saving retrofits of existing building stock, and investments in district energy and storage systems.
- Development of a decarbonized transportation infrastructure with expanded urban transit, electric vehicle charging stations, and much better inter-urban rail service.

All this construction will require hundreds of thousands of unionized skilled trades workers, from all specializations: masons, boilermakers, pipefitters, insulators, electrical workers, glaziers, HVAC, linemen, ironworkers, and many more. This report catalogues the investments required in each of these three main areas discussed above, and estimates their impacts on employment for building and construction trades.

This new report updates estimates of job opportunities for building trades workers, initially outlined in the Columbia Institute and Canada's Building Trades Unions' 2017 report, *Jobs for Tomorrow* (Bridge and Gilbert, 2017). Based on forecasts of the pace of the transition to renewable energy systems at the time, that report projected an aggregate total of 3.3 million new job-years of employment arising from energy transition investments to 2050. However, the pace of change in energy and related systems has accelerated faster than expected. Indeed, tens of thousands of those predicted jobs are already being realized today.

This accelerated pace of change has motivated us to update the title of the present report, which we have titled *Jobs for Today*. As will be documented in detail, the scale of job creation arising from the energy transition has expanded dramatically: this new report projects total employment gains that are two to three times larger than first projected in the 2017 report. Supported by strong investment, training programs, and strong protections for wages and job security, it is clear the energy transition will contribute to a positive and prosperous future for the building trades.

Jobs for Today utilizes previously published research findings regarding the employment content of investments in the three major categories of work considered: renewable energy expansion, energy conservation in buildings and communities, and non-emitting transportation infrastructure. We use accepted economic methodology to estimate the employment gains for construction trades workers from the investments in each of these areas needed to meet net-zero targets.

Across those three broad categories of energy transition investment, we project that a total of between 6.3 million and 9.5 million new job-years of work[1] for construction and building trades workers will be created, from now until 2050 (Canada's net-zero deadline). While construction projects inevitably involve fluctuating levels of employment through cycles of construction and completion, this new work represents the equivalent of 235,000 to 350,000 new ongoing jobs on average over this period — representing a 20 to 30% increase in the existing construction workforce. In addition to jobs in project construction, we expect the creation of another 60,000 to 90,000 ongoing positions in operational and maintenance roles in new facilities and projects in the electricity industry resulting from this transition – and thousands more operating roles for unionized skilled trades workers in energy-efficient buildings and transportation. Table 1 summarizes these expected impacts.

TABLE 1
Overall Employment Effects of Net-Zero Transition Investments 2024 to 2050

	LOW CASE	HIGH CASE
Construction (000 job-years)		
Clean Energy Supply and Infrastructure	2067	3101
Energy-Efficient Communities	2988	4482
Decarbonized Transportation	1270	1906
TOTAL	**6326**	**9489**
Operation (000 jobs)		
Clean Energy Supply and Infrastructure	60	90

Source: Calculations as described in text.

In sum, the shift to a net-zero economy, supported by massive investments in renewable energy, energy conservation and sustainable transportation, represents an unparalleled economic opportunity for building trades workers. Indeed, the demand for skilled construction labour arising from these investments will be so strong that significant attention and resources will need to be dedicated by governments, employers, educational institutions, and trade unions to training, recruitment, and retention efforts, just to meet the surging labour needs of this transition. Arguments that decarbonization and the energy transition somehow threaten the livelihood of building trades workers (and other workers in Canada) are in fact exactly opposite to the bright opportunities that lie ahead.

[1] A "job-year" refers to enough work for one person to work full-time for one year, as explained below. For construction trades we assume an average of 1500 on-site hours per worker per year.

Mobilizing for the Greater Good

Canada is actively participating in the global effort to reduce greenhouse gas emissions. The challenge of retooling our energy sources, our communities, and our transportation systems is massive. However, history offers a powerful precedent. To address the crisis of World War II, the government made significant new investments in Canada's industries, including construction. This effort ended the Great Depression, created hundreds of thousands of new jobs, and laid the foundation for Canada's post-war recovery. It further facilitated the rapid expansion of unions and rapid increases in workers' wages in the years following the war (Klein, 2020).

We face a comparable historic challenge today: to mobilize massive resources (human, technological, and financial) to defeat a profound threat facing our society, our economy, and our future. Without skilled trades workers to build the energy systems, energy-efficient buildings, and transportation infrastructure needed for this energy transition, we won't succeed. And these investments in renewable energy and energy efficiency must be linked to specific, enforceable commitments to create *good* jobs, with top-class skills and qualifications, good wages and benefits, and union representation.

Ultimately, it is trades workers who will build the structures and facilities needed for the net-zero transition in Canada. Recognizing their needs for quality, stable jobs with good pay and benefits is an integral part of moving towards our collective climate goals.

However, workers' trust in the ability of government to help them navigate economic transitions—by providing financial buffers, new job creation, and appropriate training opportunities—has been eroded by past experience. Shutdowns of oil refineries, shipyards, chemical plants, sawmills and pulp mills have too often resulted in workers bearing more than their share of the economic burden of transition. Too often workers have been abandoned. Major macroeconomic and trade policies have also had similar negative effects on labour. For example, the 1989 Canada-U.S. Free Trade Agreement and, subsequently, the North American Free Trade Agreement, resulted in deindustrialization and a widespread loss of well-paying jobs (especially in manufacturing).

We can and must avoid these mistakes of the past, as we prepare to manage the coming energy transition – and make the most of the economic opportunities it will open up. This requires government to engage with the labour movement in a meaningful way. Workers and their unions must play a full role in managing the energy transition. They must have the power (including through collective bargaining) to set and enforce strong standards for job security, compensation, safety, and training in the new jobs that will be created.

> Building a sustainable economy means not only recognizing and acting on the urgency of climate change, but addressing workers' needs. Working together, we have the opportunity to ensure the federal government takes steps to support workers... thoughtful planning and government supports are incredibly important."
>
> — Sean Strickland, CBTU executive director

The Sustainable Jobs Plan

There is already evidence that the employment opportunities associated with the energy transition are being realized. To support the coming shift to new work in renewable energy, energy conservation, and sustainable transportation and infrastructure, the federal government adopted an interim Sustainable Jobs Plan in 2023. That was followed by Bill C-50, the Canadian Sustainable Jobs Act, passed by the House of Commons in 2024. Informed by principles embraced by the International Labour Organization, the Act offers a framework for reaching a prosperous, post-carbon future that won't leave Canadian workers behind.

In the words of the Pembina Institute, the Sustainable Jobs Act will help "ensure that workers and communities are at the table, not on the menu" (Gordon et al., 2023).

Canadian unions, including the building trades, are now working with the federal government to establish the Sustainable Jobs Partnership Council (SJPC). Bill C-50 also requires the federal government to track the various actions taken to support workers, promote sustainable jobs, and establish a Sustainable Jobs Secretariat to support implementation.

These are promising steps. And the labour movement is continuing to work to make sure the federal government lives up to its commitment to provide strong support for workers through the energy transition – and ensure that commitment carries forward through future elections and potential changes in government.

PHOTO ANDREW ANGELOV/SHUTTERSTOCK

> "The Government of Canada understands a 'sustainable job' to mean any job that is compatible with Canada's path to a net-zero emissions and climate resilient future. The term 'sustainable jobs' also reflects the concept of decent, well-paying, high-quality jobs that can support workers and their families over time and includes such elements as fair income, job security, social protection, and social dialogue."
>
> — 2023-2025 interim Sustainable Jobs Plan

The Training Challenge

Many of the new jobs created in the transition to a net-zero economy will require new knowledge, skills and competencies to meet the requirements of net-zero construction methods, and safely and efficiently build new renewable energy and transportation infrastructure.

To provide the skilled workforce needed for the coming investments in renewable energy, energy-efficient buildings, and transportation infrastructure, the federal, provincial and territorial governments must invest much more in training qualified Red Seal construction workers.

This will require more funding for union and college training schools, tax credits to encourage training investments by employers, stronger commitments to apprenticeship targets, and better support so apprentices can afford their training.

Because apprenticeship and related construction training is largely provided by the provinces and territories, the federal government will need to work closely with them to provide the financial and policy support needed to make this happen.

Ensuring the Energy Transition Produces Good Jobs

Without doubt, the energy transition will stimulate major job-creation for unionized skilled construction workers. Job opportunities across all building trades will be opened up thanks to dozens of major capital investments. The quality of those jobs is a major concern for building and construction workers. We must ensure the labour standards built up through decades of trade unions, collective bargaining, and community and policy advocacy are sustained and further improved in the growing renewable energy and energy conservation industries.

By virtue of the large public sector role in energy transition investments (including direct public ownership of energy utilities in many provinces, and public co-investment or fiscal support for other renewable energy initiatives), there is ample scope for attaching strong labour conditions and standards to these new projects.

There are many precedents for requiring unionization and high labour standards in publicly funded construction projects. Building trades unions and community allies pioneered the use of innovative community benefit agreements (CBAs). CBAs compel contractors at large construction and infrastructure projects to offer good wages and benefits, apprenticeship and training opportunities, and targeted opportunities for disadvantaged communities (such as indigenous workers, women, and workers of colour). Successful examples include the B.C. Infrastructure Benefits (BCIB) program (James, 2020), which ensures that labour on publicly funded infrastructure projects is union-represented and paid prevailing wages and benefits. Similarly, building trades unions have negotiated numerous community benefit agreements as part of infrastructure projects in Ontario (Galley, 2015) — guaranteeing prevailing wages, apprenticeship opportunities, and employment for young workers from disadvantaged communities.

The logic is clear: since these projects benefit from important fiscal and regulatory support from the public, strong provisions must be attached to ensure they generate maximum public benefits – including, first and foremost, high-quality union jobs. If public resources are going to be committed to these initiatives – rightly so, given their importance to long-run environmental and economic well-being – then it is reasonable to expect these projects to maximize the benefits to workers, communities, and the public interest.

By attaching conditions to public support for investment in energy transition, we will create not only more construction jobs, but better jobs.

PHOTO BANNAFARSAI_STOCK/SHUTTERSTOCK

3

PREVIOUS RESEARCH ON EMPLOYMENT EFFECTS OF THE ENERGY TRANSITION

Thanks to major private and public investments to reduce carbon emissions in all regions and industries in Canada, the labour market is already benefiting from significant new employment across a wide range of sectors and occupations. These include jobs in renewable energy systems (such as wind, solar, and geothermal energy). They also include jobs in new construction and retrofits of buildings to improve energy efficiency and reduce pollution. More jobs are being created in manufacturing the components and machinery used in renewable energy systems, and/or components and machinery that use renewable energy as a power source (such as electric vehicles and components).

A growing body of economic research confirms the growing importance of these jobs in Canada's broader economy and labour market. This section of our report will review the methodology and key findings of previous research on the scale, location, and occupational composition of new jobs related to the energy transition. The main focus of our report is on the specific employment benefits of this transition for building and construction trades. Nevertheless, it is useful to place our research in the context of the broader economic and labour market footprint of investments in renewable energy and emissions reduction, and to review the methodology and data sources used in previous research.

This section of the report summarizes previous research on the job-creating effects of renewable energy projects and other dimensions of the energy transition. We consider several studies documenting the employment impacts of renewable energy and related investments in Canada, and then several international reports on parallel trends in the global economy.

Previous Canadian Studies

- In a report for the Pembina Institute, Kaddoura et al. (2020) forecast potential new employment in four areas of emissions-reducing investment in Alberta over a ten-year period. The report estimated that more than 67,000 new jobs would be created in the province over a decade, driven by investments in four broad areas: renewable electricity generation, public transit and electric vehicle infrastructure, energy efficiency improvements in buildings and industry, and a program of remediation and methane reduction in oil and gas extraction facilities. That is enough new employment to offset two-thirds of all existing jobs in the province's petroleum industry.
- In neighbouring B.C., Lee and Klein (2020) estimated the employment impacts of investing 2% of provincial GDP in renewable energy and energy conservation initiatives (as proposed by Nicholas Stern in his landmark international report, 2006). They projected an investment programme of this scale would create and maintain 42,000 jobs in the provincial economy – far more than are presently supported by fossil fuel industries in that province. Due to the higher labour content of alternative energy and related products, shifting investment from fossil fuel production to renewable energy, energy efficiency, and decarbonized transportation systems generates net employment growth.

- Another provincial-focused study was published by the Ecology Action Centre (2019) for Nova Scotia. This research simulated the employment impacts of a programme to reduce provincial GHG emissions by 50% by 2030, in line with Canada's Paris Agreement commitments. Investments in renewable energy generation, energy efficiency, and public transit would support the creation of 15,000 net new jobs in Nova Scotia – and thousands more spin-off jobs elsewhere in Canada. The province would benefit from expanded GDP growth, enhanced tax revenue, and $675 million in additional annual personal income (measured in real 2019 dollar terms).
- A project initiated by the David Suzuki Foundation modeled the investment and technological dimensions of an ambitious effort to expand and decarbonize Canada's electricity system, through the rapid deployment of renewable power sources and conversion of heating, transportation, and industrial energy uses to electric power (Thomas and Green, 2022). To decarbonize existing electricity generation (by 2035, as per existing federal standards), and then meet the extra demand for electricity from the spread of emissions-free technologies in other sectors (such as transportation and heating), an 18-fold increase in total wind and solar generation will be needed by 2050. The report also estimated the employment effects of this investment programme. The analysis considered only direct construction and operation jobs associated with economy-wide electrification; it did not include indirect (upstream) or induced (downstream) spin-off jobs (such as jobs in manufacturing activities spurred by electrification), nor jobs in other emerging technologies (such as battery storage). In this regard, the forecast is very conservative. Some 1.5 million person-years of work will be created in the construction, operation, and maintenance of new wind and solar generating capacity, and associated battery storage. That translates into about 75,000 ongoing new jobs related to electricity generation and infrastructure over the first 15 years of investment. Proportionately, the largest job growth is experienced in Alberta and Saskatchewan, where the GDP and employment gains from electrification are especially significant.
- The first edition of this report, *Jobs for Tomorrow* (Bridge and Gilbert, 2017), focused on the impacts of the energy transition for employment among building and construction trades. That report catalogued likely investments across three broad categories of emissions-reduction activity: renewable energy generation and transmission; building energy efficiency and district energy systems; and transportation. It then estimated employment impacts of those projects on the basis of previously published employment coefficients. Across those three categories of activity, the report projected that a total of 3.3 million person-years of employment would be created in construction trades by 2050. Two-thirds of that growth was concentrated in non-residential construction (as builders updated existing structures, and built new ones, to incorporate rigorous new energy efficiency standards). Clearly, the massive investments required to facilitate the energy transition in Canada and meet international emissions-reduction commitments imply very strong ongoing demand for construction trades work.[2]

[2] As described in detail below, this new edition of the report projects even larger job-creation from the energy transition, given the accelerating pace of new investments in renewable energy, energy conservation, and non-emitting transportation.

PHOTO JON BILOUS/SHUTTERSTOCK

- A deeper dive into the impacts of the energy transition for one specific trade – electricians – was undertaken by Electricity Human Resources Canada (2023). This report compiled estimates of new jobs arising from the expansion of renewable energy generation, along with transmission expansion and upgrades. The shift to renewable energy and broader electrification will accelerate demand for electricians considerably. The report projects net job growth of 12,000 positions in the five years ending in 2028. That is on top of the need to replace over 15,000 anticipated electrician retirements in the same period. There is no doubt that electricians are an occupation with increasing employment opportunities in coming years. The report urged additional investments in training and apprenticeships by employers and governments.

- Another specific construction trade that will experience new job opportunities from the growing focus on energy conservation is insulators. Calvert (2023) relates the experience of Local 131 of the insulators' union (in New Brunswick), which pro-actively undertook an independent program of free energy audits for owners of commercial and industrial buildings. The goal was to highlight for building owners the operational and cost savings from upgraded insulation and energy conservation upgrades. The campaign was successful and generated significant amounts of new work for members of the union. Other insulator union locals have also launched industry awareness programs to promote energy retrofits, similarly generating new work opportunities for union members (Calvert and Tallon, 2016; Calvert, 2019).
- Clean Energy Canada has published successive reports estimating employment growth in what it calls Canada's "clean energy economy" (Clean Energy Canada, 2019, 2021; Navius Research, 2019). The research estimated that as of 2020 some 430,000 jobs already existed in a broadly-defined clean energy sector: including renewable energy production and distribution, construction and retrofit of energy efficient buildings, clean energy transportation, and specialized clean energy industries (such as low-carbon machinery, and emission detection and control). That was an increase of 130,000 jobs (or over one-third) from 2017. And under the climate policy outlook adopted by the federal government, clean energy employment was forecast to grow by another 200,000 positions by 2030 – outweighing a projected decline in fossil fuel-related employment of 125,000 positions over the same time. Clean Energy Canada's modeling confirms net gains in employment from the transition to clean energy will be experienced in all parts of Canada, including in fossil fuel-producing provinces.
- A separate report prepared for Clean Energy Canada by Dunsky Energy Consulting (2018) considered the macroeconomic and employment effects from energy efficiency improvements, as mandated in the previous federal-provincial Pan Canadian Framework on Clean Growth and Climate Change. The Dunsky modeling traces several channels of impact from the energy efficiency provisions of that federal-provincial agreement: including energy efficiency standards in new buildings, retrofits of existing buildings, new energy efficiency standards in appliances and equipment, and industrial energy efficiency. Those efficiency improvements were expected to meet 25% of Canada's Paris commitments for emissions reduction. The economic stimulus from energy efficiency comes from two major channels: increased demand for efficiency-related goods and services (including building construction and retrofit), and reallocated savings on energy costs by consumers and businesses (which then redeploy their energy savings into other forms of expenditure). Those effects more than offset the effects of reductions in energy production resulting from enhanced energy efficiency. The efficiency improvements were forecast to produce an average net gain in employment of 118,000 over a 13-year period (to 2030), and a 1% increase in national GDP over the baseline trajectory.
- Xuereb and Hillel (2023) simulated the employment impacts of an ambitious programme of proposed investment in a range of energy transition and conservation initiatives, worth a cumulative total of $287 billion over five years. (The details of this investment programme are described in Lee et al., 2023.) Based on an allocation of investment spending across different projects in each category, this research projected that investments on this scale would support between 187,000 and 226,000 new jobs by the fifth year of the programme. The 'low' estimate

includes only direct and supply-chain jobs associated with the new investments; the 'high' estimate includes downstream jobs in consumer industries, stimulated by the increased incomes (and hence consumer spending) generated in the renewable energy and related industries.

- Researchers at RBC mapped the intersectoral employment transitions and associated skills and training requirements resulting from the shift to a net-zero economy in Canada (Guldimann and Powell, 2022). Like other research, this study projected enormous job-creation potential in clean energy, infrastructure, energy conservation, and related fields. The study forecasts between 235,000 and 400,000 new jobs will be created in occupations whose tasks and qualifications have changed because of the energy transition. That total job-creation would be even larger if Canada stepped up its investments in new energy systems; the report estimates $60 billion per year in incremental capital spending is necessary to meet climate targets. New work in these evolving and emerging occupations will substantially outweigh the gradual decline in employment in traditional fossil fuel energy production and use. RBC expects existing skills shortages for construction, managerial, technical, and manufacturing workers to become even more pressing as the energy transition gathers pace. The report calls for urgent action by governments, employers, and educators to prepare for the coming surge in demand for skilled workers in fields related to sustainable energy.
- The Centre for Future Work developed a detailed breakdown of the various channels through which employment adjustments can be facilitated during a gradual phase-out of fossil fuel production and use, and corresponding ramp up of renewable energy and energy conservation projects (Stanford, 2021). In this forecast, a gradual phase-out of direct fossil fuel-related employment (estimated at 159,000 jobs across Canada in 2019, or 0.9% of total employment) would be possible over a 20- or 25-year phase-out (consistent with reaching net-zero targets by 2050), with no involuntary layoffs. Much of this transition would be facilitated through retirements, since workers in fossil fuel industries are older than the economy-wide average. New jobs created in renewable energy and other sustainable activities (including amelioration of former fossil fuel production sites) would be important in smoothing the transition. But there are many other pathways through which fossil fuel jobs can also be replaced, including through job-creation in other sectors (such as construction, non-fossil minerals, transportation, and private and public services). Supports for the roughly 4000 non-retiring fossil fuel workers who would need redeployment each year (according to that phase-out timeline) could include income insurance programs, retraining supports, relocation incentives, and small business start-up grants. Successful transitions in other fossil fuel phase-outs (including Germany's gradual shut-down of black coal mining, or Ontario's phase-out of coal-fired electricity) prove that gradual, supported transitions of this sort can be accomplished without lay-offs – so long as timelines are long and gradual, and affected workers are supported with a portfolio of adjustment supports.

International Research

All countries are grappling with the economic and labour market issues related to the energy transition, and there is now a large body of international research attesting to the powerful employment-creating effects of major renewable energy and emissions-reduction investments. Here we summarize a few of the more notable international research efforts:

- The International Energy Agency (2021) has developed a detailed global forecast of employment opportunities generated by worldwide investments to meet commitments to net-zero emissions by 2050. These investments will involve trillions of dollars of new capital spending on renewable energy systems, transmission facilities, energy conservation, and related construction work. These investments would create 30 million new jobs globally by 2030: 14 million positions in clean energy systems, and 16 million in construction and retrofit work. That will far more than offset the 5 million jobs expected to disappear from the fossil fuel sector over the same period, as fossil energy is gradually phased out. The IEA forecast does not include new jobs in related manufacturing activity, nor the spillover employment (through upstream supply chains and downstream consumer industries) spurred by these enormous investments.
- Annual research has been published for a decade by the International Renewable Energy Agency (IRENA), documenting the steady growth of global employment in renewable energy activities. Its most recent report (2023) tallies 13.7 million renewable energy jobs worldwide in 2022, up 8% from the previous year – and almost double the number 10 years earlier (in IRENA's first report). Two-thirds of those jobs are in Asia, and over 40% are in China alone (which leads the world in new solar and wind installations). The biggest single sector for renewable energy employment is solar photovoltaic power investments, supporting 4.9 million jobs worldwide in 2022. But the employment benefits of renewable energy are widespread across several other sectors, including wind, hydro, bioenergy, geothermal, and heat pumps. The IRENA tally does not include jobs in energy conservation or upgrading work, nor jobs in manufacturing renewable energy equipment. IRENA's research highlights especially strong job-creation potential in decentralized projects, such as small-scale hydropower and decentralized solar installations.
- A project to catalogue the global employment benefits from renewable energy and emissions-reduction investments in five case-study countries was undertaken by the United Nations International Development Organization and the Global Green Growth Initiative (2015). This project estimated the macroeconomic and employment effects of an investment programme worth 1.5% of national GDP in Brazil, Germany, Indonesia, South Africa, and South Korea. The investment was divided between renewable energy projects and energy conservation and emissions reduction projects. The employment impacts of these investments considerably outweighed

employment declines associated with fossil fuel production. The employment benefits of energy transition investments were greater in developing countries (due to lower wage levels and greater labour-intensity of production methods). Final employment created for each $1 million (U.S.) of investment ranged from 9.5 jobs in Germany to over 100 in Indonesia.

- An especially ambitious modeling exercise was undertaken by Jacobson et al. (2017) to simulate a road-map for steep emission reduction (consistent with limiting global warming to 1.5 degrees C) in 139 countries by 2050. The research first compiled a plan for the scale and composition of investments required to achieve such emissions reduction. It then estimated the combined employment effects of those investments, across all 139 countries included in the project, on the basis of employment coefficients for specific types of investment spending and energy production. It anticipated a total of 52 million new jobs to be created by those investments over the period to 2050, almost double the 27 million jobs expected to disappear from fossil fuel production and use over the same period.
- A team at the University of Massachusetts Amherst has developed a template methodology for estimating the employment gains from green energy investment plans in various U.S. states, and nationally. One recent application of that template is reported by Pollin et al. (2023), describing the estimated employment impacts of three major energy-related initiatives undertaken by the former Biden administration: the Bipartisan Infrastructure Legislation, the Inflation Reduction Act, and the CHIPS Act (Creating Helpful Incentives to Produce Semiconductors). Applying employment input coefficients across all industries affected by the various measures in those Acts, and capturing indirect (supply chain) and induced (consumer spending) effects, the research predicted an average of 2.9 million new jobs over the first five years of the measures. The construction sector alone was expected to add almost one-half million new jobs under the combined effect of the three bills.
- The C40 network of mayors of major global cities (C40 Cities Climate Leadership Group, 2021) modeled the employment impacts from a proposed major green investment programme for 96 cities around the world – recognizing that large urban centres face particular challenges and opportunities in transitioning to renewable energy. Their green recovery scenario sees over 50 million net new jobs created in those city regions by 2030, powered by capital investments in renewable energy systems, urban transit, conservation and building retrofits, and other emissions reduction projects. Each $1 million U.S. in green capital spending supports 10 to 21 job-years of new employment – considerably more than conventional carbon-intensive projects and energy systems. The faster the commitment to renewable energy investments, the larger are the job benefits: in an accelerated green investment scenario (which would speed up capital spending by 2 years), some 80 million net new jobs are created in the 96 cities in the same time frame. As a case study, the C40 work also featured a focused analysis of investment and employment opportunities arising from the energy transition in Canada (Berensson et al., 2021). Their analysis forecast up to 1.8 million new person-years of employment in Canada arising between 2020 and 2030 from a major emissions-reduction investment scheme in 12 large cities, including construction, manufacturing, and operating and maintenance roles. Building construction and retrofits accounted for over half of that total.

In sum, there is a growing body of credible, peer-reviewed research confirming the net employment benefits of the energy transition, in both Canada and globally. Consistent themes that emerge from this research include:

- Meeting net-zero targets will require enormous investments in renewable energy production and distribution, energy conservation, sustainable transportation, and related infrastructure.
- Those investments require very strong labour inputs, and will stimulate the creation of large numbers of new jobs, with a measurable positive impact on labour market performance – in some cases leading to shortages of labour with relevant skills.
- The new jobs created by renewable energy and emissions-reduction projects will more than outweigh the gradual decline in employment in fossil fuel industries, as they are phased out.
- The energy transition will thus increase net labour demand: there will be more work in a net-zero economy, than in one powered by fossil fuels (thanks to the higher labour intensity of renewable energy production, energy conservation, and related activities).
- Construction work (on renewable energy projects, transmission and distribution infrastructure, energy conservation and building efficiency, sustainable transportation facilities, and more) will constitute a substantial portion of the new work arising from the energy transition.
- Most of the studies referenced above follow a broadly similar methodology: identifying an inventory and timeline for investment projects related to the energy transition, and then estimating their employment effects on the basis of applied employment coefficients. (As described in more detail in the next section, this report follows a similar approach.)

To be sure, there are significant employment transition challenges associated with the gradual phase-out of fossil fuel use (in line with national and international climate commitments).
But the scale of the investments required for decarbonization, combined with the fact that most renewable energy and emissions-reduction projects are more labour-intensive than previous fossil-based systems and technologies, means the net employment effects of the energy transition will be strongly positive. Highlighting the net employment gains of renewable energy investments will be vital for strengthening the social consensus in favour of decarbonization and meeting Canada's international climate commitments. And paired with focused transition supports for fossil fuel workers (including early retirement, retraining, relocation, and income insurance programs), the new jobs in renewable energy and emissions reduction projects can ensure that the net-zero economy is characterized by abundant employment opportunities, as well as a safer environment.

4

METHODOLOGY

This report focuses on the implications for labour demand for skilled building trades workers arising from Canada's energy transition. It updates and refines employment projections published in our initial paper, *Jobs for the Future* (Bridge and Gilbert, 2017). The general methodology followed here is consistent with the approach commonly utilized in most previous research on employment impacts of renewable energy and emissions-reduction investments and policies (summarized in the previous section). First, we compile a consolidated inventory of the major investments announced or expected in coming years, as a result of Canadian policy commitments to emissions reduction, changes in technology and relative costs, and the evolution of consumer demand. Then, we develop estimates of the demand for construction and building trades workers arising from those investments, applying employment input coefficients from official Statistics Canada data sources and previously published literature.

Specific methodological features of the report are listed as follows:

Scope: The goal of this report is to focus on employment impacts of the energy transition for one set of occupations: skilled building and construction trades. For that reason, we focus our attention on the capital and construction phases of energy transition investments. We do not include spin-off jobs in manufacturing and service sectors arising from these investments. We cover three broad categories of energy transition investments:

- Renewable energy production and transmission.
- Investments in new buildings, improved energy efficiency in existing buildings, and construction of local and district energy systems.
- Sustainable transportation infrastructure.

Direct and Indirect Employment: Many of the studies reviewed above consider both the direct jobs associated with energy transition investments, as well as indirect or spin-off jobs generated elsewhere in the economy as a result of that activity. In general, two broad categories of spin-off job-creation can be considered:

- Supply-chain or upstream work, located in the myriad of suppliers (for materials, parts, equipment, and services) which provide inputs to the initial direct projects. This is usually referred to as indirect activity.
- Downstream consumer spending effects, reflecting new work and activity stimulated by workers in direct jobs spending their new incomes. This is usually referred to as induced activity.

Including indirect and induced effects means that the overall employment impact of initial investments (and continued production after those investments are completed) is much larger – often two or three times larger — than the direct work associated with the initiating project. (The amplified spin-off impact of those initial investments on total employment is thus called a 'multiplier.'[3])

However, given our focus on construction and building trades work, we have focused only on the direct jobs associated with those investment and construction projects. Our employment estimates are thus capturing just the first step in an amplified employment-generation process that will reach upstream and downstream into all sectors of Canada's economy. In this regard, the employment estimates presented here should be understood as a conservative, first-order perspective on the initial direct job-creation impacts of the energy transition. They considerably underestimate the total employment impacts of energy transition investments, because we have excluded those indirect and induced impacts.

[3] The existence and strength of those multiplier effects depends on many factors, including whether supply-chain and consumer industries are located in the domestic or foreign economies, the existence of unemployment (without which spin-off employment impacts will be diminished), and the degree to which various tasks associated with the initial project are performed in-house by the primary producer or outsourced to independent suppliers.

Jobs and Job-Years: Construction work rises and falls in line with the timing of various projects. Those projects are not necessarily aligned in a steady stream of activity (although to the extent that major investment programmes can be scheduled to smooth fluctuations in activity, the efficiency of the overall programme would certainly be enhanced). Our estimates are based on an inventory of cumulative investment out to 2050, in each of three broad categories of energy transition work. Applying labour input coefficients to that investment programme then generates an estimate of the total labour input generated by those projects over the length of the forecast. That labour input is most appropriately measured in 'job-years': that is, work that keeps one person employed for one year. At times we convert those estimates of job-years into an average number of ongoing jobs over the forecast period, by simply dividing the total job-years by the time frame of the forecast (26 years, stretching to 2050). It should be kept in mind, however, that the actual number of jobs in existence in any particular year will rise and fall around that average, depending on fluctuations in investment activity.

Job Definition: Most employment projections assume the existence of a standard full-time-equivalent employment pattern, based typically on a 40-hour workweek (or 2080 hours of work over a year). This approach, however, does not accurately describe the nature of most work for construction and building trades workers. Because most construction projects last for some months, and then workers are redeployed to other projects (usually with some downtime between projects), a more accurate benchmark for construction work is 1500 hours per year. For construction work, therefore, where the employment estimates generated below are based on labour input parameters defined in hours of work, we convert those to job-years on the basis of 1500 hours per job-year. Moreover, where labour input parameters are defined in published work on the basis of a standard 2080-hour FTE benchmark, we adjust those parameters to integrate the 1500-hour-per-year assumption.

Nominal and Real Values: Some commitments to future investments are stated in nominal (current) dollar terms. Because of inflation over time, the real economic impact of those investments (measured in terms of real variables such as quantity of output or employment) will diminish. In contrast, some investment commitments are defined in terms of real (inflation-adjusted) dollars, or in physical terms (such as a certain quantity of electricity generating capacity, or miles of high-speed rail track, etc.). In those cases, the labour input coefficients would be unaffected by inflation. Where appropriate and possible, therefore, timelines for projected nominal investments are deflated to 2023 Canadian-dollar terms, on the assumption of 2% annual inflation (consistent with the Bank of Canada's long-term inflation target). Labour input coefficients are also adjusted, where appropriate, to be expressed in 2023 Canadian-dollar terms (this is especially relevant for labour input parameters obtained from published international research, which are often expressed in U.S. dollar terms).

Labour Input Parameters: Converting projected investments (in renewable energy, buildings, and transportation) into labour demand requires estimates of the amount of labour associated with a given quantity of activity. Labour input parameters can be developed on the basis of datasets linking total output of an industry, value-added, and employment. Most of the previous research summarized in the preceding section relied on parameters of this sort. Of course, in the real world these labour input parameters will change for various reasons, including changes in technology and productivity, changes in relative factor prices, and evolution of supply chains. Short of a complete dynamic general equilibrium analysis to capture all of these factors over time, our use of assumed employment coefficients is both pragmatic and consistent with previous published research.

The labour input parameters used in this report are collected from a range of datasets and previous research. A catalogue of these

PHOTO JACQUES TARNERO/SHUTTERSTOCK

parameters is provided in appendix Table A1. Many of those sample parameters were attained from the research studies surveyed in the previous section. Others were attained from other reports and datasets. Of particular note is the set of sector-specific direct employment coefficients published by Statistics Canada, covering a set of about 250 Canadian industries, based on the agency's detailed input-output system.[4] Those parameters are useful because they reflect Canadian conditions, and are relatively up-to-date.

Given uncertainty regarding precise employment input parameters, we have used the following methodology to generate a range of feasible coefficients. First we adjusted coefficients attained from the published literature for inflation, for the Canada-U.S. exchange rate, and (for construction work) for our practice of defining a job-year as 1500 hours of work. We then calculated an average of the labour input coefficients for each technology or activity modeled below (with nominal dollar coefficients all expressed in 2023 Canadian-dollar terms, and construction coefficients expressed in 1500-hour FTEs).[5] We then computed a range of labour input coefficients for our job-year simulations, bounded by a low labour input coefficient (equal to 80% of that mean) and a high coefficient (equal to 120% of the mean). This approach thus incorporates the inherent uncertainty regarding labour inputs in all of these activities, as both technology and economic conditions evolve in the future.

4 Statistics Canada also publishes indirect and total job multipliers, which take into account indirect and induced employment effects. For reasons explained above, we use only the direct employment coefficients.

5 Three published coordinates were excluded from this averaging process, since they were outliers (far higher) relative to the overall tendency of other estimates, and hence would have skewed our projections: Jacobson et al's (2017) labour input coefficient for geothermal construction, the IEA's (2020) labour input coefficient for building construction, and Aldieri et al's (2020) coefficient for operating jobs in wind power projects.

Table 2 summarizes these labour input parameter ranges for each of the major categories of activity simulated in the report.

TABLE 2
Labour Input Coefficients

CATEGORY OF ACTIVITY	UNIT OF MEASURE	LOW	HIGH
Renewable Energy Generation: Construction			
Hydroelectric	Job-Years per MW	12.6	18.9
Wind		3.6	5.4
Solar		20.1	30.1
Nuclear		13.3	20.0
Geothermal		6.4	9.6
Renewable Energy Generation: Operation			
Hydroelectric	Ongoing Jobs per MW	0.15	0.22
Wind		0.31	0.47
Solar		0.35	0.53
Nuclear		0.48	0.72
Geothermal		0.50	0.76
Construction and Infrastructure Activity			
Energy Efficient Buildings	Job-Years per $M Cdn (2023)	4.3	6.5
Urban Transit		4.8	7.2
High-Speed Rail		5.1	7.6
EV Charging	Job-Years per 1000 Chargers	37.4	56.0

Source: Calculations from published sources as described in text.

PHOTO PLAMEN GALABOV/SHUTTERSTOCK

Job-Year Forecasts: The following sections generate forecasts of the new investment and construction activity expected in each of three major areas arising from Canada's net-zero commitment by 2050: renewable energy production, energy conservation in buildings and communities, and non-emitting transportation infrastructure. The resulting forecasts (which are measured alternately in physical terms, such as new MW of electricity generation capacity, or monetary terms, such as billion dollars of investment) are then multiplied by the low and high labour input coefficients for each respective category. This generates an estimate of the total number of job-years created by these activities over the period ending in 2050. This can then be converted into an average number of jobs over that period by dividing by 26 (the number of years between 2024, our starting point, and 2050). The actual number of jobs in each year, of course, will vary according to the timing of the expansion program in each category of activity. Keep in mind, these refer only to direct jobs in construction and (in some cases) operation of relevant facilities. We do not consider the indirect (upstream supply chain) and induced (downstream consumer spending) employment effects of these investments, since we are primarily concerned here with the opportunities arising from the energy transition for building and construction trades workers. However, the ultimate impact of the energy transition on overall economic and employment activity in Canada will be far larger than these estimates suggest, as those broader spillover effects are experienced.

PHOTO PEOPLEIMAGES.COM - YURI A/SHUTTERSTOCK

5

EMPLOYMENT GAINS FROM NEW PROJECTS

While the commitment to mitigate and respond to the climate crisis is a massive challenge, it also presents a historic opportunity for the creation of high-quality, family-supporting jobs. The investments and jobs associated with the energy transition will play a vital role in underpinning economic growth for decades to come. This economic engine will be all the more important in light of U.S. President Donald Trump's aggressive trade actions against Canada (and other counties). His tariffs and other measures are creating deep uncertainty among companies that export to the U.S. market. In that context, strengthening investment and job-creation in renewable energy, energy efficient buildings, and transportation infrastructure will be all the more important. All these activities focus on Canadian investments and Canadian consumers, not export markets. Hence they are relatively protected against the fallout from Trump's actions, and will thus play a vital role in stabilizing and supporting Canada's macroeconomy in the challenging period ahead.

Jobs for Today forecasts the new employment resulting from the investments necessary to meet Canada's 2050 net-zero commitment. We consider three major aspects of the energy transition: renewable energy supply, energy efficient buildings and related facilities, and sustainable transportation infrastructure.

- **Renewable, non-polluting sources of electricity generation**, including hydro, wind, solar, nuclear, and geothermal energy, as well as battery storage systems and transmission facilities.
- **Energy efficient buildings and district energy facilities,** including new industrial, commercial, and institutional (ICI) construction, energy-saving retrofits of existing building stock, and development of connected district energy systems.
- **Non-emitting transportation infrastructure**, including construction of urban mass transit facilities (such as tracks, bridges, and subway tunnels), high speed rail, and the development of an infrastructure to support charging of electric vehicles.

Successfully building this infrastructure will require the expertise of the full array of skilled trades occupations: pipefitters, insulators, boilermakers, glaziers, masons, HVAC workers, linemen, ironworkers, electricians, and many more trades. Across those major areas of investment, we estimate they will **result in 6.3 to 9.5 million job-years of work over the period to 2050 (equivalent to 235,000 to 350,000 jobs, on average, over that period). That represents an increase of 20-30% in total construction employment in Canada.** Some 60-90,000 additional and ongoing jobs will be created in operations and maintenance functions in these new facilities and projects.

Expanding and Upgrading Canada's Electricity System

Canada's electricity needs are growing. Population is part of that equation: Canada's population has been growing rapidly since the COVID pandemic (by over 3%, or 1 million people, in 2023 alone). Statistics Canada (2024b) projects that Canada's total population will likely exceed 50 million people by 2050. That is a 25 per increase over the current population, and will drive a significant increase in electricity demand. Ongoing economic growth also naturally entails greater electricity use in the future.

Another factor boosting electricity demand is the increasing electrification of all aspects of modern economic, industrial, and household life. Much of our previous reliance on combustion fuels will be replaced by electricity generated from low-emission sources. A similar shift is happening around the world – in homes and cars, schools and factories.

Pollution created by electricity generation in Canada is relatively low compared to many other countries. A big reason for this is our predominantly publicly-owned hydroelectric power assets, which account for close to two-thirds of total generation. Add in other emissions-free generation sources (including nuclear, wind, solar, and geothermal power), and fossil-free electricity generation already accounts for about 80 percent of total power supply.

However, in absolute terms, pollution from fossil-fuel-powered generating electricity in Canada is still massive. In 2022 (most recent data available), electricity generation produced 47 megatonnes of pollution: 6.7% of total Canadian emissions that year. Electricity generation thus ranked as the seventh largest source of our emissions. Greenhouse gas emissions from electricity have fallen by over 60% since 2008 (mostly thanks to the closure of coal-fired power plants in Ontario and Alberta). Shifting the remainder of fossil-fuel-fired electricity generation to renewable sources remains a crucial (and relatively cost-efficient) priority for overall decarbonization.

Our forecast of the future growth and evolving composition of Canadian electricity supply considers projections developed and reported by three different forecast agencies, each simulating the path to a 2050 net-zero scenario:

- L'Institut de l'énergie Trottier's (IET) *Canadian Energy Outlook 2021* (Institut de l'énergie Trottier, 2021) estimated total generation in 2050 of **1341 TWh.**
- The Sustainable Energy Systems Integration & Transitions (SESIT) group at the University of Victoria's Institute for Integrated Energy Systems has estimated in its 2022 *Shifting Power* report (Thomas and Green, 2022) total 2050 generation of **983 TWh.**
- The Canada Energy Regulator's 2050 Canada Net Zero scenario in its *Canada's Energy Future 2023* (Canada Energy Regulator, 2023a) report estimates total 2050 generation of **1360 TWh.**

We take the average of these three forecasts, and assume that total electricity generation will increase to 1228 TWh by 2050. That represents a 90% increase from 2022 generation. In other words, thanks to population growth, economic growth, and decarbonization, overall electricity production in Canada will almost double over the next quarter-century. At the same time, the existing 20% of electricity generation arising from fossil fuel combustion will need to be mostly replaced with non-carbon sources, to meet net-zero targets. All this will require massive investments in new generation capacity, transmission and distribution facilities, and new electricity-using equipment in homes, buildings, and industries. It will also power a substantial expansion of employment in the broader electricity sector.

Different electricity demand forecasts project differing mixtures of generation types, based on assumptions about technology, relative cost, and the regulatory and policy environment. Our simulations are informed by recent trends in wind, solar, nuclear and other categories of power generation. We emphasize technologies that have been proven viable in Canada or other jurisdictions, and are scalable within the time-frame to 2050.

This approach suggests a significant role for hydro, wind, solar, and nuclear in Canada's 2050 generation mix, with an emergent role for geothermal power. Smaller sources of generation may come from other sources in coming decades, including tidal power, biomass, and small amounts of combustion power (in a net-zero scenario, coupled with carbon capture and storage). We exclude these from the simulations below, given their small scale and unproven viability.

Table 3 provides a summary of our forecast of electricity supply in 2050.

TABLE 3
Forecast Electricity Generation by Source 2050

SOURCE	TERAWATT HOURS (TWH)	SHARE OF TOTAL
Hydroelectric	429.8	35.0%
Wind	429.8	35.0%
Solar	153.5	12.5%
Nuclear	122.8	10.0%
Geothermal	61.4	5.0%
Other	30.7	2.5%
TOTAL	**1228**	**100.0%**

Source: Calculations from sources as described in text.

PHOTO SHAWN.CCF/SHUTTERSTOCK

The following sections provide more detail on the growth trajectories, and resulting employment impacts, of the five largest sources of projected electricity supply in 2050.

Hydroelectric Power

We estimate that hydroelectric power will account for 35% of Canadian electricity supply in 2050. This is smaller than the current share of hydro power, for the simple reason that overall electricity supply will need to grow more quickly than hydroelectric power can expand. Faster growth in other sources, especially wind and solar energy, will carry the lion's share of total increases in supply.

In addition to expanding total hydroelectric generation, the aging of existing hydroelectric infrastructure is an additional concern. Over half of the hydroelectric dams in Canada were built before 1969 (Morgenroth and Bayliss, 2023). While dams generally last from 50 to 100 years, some are showing their age, particularly as weather events are becoming more extreme. Some older dams may simply be obsolete, ultimately replaced by new dams with higher outputs or other reliable power sources. However, a significant percentage of Canadian dams will require refurbishment or replacement by 2050.

Currently there is approximately 85,000 MW of installed hydroelectric capacity in Canada (WaterPower Canada, 2023), generating 394 TWhs of power in 2022 (Statistics Canada, 2022c). To produce the 430 TWhs of hydropower expected in our 2050 scenario, Canada would need to expand hydro generating capacity by 9% (assuming stable capacity utilization), representing a net 7,725 MW of new capacity. In addition, further investments will be required to maintain or replace aging or failing dam infrastructure. We assume that 5% of existing hydro capacity would need to be replaced outright by 2050, and another 10% would require significant refurbishment; we further assume that refurbishment requires half the total labour input of new construction. Together, this represents new work equivalent to construction of a further 8,500 MW of capacity, for a total investment of 16,225 MW of constructed or rebuilt capacity (equivalent to over one-quarter of Canada's existing hydro capacity).

Based on our survey of labour input coefficients from previously published literature (summarized in Table 2 above), this expansion will generate substantial new employment opportunities for construction and building trades workers. As indicated in Table 4, this expansion and refurbishment of hydroelectric capacity in Canada would result in between 204,000 and 306,000 job-years of construction employment. The net addition to hydro generating capacity would also support an additional 1150 to 1750 ongoing operation and maintenance (O&M) jobs, many of which will be filled by electricians and other specialized trades.

What is Net-Zero?

Achieving net-zero emissions means the economy has eliminated most greenhouse gas emissions; remaining small volumes of emissions are offset through actions such as tree planting. Achieving a net-zero economy is essential to limiting global warming and keeping the world safe and livable for our children and grandchildren.

Canada's Plan to Reach Net-Zero

The Canadian Net-Zero Emissions Accountability Act, which became law in June 2021, enshrines in legislation Canada's commitment to achieve net-zero emissions by 2050. The Act ensures transparency and accountability as the government works to deliver its targets. The Act requires public participation and independent advice to guide the Government of Canada's efforts (Government of Canada, 2024).

TABLE 4
Employment in New Hydroelectric Facilities

CUMULATIVE EXPANSION IN CAPACITY TO 2050: 16,225 MW		
	LOW	HIGH
Construction		
Labour Input Coefficient (JY/MW)	12.6	18.9
Job-Years (000)	204	306
Operation		
Labour Input Coefficient (Jobs/MW)	0.15	0.22
Jobs	1150	1750

Source: Calculations as described in text.

Sable Island Bank is only one of several potential sites in the region. Offshore wind could be for Atlantic Canada what oil was to Texas or hydro power to Quebec. We are talking here not of something incremental, but monumental."

— Catching the Wind: How Atlantic Canada Can Become an Energy Superpower (Nicholson, 2023, p.7)

Wind Power

Wind power generating capacity in Canada has grown dramatically in recent years, and that expansion is set to continue as the overall electricity system is both expanded and decarbonized. Indeed, wind power will constitute the largest single source of new electricity generation as the transition to net-zero continues.

Between 2014 and 2022, Canada added over 5,000 MW of net new installed wind power capacity (Natural Resources Canada, 2024a). This represented an expansion of over one-half. Total wind power generation more than doubled in the same time, growing from 21TWh in 2014 to over 50 TWh by 2022 (Canada Energy Regulator, 2023a). That new generation was enough to power 2.6 million average homes.[6]

Alberta has been a leader among the provinces in developing wind power (Alberta Electric System Operator, 2024). New projects completed in the province since 2021 include the 198 MW Paintearth Wind Project near Stettler, the Hand Hills Wind Facility (see case study below), and the $400-million, 302 MW Jenner project near Brooks. Alberta's annual wind generation more than doubled between 2017 and 2022, increasing by 5 TWh (Canada Energy Regulator, 2023). Other provinces are also rapidly boosting wind power capacity and generation: Ontario's annual wind generation grew 70% in the last five years (up by 7.4 TWh), and Quebec's grew over 40% (adding 4.4 TWh of generation).

Growth in land-based wind power is encouraging. On the road to 2050, however, land-based wind could be matched or overtaken by offshore wind projects, centred in Atlantic Canada. The Public Policy Forum (Nicholson, 2023) notes that the Sable Island Bank alone could accommodate up to a thousand offshore turbines, capable of supplying more than enough power for all the homes in Atlantic Canada. Offshore wind towers are larger, with greater generation capacity, and also benefit from stronger and more consistent wind. While Canada is only beginning to exploit offshore wind power, major offshore wind investments in the U.K., Europe, Texas, and China show that this technology presents a viable—and potentially huge—opportunity for Canada.

All net-zero 2050 scenarios will require a significant role for wind power as the Canadian electricity system is decarbonized. The Institut de l'énergie Trottier (2021) projects 386 TWh of wind generation annually by 2050. The Canada Energy Regulator's (2023a) Canada net-zero forecast projects 425 TWh of wind generation in 2050. The Institute for Integrated Energy Systems Zero-Plus scenario (Thomas and Green, 2022) envisions wind generation in excess of 700 TWh.

[6] Statistics Canada (2024d) reports average electricity consumption per household in Canada of 39.1 gigaoules in 2021 (equivalent to about 10,800 kilowatt hours). The increase in wind generation from 2014 to 2022 (28.5 more TWh) was thus enough to power 2.642 million households.

These forecasts may seem ambitious based on current wind generation of 50-60 TWh per year. However, the required rate of growth to meet this target over the next 25 years is consistent with the current boom in wind power globally. Rapid growth in wind energy is being fueled by climate policy (supporting faster investment in renewable energy sources), but also by innovation—more efficient towers and rotors enable turbines to generate more power per day—and overall lower costs per installed MW. Access to more affordable technology makes new wind energy projects more attractive. Globally, the cost of building wind power capacity has dropped 63 percent per MW since 2009 (Canadian Renewable Energy Association, 2024a).

Our scenario projects wind power becoming a major source of energy in Canada by 2050, providing 35% of power generation (430 TWh), matching hydroelectric power as the largest source of electricity. This will require building about 105 GW of new wind power generation capacity, assuming existing capacity utilization rates. Based on typical labour input coefficients in published literature, this suggests total labour demand of 375,000 to 565,000 job-years of construction work (see Table 5). Ongoing operational labour requirements will also be substantial, ultimately creating another 33,000 to 49,000 jobs.

TABLE 5
Employment in New Wind Power Generation

CUMULATIVE EXPANSION IN CAPACITY TO 2050: 104,750 MW		
	LOW	**HIGH**
Construction		
Labour Input Coefficient (JY/MW)	3.6	5.4
Job-Years (000)	375	563
Operation		
Labour Input Coefficient (Jobs/MW)	0.31	0.47
Jobs	32,700	49,000

Source: Calculations as described in text.

Clearly, the massive expansion in wind energy generation that will be required to decarbonize Canada's electricity system (even as the overall system grows rapidly to meet new electricity demand) will provide a substantial and ongoing boost to employment for specialized trades in both construction and operation. Wind power construction projects require work by many unionized skilled trades classifications, including crane and heavy equipment operators, electrical workers, masons, and ironworkers. Specialized operations and maintenance jobs include high- and low-voltage electricians, site managers, wind turbine technicians, and mechanical engineers.

CASE STUDY: HAND HILLS WIND FACILITY

The Hand Hills Wind Facility began operation in August of 2023. Located near Drumheller, Alberta, the 145 MW facility consists of 29 wind turbines with a substation and related infrastructure, and produces enough energy to power 68,000 homes. Building Hand Hills created 225,000 person-hours of direct construction labour, equivalent to 150 job-years.

The project is one of 45 currently operational utility-scale wind installations in Alberta, with a combined generation capacity of about 4,500 MW in 2023 (Canadian Renewable Energy Association, 2024). Wind power projects have spurred over $5 billion in investment in the province, and created thousands of jobs. The rapid expansion of wind power in Alberta has exceeded expectations and forecasts (such as earlier estimates by the Alberta Electric System Operator and the Canada Energy Regulator).

As of mid-2023, 118 renewable energy projects were in development in Alberta—waiting for permits or poised to submit approval applications. This strong trajectory was disrupted, however, by the provincial UCP government's unusual and concerning moratorium on clean energy projects, announced in 2023, followed by a new set of onerous restrictions on future projects (Fletcher, 2024). These actions are especially puzzling given the demonstrated success (both economically and environmentally) of Alberta's wind power sector. Collectively, the 118 projects currently awaiting go-ahead are estimated to represent $33 billion of further investment, and over 24,000 job-years of construction work (Wang and Noel, 2023). Alberta will need to quickly reform its approach to development approvals for renewable energy, or the province will lose its leadership role in this field as other provinces power ahead with new investments.

Solar Power

Solar power, generated through both large-scale centralized facilities, and decentralized equipment (such as rooftop installations), constitutes another vital component of the expansion of renewable energy in Canada's net-zero trajectory. Our scenario envisions solar generation constituting 12.5% of total Canadian electricity supply by 2050.

Traditionally, many observers were skeptical about the prospects for solar power in Canada, given our climate and geography. To be sure, the efficiency of solar generation in many parts of Canada is lower than in very sunny locations (like desert regions in the U.S., Australia, or China). However, advances in both generation technology and power storage have enhanced the viability of solar in Canada, and it is now a proven and growing part of our overall electricity network. By 2022, solar power generated over 10 TWh of total electricity (1.6% of total Canadian electricity production), quintupling in just five years (Canada Energy Regulator, 2023a), and that rapid growth is set to continue.

Similar to wind, costs for solar power have fallen dramatically in the past decade, with overall costs for utility-scale solar dropping by over 82 percent (National Renewable Energy Laboratory, 2021). In Canada, solar energy capacity grew by 26 percent in 2022 alone, with installed capacity now approaching 5,000 MW (Canadian Renewable Energy Association, 2024).

Expanding solar generation to represent 12.5% of Canada's total electricity supply (or over 150 TWh) by 2050 will require a very rapid increase in installed solar capacity. With current efficiency rates, that would imply some 63 GW of new capacity. However, it is reasonable to expect steady improvements in generation efficiency as solar technology continues to improve; assuming a 10% improvement in generation efficiency across all solar installations reduces the required new capacity to about 56.5 GW of new capacity.

A majority of this growth will likely continue to be in commercial and utility-scale solar projects, which so far are the dominant form of solar in Canada. Construction trades required in building solar arrays include heavy equipment operators, electricians, welders and structural iron and steelworkers.

TABLE 6
Employment in New Solar Power Generation

CUMULATIVE EXPANSION IN CAPACITY TO 2050: 56,585 MW		
	LOW	**HIGH**
Construction		
Labour Input Coefficient (JY/MW)	20.1	30.1
Job-Years (000)	1135	1703
Operation		
Labour Input Coefficient (Jobs/MW)	0.35	0.53
Jobs	20,031	30,047

Source: Calculations as described in text.

Solar power installations (both centralized utility-scale, and decentralized modules) are more labour-intensive than most other forms of electricity generation. Based on labour input coefficients sourced from previously published literature, this expansion in solar capacity would result in between 1.1 million and 1.7 million direct job-years of construction employment (see Table 6). Skilled jobs required in these projects include electricians, welders, equipment operators, ironworkers, and more. Solar capacity of this size would also require another 20,000 to 30,000 ongoing operations and maintenance jobs (including electricians and other skilled trades) in utility-scale solar facilities, and to service decentralized equipment.

> "There is an urgent need to address climate change and Canada is committed to do its part. As climate change makes weather patterns more extreme and volatile, weather-related disasters (e.g. floods, storms and wildfires) are becoming more frequent and costlier.
>
> Insured losses as a result of catastrophic weather events in Canada totaled over $18 billion (2019 $CAD) between 2010 and 2019, while the number of catastrophic weather events in this period was over three times higher than it had been between 1980 and 1989.
>
> In order to achieve net-zero GHG emissions economy-wide by 2050, the electrification of energy-intensive activities, such as transportation, heating and cooling of buildings and various industrial processes, will be needed. For that electrification to have the desired impact, electricity generation will need to come from low and non-emitting electricity generation sources … and this will need to happen much earlier than 2050."

— Draft Clean Electricity Regulations, Regulatory Impact Analysis Statement, August 19, 2023 (Government of Canada, 2023)

Nuclear Power

Canada has six nuclear power facilities (five in Ontario), with combined capacity of about 15 GW, and they produced about 13% of Canada's total electricity generation in 2022.

Ontario has decided to move ahead with ambitious renewal of many of its nuclear facilities, along with new generation capacity added in some locations (discussed further below). Our assessment is that nuclear generation will increase by about half in aggregate output (reaching close to 125 TWh by 2050), but its share of total power supply will decline modestly (from 13% in 2022, to 10% by 2050), due to the faster growth of overall electricity supply.

Canada was a signatory, along with 21 other countries—including the United States, the UK, Sweden and France—to a pledge at the COP28 climate summit in Dubai to triple global nuclear capacity by 2050 (Natural Resources Canada, 2023). This is encouraging to proponents of nuclear power in Canada. However, it is important to note that the creation of new nuclear generation facilities—as well as refurbishment of existing infrastructure—will require ample support at the provincial and federal levels, including fiscal guarantees. Continuing concerns around safety, waste disposal, and security will also have to be resolved, before further nuclear development is assured. Nevertheless, the size of these projects, and their substantial inputs of skilled labour for both construction and operations, means the nuclear component of Canada's electricity system will certainly constitute a significant source of future employment.

Indeed, major nuclear projects already underway in Ontario have created major job opportunities. Several facilities are being refurbished, and Ontario Power Generation (OPG) has begun a small modular reactor project (SMR, see box below) at the Darlington site in Ontario. OPG plans to build four 300 MW SMRs there, which would add 1,200 MW of generation capacity when completed (Ontario Power Generation, 2023).

The four existing conventional reactors at Darlington have also been part of a long-term refurbishment project that began in 2016. Two of these reactors have been successfully completed and are back online; workers finished the necessary refurbishments on one of those reactors, Unit 3, in July 2023, more than five months ahead of schedule. The other two reactors under refurbishment will be employing hundreds of unionized construction workers until the end of 2026.

Other nuclear developments are also moving ahead in Ontario:

- The refurbishment of the Bruce Power generating station in Kincardine, Ontario is underway; work to replace major components (including steam generators, pressure tubes and other infrastructure) commenced in 2020. Three of the site's eight reactors have been completed, with the remaining five to be refurbished by 2033 (NS Energy, 2020).
- The Ontario government has announced its intention to build an additional 4,800 MW nuclear generating station at Bruce, which would nearly double the site's current generating capacity (Butler, 2023).
- The province has also sought approval to refurbish the Pickering plant, which had initially been slated for decommissioning in 2026 (Crawley, 2023). Ontario Power Generation (OPG) cites the successful refurbishment at Darlington as part of their decision, noting that the earlier project had stimulated development of a specialized supply chain, and a pool of specialized skilled trades workers, that makes subsequent refurbishment work faster and less expensive.

If all of the announced or intended plans in Ontario unfold as planned—refurbishing ageing plants, and building new reactors—installed nuclear capacity in Canada would grow to as much as 20 GW, supporting a corresponding rise in total generation (perhaps to 150 TWh).

However, there are some risks related to the nuclear refurbishments and new projects (including potential delays and cost constraints), so for purposes of forecasting future employment impacts of nuclear developments, we take a somewhat more cautious approach. We project total nuclear generation growing to 125 TWh by 2050, capable of providing about 10% of total electricity supply. This implies 6000 MW of net new capacity (equivalent to the new reactors planned for Bruce, and the SMRs at Darlington). In addition, at least 10,000 MW of existing capacity will be refurbished; we assume half the labour input for refurbishment as for new capacity, so this is equivalent to building another 5000 MW of new capacity.

TABLE 7
Employment in Expanded and Refurbished Nuclear Power Generation

CUMULATIVE EXPANSION IN CAPACITY TO 2050: 6,000 MW (+10,000 MW REFURBISHED)		
	LOW	HIGH
Construction		
Labour Input Coefficient (JY/MW)	13.3	20.0
Job-Years (000)	146	220
Operation		
Labour Input Coefficient (Jobs/MW)	0.48	0.72
Jobs	2880	4320

Source: Calculations as described in text.

Small Modular Reactors (SMRs)

"Small modular reactors (SMRs) are advanced nuclear reactors that have a power capacity of up to 300 MW(e) per unit, which is about one-third of the generating capacity of traditional nuclear power reactors. SMRs, which can produce a large amount of low-carbon electricity, are:

- Small – physically a fraction of the size of a conventional nuclear power reactor.
- Modular – making it possible for systems and components to be factory-assembled and transported as a unit to a location for installation.
- Reactors – harnessing nuclear fission to generate heat to produce energy."

— International Atomic Energy Agency (Liou, 2023)

In Canada, interest in SMRs was first sparked by OPG's plan to build four at its Darlington site. Growing interest has also sparked federal investment of $29.6 million to develop supply chains and fund research on waste management, as well as an action plan to support future innovation in the technology (Natural Resources Canada, 2023b).

Construction (and refurbishment) of nuclear facilities is very labour intensive. The combination of new expansion and refurbishing work would create between 145,000 and 220,000 job-years of construction work, for a highly specialized unionized skilled trades workforce (see Table 7). The 6000 MW net expansion in capacity would also support the creation of between 2,900 and 4,300 ongoing specialized jobs in operations and maintenance.

Despite these ambitious plans for nuclear energy, there are many hurdles in Canada and globally that must be overcome to achieve these goals. Cost overruns and safety concerns have contributed to skepticism regarding the ultimate potential of nuclear power.

Fuel supplies are another issue. While Canada is one of the world's largest producers of uranium, the fuel used in most SMRs is an enriched form of uranium: high-assay low-enrichment uranium (HALEU). Currently the only country in the world producing HALEU at commercial scale is Russia, which complicates delivery and cost as demand increases, and raises national security concerns (Natural Resources Canada, 2023c).

Geothermal Power

Geothermal power relies on heat embedded in underground water reservoirs, or in subsurface soil and rock, to provide a variety of energy uses—including electricity generation, direct heating and cooling of buildings, and even community-wide heating systems. Canada has abundant geothermal resources.

A key advantage of geothermal projects is that the nature of work involved is very similar to the work and skills of workers in the existing oil and gas sector (including construction and related trades activity). Moreover, the location of prime geothermal resources in Western Canada also overlaps with the location of current petroleum activity (Canada Energy Regulator, 2023b). For both reasons, expanding geothermal generation capacity could play a very valuable role in facilitating strong employment transitions for workers who will move out of the petroleum industry as fossil fuel use is gradually phased out.

Capital costs for installing geothermal electricity generation projects are higher than wind and solar power, both of which have benefited from dramatic cost declines in the past decade. Moreover, geothermal projects are often located far from end-point users, requiring new transmission infrastructure. Nevertheless, the capital costs for geothermal projects are certainly lower than nuclear plants, and like other 'baseload' power sources (hydro, nuclear, and combustion), geothermal facilities can provide steady power 24 hours a day, 7 days a week.

With recent advances in drilling and deployment technology, the prospects for geothermal in Canada will expand considerably between now and 2050. One innovation currently garnering international attention is a new technique pioneered by an Alberta company, Eavor. The company's Eavor-Loop approach has been shown to reduce costs and enhance performance. Eavor broke ground in 2022 on a $290-million project in the town of Geretsried, Germany (Eavor, 2022); the facility will provide both power (9MW) and heat (equivalent to 65MW) sufficient for 30,000 homes. The project is expected to begin generating energy in 2024. The Canadian federal government has recently invested $90 million in equity in Eavor to support the company's further expansion (Scace, 2023).

Indeed, Europe is in the midst of a geothermal boom as Germany, France, Switzerland and other countries seek alternatives to dependence on imported gas. Total installed geothermal capacity on the continent is expected to jump almost 60 percent by 2030, reaching over 6GW, thanks to over $7 billion in investment (Rystad Energy, 2022). Meanwhile, in the U.S., the federal government is offering major financial support for geothermal research and deployment funding, and private investment in geothermal power is growing rapidly.

In addition to Eavor's promising investments, other geothermal projects (many also receiving federal fiscal support) are also moving forward (Graney, 2021): including the DEEP project in Saskatchewan (with 200 MW of baseload capacity), and British Columbia's 15MW Tu Deh-Kah project in Fort Nelson.

We project that falling costs and improved technology will underpin an expansion of geothermal generation to reach 5% of total electricity generation in Canada by 2050 (or just over 60 TWh). This would require adding about 8000 MW of installed capacity (assuming a 90% utilization rate; see U.S. Department of Energy, n.d.). This will create thousands of jobs for drilling rig and excavator operators, pipefitters, steamfitters, plumbers, welders, electricians, HVAC technicians, machinists, and other skilled trades—many of which, as noted, could be recruited from former petroleum vocations.

TABLE 8
Employment in Geothermal Power

CUMULATIVE EXPANSION IN CAPACITY TO 2050: 8,000 MW		
	LOW	**HIGH**
Construction		
Labour Input Coefficient (JY/MW)	6.4	9.6
Job-Years (000)	51	77
Operation		
Labour Input Coefficient (Jobs/MW)	0.50	0.76
Jobs	3024	4536

Source: Calculations as described in text.

Table 8 summarizes our estimates of new employment arising from this expansion of geothermal power generation. Based on labour input coefficients in previous published research, 8000 MW of new geothermal capacity would require about 50,000 to 75,000 job-years of construction employment. Servicing this capacity would also support another 3000 to 4500 ongoing jobs in operations and maintenance.

> “Workers stand on the front lines of climate change, including fighting wildfires, restoring downed power lines, and rebuilding our communities after extreme weather hits. Workers are also front and centre dealing with the impacts of this economic transition.”
>
> — Canadian Labour Congress President Bea Bruske (2023)

Transmission Line Construction

Building a renewable electricity system to meet Canada's 2050 electricity needs in a net-zero world will also require major investments in transmission lines and distribution facilities. Many non-emitting electricity sources embody a relatively dispersed geographical distribution, compared to traditionally centralized power plants. This implies a greater need for further-flung transmission and distribution systems to efficiently deliver that power to end users, and also to manage the uneven flows of electricity that result from normal fluctuations in solar and wind generation.

Canada currently has over 166,000 kilometers of transmission lines (Electricity Canada, n.d.). Many major transmission corridors run north-south, partly because major hydro projects are located in the northern regions of major hydro-producing provinces (like Manitoba, Quebec, and Labrador).

Splintered jurisdiction over electricity generation in Canada has also contributed to a north-south orientation of the transmission grid. Some provinces have oriented their systems to exports of surplus power to the United States, rather than strengthening interprovincial electricity trade. Enhanced east-west transmission linkages between provinces would help Canada better meet its 2050 goals—allowing jurisdictions to more easily share power and manage fluctuations in supply from new renewable sources.

Beyond improving interprovincial power cooperation, there are other challenges associated with the expanded transmission network that Canada will need to integrate new generation sources and support electrification in all parts of the economy (Energy+Environmental Economics, 2022). These include shortages of essential materials for transmission construction (for example, copper), and winning approvals for new transmission projects from landowners, utilities and government agencies. In general, the federal and provincial governments have acknowledged these challenges (see box above), and are mobilizing both fiscal and regulatory resources to meet them.

"A nation-building project"

"Enabling the building of grids across the country that are reliable, affordable, and non-emitting, at the pace and scale necessary, is an enormous undertaking—a nation-building project of unprecedented scale and importance in our history. And it must be done in a way that respects provinces' and territories' jurisdiction and advances the self-determination of Indigenous communities.

That is why the Government of Canada is publishing this vision for a clean, affordable, and reliable electricity system for every region of Canada as a call to action to help advance a discussion—among provinces and territories, Indigenous partners, industry and labour, environmental organizations, and civil society—about how to build a clean, reliable, and affordable electricity grid from coast to coast to coast."

— Powering Canada Forward: Building a Clean, Affordable, and Reliable ElectricitySystem for Every Region of Canada, Natural Resources Canada (2023d)

The Canada Energy Regulator projects a 27% expansion in aggregate interprovincial transmission capacity by 2035, in order to meet the net-zero target in Canada by 2050 in a more cost-efficient and reliable manner (allowing for demand and supply smoothing, and capacity redundancy, across provinces). But the overall investment in transmission and distribution capacity, including intra-provincial transmission, will need to be much larger to support the more than doubling of total Canadian electricity generation expected in a net-zero scenario.

We estimate that a net expansion in transmission capacity of at least one-third will be required to support the widespread electrification required to meet net-zero targets by 2050. This is equivalent to 55,000 new kilometers of transmission line infrastructure.

TABLE 9
Employment in Transmission Expansion

CUMULATIVE EXPANSION IN CAPACITY TO 2050: 50,000 KM		
	LOW	HIGH
Construction		
Labour Input Coefficient (JY/km)	3.1	4.7
Job-Years (000)	155	233

Source: Calculations as described in text.

As summarized in Table 9, based on previously published estimates of labour input coefficients for transmission investments, this would result in between 155,000 and 235,000 job-years of direct construction work, engaging a wide variety of skilled trades work (including heavy equipment, electrical, lineman duties, steel and ironwork, and more). Operation and maintenance of transmission facilities is integrated into overall employment of the electrical system, and hence difficult to disaggregate. But there will certainly be additional new ongoing jobs associated with this major expansion in electricity infrastructure.

Expanding and Modernizing Canada’s Electricity System: Total Employment Impacts

Table 10 compiles the job-creation estimates associated with all of the foregoing technologies and facilities—including five sources of non-emitting electricity generation (hydroelectric, wind, solar, nuclear, and geothermal), and investments in expanded transmission and distribution. Together, this qualitative and quantitative expansion of Canada’s electricity system would spur a powerful increase in total employment for specialized construction and skilled trades workers. The great bulk of new work will be associated with construction of these facilities, but there will also be many thousands of ongoing unionized skilled trades jobs in operation and maintenance functions once the construction is complete.

Including upgrades and expansion of hydroelectric, wind, nuclear, solar and geothermal installations, along with upgraded and expanded transmission lines, this electricity construction boom would result in between 2.1 million and 3.1 million job years of direct construction work for skilled trades in the period to 2050.[7] It would also support ongoing work in operations and maintenance positions for 60,000 to 90,000 specialized workers, many of them skilled and construction trades.

TABLE 10
Combined Employment in New Electricity Investments

	LOW	HIGH
Construction (000 job-years)		
Hydroelectric	204	306
Wind	375	563
Solar	1135	1703
Nuclear	146	220
Geothermal	51	77
Transmission	155	233
SUB-TOTAL	**2067**	**3101**
Operation (jobs)		
Hydroelectric	1,153	1,730
Wind	32,690	49,035
Solar	20,031	30,047
Nuclear	2,880	4,320
Geothermal	3,024	4,536
SUB-TOTAL	**59,779**	**89,668**

Source: Calculations as described in text.

7 This estimate is larger than the employment forecasts reported by Thomas and Green (2022), summarized above; they projected 1.5 million job years of work in wind, solar, and transmission investments by 2050. Our forecast is larger because we have included other forms of renewable energy in the job estimates, and also project a somewhat larger expansion in total electricity supply.

PHOTO NAVINTAR/SHUTTERSTOCK

Smart Communities: Energy Efficient Buildings & District Energy

In this section we focus on construction of highly energy efficient institutional, commercial and industrial (ICI) buildings, ICI retrofits, and district energy facilities, given their direct relevance to job opportunities for building trades workers.

Energy Efficient Buildings and Communities

In addition to decarbonizing and expanding our use of electricity in all areas of life, reducing carbon emissions will also require important changes to the built environments in which Canadians work, live, and play. Important improvements in the energy-efficiency of buildings, communities, and physical infrastructure will be required to reduce energy consumption (and hence emissions) and support a high quality of life without carbon pollution.

In this section of the report, we concentrate on two specific dimensions of these changes in the built environment: the shift toward high energy efficiency in industrial, commercial, and institutional buildings, and the construction of new district or community energy systems, which pool facilities for electricity, heating, and cooling across clusters of buildings or even entire neighbourhoods to support greater efficiency and energy conservation. Like the preceding investments in an expanded electricity system, these investments will require massive inputs of labour by unionized building and skilled trades workers, reinforcing the positive employment prospects associated with the energy transition.

WHAT'S IN A GREEN BUILDING?

The definition of a 'green' building in Canada is not standardized. The Canada Green Building Council (CaGBC) defines green buildings as those that demonstrate:

- A certification system with documented and verified increased performance level (LEED®, Zero Carbon Building Standard®, BOMA BEST®, BUILT GREEN®, Novoclimat®);
- An energy rating standard (ASHRAE 90.1, ASHRAE 100, Passive House, EnerGuide 80, ENERGY STAR®, R-2000®); and/or
- Evidence of exemplary equivalent performance by other means in the areas of energy efficiency, water efficiency, material and/or resource efficiency, including through building code and/or municipal bylaw minimum standards.

To reach zero-carbon, jurisdictions ultimately need to measure total building emissions, not only building efficiency. Additional consideration must also be given to the significant emissions embodied in the materials used in building construction.

Green ICI Buildings & Retrofits

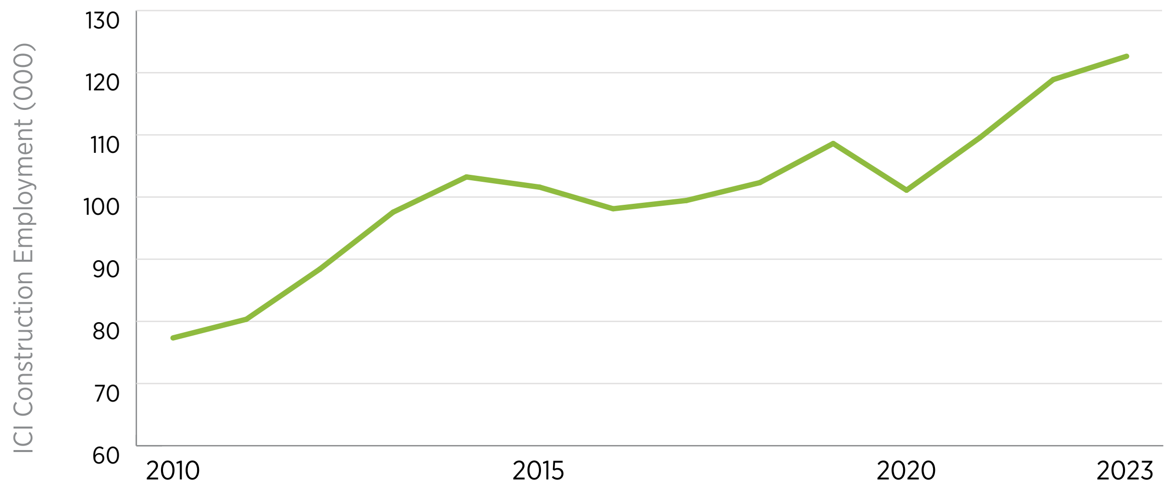
Commercial and industrial buildings are an important source of GHG emissions in Canada. To meet its climate commitments, Canada will need to ensure all new buildings are zero-carbon—meaning structures that are far more energy-efficient than most of our existing building stock, and whose construction processes minimize greenhouse gas GHG emissions from building materials and operations.

In addition to construction of new energy-efficient buildings, Canada will need to retrofit existing buildings to incorporate more efficient systems and materials—from building envelopes to mechanical insulation to energy sources. Physical plant systems will need to be updated, with existing heating, cooling, and refrigeration systems replaced with improved, energy-efficient versions—including pumps, ventilators, compressors, and conveyers. Switching from natural gas to alternative energy sources for heating and cooling (such as heat pumps) will also make a significant contribution to emissions reduction.

Green building techniques can be applied in office towers, hospitals, universities, conference centres, factories, multi-unit residential buildings (MURBs), and other settings. These buildings need to be designed, constructed, and operated to be energy efficient, minimize total environmental impacts, and create healthy places for people to live and work.

In recent years Canada has seen rapid growth in green industrial, commercial and institutional (ICI) building projects, with tens of thousands more skilled workers employed in this work. The total number of waged employees in ICI construction grew almost 25% between 2017 and 2023, representing the addition of almost 25,000 new jobs, and reaching a total of 123,000 positions (see Figure 5). This does not count work done by specialized construction contractors (who work across different sectors of construction), or self-employed construction workers (who are not included in Statistics Canada's payroll-based employment totals). So the data presented in Figure 5 understate the total employment in ICI construction.

FIGURE 5
Non-Residential Building Construction Employment



Source: Statistics Canada Table 14-10-0202-01.

The strong growth in ICI employment reflects both the expanded scale of ICI building construction in all parts of Canada, but has been reinforced by efforts to achieve more energy efficiency in the new building stock (which requires greater labour content than traditional building methods).

Major gains in employment have also occurred in other segments of construction, including residential construction (up 25,000 jobs since 2017), heavy and civil construction (20,000 new jobs), and other specialty trades and contractors (almost 100,000 new jobs). The total construction sector now engages 1.2 million employees in Canada (and 375,000 more self-employed workers[8]), and will undoubtedly create many more new jobs in the decades ahead. Investments in new and retrofitted energy-efficient buildings of all sorts, motivated by the commitment to net-zero by 2050, will clearly reinforce this job-creation momentum. The claim by fossil fuel lobbyists that the energy transition threatens the jobs of skilled trades workers is in fact opposite to the empirical reality: energy efficiency investments are already spurring tens of thousands of new jobs in construction.

In this section of the report, we estimate the employment gains that can be expected from just one dimension of this historic transformation in Canada's construction industry: the construction and retrofit of energy-efficient ICI buildings. Of course, other segments of the broader construction sector (such as single-family residential buildings) will also be impacted by the energy transition and the path to net-zero—adopting new, higher-efficiency materials, designs, and equipment. There will be tens of thousands of new jobs created in those segments, as well, from the shift toward more efficient buildings and structures of all kinds. We isolate the employment implications of energy-efficient buildings and retrofits in the ICI sector as just a first estimate of the employment opportunities in construction arising from the energy transition.

[8] Statistics Canada Table 14-10-0027-01.

Building codes, standards, and certification processes for advanced energy efficiency have progressed rapidly in recent years. The National Energy Code of Canada for Buildings (NECB; National Research Council, 2022) establishes increasingly stringent energy efficiency standards. The upcoming 2025 update to the National Building Code will include new provisions directly regulating GHG emissions from buildings (Saunders, 2023).

Many provinces and cities have moved ahead with adopting their own building codes to regulate emissions from buildings. For example, British Columbia has introduced the Zero-Carbon Step Code, which allows individual municipalities to schedule their own adoption of low-carbon building codes. Additionally, Canadian municipalities are beginning to account for the embedded emissions in building materials; for example, Toronto requires developers to track the emissions content of building materials in order to qualify for certain incentives.

With a larger supply of energy-efficient materials and skilled workers, the green ICI building sector is already substantial, and continues to mature and grow. Much of the growth in ICI construction employment, therefore, already consists of 'green' jobs arising from the emphasis on energy conservation in new buildings. Given the CaGBC definition of green building (see box above), we estimate that 40% of current ICI construction jobs are already related to projects which encompass advanced energy efficiency considerations in design, materials, and equipment. This is an outstanding example of how the energy transition truly is creating *Jobs for Today*.

CASE STUDY: **OTTAWA HOSPITAL CIVIC CAMPUS**

The new Civic Campus of the Ottawa Hospital began construction in 2024. The 2.5 million square-foot project sprawls across 50 acres, and is one the largest infrastructure builds ever in Ottawa (Infrastructure Ontario, 2024). Work is occurring under a project agreement with the Unionized Building and Construction Trades of Eastern Ontario and Western Quebec. Projected to cost $2.8 billion, the project will create thousands of person-years of direct construction employment.

The project embodies advanced architectural specifications to cope with temperature rise and other factors related to climate change, as well as to attain maximum energy efficiency and emissions reduction. Architect Peter Duckworth-Pilkington explained the strategy for ensuring superior environmental performance:

"We do a deep site analysis to look at the climate that is present in Ottawa, the wind direction, solar positioning and more… Then we explore how to adapt the design to take advantage of that. Things like using the sun to passively heat the building or planting trees to provide shade in the summer."

The Ontario provincial government has committed to investing $50 billion in over 50 hospital projects in the coming decade, which will generate tens of thousands of person-years of employment for construction trades.

However, the scale of employment in green ICI construction is set to expand substantially in coming years, based on the continuing spread of these new energy standards and technologies throughout the ICI sector. These employment gains will be experienced in both new construction, and emissions-reducing retrofits of existing structures.

NEW BUILDINGS

Improvements in technology, desire to capture energy cost savings, and regulatory and building code changes will all drive a steady expansion of 'green' building techniques in the ICI sector in coming years. By 2050, effectively all ICI construction work will incorporate advanced energy-conserving techniques, materials, and skills. The energy transition will thus drive the creation of tens of thousands of construction jobs through two parallel forces: expansion in the total volume of ICI construction activity, and steady expansion in the use of advanced energy conservation technologies and construction methods.

Economic forecasts expect continued steady growth in overall construction employment, including the ICI sub-sector. The most recent federal government occupational forecasts (Employment and Social Development Canada, 2023) foresee annual employment growth of 1.275% in construction over the next decade. If that pace of new employment is maintained, and broadly replicated in the ICI sector, then the number of waged employees in ICI will reach close to 175,000 by 2050. (Again, that does not include workers on multi-unit residential complexes, specialized contractors, or self-employed workers.) Over the same period, meanwhile, state-of-the-art energy-conserving construction methods will become the norm across the entire ICI sector. In essence, everyone in the ICI sector will be working with advanced energy-conserving techniques and projects by 2050 (up from an estimated 40% today).

TABLE 11
Employment Impacts of ICI New Construction

Current ICI Waged Employment (000)	122.6	
Current 'Green' Work Share	40%	
Annual Growth Employment to 2050	1.275%	
'Green' Work Share by 2038	100%	
Waged Employment by 2050 (000)	172.7	
	LOW	**HIGH**
Additional Job-Years 2024-2050 (000)	1678	2517

Source: Calculations from sources as described in text.

We use this projection, and apply our standard 1500-hour FTE definition for construction workers; we then introduce the same range bracket for low and high estimates (20% below, and 20% above, the average estimate) as above. On this basis, we project between 1.7 million and 2.5 million job-years of employment will be created in green ICI construction (over and above the pace of such work already occurring) by 2050, as summarized in Table 11.

RETROFITS

Commercial and institutional buildings, while ahead in adopting greater efficiency practices, still lag residential buildings in providing building heat without fossil fuels. Currently, only 15 percent of heating in ICI buildings is provided via electricity. The pace of retrofits in recent years has been inadequate to meet net-zero targets by 2050: Natural Resources Canada (2024c) estimates it would take 70 years at the current pace of renovations to retrofit all existing industrial and commercial buildings. Canada ranks 5th out of G7 nations in the pace of energy retrofits (Kilgour et al., 2022).

As an interim target, the International Energy Agency (2023) urges member countries to ensure 20% of industrial and commercial buildings are renovated to become "zero-carbon-ready" by 2030. This will require a substantial acceleration of deep retrofit activity—and will drive a substantial increase in employment for a wide range of construction, building, and skilled trades workers (including HVAC, insulation, mechanical, and other trades).

To build a thriving market for large building retrofits, a mission-oriented policy approach, with new financing mechanisms, and support of unions and industry organizations for training and advocacy, is required (see box below). Recent federal, provincial, and municipal initiatives will strengthen this momentum. The federal government's Canada Green Buildings Strategy (Natural Resources Canada, 2023c) integrates many of these policy levers into a consolidated strategy to accelerate retrofit activity. A spate of retrofit incentives from governments (including the federal government, and every provincial and territorial government), public financial institutions (like the Canada Infrastructure Bank and the CMHC), and other funders provides attractive financing for ICI retrofits of all sizes (Natural Resources Canada, 2024b).

Meanwhile, a supply chain of specialized designers, engineers, and contractors is emerging to meet the growing need for deep energy retrofits. Programs like BOMA Enspire and the Deep Retrofit Accelerator Initiative provide further management and strategic advice to building owners looking to save on energy costs, as well as meet increasingly stringent energy benchmarks (Building Owners and Managers Association Canada, 2023).

Most labour on retrofit programs is not included in data on new ICI construction employment considered above. Therefore, we separately estimate the employment effects of accelerated ICI retrofit investments as follows. BuildForce Canada (2024, Figure 9) reports that some 130,000 workers were employed in non-residential building maintenance, operations, and upkeep in 2023 (representing close to 10% of total construction employment that year). We assume one quarter of that workforce is engaged in retrofit-related activity. We then assume that number of employees must be tripled, phased in over the next decade, and then sustained at that level to 2050, in order to effectively reduce the turnover time for retrofitting all buildings from 70 years at the present pace, to 25 years (in time to meet 2050 net-zero timetables). That will generate dramatic energy and emissions savings from this sector, as well as tens of thousands of new jobs.

PHOTO YUTTANA CONTRIBUTOR STUDIO/SHUTTERSTOCK

TABLE 12
Employment Impacts of Deep ICI Retrofits

Current Non-Residential Maintenance Employment (000)	130	
Assumed Share of Retrofit and Renovation	0.25	
Initial Retrofit Workforce (000)	32.5	
Triple Retrofit Workforce by	2033	
	LOW	**HIGH**
Additional Job-Years 2024-2050 (000)	1170	1755

Source: Calculations from sources as described in text.

Table 12 summarizes the impact of this scenario on overall employment in ICI retrofits. The retrofit workforce doubles by 2033, and then remains stable as the enhanced pace of retrofits is sustained to 2050. Over the cumulative period to 2050, this generates (with 1500-hour FTEs and our standard low and high brackets for labour input coefficients) between 1.2 million and 1.8 million job-years of employment in deep retrofit work.

This retrofit work will require a highly skilled workforce, given the wide variety of types and sizes of buildings that were built at different times and for different uses, that must all now be equipped with state-of-the-art energy-conserving materials and equipment. Knowing how to maximize energy savings across such a wide range of buildings requires a deep knowledge of building science, and a comprehensive understanding of the different construction methods used in different vintages of buildings. This work will require major investments in training, continued expansion of the Red Seal program (to include new skills related to energy retrofits), and strengthening the commitment of both employers and project funders to developing a reliable flow of apprenticeship spaces.

UNLOCKING RETROFITS

Key to unlocking the retrofit market will be the development of innovative business models and finance mechanisms to assist building owners with the upfront costs of improvements in energy efficiency. Metered Energy Efficiency Transaction Structures (MEETS) is one such solution, inspired by the success of similar incentives in the wind industry in the U.S. (MEETS Accelerator Coalition, 2021).

For U.S. wind turbine projects, energy companies acted as "tenants" and did not require landowners to finance the project or purchase the resulting energy, which was sold directly to utilities via long-term power-purchasing agreements (PPAs). Adapting this model to investments in large building retrofits, the building owner would take on an energy service company (ESCO) as a "tenant", with the ESCO selling the metered saved energy to the utility as part of a PPA.

The MEETS model is just one of several innovations in business models and financing for energy efficient retrofits in the U.S. Another approach is the Property-Assessed Clean Energy (PACE) model, which attaches financing required for retrofits to the property title, allowing it to be easily transferred on sale. The PACE market has been doubling on an annual basis, enabled by new legislation in US states.

Canada's electricity system has a different history, and different ownership structures, than in the U.S. In particular, the central role played by publicly-owned power utilities in most provinces enables greater capacity for planning, public investment, regulations, and subsidies to encourage energy conservation investments by household, industrial, and commercial power users. So these models need to be carefully adapted to the circumstances in each province. Nevertheless, there are many innovative ways to encourage and support building owners to invest in energy conservation, and then facilitate repayment of up-front retrofit costs through subsequent energy bill savings.

District Energy and Storage Systems

Heating the indoor spaces where people work and live accounts for over fifty percent of the energy demand in residential and commercial sectors. At present in Canada, most of this heating is provided by burning natural gas. While natural gas is promoted by its proponents as a 'cleaner' fuel, growing scientific evidence confirms it is just as polluting, or even more so, than other fossil fuels. This is because of emissions of methane during both production and consumption of natural gas; methane is a greenhouse gas 86 times more potent than carbon. Finding more efficient, non-carbon sources of heat for buildings will thus make a crucial contribution to Canada's emissions reduction trajectory.

One promising avenue for this goal is the development of district energy systems (DES). These are facilities that supply both thermal energy and (in some cases) electricity to buildings in a given neighbourhood from a central generation plant – or from regional networks of interconnected plants. Using locally available energy supplies to meet needs for heat, cooling, and electricity in cities and towns, DES's have the potential to lower energy costs and reduce municipal GHG emissions. Heat can be captured for use from many possible sources: including industrial facilities, organic waste composting, geothermal exchange (like heat pumps), solar or wind power, small-scale cogeneration facilities (simultaneously producing both electricity and heat), or biomass. The potential benefits of DES's will be further enhanced by new innovations in neighbourhood or regional pooling of electricity storage: using centralized batteries, or even dispersed batteries (including individually owned electric vehicles plugged into the grid when not in use) to smooth out fluctuations in electricity supply and demand.

In some cases, cooling of buildings can also be achieved using ocean or deep lake water, as in Toronto's Enwave facility that cools over 100 downtown buildings – including hotels, a brewery, Toronto General Hospital and City Hall. That system saves 90,000 MWhs of electricity each year, enough to power 25,000 homes, and reduces peak load on the provincial electricity system by 60MW. The system is now being expanded (Manucdoc and Draaisma, 2024), with a complex tunnelling and construction project that will generate thousands of person-years of employment.

Many other DES projects and expansions are underway or in the planning process. These include the Squamish First Nation Senakw development in Vancouver, where captured energy will be used to heat over 6,000 units; an ocean heat-exchange project in BC's Horseshoe Bay; a district energy project linking Thompson Rivers University and the City of Kamloops; and geo-exchange projects in Etobicoke and other locations in the Toronto area.

Construction of district energy systems requires the skilled labour of ironworkers, pipefitters, masons, drilling rig and excavator operators, and insulators. Battery and storage projects require electrical workers and other specialists, in addition to the full range of construction trades.

District energy and storage systems vary widely in terms of type and scale, and therefore estimating construction job impacts is challenging. In their zero-plus scenario for decarbonizing Canada's electricity system, Thomas and Green (2022) forecast a cumulative total of $19 billion (in present-value 2018 Canadian dollar terms) investment in energy storage systems to 2050, to achieve 35 GW worth of storage capacity and meet up to 8% of total peak load (by offsetting fluctuations in wind and solar power generation). We assume an equivalent cumulative investment in district energy systems over the same period; this is equal to about 16 projects equivalent to Enwave's current expansion over the next quarter-century.[9] Together, this represents cumulative investment over the next 25 years of $46.7 billion (in 2023 dollar terms) – or about $2 billion per year.

TABLE 13
New Employment in District Energy and Storage

Cumulative Investment (b $2023C)	46.7	
	LOW	**HIGH**
Labour Input Coefficient (JY/$m)	3.0	4.5
Job-Years (000)	140	210

Source: Calculations as described in text.

9 The Enwave expansion of deep water cooling in Toronto and parallel projects in Mississauga is being financed by $1.4 billion in investment from the Canada Infrastructure Bank (2021).

As summarized in Table 13, based on published labour input coefficients (also adjusted for 2023 Canadian dollar values and 1500-hour FTEs), this scale of investment would generate between 140,000 and 210,000 job-years of new construction employment. Note that this estimate (like the estimates elsewhere in this paper) does not include jobs associated with manufacturing the batteries and other specialized components installed in these facilities.

CASE STUDY: UNIVERSITY OF TORONTO

Heating and energy systems at the University of Toronto's three campuses are undergoing a major overhaul. Since 2018, construction workers at the Science and Humanities Wing at the Scarborough campus—one of the university's oldest buildings—have been gradually converting heating systems to use high-efficiency boilers and ground-source heat pumps (University of Toronto, 2020).

The university also houses Canada's largest urban geoexchange system. Below a parking garage of the downtown St. George campus, crews have drilled 370 boreholes, some as deep as 250 meters, fitted with piping. Filled with glycol and water, the pipes—185 kilometers long in total—are linked to heat pumps that connect to heating and cooling infrastructure in buildings across the campus. Work on this project began in 2020, part of a university-wide 30-year project to decarbonize the university's operations.

In 2022 the Canada Infrastructure Bank committed to $56 million in funding to support the university's plans to reduce emissions via deep energy retrofits (Canada Infrastructure Bank, 2022). Projects include the installation of a supplemental steam turbine, replacing one of the gas boilers with electric, and building energy storage and waste-to-fuel capacity.

Meanwhile, another $138-million overhaul of energy infrastructure at the St. George campus, called Project Leap, aims to cut emissions in half within three years, largely by phasing out natural gas. In sum, these various streams of smart community energy-efficient infrastructure will support many thousands of job-years for construction trades at the University of Toronto alone.

PHOTO LUCKY-PHOTOGRAPHER/SHUTTERSTOCK

Smart Communities: Total Employment Impacts

Table 14 summarizes the employment benefits of these emissions-reducing investments in the built environment, including new energy-efficient ICI construction, deep energy-conserving retrofits of existing ICI buildings, and construction of district energy and storage facilities.

TABLE 14
Combined Employment in Smart Community Investments (000 Job-Years)

	LOW	HIGH
Green ICI Construction	1678	2517
ICI Deep Retrofits	1170	1755
District Energy and Storage	140	210
TOTAL	**2988**	**4482**

Source: Calculations as described in text.

The combined employment impacts across these dimensions of smart community infrastructure amount to between 3 and 4.5 million job years over the period up to 2050. This amounts to almost half of the total new work for construction trades that we forecast from the energy transition, even more than the job gains resulting from the expansion and decarbonization of the national electricity system. Clearly, a strong commitment to energy transition and emissions reduction, backed by necessary capital spending in all dimensions of the built environment, will usher in an era of immense opportunity for construction and building trades workers.

Dercarbonizing Transportation

Transportation is one of the biggest contributors to global greenhouse gas emissions, and Canada is no exception. Canada's transportation sector produced 156 megatonnes of greenhouse gas emissions in 2022 (Environment and Natural Resources Canada, 2024). That makes transportation the second-largest source of GHG emissions in Canada (second only to the petroleum industry itself), accounting for 22 percent of total emissions.

Canadians rely heavily on vehicles (mostly with fossil-fuel-fired internal combustion engines) for transportation of both people and goods. To reach net-zero climate commitments, Canada will need to dramatically reduce transportation emissions. The adoption of zero-emission vehicles (ZEVs) for both personal and goods transportation will be crucial in this task, as will the expansion of non-emitting public transportation.

Major changes in the nature of transportation will create substantial employment opportunities for unionized skilled trades workers in constructing relevant infrastructure: such as a Canada-wide network of charging stations for electric vehicles (EVs), public transportation infrastructure in urban areas (such as subway, light rail, and tram facilities), and high-speed rail systems for interurban transportation.

Electric Vehicle Charging Stations

Sales of electric vehicles have grown strongly in recent years, with more than 14 million EVs sold globally in 2023, representing 16 percent of global vehicle sales (Irle, 2024). Canada is keeping up with this global trend: quarterly

> "Transportation is also a quality-of-life issue. In comparison to transit passengers, those who get around by personal vehicle are more likely to suffer from traffic congestion-related stress, property damage, and even death. In a single year, public transportation has been estimated to save Canadians about $12.62 billion in vehicle operating costs and $3.17 billion in collision costs. There is an urgent need to rethink how we transport people."
>
> — Green Economy Network (2023), "Green Transit, Good Jobs"

registrations of new zero-emission vehicles (ZEVs) tripled between 2021 and 2024.[10]

Federal and provincial policies are supporting this shift. The Government of Canada has committed to ensuring that ZEVs will make up 20 percent of all new light vehicle sales in Canada by 2026, increasing to 60 percent by 2030, and 100 percent by 2035 (Transport Canada, 2024).

To support the use of EVs, Canada will need to develop an extensive network of charging stations, including both "Stage 2" and "Stage 3" chargers (the latter use direct current and hence can charge a vehicle much faster). Analysis conducted for the federal government predicts Canada will need 200,000 charging stations by 2030 to support targeted use of EVs (Rabson, 2023). Demand for charging infrastructure will grow much further if plans to fully convert the passenger vehicle fleet to ZEVs are fulfilled. Analysts typically recommend one public charging station for every 10 vehicles on the road for a fully effective system (Canadian Vehicle Manufacturers' Association, 2022). In the event of a full changeover to ZEVs, combined with population growth, this implies a need for 3.9 million chargers by 2050 (Canadian Vehicle Manufacturers' Association, 2022).

Building this charging infrastructure will require significant investments of capital, materials, and labour. Federal and provincial governments have already committed substantial funds to begin expanding charging infrastructure. Research provided for the National Research Council suggests Canada will need to invest $20 billion in public charging infrastructure over the next 30 years to match projected market penetration of EVs (Natural Resources Canada, 2022).

TABLE 15
Employment in EV Charger Installation

CUMULATIVE INSTALLATIONS TO 2050 (M): 3.9		
	LOW	HIGH
Labour Input Coefficient (JY/1000)	37.4	56.0
Job-Years (000)	146	219

Source: Calculations as described in text.

Based on labour input coefficient from previously published studies, developing a ZEV public charging infrastructure on this scale by 2050 would provide between 145,000 and 220,000 job-years of employment over the period to 2050 (Table 15). This work will employ a wide variety of skilled construction trades, including linesmen, electrical workers, heavy equipment operators, and fabricators.

[10] Statistics Canada Table: 20-10-0025-01.

ON THE FRONT LINES

Construction and building trades workers are on the front lines of the climate crisis. Because of the nature of their work, many are already feeling the impact of working during heat waves, air pollution advisories (such as those caused by wildfire smoke), and intense weather events. Many have seen their jobs put on hold during extreme weather events.

Warnings of a 1.5° or 2° C rise in global average temperatures may sound unremarkable, but global warming results in much greater extremes at the local level—where workers from Lytton to Halifax have seen temperatures rise for days as much as 20°C above seasonal averages.

Shifting the economy away from polluting energy sources and towards low-emission infrastructure and transportation means not only good jobs during the investment and construction phases of these projects, but will also help ensure decent conditions for workers (and all Canadians) into the future.

At its 2023 convention, the Canadian Labour Congress (CLC), which represents over three million workers and is the largest labour organization in the country, committed to "tackling the climate crisis"—raising awareness about global warming, while opposing carbon-intensive projects (Bulowski, 2023).

The same resolution committed the CLC and its member unions to working to guarantee "a just transition for workers impacted by the fight against climate change."

Urban Transit

Canadians value public transit, and providing reliable, efficient public transportation options will be vital in reducing private passenger car use and related emissions. Improving the quality of transit service, especially in major cities, also supports other improvements in quality-of-life: reducing congestion and local pollution, reducing commuting times, and improving safety.

Investments in upgraded and expanded public transit infrastructure require very large labour inputs, producing tens of thousands of jobs for building and construction trades of all specializations. Transit funding in Canada reflects a complex and ever-changing combination of federal, provincial, and municipal investments, supplemented by fares paid by transit users. It is impossible to make firm forecasts of the total value of public transit capital spending that will be forthcoming in future decades as part of Canada's transition to a net-zero economy—but there is no doubt these investments, and the number of jobs created, will be huge.

The federal government has created a new permanent fund to support transit investments in all parts of Canada, supported by annual injections of $3 billion (Housing, Infrastructure and Communities Canada, 2024a). This will ensure transit investments can proceed with greater certainty (compared to previous ad-hoc and unpredictable cost-sharing agreements between different levels of government).

Federal funds will be supplemented by major investments from provincial and municipal governments. For example, through the "Investing in Canada Infrastructure Program," provinces and municipalities are required to provide 50 percent of "rehabilitation" project costs for public transit infrastructure, and 60 percent of the cost of new transit construction (Housing, Infrastructure and Communities Canada, 2024b).

We assume the $3 billion annual federal contribution to transit capital projects continues (in 2023 constant-dollar terms) through to 2050, and is supplemented at a ratio of 1.22:1 by provincial and municipal funding.[11] This cumulates to a total investment in public transit of $180 billion (in 2023 dollar terms) by federal, provincial and municipal governments between now and 2050—including light rail tracks, bridges, tunnels, transit station, bus infrastructure, and more.

TABLE 16
Employment Effects of New Transit Construction

Annual Federal Funding ($b 2023/yr)	3.0	
Provincial/Municipal Match (55-45)	1.22	
Total Capital Funding ($b 2023/yr)	6.7	
Cumulative Investment to 2050 ($b 2023)	180.0	
	LOW	**HIGH**
Labour Input Coefficient (jy/$mC)	4.8	7.2
Job Years (000)	860	1291

Source: Calculations as described in text.

Based on labour input coefficients reported in previously published literature, this scale of investment would generate between 860,000 and 1.3 million job-years of new employment over the period to 2050 (see Table 16). Clearly the construction of transit infrastructure in Canada, essential to meeting net-zero targets, will be a massive source of new work for building and construction trades workers.

There will also be significant new ongoing work in transit operations arising from this expansion in the public transit system.[12] Most of these jobs will be for vehicle operators, administrative staff, and other non-construction roles. However, some of those ongoing jobs will be filled by skilled trades workers (including electrical, mechanics, and construction staff). Those jobs are not included in the estimates reported in Table 16, which thus underestimate the total employment benefits of public transit investment for unionized skilled trades occupations.

Inter-Urban Rail

Unlike most industrial countries in Europe and Asia, Canada presently has no high-speed rail (HSR) services.[13] However, this is set to change. The federal government has recently announced its intention to construct a 1000-kilometre high-speed rail system, called 'Alto,' in the high-traffic corridor from Toronto to Quebec City.

[11] Assuming half of the spending is remediation (shared 50-50) and half is new construction (shared 60-40), this implies an average funding mix of 55-45, hence $1.22 in lower-level spending for each dollar of federal funds.
[12] Statistics Canada's input-out system estimates 19.4 jobs in total for every $1 million in gross output in public transit operations, a relatively strong jobs multiplier.
[13] Conventionally, "high-speed rail" refers to trains which can travel at peak speeds of over 200 km/hour.

Trains would travel 300 km per hour, and would include stops in Peterborough, Ottawa, Montreal, Laval, and Trois-Rivières (Zimonjic et al., 2025). The new service would use dedicated tracks, thus resolving a current major weakness of existing inter-urban rail in Canada – namely, that passenger trains often share tracks with more frequent freight train service, resulting in regular delays. The project will start with a six-year $3.9 billion design and engineering phase, with construction slated to begin in 2031. The project is described as the biggest infrastructure project in Canadian history, and would support over 50,000 construction jobs during construction.

Canada has been a laggard in adopting HSR technologies. Nevertheless, it is better to start building this infrastructure late than never – and the benefits for both the environment and the economy will be enormous. Frequent, reliable HSR service in the Toronto-Ottawa-Montreal triangle will reduce demand for both air travel and highway use, reducing pollution and congestion. And in addition to tens of thousands of construction jobs during the building phase, the project will support thousands more new jobs in ongoing operations and maintenance once the system is in place.

It is possible that HSR could also be introduced in Western Canada in coming years. Currently the B.C. and Alberta governments are exploring both privately and publicly funded projects to develop HSR infrastructure for two high-traffic routes: linking Calgary and Edmonton, and linking Vancouver with major West Coast cities in the U.S. In 2022, the B.C. government supported a feasibility study for a HSR link between Vancouver, Seattle and Portland. In December 2023 the U.S. federal government announced its own support for preliminary studies of the project. Meanwhile, the Alberta government has retained construction contractors EllisDon and Aecom to explore the feasibility of a $9-billion HSR line between Calgary and Edmonton.

The Green Economy Network (2023) estimated that the combined capital cost for all three of these HSR projects (including only the Canadian portion of the Cascadia system) would total $52 billion (in constant-dollar 2023 terms). That estimate is likely conservative.

TABLE 17
Employment Effects of New Inter-Urban Rail Construction

Cumulative Investment ($b 2023)	52	
	LOW	**HIGH**
Labour Input Coefficient (jy/$mC)	5.1	7.6
Job Years (000)	264	397

Source: Calculations as described in text.

HSR construction requires higher labour inputs than conventional public transit capital projects, by virtue of the more sophisticated techniques and tolerances required for HSR equipment. Based on labour input coefficients in previously published research, a capital program on this scale would generate between 265,000 and 400,000 job-years of employment across the full range of construction trades (Table 17). Again, thousands of ongoing jobs in operations and maintenance would also be associated with these projects, many also filled by skilled trades workers.

Even without HSR capability, it is clear that Canda's exiting inter-urban rail infrastructure is inadequate to our economic, population, and environmental needs. Other investments will be required to upgrade inter-urban rail equipment and capacity (including in regions of Canada which will not be served by any of these HSR projects). There is no doubt that expanded, improved inter-urban rail services will play an important role as Canada transitions to a net-zero economy – and that in turn will stimulate significant employment opportunities in construction.

Modernizing Transportation: Total Employment Impacts

We have identified three major dimensions of coming investments in transportation infrastructure that will be required to support decarbonization of Canada's transportation system – one of Canada's worst polluting sectors. Each of these categories (EV charging network, public transit expansion, and inter-urban rail improvements) will require tens of billions of dollars in new investment over the coming quarter-century, generating abundant new employment opportunities for construction trades.

TABLE 18
Combined Employment Effects of Investments in Decarbonized Transportation (000 Job-Years)

	LOW	HIGH
EV Charging Network	146	219
Public Transit	860	1291
Inter-Urban Rail	264	397
TOTAL	**1270**	**1906**

Source: Calculations as described in text.

In total, we project that these investments in a net-zero transportation infrastructure in Canada will support between 1.3 and 1.9 million job-years of employment for construction and building trades workers over the period to 2050 (see Table 18). Thousands of additional jobs will be created for skilled trades in maintaining and operating those systems. These transportation investments thus constitute a third pillar of robust job-creation for construction and building trades workers, arising from the energy transition.

PHOTO SACH336699/SHUTTERSTOCK

6

CONCLUSION

This report considers the employment implications of Canada's commitment to reach net-zero emissions reduction targets by 2050. We have focused on several areas of the energy transition that are of particular interest to construction and building trades workers: massive investments in renewable energy supply and infrastructure, energy efficient buildings and communities, and decarbonized transportation infrastructure. Each of these investment priorities will generate very promising employment opportunities for building trades workers of all specializations. Put together, and it is no exaggeration to conclude that, thanks to the energy transition, the future job prospects for skilled trades workers have never been more secure.

Table 19 summarizes the total expected employment impacts of the investment programmes described above, across these three priority areas. Of the three, massive employment demand arising from energy conservation investments in the built environment (new ICI construction, deep energy-saving retrofits, and construction of district energy and storage systems) are the largest single source of new work: generating between 3 million and 4.5 million job-years of work over the period to 2050, almost half of the total. Strong employment opportunities also arise from construction of renewable energy generation and infrastructure (2.1 million to 3.1 million job-years), and decarbonized transportation (1.3 to 1.9 million job-years). These estimates do not include the hundreds of thousands of new jobs that would also be stimulated by these investments – both upstream in supply-chain (or indirect) jobs, and downstream in consumer goods and services (induced) industries.

TABLE 19
Overall Employment Effects of Net-Zero Transition Investments 2024 to 2050

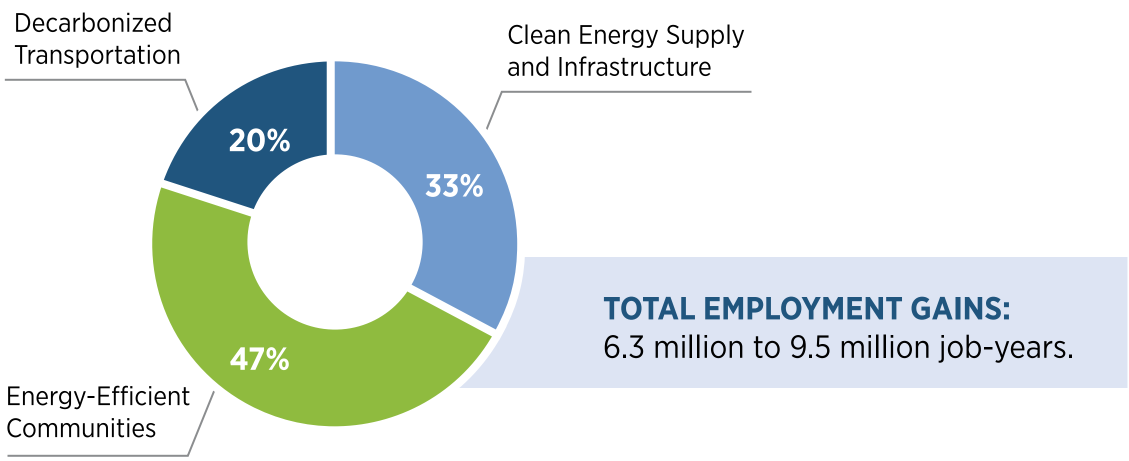
	LOW	HIGH
Construction (000 job-years)		
Clean Energy Supply and Infrastructure	2067	3101
Energy-Efficient Communities	2988	4482
Decarbonized Transportation	1270	1906
TOTAL	**6326**	**9489**
Operation (000 jobs)		
Clean Energy Supply and Infrastructure[1]	60	90

Source: Calculations as described in text.

[1] *In clean energy supply and infrastructure only; ongoing operation jobs not estimated for the other two sectors.*

Across these three major areas of investment, we project total increases in employment demand for construction and skilled trades workers of 6.3 million to 9.5 million job years over the period to 2050. On an average basis, that amounts to the equivalent of 235,000 and 350,000 ongoing jobs – representing a substantial boost to overall employment in the construction sector. (The specific number of jobs created in each year depends on the timing and trajectory of the investment programmes in each area; these figures represent annual averages attained over the whole period to 2050.) The new employment associated with net-zero investments therefore amounts to a permanent increase of 20-30% in existing waged employment levels in the broader construction sector. There is no doubt, therefore, that the massive new investments required to meet Canada's net-zero targets will be a powerful job-creating engine, benefiting construction and building trades workers in all parts of Canada.

FIGURE 6
Employment Gains from Net-Zero Investments (million job-years by 2050)



Source: Calculations from published sources as described in text.

Figure 6 illustrates the composition of the employment gains arising from the construction phase of these investments. Almost half the total job gains come from investments in energy efficient ICI buildings, and district energy and storage systems. One-third are associated with investments in an expanded clean energy generation and transmission system. And the remaining one-fifth will be generated by investments in decarbonized transportation infrastructure.

Meanwhile, in all three of these broad investment areas, thousands more ongoing jobs in operations and maintenance will be created for unionized skilled trades workers in various occupations (including electricians, mechanical trades, construction, and more). Only in the case of renewable energy generation and infrastructure did published data on employment in operations and maintenance allow us to estimate those impacts explicitly: we expect between 60,000 and 90,000 permanent O&M jobs for skilled workers in the expanded, decarbonized electrical system by 2050. In energy efficient communities and decarbonized transportation, it is more difficult to distinguish ongoing building trades jobs from the other permanent jobs created in those sectors, but those permanent roles will certainly constitute an important supplement to the overall employment effects of these investments.

Recall, our analysis has considered only direct jobs in activities where building and construction trades are centrally employed. It has not considered the hundreds of thousands of spin-off or indirect jobs that would be sparked by an investment programme of this magnitude. We have not included upstream or supply-chain jobs in the myriad of industries producing inputs, materials, machinery, and services that feed into those construction projects – everything from lumber and steel, to batteries for district storage, to engineering and architectural services. Nor have we included downstream consumer-led 'induced' activity and jobs, sparked by hundreds of thousands of newly-hired unionized construction workers spending their new incomes. If these indirect and induced effects were added (as many other studies have done), the total employment impacts would be two to three times larger. However, given our focus in this report on employment opportunities for building and construction trades workers, we have chosen to limit our projections to direct impacts only. Our employment forecasts are thus deliberately and considerably conservative.

The large size of these employment effects confirms that the net-zero transition in Canada opens enormous opportunities for the construction trades. Canada has a moral responsibility to join countries around the world in moving towards net-zero by 2050, and living up to the firm emissions-reduction commitments we have made as part of global agreements. But this energy transition should not be interpreted as just a cost or a disruption. Instead, it is an historic economic opportunity. And unionized construction workers, by virtue of the huge capital investments required to make net-zero a reality, will be at the front of the line in capturing the resulting employment and income benefits. This powerful stimulus for investment and job-creation will be all the more important as Canada grapples with the economic uncertainty created by aggressive trade policy measures threatened by the U.S.

Indeed, the employment impacts of net-zero investments are so significant, that it raises immediate issues about how to ensure that an adequate supply of properly trained and accredited trades workers will be available to fill the hundreds of thousands of new positions that will be created. Thus, at the same time as moving forward with ambitious regulatory and fiscal policies to achieve these net-zero benchmarks by 2050 (and unleash the massive capital spending required to meet them), governments at all levels – together with employers, trade unions, and educational institutions – must move aggressively to boost training, apprenticeship, and recruitment efforts.

The outlook for construction and building trades workers, given the enormous energy transition projects that will be unrolled in coming decades, is indisputably bright. Backed by high-quality training and apprenticeship programs, strong trade unions, and a firm commitment to living up to our international climate commitments, construction and building trades workers will make an enormous contribution to achieving the net-zero economy of tomorrow. This will be good for the environment and the well-being of future generations. But it will be good for the economy, too.

PHOTO JULIADORIAN/SHUTTERSTOCK

7

REFERENCES

Aldieri, Luigi, Jonas Grafström, Kristofer Sundström, and Concetto Paolo Vinci (2020). "Wind Power and Job Creation," *Sustainability* 12(1), p. 45.

Berensson, Markus, et al. (2021). *Canada: The Case for an Urban Green and Just Recovery, Technical Report* (London: C40 Cities), https://council.cleanairpartnership.org/wp-content/uploads/2021/05/C40-Cities-2021-Canada-The-case-for-an-urban-green-and-just-recovery-Technical-report.pdf.

Bloomberg New Energy Finance (2023). "Cost of Clean Energy Technologies Drop as Expensive Debt Offset by Cooling Commodity Prices," June 7, https://about.bnef.com/blog/cost-of-clean-energy-technologies-drop-as-expensive-debt-offset-by-cooling-commodity-prices/.

Bridge, Tyee, and Richard Gilbert (2017). *Jobs For Tomorrow: Canada's Building Trades and Net Zero Emissions* (Vancouver: Columbia Institute), https://columbiainstitute.eco/wp-content/uploads/2017/09/Columbia-Jobs-for-Tomorrow-web-revised-Oct-26-2017-dft-1.pdf.

C40 Cities Climate Leadership Group (2021), *The Case for a Green and Just Recovery* (London: C40 Cities), https://c40.my.salesforce.com/sfc/p/#36000001Enhz/a/1Q000000gRCH/24OgSbRwj1hZ305yJbyPMZJQKhXXWNYE8k8sr2ADsi8.

Calvert, John (2019). "The BC Insulator Union's Campaign to Promote Climate Literacy in Construction (Salamander Report): Documenting Its Efforts to 'Green' The Industry's Culture," Adapting Canadian Work and Workplaces, York University, https://yorkspace.library.yorku.ca/server/api/core/bitstreams/69e39983-f9e2-483e-897e-7511bf10159d/content.

Calvert, John (2023). "Just Transition in the Construction Industry: A Union's Campaign to Create Jobs by Promoting Climate Change Upgrades in Buildings," *Alternate Routes: A Journal of Critical Social Research*, 35, 101-117.

Calvert, John, and Corrine Tallon (2016). "The Union as Climate Change Advocate: The BC Insulator's Campaign to "Green" the Culture of the Building Industry in British Columbia," Working Paper # ACW-08, Adapting Canadian Work and Workplaces, York University, April, https://yorkspace.library.yorku.ca/server/api/core/bitstreams/6f6deaf4-7d95-4c45-8b5d-6e3692eb54d5/content.

Canada Energy Regulator (2023). *Canada's Energy Future 2023: Energy Supply and Demand Projections to 2050* (Ottawa: Canada Energy Regulator), https://www.cer-rec.gc.ca/en/data-analysis/canada-energy-future/2023/.

Canadian Climate Institute (2024). "Evidence of progress: Canadian emissions down from peak as economy decouples emissions from growth," May 2, https://climateinstitute.ca/news/evidence-of-progress-canadian-emissions-down-from-peak-as-economy-decouples-emissions-from-growth/.

Canadian Renewable Energy Association (2024). "New 2023 data shows 11.2% growth for wind, solar & energy storage," News Release, January 31 (Ottawa: Canadian Renewable Energy Association), https://renewablesassociation.ca/news-release-new-2023-data-shows-11-2-growth-for-wind-solar-energy-storage/.

Carr, Edward W., James J. Winebrake, and Samuel G. Winebrake (2021). Workforce Projections to Support Battery Electric Vehicle Charging Infrastructure Installation (Wilmington NC: Energy and Environmental Research Associates), https://www.etcommunity.org/wp-content/uploads/2024/03/Workforce-ProjectionstoSupportBatteryElectricVehicleChargingInfrastructureInstallation.pdf.

Clean Energy Canada (2019). *Missing the Bigger Picture* (Vancouver: Clean Energy Canada), https://cleanenergycanada.org/wp-content/uploads/2019/05/Report_TER2019_CleanJobs_20190516_v3_ForWeb_FINAL.pdf.

Clean Energy Canada (2021). *The New Reality* (Vancouver: Clean Energy Canada), https://cleanenergycanada.org/wp-content/uploads/2021/06/Report_CEC_CleanJobs2021.pdf.

Dunsky Energy Consulting (2018). *The Economic Impact of Improved Energy Efficiency in Canada: Employment and Other Economic Outcomes from the Pan-Canadian Framework's Energy Efficiency Measures* (Montreal: Dunsky Energy Consulting), https://cleanenergycanada.org/wp-content/uploads/2018/04/TechnicalReport_EnergyEfficiency_20180403_FINAL.pdf.

Ecology Action Centre (2019). *Nova Scotia Environmental Goals and Sustainable Prosperity Act: Economic Costs and Benefits for Proposed Goals* (Halifax: Ecology Action Centre), https://ecologyaction.ca/sites/default/files/2022-06/EAC_GP_Climate%20Jobs%20Report_Sept2019_0.pdf

Economic Development Research Group (2020). *Economic Impact of Public Transportation Investment: 2020 Update* (Washington: American Public Transportation Association), https://www.apta.com/wp-content/uploads/APTA-econ-impact-transit-investment-2020-ES.pdf.

Electricity Human Resources Canada (2023). *Electricity in Demand: Labour Market Insights, 2023–2028* (Ottawa: Electricity Human Resources Canada), https://ehrc.ca/wp-content/uploads/2024/05/Electricity-in-Demand-Labour-Market-Insights.pdf.

Energy and Climate Intelligence Unit (2024). "Net Zero Scorecard," https://eciu.net/netzerotracker.

Energy Storage Canada (2020). *Energy Storage: A Key Pathway to Net Zero in Canada* (Toronto: Energy Storage Canada), https://static1.squarespace.com/static/61f81e15f490ed3db8dadda2/t/6345a24b3ee2440f883c885f/1665507916398/2022+Energy+Storage+-+A+Key+Pathway+to+Net+Zero+in+Canada.pdf.

Galley, Andrew (2015). Community Benefits Agreements (Toronto: Mowat Centre), https://communitybenefitsagreements.ca/.

Gao, Xin, et al. (2023). *Energy Storage in Canada: Recent Developments in a Fast-Growing Industry* (Vancouver: McCarthy Tetrault), https://www.mccarthy.ca/en/insights/blogs/canadian-energy-perspectives/energy-storage-canada-recent-developments-fast-growing-industry.

Gerbet, Thomas, Louis Blouin, and Mathieu Prost (2024). "Federal government going ahead with high-speed rail between Quebec City and Toronto," CBC News, October 28, https://www.cbc.ca/news/politics/high-speed-rail-canada-1.7365835.

Guldimann, Colin, and Naomi Powell (2022). *Green Collar Jobs: The skills revolution Canada needs to reach Net Zero* (Toronto: RBC Canada), https://thoughtleadership.rbc.com/green-collar-jobs-the-skills-revolution-canada-needs-to-reach-net-zero/.

International Energy Agency (2020). *Sustainable Recovery 2020: World Energy Outlook Special Report* (Paris: International Energy Agency), https://www.iea.org/reports/sustainable-recovery/evaluation-of-possible-recovery-measures#summary.

International Energy Agency (2021). *Net Zero by 2050* (Paris: International Energy Agency), https://iea.blob.core.windows.net/assets/deebef5d-0c34-4539-9d0c-10b13d840027/NetZeroby2050-ARoadmapfortheGlobalEnergySector_CORR.pdf.

International Labour Organization (2015). "Guidelines for a just transition towards environmentally sustainable economies and societies for all" (Geneva: International Labour Organization), www.ilo.org/wcmsp5/ groups/public/@ed_emp/@emp_ent/documents/publication/ wcms_432859.pdf.

International Labour Organization (2023). *Achieving a Just Transition Towards Environmentally Sustainable Economies and Societies for All*, Report ILC.111/VI, presented at the International Labour Conference, 111th Session, 2023 (Geneva: International Labour Organization), www.ilo.org/ wcmsp5/groups/public/---ed_norm/---relconf/documents/ meetingdocument/wcms_876568.pdf.

International Renewable Energy Agency (2023). *Renewable Energy and Jobs Annual Review 2023* (Abu Dhabi: IRENA), https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2023/Sep/IRENA_Renewable_energy_and_jobs_2023.pdf.

Jacobson, Mark Z., et al. (2017). "100% Clean and Renewable Wind, Water, and Sunlight All-Sector Energy Roadmaps for 139 Countries of the World," *Joule* 1(1), pp. 108-121, Supplementary Tables Available at https://ars.els-cdn.com/content/image/1-s2.0-S2542435117300120-mmc1.pdf.

James, Carole (2020). "B.C. Infrastructure Benefits Mandate Letter," B.C. Ministry of Finance, January 14, https://www.bcib.ca/wp-content/uploads/2023/05/BCIBMandateLetter2020.pdf.

Jeyakumar, Binnu (2016). *Job Growth in Clean Energy: Employment in Alberta's emerging renewables and energy efficiency sectors* (Calgary: Pembina Institute), https://www.pembina.org/reports/job-growth-in-clean-energy.pdf.

Jones, Betony, Peter Phillips, and Carol Zabin (2016). *The Link Between Good Jobs and a Low Carbon Future: Evidence from California's Renewables Portfolio Standard* (Berkeley, CA: Center for Labor Research and Education, University of California, Berkeley), https://laborcenter.berkeley.edu/pdf/2016/Link-Between-Good-Jobs-and-a-Low-Carbon-Future.pdf.

Kaddoura, Saeed, et al. (2020). *Alberta's Emerging Economy: A Blueprint for Job Creation through 2030* (Calgary: Pembina Institute), https://www.pembina.org/reports/albertas-emerging-economy.pdf.

Klein, Seth (2020). *A Good War: Mobilizing Canada for the Climate Emergency* (Toronto: ECW Press).

Lee, Marc, and Seth Klein (2020). *Winding Down BC's Fossil Fuel Industries: Planning for Climate Justice in a Zero-Carbon Economy* (Vancovuer: Canadian Centre for Policy Alternatives), https://www.policyalternatives.ca/sites/default/files/uploads/publications/BC%20Office/2020/03/ccpa-bc_Winding-Down-BCs-Fossil-Fuel-Industries.pdf.

Lee, Marc, Caroline Brouillette, and Hadrian Mertins-Kirkwood (2023). *Spending What it Takes: Transformational Climate Investments for Long-Term Prosperity in Canada* (Ottawa: Canadian Centre for Policy Alternatives), https://policyalternatives.ca/publications/reports/spending-what-it-takes.

National Renewable Energy Laboratory (n.d.). "Jobs & Economic Development Impact Models" (Golden CO: National Renewable Energy Laboratory), https://www.nrel.gov/analysis/jedi/, accessed September 26 2024.

Navius Research (2019). *Quantifying Canada's Clean Energy Economy: An Assessment of Clean Energy Investment, Value-Added and Jobs* (Vancouver, Navius Research), https://cleanenergycanada.org/wp-content/uploads/2019/05/2019-03-13-Clean-Energy-Economy-FINAL-REPORT.pdf.

Nuclear Energy Agency and the International Atomic Energy Agency (2018). *Measuring Employment Generated by the Nuclear Power Sector* (Paris: Organization for Economic Cooperation and Development), https://www.oecd-nea.org/jcms/pl_14912/measuring-employment-generated-by-the-nuclear-power-sector?details=true.

Pollin, Robert, et al. (2023). *Employment Impacts of New U.S. Clean Energy, Manufacturing, and Infrastructure Laws* (Amherst, MA: Political Economy Research Institute), https://peri.umass.edu/images/publication/BIL_IRA_CHIPS_9-18-23-1.pdf.

Rabson, Mia (2023). "Less than one in five federally funded EV charging stations are operational: new data," *The Canadian Press*, August 30.

Ritchie, Hannah, and Pablo Rosado (2024). "Electricity Mix," *Our World in Data*, https://ourworldindata.org/electricity-mix.

Stanford, Jim (2021). *Employment Transitions and the Phase-Out of Fossil Fuels* (Vancouver: Centre for Future Work), https://centreforfuturework.ca/wp-content/uploads/2021/01/Employment-Transitions-Report-Final.pdf.

Statistics Canada (2023a). "Harnessing the power of the wind and the sun," StatsCAN-Plus, June 6 (Ottawa: Statistics Canada), https://www.statcan.gc.ca/o1/en/plus/3779-harnessing-power-wind-and-sun.

Statistics Canada (2023b). "Input-output multipliers, detail level" (Ottawa: Statistics Canada), https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=3610059401.

Statistics Canada (2024). "Environmental and Clean Technology Products Economic Account: Human Resource Module, 2022," The Daily, May 28 (Ottawa: Statistics Canada), https://www150.statcan.gc.ca/n1/daily-quotidien/240528/dq240528c-eng.htm.

Stern, Nicholas (2006). *The Economics of Climate Change: The Stern Review* (Cambridge: Cambridge University Press).

Thomas, Stephen, and Tom Green (2022). *Shifting Power: Zero-Emissions Electricity Across Canada by 2035* (Vancouver: David Suzuki Foundation), https://davidsuzuki.org/wp-content/uploads/2022/05/Shifting-Power-Zero-Emissions-Across-Canada-By-2035-Report.pdf.

United Nations International Development Organization and the Global Green Growth Initiative (2015). *Global Green Growth: Clean Energy Industry Investments and Expanding Job Opportunities* (Vienna: UNIDO), https://gggi.org/wp-content/uploads/2017/11/2015-06-Global-Green-Growth-Clean-Energy-Industrial-Investments-and-Expanding-Job-Opportunities-Overall-findings.pdf.

Xuereb, Slias, and Inez Hillel (2023). *Job Creation Through Transformational Climate Investments: Assessing the Impact of Proposed Climate Investments in Canada* (Ottawa: Vivic Research), https://vivicresearch.ca/work/employment-impacts-of-spending-what-it-takes.

Zimonjic, Peter, Mathieu Prost, and Stéphane Bordeleau (2025). "High-speed rail line with 300 km/h trains will run between Toronto and Quebec City, Trudeau announces," CBC News, February 19, https://www.cbc.ca/news/politics/trudeau-announces-high-speed-rail-quebec-toronto-1.7462538.

TABLE A1
EMPLOYMENT COEFFICIENTS FOR RENEWABLE ENERGY AND EFFICIENCY INVESTMENTS

Multiple Sector Estimates

Jones et al (2016): Construction Job-Years per MW	PV Solar	Land-Based Wind	Geo-thermal	Small Hydro
	3.9	0.6	4.4	7.1
Jacobson et al (2017): Job-Years per MW		Onshore Wind	Offshore Wind	Geothermal
	Construction	7.06	9.3	31.78
	Operation	0.37	0.63	0.46
IEA (2020) Jobs per $1m US (2020)	Spending (Developed Countries)	New Vehicles	Appliances	Batteries
		6.4	9.1	6.5
	Capital (Construction Only)	New Grids	Existing Grids	New Hydro
		4.4	5.3	1.3
Kaddoura et al (2020) FTE/MW		Utility Solar	Residential Solar	Commercial Solar
	Construction	10	20	15
	Operation	.2	1	.3
NREL (n.d.) Job-Year per MW		Conventional Hydro	Concentrating Solar	Geothermal
	Construction	17.4	2.9	7.1
	Operation	0.18	0.45	0.8
Pollin et al (2023) Job-Years per $1m US (2023)	Transport Infrastructure	Public Transit	Energy and Remediation	Renewable Energy Storage
	3.9	4.4	3	2.4
Statistics Canada (2023b) Jobs per $1m (C 2020) Output	Electricity Operation	Residential Construction	Non-Res. Construction	Transportation Construction
	1.7	3.7	4.1	3.0

Hydro-electric	Residential PV	Utility PV	Transmission (/km)	Distribution (/km)		
12	38.23	21.29	5.11	2.33		
0.3	0.32	0.85	na	na		
Biofuels	Recycling					
14.7	13.1					
New Nuclear	Wind	PV Solar	Urban Transit	High-Speed Rail	Retrofit Buildings	New Efficient Buildings
0.8	0.9	6.8	11.4	6.6	14.8	15.2
Wind	Conventional Hydro	Small Hydro				
0.37	8.87	5.76				
0.17	0.08	0.04				
PV Solar	Transmission (jy/mile)					
12.0	3.45					
0.1	0.05					
Building Efficiency	Electricity Network					
4	3.1					
Electricity Construction	Other Construction	Repair and Retrofit	Urban Transit			
2.1	3.1	5.8	19.4			

TABLE A1 (CONT'D)
EMPLOYMENT COEFFICIENTS FOR RENEWABLE ENERGY AND EFFICIENCY INVESTMENTS

Single Technology Estimates				
EDRG (2020): Public Transit, Jobs per $1m US[1]	Construction	Operation	Weighted Avg.	
	20	13	17.9	
Aldieri et al (2020): Wind Power, Jobs per MW		Low	High	
	Construction	2.35	5.76	
	Operation	2	3.44	
NEA/IAEA (2018): Nuclear, Job-Years per MW	Construction	Operation		
	12	0.6		
Carr et al (2021): EV Charging, Job-Years per 1000 Chargers	NREL	Biden Plan	California	Average
	42.4	57.9	39.6	46.7

Source: Authors' compilation from referenced sources. Includes direct employment impacts only (unless otherwise noted).

[1] *Includes indirect and induced jobs.*

Centre for Civic Governance

Suite 440 - 789 West Pender Street
Vancouver, B.C., V6C 1H2, Canada
Tel: 604-408-2500
www.ccg.eco