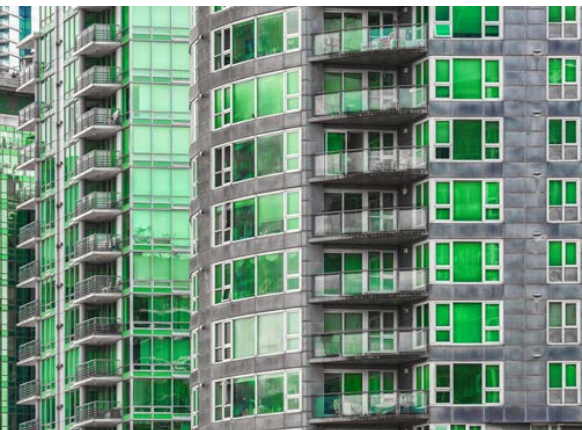


JOBS FOR TOMORROW

CANADA'S BUILDING TRADES AND NET ZERO EMISSIONS



JULY 2017

Commissioned by Canada's Building Trades Unions

JOBS FOR TOMORROW: CANADA'S BUILDING TRADES AND NET ZERO EMISSIONS

July 2017

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Commissioned by Canada's Building Trades Unions

Graphic design by Nadene Rehnby,
Hands on Publications

Cover photos: Maarten van den Heuvel/Unsplash,
Ken Lane/Flickr, Mark Klotz/Flickr

ISBN 978-0-9781918-5-6



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Key Messages

TO DATE, VERY LITTLE RESEARCH has been undertaken on the construction industry's role in Canada's transition to low-carbon development. This study marks the first time original research has been undertaken to examine potential impacts on Canada's construction industry.

Global Context

- In 2015, 197 nations signed on to the Paris Agreement committing to slash greenhouse gas emissions (GHGs) in order to keep global warming below 2°C and to work toward 1.5°C of warming.
- The global transition to a low-carbon economy will require an investment of an additional US\$220 billion by 2020. This is less than 4 per cent of the current total global annual investment in construction activity.
- Countries worldwide are “decarbonizing” their infrastructure, industries, and economies. This shift is gaining momentum and will impact all sectors of our society.
- Recent studies indicate that over the past three years the global economy grew while GHGs from energy production and delivery declined.
- The International Trade Union Confederation forecasts that investments of 2 per cent of gross domestic product (GDP) in the green economy over a five-year period in 12 countries could create up to 48 million new jobs, or up to 9.6 million new jobs per year, including more than 17 million jobs in the construction sector.
- The World Green Building Council has called for all buildings to be net zero by 2050 through new construction and deep renovation. (Homes and buildings account for one quarter of all of Canada's emissions.)
- As the move to net zero emissions accelerates, the building trades are seeing benefits for their members globally.



This study examines the construction industry's role in Canada's transition to low-carbon development.

TOP PHOTO COURTESY
MATTHEW HENRY/UNSPLASH;
BOTTOM PHOTO SHUN KAMBE



The construction industry has a vital role to play in meeting Canada's climate goals by supporting production in other sectors, including electricity generation, efficient buildings, and new transportation infrastructure.

SARNIA SOLAR
PHOTO COURTESY
SAYCHEESE/Flickr

Canadian Context

- Canada's ability to meet its Paris commitments will be based on the construction of new infrastructure for the generation of electricity using renewable sources.
- Serious efforts to decarbonize the Canadian economy will create significant opportunities for those in construction trades.
- Getting to net zero in Canada will mean replacing GHG-emitting sources of power with cleaner energy. At the same time, Canada's population is projected to grow to 48 million by 2050.

Building Trades and Net Zero Emissions

- The construction industry has a vital role to play in meeting Canada's climate goals by supporting production in other sectors, including electricity generation, efficient buildings, and new transportation infrastructure.
- Canada's ability to meet our climate goals will be based on the construction of new facilities for the generation of electricity using renewable sources, including hydro, wind, solar, tidal, biomass, and geothermal energy.
- In addition, it will require the construction and maintenance of more efficient buildings and transportation infrastructure.
- These net zero initiatives will require the work of a variety of tradespeople, including masons, boilermakers, pipefitters, insulators, electrical workers, glaziers, HVAC, linemen, ironworkers, and other construction trades.

Potential for Building Trades Jobs — By the Numbers

Electricity Supply: Building Tomorrow's Grid

Building tomorrow's grid will result in significant jobs for Canadian construction workers. Moving to an electrical supply grid composed primarily of hydroelectric (40 per cent), new wind, solar, geothermal, and tidal power generation (44 per cent combined), and legacy nuclear (5 per cent), would result in over 1,177,055 direct construction jobs by 2050. This total assumes a low-end 2050 demand scenario.

Here's how it breaks down:

- Wind power: at 25% by 2050 creates 209,360 full-time construction jobs;
- Solar power: at 10% by 2050 creates 438,350 construction jobs;
- Tidal and wave power: at 5% by 2050 creates 109,770 construction jobs;
- Geothermal power: at 4% by 2050 creates 30,300 jobs for construction workers;
- Hydroelectric power: at 40% by 2050 creates 105,000 person-years of construction employment;
- Nuclear power: at 5% by 2050 creates 30,360 construction jobs; and
- Transmission line construction would create 200,000 construction jobs.

Smart Communities: Efficient Buildings and District Energy Systems

- Net zero building retrofits and new “green” commercial, industrial, and institutional building construction are predicted to account for 1,997,640¹ direct non-residential construction jobs.
- Building small district energy systems in half of Canada's municipalities with populations over 100,000 would create over 547,000 construction jobs by 2050.

Transportation

- Building out \$150 billion of urban transit infrastructure — including rapid transit tracks and bridges, subway tunnels, and dedicated bus lanes — between now and 2050 would create about 245,000 direct construction jobs.

IN TOTAL, MEETING CANADA'S CLIMATE GOALS could generate over 3.9 million direct jobs in the building trades by 2050, and 19.8 million jobs if induced, indirect, and supply-chain jobs are included.



Meeting Canada's climate goals could generate over 3.9 million direct jobs in the building trades by 2050.

PHOTO COURTESY
BC BUILDING TRADES

About this Study

This paper goes beyond Canada's current commitments, accelerating the transition to envision an aspirational scenario in which the Canadian economy has achieved net zero by 2050.

THIS PAPER EXPLORES some possible implications for the building trades in the context of global warming and Canada's commitments to climate action. The construction industry plays a critical role in the national economy by supporting production in all other sectors. Rather than resulting in net job losses, a net zero Canadian economy has the potential to create huge opportunities for those in construction and other industries.

As one of 197 international signatories to the Paris Agreement, Canada has pledged to achieve net zero emissions — a balance between greenhouse gas emissions and their absorption across Canada by natural and man-made means — between 2050 and 2100 in order to keep global warming below 2°C and work toward 1.5°C of warming.

Without policies in place to address global warming, the world is on track to reach average temperatures of over 4°C by the end of this century.² Canada's current national commitment is to reduce emissions by 30 per cent below 2005 levels by 2030.

This paper goes beyond Canada's current commitments, accelerating the transition to envision an aspirational scenario in which the Canadian economy has achieved net zero by 2050.



Carbon dioxide (CO₂) is one of the primary greenhouse gases (GHGs) causing global warming, and GHGs like methane and nitrous oxide are generally measured in a single unit called a carbon dioxide equivalent (CO₂e). Because of this, a net zero economy is sometimes called a “low carbon” economy — and movement in that direction is called “decarbonization” by many agencies.



Part 1: Getting to Net Zero

The first section of this study is a broad-brush analysis in an emergent field of study. It explores possible pathways that would assist Canada in achieving net zero emissions by 2050. This is an ambitious and aspirational scenario, chosen for the sake of exploring potential employment effects of such a transition. The shift away from carbon and other greenhouse gases will take several decades and, as noted above, the current global emissions track is toward achieving net zero at some point between 2050 and 2100.

We have defined five major transition areas in a shift toward zero emissions: clean energy supply, smart communities, transportation, industrial retrofits, and direct capture (of emissions). This study focuses on the first three, envisioning the construction and building trades jobs that could be generated. Based on a widespread literature review, this section draws in part on two foundational analyses: *Canada's Challenge & Opportunity* (2016) by the Trottier Energy Futures Project and *Pathways to Deep Decarbonization in Canada* (2015).

Part 1 envisions the construction and building trades jobs that could be generated.

Part 2 provides a more detailed report on GHG emissions and the major drivers of emissions growth.

MONTREAL PHOTO COURTESY
CHRISTIAN BARRETTE/Flickr

Part 2: Environmental Scan

The second part of this paper provides a more detailed report on greenhouse gas emissions in Canada and the major drivers of emissions growth. It profiles the characteristics and central role of the construction industry in Canada's economy — examining low-carbon economic restructuring and the resulting demand for construction employment in renewable energy and energy-efficient buildings.

This section lays out key milestones in Canada's low-carbon journey, drawing on the 2015 report *Pathways to Deep Decarbonization in Canada*, and IDDRI's issue brief *The impact of the Deep Decarbonization Pathways Project (DDPP) on domestic decision-making processes — Lessons from three countries* (2016).



Getting To Net Zero: The Vision

By Tyee Bridge

WHAT WOULD AN ECONOMY with net zero emissions look like? Where would our power come from? In a country like ours that has invested heavily in fossil fuel extraction and export, what would the job landscape be?

There are many unknowns, and the advent of next-generation (nex-gen) technologies, new government policies, and changing world and domestic markets makes the crystal ball seem hazy. But there many signals telling us where the new economy will go. We can be fairly certain that as Canada moves to net zero emissions over the coming decades, there are five major transition areas that communities, industry, and governments will collaborate on: clean energy supply, smart communities, transportation, industrial retrofits, and direct capture.

Each of these areas shows promise for the construction trades, but this study focuses on the first three of those categories.

Managing the transition over the coming decades will avoid economic disruption and mitigate job losses — and as Canada goes further down the path of the transition, our job environment will become more stable. Economic reliance on fossil fuels — building and maintaining oil and gas infrastructure, as well as operations jobs — makes Canadian workers vulnerable to global commodity price shocks. The negative impact of distant decisions on Canadian workers was seen in the wave of layoffs following the OPEC-induced crash of oil prices in 2015, where more than 35,000³ people in the oil patch lost their jobs. A clean energy economy, where industries are powered by renewables like wind, solar, hydro, geothermal, and tidal generation, is far less at risk.

PHOTO: WELLINGTON COUNTY, ONTARIO – WORKERS MOUNTING AN ELECTRICAL POWER GENERATING COMPONENT ON TO THE TOP OF A WIND TURBINE.



Moving to a net zero economy will not happen overnight.

TORONTO AT NIGHT
PHOTO COURTESY ZIA
SYED/UNSPLASH

Introduction

Countries worldwide are “decarbonizing” their infrastructure, industries, and economies as they move to net zero emissions. This shift is gaining momentum and will impact all sectors of our society. It will alter the buildings and factories in which we work, how we move goods and people around, the way we power our homes, and much more.

As the federal government’s 2016 *Mid-Century Long-Term Low-Greenhouse Gas Strategy*⁴ report puts it:

Canada is committed to creating a cleaner, more innovative economy that reduces emissions and protects the environment, while creating well-paying jobs and promoting robust economic growth.

A low-greenhouse gas future represents an opportunity to increase prosperity and the well-being of Canadians, to improve the livability of the built environment, modernize transportation, and enhance the natural environment.

Canada’s actions on climate change will help communities in Canada in tangible and meaningful ways, since clean growth is not just good for the planet — it’s also good for the economy.

In 2011, the National Roundtable on the Environment and the Economy (NRTEE) found that climate change costs for Canada could rise from roughly \$5 billion per year in 2020 to between \$21 billion and \$43 billion per year by 2050. “The magnitude of costs,” the NRTEE noted, “depends upon a combination of two factors: global emissions growth and Canadian economic and population growth.”⁵ These costs are a combination of impacts on forestry, health,

climate-induced flooding, fires and storms, and many other factors. To keep costs as low as possible, the NRTEE called for “global mitigation leading to a low climate change future” and stated that “Canada would benefit environmentally and economically from a post-2012 international climate arrangement that systematically reduced emissions from all emitters — including Canada — over time.”⁶

Nicholas Stern, former chief economist for the World Bank and author of the 2006 *Stern Review on the Economics of Climate Change*, in 2015 noted that having “a reasonable chance” of avoiding a rise of more than 2°C globally “could be achieved for an equivalent annual investment of no more than 2 per cent of global GDP, and possibly for much less.”⁷

Moving to a low-emission economy will not happen tomorrow, or all at once. The transition toward net zero will take decades. For the construction trades that will build, retrofit, and restore society’s infrastructure in the emerging net zero economy, this is a historic undertaking and a major opportunity. The net zero shift will encompass everything from new transit lines, subway tunnels, and district energy systems in major cities to wind farms and emissions-free buildings. These will require trades of all kinds, including but not limited to boilermakers, pipefitters, insulators, electrical workers, masons, and glaziers.

In this study, we lay out some of the likely pathways Canada can take to reach net zero by 2050, and what these mean for the building trades. How many jobs will be created by these pathways? What kind of trades will be needed? What training should be in place? Can we expect more mega-projects, or a larger number of smaller projects?



We draw from many source reports, but do not necessarily concur with all of the assumptions or conclusions reached by those reports. We have based our work on the best research we found, but job calculations such as those set out in this study will necessarily evolve as the state of research itself progresses. For how a “job” is defined, as well as “construction,” see the glossary on page 64.

In addition to the construction numbers laid out here, many trades do a significant amount of maintenance work on infrastructure and factories, especially within energy, industrial, and petro-chemical facilities. Maintenance hours are accumulated every year of facility operations, “which can amount to 85 per cent of some trades, but average 20 per cent,” according to Bob Blakely, Canadian Operating Officer at Canada’s Building Trades Unions.

Except where noted, job numbers do not include indirect, induced, or supply-chain jobs, nor do they include non-productive support work — such as surveyors and camp attendants — that does not directly assist construction. It is worth pointing out that including those numbers would significantly increase these job totals, in some cases by as much as a factor of five.

In this report, we lay out some of the likely pathways Canada can take to reach net zero by 2050, and what these mean for the building trades. How many jobs will be created by these pathways? What kind of trades will be needed? What training should be in place? Can we expect more mega-projects, or a larger number of smaller projects?

EVERGREEN SKYTRAIN LINE
CONSTRUCTION IN METRO
VANCOUVER, PHOTO PROVINCE OF BC

Context and Opportunities

Decarbonizing is not new. In Canada, as in many other countries, we have been decoupling economic benefit from carbon for the past 25 years. One measure of this is emissions intensity — the amount of carbon and other GHGs produced per dollar of gross domestic product (GDP). Although overall GHG emissions in Canada have risen over 19 per cent⁸ since 1990, Canada's GDP has meanwhile grown by 161 per cent.⁹ Overall, our emissions intensity per unit of GDP has declined 32 per cent.¹⁰

Decoupling from carbon may not be new, but the trend is accelerating in global markets. The International Energy Agency (IEA) reported in 2016 that for three years running (2013 to 2015) global emissions stabilized at 32.1 billion tonnes. The IEA noted:¹¹

In the more than 40 years in which the IEA has been providing information on CO₂ emissions, there have been only four periods in which emissions stood still or fell compared to the previous year. Three of those — the early 1980s, 1992 and 2009 — were associated with global economic weakness. But the recent stall in emissions comes amid economic expansion: according to the International Monetary Fund, global GDP grew by 3.4% in 2014 and 3.1% in 2015.

This decoupling is related to growth in low-emission technologies. Bloomberg New Energy Finance (BNEF) reported¹² in 2016 that investment in renewable energy from 2008 to 2015, even excluding big hydro, was *double*¹³ that of investment in natural gas and coal. In 2015 alone, investments in oil and gas declined by 25 per cent in one year — from \$750 billion in 2014 to \$583 billion.¹⁴ Whether this trend continues is dependent on many factors, including global

markets and oil prices, as well as ongoing national and international regulation of GHG emissions.

Meanwhile in 2015, the amount of installed renewable electricity generation capacity rose by 147 GW,¹⁵ almost 9 per cent in one year. In the U.S., more people are employed in the solar industry than in oil and gas extraction.¹⁶ This shift is due, in part, to advances in technology. For example, the cost of solar cells is 1/150th of their price in the 1970s; meanwhile the amount of installed solar has grown 115,000-fold¹⁷ globally. While oil demand will remain steady for some years, in the medium to long term there is reason to believe that petroleum may follow a similar if less sharp decline path as coal. Coal demand has plummeted, reducing the market values of four major producers by 99 per cent¹⁸ in the past five years and pushing six U.S. coal companies,¹⁹ including Peabody Coal and Arch Coal, into bankruptcy.

In the context of climate change and increasing regulation (carbon taxes, requirements for expensive carbon capture technologies), decoupling from carbon is increasingly seen as a wise institutional investment strategy. Mark Carney of the Bank of England noted this in a talk with U.K. insurance companies,²⁰ when discussing the IPCC's "carbon budget" to keep global warming under 2°C.

The IPCC has stated that that budget would allow only 20 to 30 per cent of the world's proven oil, gas, and coal reserves to be burned. According to Carney:

If that estimate is even approximately correct it would render the vast majority of reserves 'stranded' — oil, gas and coal that will be literally unburnable without expensive carbon capture technology, which itself alters fossil fuel economics. The exposure of UK investors, including insurance companies, to these shifts is



potentially huge... On the other hand, financing the de-carbonization of our economy is a major opportunity for insurers as long-term investors. It implies a sweeping reallocation of resources and a technological revolution, with investment in long-term infrastructure assets at roughly quadruple the present rate.

For Canada, the sixth-largest²¹ producer of crude oil in the world and the fifth-largest²² producer of natural gas, these shifts are of special concern. The discussion about stranding assets is already underway here: Steve Williams, CEO of oil sands giant Suncor, has asked the Alberta government²³ for the option to leave some of its more high-cost, high-emission reserves in the ground.

The IEA predicts²⁴ that demand for oil will continue to rise in the near term, but all stakeholders in Canada's economy will benefit from looking beyond five to 10-year timelines. In March 2017, Royal Dutch Shell, the world's second largest oil company, agreed to sell most of its Athabasca oil sands investment to exploration firm Canadian Natural Resources. Shell has tied 10 per cent of its directors' bonuses to how well the company manages emissions. Business website TriplePundit reported²⁵ on the decision:

Shell's latest move signals a strategic shift for the company, which admits it's been under investor pressure to address climate change impacts. Shell's chief executive, Ben van Beurden, said the decision to sell its share of the Athabasca development to Canadian Natural Resources comes after careful thought about the sustainability of the carbon fuel market and Shell's economic future.

In the U.S., more people are employed in the solar industry than in oil and gas extraction. This shift is due, in part, to advances in technology. The cost of solar cells is 1/150th of their price in the 1970s, for example; meanwhile the amount of installed solar has grown 115,000-fold globally.

"We have to acknowledge that oil demand will peak and it could already be in the next decade," van Beurden told the CERAWEEK energy forum in Houston, Texas, last week. He said the public response to high-carbon emissions development is just as significant.

"Social acceptance is just disappearing," van Beurden said, acknowledging that the company is under significant scrutiny and pressure to make sound environmental decisions, an offshoot of eroding public trust. "[It] is becoming a serious issue for our long-term future."

The Paris Agreement takes into account the dynamic nature of global demand, and the unknown nature of emergent technologies, which sets it apart from other international climate agreements like Kyoto and Copenhagen. Paris has a built-in system of "ratcheting," whereby nations re-evaluate their progress and recommit to meeting their goals every five years.

As the move to net zero emissions accelerates, the building trades are seeing the benefits for their members. The World Green Building Council (WGBC), which represents 74 green building councils and 27,000 member companies, has called for all buildings to be net zero by 2050 through new construction and deep renovation. (When their share of electricity use is factored in, homes and buildings account for one quarter of all of Canada's emissions.)²⁶

Good jobs are a significant benefit of climate action. One coalition has called²⁷ on the Canadian government for a bold national action plan for energy efficient buildings that will set the stage “for deep energy retrofits (energy reductions of 25 to 50 per cent) of 30 per cent of the building stock by 2030.”

Citing a 2014 report by the Acadia Center called *Energy Efficiency: Engine of Economic Growth in Canada*, the coalition noted that investing in the efficiency of Canadian buildings

creates substantial co-benefits, including improved energy productivity and competitiveness, green jobs, and improvements to the quality of the places Canadians live and work.... The study²⁸ estimated that \$1.9 billion to \$8.5 billion spent on energy efficiency programs across Canada could result in annual GDP and job growth potential at between \$19 billion and \$48 billion, and between 100,000 and 300,000 jobs, respectively.²⁹

This massive net zero restructuring of the Canadian economy will create significant opportunities for those in construction. California’s successful ongoing shift to a post-carbon economy shows that unions are key to the transition.

With the exception of some smaller commercial photovoltaic projects (between 0.25 and 1 MW), almost all of the large-scale renewable energy construction work in California in the past 14 years was done by union contractors — or non-union contractors paying union rates under project labour agreements. The average blue-collar wage on large renewable energy projects in California between 2002 and 2015 was \$36.84 an hour, and these jobs contributed:³⁰

- Almost \$340 million to worker pension funds;
- \$400 million to health benefit plans; and
- \$46 million to apprentice training programs.

Electricity Supply: Building Tomorrow’s Grid

The move to decarbonize our energy supply is a significant pillar of the net zero transition. The scenario laid out below predicts a doubling of demand in Canada to 2050, and over 1,177,055 direct construction jobs created to build the necessary clean power infrastructure.

A report led by Stanford University researchers — *100% Clean and Renewable Wind, Water, and Sunlight (WWS) All Sector Energy Roadmaps for 139 Countries of the World* — has passed considerable global peer review, and it predicts that Canada’s electricity demand will quadruple by 2050, even taking efficiencies of a clean grid into account.³¹ In that case, the job

figures predicted here would roughly double to approximately 1.5 million direct construction jobs.

In 2014, public electricity and heat generation in Canada produced tonnes of pollution — equivalent to the weight of 826,000 D11T Caterpillar³² bulldozers. This is nearly 12 per cent of the total national GHG emissions. Relative to pollution produced by other national electrical grids, this is relatively low. Canada’s emissions intensity for electricity generation is about one third the average of countries³³ in the Organization for Economic Cooperation and Development (OECD), which includes Germany, France, and the United States. A major reason for this is our reliance



on hydroelectric power. As of 2014, Canada got over 63 per cent of its electricity from hydro, and 14.5 per cent from nuclear.³⁴ By comparison, the U.S. produces only 7 per cent of its electric power from hydroelectric sources.³⁵

Getting to net zero in Canada will mean replacing GHG-emitting transport fuels and other emitting sources of power with clean electricity. That means that at that same time that we are trying to slash GHGs from electricity production, we are trying to double our power generation by 2050. The need to decarbonize the Canadian grid is therefore critical. Doing so will be a particular challenge in provinces like Alberta that currently rely heavily on coal-fired generation plants. (Fifty-five per cent of Albertans' power was supplied by coal in 2014; the provincial government announced plans in 2016 to phase them out by 2030.³⁶)

There are other reasons to shift to renewable energy sources. Canada is historically used to, and currently dependent on, centralized energy production from large power plants, and “line losses” of energy during transmission to consumers average about 7 per cent.³⁷ This is a massive amount of lost power, equivalent at the national scale to the yearly output of eight hydroelectric facilities on the scale of the Site C dam project.³⁸ More differentiated, renewable technologies — solar, wind, geothermal, biogas, and biomass — can be located very close to the point of consumption. This means less energy loss and greater efficiency. Diversity of power sources also makes towns and cities less vulnerable to blackouts, resource price shocks, and pollution.

Canada is currently dependent on centralized energy production from large power plants, and “line losses” of energy during transmission to consumers average about 7 per cent. This is a massive amount of lost power. More differentiated, renewable technologies can be located very close to the point of consumption.

TRANSMISSION LINES, TIVERTON ONTARIO,
PHOTO COURTESY ONE.JUNIPER/Flickr

As Canada undergoes a historic shift to clean electricity, the construction trades will be essential in building that capacity.

Major changes are already afoot, as Alberta policies demonstrate. In the 2016 Trottier Energy Futures Report, the Canadian Academy of Engineering reported the “important observation” that “minimum cost solutions resulted in early and rapid decarbonizing of electricity supply, with the supply systems for all of Canada being essentially fully decarbonized by 2030 (within 15 years).”³⁹

Construction of new power generation facilities in Canada will include:

- Wind;
- Solar;
- Tidal and wave energy;
- Geothermal;
- Biogas; and
- Biomass.

Additionally, the grid will continue to consist of hydroelectric (large-scale and run-of-river) and nuclear. It is unlikely that any new nuclear power plants will be built, but existing plants

will need upkeep and likely upgrading in the decades to come. Hydroelectric mega-projects are increasingly encountering public opposition, but these may also be on the horizon. If nex-gen

carbon-capture and storage (CCS) technologies become economically viable, natural gas powered turbine generation will also be part of the mix in a net zero economy.

What projects will be required, and how many jobs will come of this shift?

In 2015, Canada used 511 TWh⁴⁰ of electricity. Utilities and industries generated almost 20 per cent more than we used: 611 TWh. That massive amount of power — 600 trillion kilowatt hours — came from these sources:⁴¹

- Hydro: 388 TWh, or 63.3%
- Nuclear: 89 TWh, or 14.5%
- Combustion (coal, natural gas, or other fuel): 126 TWh, or 20.6%
- Tidal: .01 TWh, or 0%
- Wind: 9 TWh, or 1.5%
- Solar: 0.06 TWh, or 0%

By 2050, Canada's population is projected to grow to 48 million.⁴² Even if our population were to stay the same, electricity demand would still increase as we replace⁴³ combustion-based power — in cars, transport, and buildings — with low-emission electricity. Taking into consideration more efficient, nex-gen technologies and waste reduction, a low-end estimate for Canada's electricity demand by 2050 would be a rough doubling of our current consumption.⁴⁴ (As noted above, the study led by Stanford University puts 2050 power consumption at 2105 TWh,⁴⁵ more than quadruple current demand.)

Roughly doubling the 2015 figure of 511 TWh — to a round number of 1,000 TWh — gives a baseline estimate.⁴⁶ How would Canada

generate that much power in a net zero emissions economy?

The following examples describe one scenario for Canada's 2050 electricity generation. All of the components set out below would require significant construction infrastructure. As the Canadian Electricity Association (CEA) stated in its report on a 2050 grid:

Renewable energy resources that currently have a relatively small market share — like wind, solar, biomass and tidal — are likely to grow their collective share of the overall generation mix.⁴⁷

In terms of actual percentages for these energy sources, the 2050 reality could vary significantly, but the following scenario shows some likely pathways.⁴⁸

Wind Power: 25% by 2050

Canada produced about 9 TWh⁴⁹ of power from wind farms in 2015. The wind industry has been growing nationally by an average of 23 per cent a year⁵⁰ for the past five years, with major energy companies starting to get on board. Suncor has built 187 MW of installed power, enough to power 65,000⁵¹ homes, and Enbridge has invested in 2,800 MW of wind power globally, enough to power almost a million homes.⁵² Given this growth rate, and the vast availability of wind power across

the country, by 2050 wind power could make up 25 per cent⁵³ of Canada's electrical supply — a figure in line with the renewables track in other countries. Denmark, Spain, and Germany are all tracking toward 25 to 30 per cent penetration of wind power. Germany produces about the same amount of electricity as Canada, with 13 per cent of it already supplied annually by wind.⁵⁴

Assuming total generation of 1,000 TWh in 2050, to bring Canada to 25 per cent wind power

would require 241 TWh of new wind power. This would mean building out generation capacity equivalent to 228,750 MW.⁵⁶ Looking to the case study below, that is the equivalent of 2,000 wind farms the size of Halkirk wind farm in Alberta. Some sites would be larger, some smaller. Research on construction employment in wind farms shows that building out Canada's wind capacity to this level would mean:⁵⁵

■ **209,360 full-time construction jobs.**



Case Study: Halkirk Wind Project

The Halkirk Wind Project,⁵⁹ located in Alberta, is rated at 150 MW of installed capacity. It can produce enough power for 50,000 homes. The facility consists of 83 wind turbines, with three blades on each turbine. Each blade is 44 metres long; they must be hoisted onto the massive turbines by a 600-tonne crane. Turbines are 80 metres high and weigh 160 tonnes.

Project construction, which included a communications tower and a power substation, resulted in 250,000 person-hours⁶⁰ of work — or about 166 jobs. Halkirk's construction employed electrical workers, masons, and ironworkers among many others. Now complete, the project continues to provide 18 permanent jobs for maintenance and operation.



HALKIRK WIND PHOTOS COURTESY DAVID DODGE/FLICKR

These wind facilities would also ultimately create 18,750 permanent operations jobs.⁵⁷ These jobs include entry-level meteorological technicians, high- and low-voltage electricians, site managers, wind turbine technicians, blade/composite technicians (working on fiberglass/carbon fiber repairs at height), and mechanical engineers.⁵⁸ These would provide 237,750 person-years of employment between now and 2050.

Solar Power: 10% by 2050

Solar electricity generation worldwide has grown by nearly 50 per cent a year for the past decade.⁶¹ By 2050, the International Electricity Agency (IEA) predicts that solar could supply 27 per cent⁶² of the world's electricity. There was 2,500 MW of installed solar power capacity in Canada in 2015, supplying almost 9 TWh of power — or about 1.5 per cent⁶³ of our total production.

Solar power supplies over 6 per cent of electricity in Germany.⁶⁴ To rise to form 10 per cent⁶⁵ of Canada's electricity grid and 100 TWh by 2050, solar capacity in Canada would have to add 91 TWh⁶⁶ of generation.

Solar power is a job-rich electricity source for construction. Based on Job and Economic Development Impact (JEDI) standards used⁶⁷ in the United States, which calculates 3.9 jobs per MW of installed solar power — combining averages for large arrays with commercial and residential installation — this would result in approximately:

■ 438,350 construction jobs.

Operations add an additional 45,880⁶⁸ ongoing jobs. As with wind power, solar panels have roughly 25 to 30 year life spans, and thus replacements of solar arrays will result in jobs that continue in perpetuity beyond 2050.

Geothermal Power: 4% by 2050

Geothermal energy draws from the planet's own warmth, providing renewable, low-emission energy. Because the temperatures are stable, geothermal offers reliable base load capacity as in traditional fuel-based power plants or hydroelectric projects.⁶⁹

Canada has plentiful⁷⁰ geothermal resources, and is home to many leading geothermal power developers. While geothermal is the cheapest form⁷¹ of power over the long-term, drilling for geothermal entails significant risks and upfront costs. In part due to a lack of policy frameworks and incentives, the industry has yet to gain a foothold here — and Canadian geothermal developers are instead developing projects in other countries⁷² like the United States, Chile, and Iceland.

But there are signs of a shift. The Kitselas First Nation has begun working with Borealis GeoPower on a 15 MW plant near Terrace.⁷³ In 2017, Saskatoon-based Deep Earth Energy Production (DEEP) will begin exploratory drilling toward what could be the first commercial geothermal power plant in Canada. In 2016, a consortium of oil companies began prepping an abandoned oil well to convert it to a geothermal energy source — part of the Leduc #1 Energy Discovery Centre in Devon, Alberta. As Mitchell Pomphrey, manager of the Living Energy Project, said in a 2016 article in *Alberta Oil* magazine:

*Alberta has nearly 220,000 disused oil wells. Converting them to geothermal energy helps oil companies' bottom line, cuts down methane leakage, produces free energy and gets oil service firms back to work. It's win-win-win for the industry, taxpayers and the environment.*⁷⁴

The Living Energy Project proposes converting 10 per cent of Alberta's 78,000 dormant



PHOTO COURTESY CAPE SHARP TIDAL

(suspended) wells to geothermal heating systems for greenhouses, to create up to 5,000 permanent agriculture jobs and work for thousands of oil service workers.⁷⁵

In terms of actual electricity generation, the Canadian Geothermal Energy Association (CanGEA) believes that Canada could readily add 5,000 MW of baseload power to its grid over the next 15 years, which could produce up to 43 TWh⁷⁶ of power annually.

Like most energy infrastructure, geothermal plant construction requires a wide variety of skilled labour: electrical, welders, exploration drillers, pipefitters, machinists, construction equipment operators, rig transport crews, HVAC technicians, and drilling equipment operators.⁷⁷

Building out this portion of Canada's geothermal potential would result in:

- **30,300⁷⁸ jobs for construction workers.**

It would also result in 5,850⁷⁹ permanent operations jobs.

Tidal and Wave Power: 5% by 2050

There are not many countries in the world harnessing wave and tidal power, but Canada is one of the top four — along with France, Korea, and the United Kingdom. Korea's Sihwa Lake Tidal Power Station began construction in 2004, was opened in 2011, and now produces about 550 GWh⁸⁰ annually.

Globally, harnessing tidal and wave power is still in its infancy, but Canada has large tidal and wave power potential:

The total wave energy potential at depths of 1 km off Canada's Atlantic and Pacific coasts is more than double Canada's current electricity demand. The potential tidal power at 190 sites on the Atlantic, Pacific and Arctic coasts collectively exceeds an annual average of 42,000 MW, or roughly two-thirds of Canada's current electricity demand.⁸¹

Tidal power has the benefit of being predictable and consistent, and fish-friendly designs reduce

their impacts on ocean creatures. However, tidal turbines — “barrages” as they are called — are costly to build and their underwater sonic effects on marine mammals are not well understood.⁸² Construction of such facilities can be complex, involving the creation of cofferdams and temporary roads.

As an energy source, tidal and wave power are still miniscule in Canada, producing only 12,820 MWh of generated power in 2015 — about .002 per cent of the national grid.⁸³ Bringing this to 5 per cent, or 50 TWh, would mean a massive increase⁸⁴ in these generation facilities. Building out an additional 22,727 MW of tidal and wave generation capacity would be a significant undertaking, but already there are small projects — like the new Cape Sharp⁸⁵ tidal generator in the Bay of Fundy — making an impact.

A labour study on a proposed 320 MW tidal project in Wales posited over 1,700 construction jobs⁸⁶ for the project. Based on this and other factors, we estimate building out 5 per cent of Canada’s grid with tidal and wave generation facilities would create:⁸⁷

- **109,770 construction jobs.**

Hydroelectric Power: 40% by 2050

In its 2016 report *Canada’s Energy Future*, the National Energy Board (NEB) predicts that hydroelectric power will shrink to 51 per cent of our national energy supply by 2040.⁸⁸ Extending that trajectory to 2050 in this alternate scenario, and allowing for growth of other sectors considered above, we consider a hydroelectric scenario of 40 per cent. This would mean building facilities that would generate an additional 12 TWh of generation.

If this new capacity is made up equally of large-scale dams and small-scale (run-of-river) hydro projects, that means 6.5 TWh of each.

Based on this, we can project construction jobs of approximately:⁸⁹

- **74,865⁹⁰ jobs to build new run-of-river projects, and 84,050⁹¹ jobs in new large hydro projects. Together, this is 158,915 person-years of construction employment.**

Once in place, run-of-river projects would also produce 1,395⁹² ongoing operations jobs; large hydro would create an additional 530 permanent operations jobs.

Nuclear Power: 5% by 2050

The role of nuclear energy in Canada is expected to diminish over the next three decades. There are currently four nuclear power generation facilities⁹³ in Canada — three in Ontario and one in New Brunswick. (Gentilly, Quebec’s only nuclear plant, closed in 2012.⁹⁴) While nuclear currently provides 50 per cent of generating capacity in Ontario, the province recently scrapped plans for two new reactors, and the Pickering nuclear plant (built in 1971) is slated to be decommissioned in 2024,⁹⁵ if not before.

The National Energy Board predicts that by 2040 nuclear will have declined to 6 per cent of generation capacity in Canada, down from a 2015 share of 10 per cent.⁹⁶ If nex-gen nuclear technology comes into play — small “modular” reactors with a few hundred megawatts of capacity — this number could increase.⁹⁷

While this study does not predict significant jobs from building new nuclear capacity, construction jobs will come from refurbishing nuclear facilities in Ontario. (New Brunswick’s station, Point Lepreau, completed a refurbishment in 2012, and is hoped to run without upgrades for another 27 years;⁹⁸ as it was originally built in 1983 it’s not clear if it will be refurbished once again.) In early 2016, the Ontario government announced

a \$12.6 billion refurbishment of the Darlington nuclear generating station over 10 years,⁹⁹ and Bruce Power has announced a \$13 billion¹⁰⁰ refurbishment of its station in Kincardine, Ontario, to take place over 15 years.

A 2010 report¹⁰¹ estimates that refurbishing Darlington and Bruce nuclear plants would produce 55,000 person years of employment, with 40 per cent of those as direct construction jobs for boilermakers, masons, pipefitters, and other skilled trades. This would equal:

- **30,360 construction jobs.**

Transmission Line Construction

Renewable power is more distributed than our current grid — that is, power sources (solar, wind, geothermal) are often closer to demand-points than power produced at larger megaproject dams, requiring less transmission distance.

Nevertheless, our increased grid will require some transmission line construction. As of 2011, Canada had 80,000¹⁰² km of transmission line. A low estimate — particularly bearing in mind the Stanford scenario of quadrupled demand by 2050, rather than doubling as envisioned here — would be 40,000 km of new transmission line. This would create:

- **200,000 construction jobs.**¹⁰³

This is a low number when considering the need for ongoing investment in Canada's existing transmission grid, which needs replacing and upgrading. The Conference Board of Canada estimates that about 34 per cent of the needed \$15 billion annual investment in Canada's electrical systems should be put toward distribution and transmission systems.¹⁰⁴

One concern to be managed in particular in distribution system upgrades, the Conference

Board has noted, is the “potential for load spikes as vehicles are connected for charging.”¹⁰⁵

Altering the north-south orientation of Canada's transmission grid, and bringing in greater east-west transmission capacity, is also another potential area for construction work growth if investments are made in interprovincial connections.

Other Construction Opportunities: CCS and Refurbishment

These two categories do not have associated job number estimates, but both are likely to result in significant employment for those in the construction trades.

Combustion with CCS (Natural Gas, Biomass, or Other Fuel)

Currently, combustion technologies — coal, natural gas, and biomass — generate over 20 per cent of Canada's electricity. As coal-fired power generation is phased out nationwide, the National Energy Board projects that by 2040 natural gas and biomass together will grow proportionally to absorb that percentage of generation, together accounting for 24 per cent of production.¹⁰⁶

However, as with nuclear power and large hydro, public opinion may slow the growth of natural gas-powered generation plants due to concerns over environmental impacts; specifically, in the case of natural gas, concerns over fugitive emissions. (Methane is a potent greenhouse gas,¹⁰⁷ and researchers have noted that estimates of methane leakage in B.C.'s natural gas industry are likely too low by a factor of five,¹⁰⁸ if not more.)

Taking a low estimate of a 10 per cent share of electricity generation by 2050 would equal 100 TWh. While this is a net reduction from the current level of 126 TWh, to make these combustion-based generation plants align with a net zero emissions



The 660 MW Mactaquac Dam in New Brunswick is in need of maintenance to extend its lifespan to 2068. PHOTO NB POWER

goal by 2050, carbon capture and storage technology will need to be built into them.

There have been promising pilot projects in the U.S. — such as the 1,000 tonne per day sequestration project at a corn-to-ethanol plant in Decatur, Illinois — but there are few available resources¹⁰⁹ on job numbers.

Refurbishing Existing Electrical Systems

Refurbishment in general of Canada's existing energy infrastructure has not been considered in this electricity supply section, but this effort over the coming decades will be significant in terms of employment, as the Canadian Electricity Association (CEA) has noted the need for major upgrading:

*The Canadian electricity system is in need of massive infrastructure renewal. The Conference Board of Canada estimates that by 2030, close to \$350 billion in new investment will be required just to maintain existing electricity capacity, with most of Canada's non-hydro assets needing renewal or replacement by 2050.*¹¹⁰

The CEA sums up the history and context of the situation in its 2014 report, *Vision 2050: The Future of Canada's Electricity System*.

The 1970s and 80s saw dramatic investments in electricity infrastructure — in 2011 dollars, about \$10.5 billion per year. Then in the 1990s, things started to slip: the rate slowed to \$9.2 billion... So over the past four decades, investments have averaged above \$9 billion and below \$11 billion in today's dollars. To keep the system running will require, on average, \$15 billion per year. We'll need to keep that up for the next two decades... just to maintain the reliability of what we have today.

The 660 MW Mactaquac Dam in New Brunswick, for example, is in need of maintenance to extend its lifespan to 2068. Provincial authorities have estimated the cost of this refurbishment to be \$2.9 to \$3.6 billion.¹¹¹

Clean Electricity Supply: Totaling the Impacts

Building tomorrow's grid will result in significant jobs for Canadian construction workers. Again, this total assumes a low 2050 demand scenario that may well be doubled in a 2,000 TWh grid, and does not include:

- Indirect and induced jobs;
- Jobs created by refurbishing existing infrastructure (with the exception of nuclear power); or
- Jobs created by installing CCS technology in hydrocarbon-emitting power plants.

A rough estimate of the direct jobs created by building out new generation facilities for Canada's clean energy supply to a 1,000 TWh grid is:

■ **1,177,055 direct construction jobs.**

This is equivalent to the jobs created by more than 29 projects¹¹² at the scale of the Hebron offshore oil platform project.



International Case Study: California

The State of California shows the rapid gains that can be made in building a cleaner grid, and the impacts of such initiatives on the construction trades. Since 2003 California has tripled its renewable energy capacity from 7,000 to 23,500 MW using a mixture of solar, wind, geothermal, and biomass.

The shift has been spurred by a policy known as the Renewable Portfolio Standard (RPS), which requires utilities to adopt a progressively larger percentage of renewable generation, while allowing them to decide which ones to use. Thirty-two U.S. states now have some kind of RPS program, with California and Hawaii leading the way in terms of ambitious targets.

Some facts about the California shift:

- Installed, in-state, electrical generation capacity is now at 39 per cent¹¹³ renewables — about 27 per cent¹¹⁴ of the power consumed by Californians comes from renewable power;
- California in 2015 legislated that public utilities reach 50 per cent¹¹⁵ renewable-source generation by 2030;
- California cut its CO₂ emissions from electricity generation by 7.5 per cent between 2001 and 2014, dropping by 28.8 million tonnes¹¹⁶ annually;
- In that same timeframe, California's population grew over 12 per cent, from 34.5 to 38.8 million people;
- Coal-fired generation reduced by 87 per cent and nuclear by 44 per cent;¹¹⁷
- Wind power is up 265 per cent, solar farms up 193 per cent, and solar photovoltaic up 419,000 per cent;¹¹⁸ and
- Grid reliability has improved, with California seeing fewer blackouts and brownouts¹¹⁹ than it did prior to 2003 — improved or stable reliability is common¹²⁰ in jurisdictions that have moved toward greater penetration of renewables.

The shift has been a positive boost for the state's construction trades:

- Between 2002 and 2015, the RPS created 25,500 direct blue collar construction jobs and another 7,200 white collar construction jobs;¹²¹
- The majority of RPS projects are located in areas of high unemployment;
- The average blue collar wage on large renewable energy projects in California between 2002 and 2015 was \$36.84¹²² an hour; and
- These jobs contributed almost \$340 million to worker pension funds, \$400 million to health benefit plans, and \$46 million to apprentice training programs.¹²³

Smart Communities: Low-Impact Livability

WE NEED TO BUILD communities that encourage and support low-carbon lifestyles. Smart communities as a category of Canada's 2050 net zero transition includes:

- Walkable and complete communities (including industrial sites for jobs);
- New green buildings and deep, net zero building retrofits;
- District energy — greater energy efficiency throughout via distributed power generation (power produced closer to where it is used);
- Fuel switching — electric vehicle (EV) charging infrastructure, biofuels; and
- Zero waste with composting and recycling facilities.

While all of these areas will require some form of construction, in this section we focus on green buildings and district energy facilities.

As noted below, just two of these elements in a net zero 2050 scenario — green buildings and district energy — would produce 2,545,390 construction jobs.

Green Buildings and Net Zero Building Retrofits

Canada's residential and commercial buildings burn oil and natural gas for space and water heating, which results in 87 million tonnes¹²⁴ of GHGs per year — about 12 per cent of our national annual total. Buildings also use electricity for heating, as well as for air conditioning, lighting, and appliances. Taken together, buildings are responsible for approximately 30 per cent of Canada's energy consumption, and nearly one quarter of our GHG emissions.¹²⁵

There is much work ahead for Canada in reducing these emissions. Canada ranks 6th out of 23 countries for rigorous energy efficiency policy, but we are in 18th place on actual performance.

“This signals that Canada still has room to implement stronger energy efficiency measures, which are presently underutilized,” says Thomas Mueller,¹²⁶ CEO of the Canadian Green Building Council (CaGBC).

Green buildings — whether office towers, hotels, universities, conference centres, or residences — are designed, constructed, and operated to be energy efficient, minimize total environmental impacts, and create healthy places for people to live and work. The CaGBC defines the sector as those building that achieve “clearly defined environmental, economic, and social performance objectives that are measurably above and beyond the norm,” via adherence to a rating certification system (i.e., LEED, BOMA BEST, Built Green, or Novoclimat).¹²⁷

There are two categories of green building construction employment: green retrofits and new buildings.

Existing commercial, residential, and industrial buildings will need to be retrofitted with new-generation LED lighting and efficient insulation in walls, roofs, and windows — as well as mechanical insulation. Mechanical insulation, as the B.C. Insulators union and the Mechanical Contractors Association of B.C. have pointed out,¹²⁸ could annually save 320,000 kilowatt hours in a single, 25-storey, electrically heated residential apartment building. Physical plant systems will need to be optimized, with existing heating, cooling, and refrigeration systems replaced with improved, energy-efficient versions — including pumps, ventilators, compressors, and conveyers.

As an example, the City of Vancouver is aiming to use retrofits to reduce GHG emissions in



existing buildings 20 per cent below 2014 levels by 2020.¹²⁹ Building emissions are a major source of Vancouver's GHG pollution, at about 56 per cent. This is a massive undertaking. Setting aside single-family homes and duplexes, Vancouver's building stock consists of 5,700 apartment buildings, 5,200 commercial and institutional buildings, and 250 industrial facilities.¹³⁰ Retrofitting all or most of them will require significant investment and have many positive economic impacts. The City of Vancouver predicts even a 20 per cent drop in GHG emissions will save residents and businesses \$90 million annually¹³¹ in energy costs. A key component of Vancouver's retrofit strategy for existing buildings is the city's Energy Benchmarking Program for large buildings. Vancouver's bylaws require all new homes to be designed for energy efficiency.

As Canada moves to a net zero emissions target, municipalities are increasingly mandating high efficiency standards for new buildings. The Leadership in Energy and Environmental Design (LEED) standard has pioneered these approaches. Growth in LEED buildings has risen over 1,200 per cent in Canada in the last decade, from 0.8 per cent (2004 to 2009) to a 2014 rate of 10.7 per cent for all new construction floor space. In 2014, about 22 per cent of all new commercial buildings built in Canada — and around 30 per cent of all new institutional buildings — were LEED certified.

The trend is now moving beyond LEED to "zero emission" buildings. In 2016, the City of Vancouver approved a Zero Emissions Building Plan. The plan makes Vancouver the first major city in

The City of Vancouver is aiming to use retrofits to reduce GHG emissions in existing buildings 20 per cent below 2014 levels by 2020. Retrofitting buildings in Vancouver is a massive undertaking.

VANCOUVER PHOTO COURTESY MSVIRK LULKO/Flickr

North America to set specific targets and actions for reaching zero emissions in all new buildings. Described as "a phased approach to aggressively combat and reduce carbon pollution," it aims to reduce emissions from new buildings 70 per cent by 2020 and 90 per cent by 2025.¹³² It mandates that new buildings "produce little to no GHG emissions" through zero emission construction (such as the Passive House standard, which reduces energy use) or connection to a district energy utility.¹³³

Retrofits don't just save on energy bills: they create jobs. As noted by the Pacific Institute for Climate Solutions in its 2015 report¹³⁴ on building efficiency upgrades:

Investments in the building sector create more jobs per dollar invested than investments in resource extraction or the energy sector. Research by the University of Massachusetts estimates¹³⁵ that the total number of jobs (direct, indirect and induced) from efficiency capital upgrades in multifamily buildings to be 13.41 per million dollars invested — more than double the number of jobs created for a similar investment in energy generating infrastructure (5.32 per million dollars invested).

Case Study: Brock Commons

Buildings can also act as carbon storage by using wood products, even in high-rise structures such as the new 18-storey mass-timber Brock Commons residence at the University of British Columbia. (Brock Commons incorporates cross-laminated-timber (CLT) floors and walls, and uses both concrete cores and glulam for load-bearing structure.)

The 162,500 square foot building used 1.7 million¹³⁹ board feet of lumber. Relative to other construction materials such as concrete, building Brock Commons as a mass-timber structure is estimated to have saved over 2,400 tonnes of carbon dioxide,¹⁴⁰ about the same as taking 500 cars off the road for a year.¹⁴¹

The project created about 198 direct blue collar and management construction jobs.¹⁴²



Levels of investment are dependent on regulatory and market incentives.

Green building construction, both in new builds and retrofits, is already a significant part of the Canadian economy. As the Canadian Green Building Council (CaGBC) notes:

Companies active in the Construction and Trades segment accounted for the largest percentage (55 per cent) of green building employment and GDP in Canada, equal to approximately 164,445 jobs (approximately 13 per cent of Canada's total construction work force) and \$13.13 billion dollars in GDP.¹³⁶

As construction of commercial, institutional, and industrial facilities increasingly moves toward high standards of efficiency and low-GHG emissions, the vast majority of building construction jobs will be “green” by default. In a recent survey of contractors, architects, building owners, and engineers (by McGraw Hill Construction for CaGBC), over half of Canadian respondents stated that 30 per cent of their current projects are green, and that more than 60 per cent of their

projects will be green going forward from 2017.¹³⁷ Green building practices will gain momentum under stronger municipal and provincial efficiency regulations. Including life-cycle costs in the bidding process — so that ongoing expenses beyond construction, e.g., those related to heating, cooling, and building maintenance, are included — would also help to spur the use of efficient building technologies.

Based on current construction employment figures in the green building sector, and predicting a scenario of gradual saturation of the industry with eco-friendly standards, the green building sector as we approach a 2050 net zero scenario amounts to:

■ 1,997,640 direct non-residential building construction jobs.

Including the residential sector would potentially mean another 14 million jobs as the sector “greens” to 2050, as there are currently approximately 500,000 Canadians employed in building residential — and as of 2014, only 23,000¹³⁸ of those were considered green.

District Energy

District energy systems (DES) supply thermal energy — and in some cases electricity — to buildings from a central generation plant, or from interconnected plants. Using locally available supplies to meet needs for heat and cooling in cities and towns, DES has the potential to lower energy costs and reduce municipal GHG emissions. Waste heat can be captured for use from industrial facilities, or from other sources: organic waste composting, geexchange from the ground, solar, small-scale “cogeneration” facilities (producing electricity and heat), or burning biomass from waste wood.¹⁴³ In some cases, cooling of buildings can be achieved using ocean or deep lake water, as in Toronto’s Enwave¹⁴⁴ facility that air-conditions 3.2 million m² of office space.

Scandinavian cities are world leaders in district heating systems. Copenhagen captures waste heat from electricity generation stations — energy that would ordinarily be released into the air or ocean — and pipes it through an underground network as hot water or steam to provide space heating. Of the city’s 35,000 buildings, 97 per cent¹⁴⁵ do not have boilers or furnaces.

Copenhagen residents save approximately \$2,000 a year¹⁴⁶ on utility bills as a result.

The city of Reykjavik in Iceland (population 110,000) sits in a volcanic zone with abundant geothermal heat. Public utility Reykjavik Energy¹⁴⁷ captures it to produce electricity and warm buildings and homes. High heat at relatively shallow depths allows the city to pipe in hot water from 27 km away,¹⁴⁸ a relatively long distance; generally geothermal heat cannot be economically transported more than 8 km.¹⁴⁹ The system enables the city to save the equivalent of 4 million tonnes of GHGs per year.

In Canada, district energy systems are gaining traction, with Ontario and B.C. leading the way: a recent inventory tallied 44 in Ontario and 42 in B.C.¹⁵⁰ out of a national total of 159 facilities. They are present in municipalities of all sizes, from rural to urban. Construction has surged in the past 15 years, with half of all DES infrastructure commissioned since 2000 and one quarter in the past five years.¹⁵¹

The average DES in Canada heats 37 buildings, with an average floor space of 470,000 square meters — about 5 million square feet. In practice, the numbers range from as few as three buildings

AFTER CONSTRUCTION: MAINTENANCE MEANS MORE JOBS

Much of the work of building trades is in maintenance of existing facilities. These maintenance hours, clocked year after year, are vital to keeping infrastructure functioning and are in addition to hours spent in construction.

The United Association of Plumbers and Pipefitters Local Union 488 (UA 488) in Edmonton, Alberta is the province’s largest construction union local, with more than 10,000 members,¹⁵² and the largest supplier of pipe trades professionals in Canada.¹⁵³ Of their over 12.5 million total hours worked in 2016, 4.8 million were in maintenance — about 38 per cent.

Other trades have a similar experience, and in some cases maintenance of existing projects is a mainstay: for the Boilermakers union, about 85 per cent of work is in maintenance.

A rough average of 20 per cent for maintenance work across the building trades captures the magnitude involved each year in keeping existing facilities operational.

to as many as 300.¹⁵⁴ In 2012, Prince George, B.C. completed construction of a district energy system. Powered by waste sawmill wood, it heats 11 downtown buildings and eliminates 2,000 tonnes of GHGs annually.¹⁵⁵ The City of Surrey, one of the fastest-growing urban centres in Canada, is planning a hot water heating system for its City Centre area, to be powered by a variety of sources: waste sewer heat, industrial heat, refrigeration heat, geoexchange, biomass, solar, and electricity generation. By 2045, the system is expected to offer linked service to 25 million square feet of new development, along with existing buildings (including a hospital and several schools).¹⁵⁶

Construction of district energy systems requires the skills of many different trades including pipefitters, ironworkers, masons, and insulators. District energy systems vary widely in terms of type, however, and estimating construction job numbers for this sector is challenging. There are

approximately 400 municipalities in Canada with populations over 10,000.¹⁵⁷ If, by 2050, half of those were to install only one DES plant servicing the national average of 37 buildings, that would likely mean a minimum investment of \$21.9 billion and the creation of:

- **547,750 direct construction jobs.**¹⁵⁸

Smart Communities: Totaling the Impacts

The combined total jobs for just these two aspects of smart communities — non-residential green buildings and district energy — gives a total of:

- **2,545,390 direct construction jobs.**

This is equal to more than 254 Site C Dam projects.

Case Study: Southeast False Creek Neighbourhood Energy Utility

Usually the energy that goes into heating dishwater or bathwater goes down the drain. Vancouver's Southeast False Creek utility captures this wasted heat from sewage water and recycles it back into the surrounding community — providing space heating and domestic hot water.¹⁵⁹

Servicing 27 buildings and over 4,300 residences¹⁶⁰ (amounting to 4.2 million square feet of floor area) the Southeast False Creek utility incorporates over 4.7 km of dedicated piping.¹⁶¹ As a profile of the system in the quarterly magazine of the International District Energy Association noted, the system integrates a municipal pump station “where, similar to a geothermal application, heat pumps transfer thermal energy from the sewage to a hot water distribution network.”

The system eliminates more than 60 per cent of the emissions pollution created by heating space and water in community buildings and hot water use in buildings, saving about 2,400 tonnes of GHGs per year.¹⁶²

The city has approved two more new district energy facilities,¹⁶³ at River District in South Vancouver and Northeast False Creek.



PHOTO COURTESY FRANCL ARCHITECTURE

Transportation: Building Modern Infrastructure

THE TRANSPORTATION SECTOR is a major source of emissions worldwide, accounting for about one quarter of global GHGs. In 2014, transportation emissions accounted for 203 million tonnes¹⁶⁴ of GHG emissions in Canada, which at slightly more than one quarter of the national total, places Canada in line with the global average.

- The pathways to net zero emissions in the transportation sector include many different innovations and investments. Making transport clean, and moving people and freight within cities and between cities without GHG pollution, will encompass:
- Building out rapid transit and public transportation services;

- Fuel switching to E.V.s, including light trucks;
- Electrification of rail and HSR installation (e.g., Calgary to Edmonton); and
- Biodiesel engines for freight trucks.

These innovations will result primarily in jobs in the manufacturing sector. But there are significant construction opportunities that will arise from building transit infrastructure. Building out Canada's public transit infrastructure would create approximately 244,950 construction jobs. This is equal to the jobs that would be supplied by six projects at the scale of the Hebron offshore oil platform project — or building 410 Burnaby-class ferries¹⁶⁵ (130 metres long, with 145-vehicle capacity).



The Big Picture

As the world urbanizes, transportation emissions in cities will rise. More and more people are moving to cities, part of a long-standing trend over the past 60 years. In 1950, less than a third of the world's population lived in cities; now over half of us are urban, with this proportion expected to grow to two thirds¹⁶⁶ by 2050, when 6.3 billion people¹⁶⁷ are expected to swell the world's cities. In Canada, the trend is even more pronounced: as of 2011, 81 per cent¹⁶⁸ of Canadians lived in urban areas.

Transportation emissions are a significant driver of climate change, but they also have direct human health impacts: black carbon soot from diesel vehicles are known as a leading factor in mortality in urban areas, responsible for a staggering 3.2 million early deaths each year.¹⁶⁹ In Canada, the Canadian Medical Association estimated that in 2008 alone, air pollution was responsible for 21,000¹⁷⁰ deaths. Tailpipe emissions are also a cause of cardiopulmonary problems, asthma, lung cancer, and child respiratory problems.

One study estimates that government, municipalities, and transport companies globally will need to add close to 25 million paved road lane-kilometres (km) and 335,000 rail track kilometres (track-km) by 2050 — a 60 per cent increase over 2010 road and rail capacity.¹⁷¹ Whether this can be done without catastrophic impacts on human health and the biosphere is a pressing question. Reducing transportation emissions will require fuel-efficiency initiatives and electrification of passenger and freight vehicles — via batteries, third rails, or overhead catenary power lines — where possible. It will also require a historic investment in urban transit systems that can move passengers around cities efficiently and with a minimum of pollution.

Currently, electrification of freight rail systems in North America remains purely hypothetical

due to the nature of our rail infrastructure. In EU countries as well as China and Russia, publicly-funded electric passenger rail preceded electric freight trains.¹⁷² In Canada and the United States, railroad infrastructure is privately owned, and the incentive to overhaul and electrify freight rail is hampered by high costs.¹⁷³ Electrification of freight is a worthy long-term goal, but when and how such a transition process would happen in Canada remains vague. This may change in the coming five to 10 years, but for the moment the next steps toward freight rail electrification are too undefined to name it as a likely pathway.

Urban Transit Infrastructure

A more likely pathway in the net zero transition in Canada is the creation of robust urban transit infrastructure. In a 2012 poll asking Canadians about the importance of public transit in their communities, over 94 per cent of respondents felt that transit is either “very important” or “important.” Along with this social license, the economic benefits of transit development are significant. A report by the Political Economy Research Institute (PERI) has noted: “The highest direct and indirect employment impacts are associated with investments in mass transit systems.”¹⁷⁴

Research by the Canadian Urban Transit Association (CUTA) projects 86 per cent¹⁷⁵ growth in transit ridership across Canada by 2040 — from 1.76 billion trips in 2007 to 3.28 billion trips. Accommodating this increased demand to 2050 will require not only major new infrastructure, but continued upkeep of existing infrastructure.

CUTA commissioned a study in 2008 to determine necessary levels of investment in transit nationally. The report determined that a one-time investment of \$91.8 billion¹⁷⁶ would have been necessary in 2006 to “enable optimal service levels” and take full advantage of the economic

benefits of expanded transit. This hypothetical exercise gives a general idea of the deficit Canada is in with regards to satisfying the demand for transit among the 81 per cent of us who live in cities.

In late 2016, the federal government announced transit infrastructure funding at \$25.3 billion¹⁷⁷ over the next 11 years. These funds are to be matched with provincial funding up to a 50/50 investment in transit infrastructure projects.¹⁷⁸ If this level of investment — about \$4.6 billion per year — continues to 2050 that will amount to approximately \$150 billion in 2016 dollars. This estimate is at the low end, as provincial and municipal investment in these projects is frequently much more than 50 per cent relative to federal investment. In the case of the Evergreen Line in Metro Vancouver (see case study below),¹⁷⁹

In 1950, less than a third of the world's population lived in cities; now over half of us are urban, with this proportion expected to grow to two thirds by 2050, when 6.3 billion people are expected to swell the world's cities. In Canada, the trend is even more pronounced: as of 2011, 81 per cent of Canadians lived in urban areas.

the federal government kicked in less than one third (29.6 per cent) relative to provincial, municipal, and private funds — about \$424 million of the \$1.43 billion total.

This level of investment in building urban transit infrastructure — including rapid transit tracks and bridges, subway tunnels, and dedicated bus lanes — would result in approximately:

- **244,950 construction jobs.**¹⁸⁰

Case Study: The Evergreen Line

The Evergreen Line extension in Metro Vancouver connects Port Moody and Coquitlam with existing SkyTrain facilities in Burnaby. The automated rapid transit tracks runs for 11 kilometres and incorporates seven new stations, five power substations, parking and maintenance areas, a two-kilometre tunnel, and several other complementary facilities. The project had many technical hurdles to overcome, as noted by infrastructure magazine *ReNew Canada*: “The alignment navigates existing roadways, CPR tracks, and water crossings, with an incline ranging from one to six per cent through challenging ground conditions.”¹⁸²

Completed in December 2016, the total project cost was \$1.431 billion, and was projected by SNC-Lavalin to create 8,000 jobs during construction.¹⁸³





Getting to Net Zero: Conclusion

This section has contemplated a few areas of a net zero transition in Canada by 2050 — selected aspects of clean energy supply, smart communities, and transportation — that are of particular interest to the building trades.

■ **Total for these three areas of the net zero transition: 3,967,400 jobs.**

While impressive, this is a figure that may well be considerably higher, even if only direct construction jobs for these project are tallied. When induced, indirect and supply chain jobs are added, that number could increase by a factor of five, which would be the equivalent of over 19,800,000 jobs.

There are many areas within these three categories that have not yet been tallied, and there are two other significant sectors of the net zero transition for which we do not yet have estimates: industrial retrofits and direct capture. These

areas would begin to account for reducing the approximately 26 per cent of Canadian emissions that are created by oil and gas production.

This is an emergent field, and there is much robust research that has yet to be done in this and many other areas of the post-carbon economy. However, these early numbers are encouraging and demonstrate the massive potential for the building trades in shifting to a clean economy.

The construction industry will be a critical factor in Canada's ability to meet the challenges of climate change and transitioning to a net zero economy. This will require new facilities for electricity generation (including hydro, wind, solar, tidal, biomass, and geothermal), efficient buildings, and new transportation infrastructure. To date, very little research has been undertaken on the construction industry's role in Canada's ongoing economic restructuring and low-carbon development.

Getting to Net Zero: Section Highlights

All Building Trades Are Needed

The new infrastructure for a net zero economy — everything from wind farms to district energy systems and rapid transit trackways — will require the work of masons, boilermakers, pipefitters, insulators, electrical workers, glaziers, HVAC, linemen, ironworkers, and other construction trades.

Tomorrow's Electrical Grid

- Electricity generation in Canada produces annually about 86 million tonnes of GHGs — equivalent to the weight of 826,000 D11T Caterpillar bulldozers.
- Moving to an electrical supply grid composed primarily of hydroelectric (40 per cent), new wind, solar, geothermal, and tidal power generation (43 per cent combined), and legacy nuclear (5 per cent), would result in over 1,177,055 direct construction jobs by 2050.

Efficient Buildings and District Energy Systems

- Not including their electrical usage, Canada's residential and commercial buildings annually produce 77 million tonnes of GHG pollution.

- Net zero building retrofits and new “green” commercial, industrial, and institutional building construction are predicted to account for nearly two million direct non-residential construction jobs.
- Building relatively small district energy systems (those that can service the national average of 37 buildings)¹⁸⁴ in half of Canada's municipalities with populations over 100,000 would create over 547,000 construction jobs by 2050.

Transportation

- Transportation accounted for 203 million tonnes of GHGs in Canada in 2014.
- Building out \$150 billion of urban transit infrastructure — including rapid transit tracks and bridges, subway tunnels, and dedicated bus lanes — between now and 2050 would create about 245,000 direct construction jobs.

Total Impacts

- In an aspirational scenario where Canada reaches net zero emissions by 2050, these three areas would create more than 3.9 million direct construction jobs.



Environmental Scan

By Richard Gilbert

Introduction

UNDER THE PARIS AGREEMENT, Canada is one of 197 countries committed to holding the increase in the global average temperature to below 2°C above pre-industrial levels and to work toward 1.5°C.

Canada's ability to meet this challenge will be based on the construction of new infrastructure for the generation of electricity using renewable sources. The restructuring of the national economy to low-carbon development will take place through the transformation to renewable energy sources from fossil fuels. This study undertakes original macroeconomic research on the construction industry, economic restructuring and low-carbon development in Canada. The restructuring of the Canadian economy to low-carbon may take decades, but the rapidity and impact of these changes is still to be determined.

This section lays out key milestones in Canada's low-carbon journey, drawing on the 2015 report *Pathways to Deep Decarbonization in Canada*, and IDDRI's issue brief *The impact of the Deep Decarbonization Pathways Project (DDPP) on domestic decision-making processes — Lessons from three countries* (2016).

COLUMBIA ICEFIELD, ALBERTA, PHOTO COURTESY CALYPSO ORCHID/FLICKR



This study undertakes original macroeconomic research on the construction industry, economic restructuring and low-carbon development in Canada.

PHOTO COURTESY BC BUILDING TRADES

Climate Change and the Fossil Fuel Industry

Canada's emissions growth between 1990 and 2014 was driven by mining, oil and gas production as well as transport. The oil and gas sector was the largest GHG emitter in Canada in 2014, with 26 per cent of total emissions (192 Mt CO₂e), while transportation emitted 171 Mt CO₂e (23 per cent). GHG emissions from the oil and gas sector in Canada increased by 79 per cent to 192 Mt CO₂e in 2014, from 107 Mt of CO₂e in 1990. This increase was driven by production of crude oil and the expansion of Alberta's oil sands, which contributed 9.3 per cent of Canada's GHG emissions in 2014.

Fossil Fuel and GHG Emissions

There is a relationship between oil and gas sector value-added as measured by gross domestic product (GDP) and GHG emissions, in which both variables move in the same direction. A divergence between oil and gas sector value-added and GHG emissions emerges in 2014.

The relationship is seen during the recession in 2009, when oil and gas value-added declined due to falling demand for energy. A similar pattern is also seen between the value of oil and gas production and GHG emissions during periods of economic growth in the early and mid-2000s and the recovery in 2010.

Construction and the National Economy

Construction value-added was \$118 billion in 2015 and accounted for about 7.2 per cent of total GDP (\$1.65 trillion). The share of construction value-added in the total economy was 6 to 7 per cent between 1997 and 2015. Construction value-added expanded rapidly during the oil boom (2000–2008), with rates of 7 per cent in 2001 and 6 per cent in 2004. During the recession in 2009, construction value-added declined by 6 per cent, and recovered with a growth rate of 8 per cent in

2010 and 2012. The construction industry grew at a faster rate than the economy during periods of growth (2000–2008 and 2010–2012), and declined at a faster rate than the economy during periods of economic decline (2008 and 2015).

Large fluctuations in output are one of the main characteristics of the construction industry in Canada, because the industry produces capital or investment goods, such as a factory or office building. The products of the construction industry are required in the production of other goods and services.

Construction Labour and the National Economy

The total construction labour force in Canada was about 2.6 million in 2015, while the total labour force was around 17.9 million. The total construction labour force represented 14 to 15 per cent of the total labour force in Canada between 1990 and 2015. The total number of industrial, electrical, and construction trades workers was about 936,000 in 2014. There is a tendency for the construction labour force to expand at a faster rate compared to the total labour force during periods of growth, as well as fall at a faster rate than the total labour force, during periods of economic decline.

Deep Decarbonization Pathways and Roadmaps

The structural transformation of the national economy is one of the most important pathways to low-carbon development. Structural change in the Canadian economy will be driven by federal climate change policy, and the global demand for commodities, such as oil and gas. The restructuring of the Canadian economy to low carbon development will take place through public and private investment in the decarbonization and conversion of existing energy infrastructure.



Renewable Energy and Climate Change Policy

Canada submitted a plan to the United Nations in 2015 that outlined a plan to build on a strong base of clean electricity generation. This plan is being supported by stringent coal-fired electricity standards that ban the construction of traditional coal-fired electricity generation units. Canada's current goal is to reduce GHG emissions to 30 per cent below 2005 by 2030. The commitments made so far by the federal and provincial governments are not sufficient to achieve the reduction target.

The Canadian Energy Strategy (CES) allows provinces and territories to use a range of policies that depend on market forces to reduce or eliminate emissions. This includes setting a price on carbon, which is the foundation for developing an economic policy for the mitigation of climate change. The Liberal government launched a pan-Canadian policy for carbon pricing in October 2016. Under this policy, provinces and territories can implement a price-based system or a cap-and-trade system.

The federal government is planning to invest more than \$180 million in infrastructure between 2016–2017 and 2027–2028. This represents the largest investment in public infrastructure in Canadian history.

PONT JACQUES-CARTIER BRIDGE UPGRADE, PHOTO CARIBB/FICKR

Public Investment and Renewable Energy

Putting a price on carbon pollution presents an opportunity for economic transformation by providing a new source of government revenue. Public infrastructure investment is required for the decarbonization and reshaping of the economy along low-carbon pathways. The federal government is planning to invest more than \$180 million in infrastructure between 2016–2017 and 2027–2028. This represents the largest investment in public infrastructure in Canadian history. Phase 2 of the plan will make strategic investments in the construction of infrastructure in the long term, which will support the transformation to low-carbon development.

Construction, the National Economy, and Climate Change



This chapter provides an overview of construction's importance to the Canadian economy, in order to outline the industry's role in achieving national climate goals, as well as the objective of limiting global warming to below 2°C and to work toward 1.5°C.

HALKIRK WIND FARM,
ALBERTA, PHOTO COURTESY
DAVID DODGE/Flickr

The construction industry and the transformation to low-carbon development in Canada is a macroeconomic issue. This section provides an overview of construction's importance to the Canadian economy, in order to outline the industry's role in achieving national climate goals, as well as the objective of limiting global warming to below 2°C and to work toward 1.5°C. Time-series data are used to identify a relationship between several measures of construction activity and the national economy to understand the pathways to low-carbon development.

The construction industry plays a critical role in the national economy by supporting production in all other sectors, including infrastructure and facilities for production in the fossil fuel energy sector; coal, oil and gas. Extracting and burning these fossil fuels is a major source of greenhouse gas (GHG) emissions, increasing global temperatures, which risks crop failures, famine, heat waves, flooding, and mass migration as rising sea levels change the map of the world.

Canada's ability to meet this global warming challenge will be based on the construction of new facilities for the generation of electricity using renewable sources, including hydro, wind, solar, tidal, biomass, and geothermal energy. In addition, it will require the construction and maintenance of more efficient buildings and transportation infrastructure. Despite this fact, no research has been undertaken on the construction industry, economic restructuring, and low-carbon development in Canada.

The restructuring of the national economy to low-carbon will take place through the transformation to renewable energy sources from fossil fuels. This economic restructuring to low-carbon in Canada may take decades, but the rapidity and impact of these changes is still to be determined.

Global Alliance for Buildings and Construction

In the run up to the Paris Agreement in December 2015, 20 countries, including Canada, launched the Global Alliance for Buildings and Construction, which aims to harness the sector's huge potential to reduce its emissions and build greater climate resilience into future cities and infrastructure. The Alliance estimates that about 3.2 Gigatonnes (Gt) CO₂ could be avoided by 2050 through the construction of energy-efficient buildings and a deep renovation of the existing stock of buildings.¹⁸⁵

This economic transformation on a global level will require an investment of an additional US\$220 billion by 2020, which is almost a 50 per cent increase on 2014 investment in energy efficient buildings. This is less than 4 per cent of the current total global annual investment in construction activity (\$8.5 trillion/year). Returns on this investment could be as high as 124 per cent if ambitious policy and technology actions are taken.

The members of the Alliance include: the International Union of Architects (UIA) representing about 1.3 million architects worldwide; the World Green Building Council (WGBC) representing 27,000 companies involved in green buildings business worldwide; the Royal Institution of Chartered Surveyors (RICS) representing 180,000 building surveyors globally; and the European Construction Industry Federation (FIEC) represents the construction sector employers through 33 national federations in 29 countries. It is useful to note that this alliance does not appear to include recognized labour organizations.

Job Creation and the Green Economy

The International Trade Union Confederation commissioned a study in 2012, which forecast that investments of 2 per cent of Gross Domestic Product (GDP) in the green economy over a five-year period in 12 countries could create up to 48 million new jobs or up to 9.6 million new jobs per year. More than 17 million jobs could be created in the construction sector, in part due to the high labour intensity of the industry. Nationally-based analysis involved case studies of Germany, Spain, Bulgaria, Brazil, Dominican Republic, USA, South Africa, Ghana, Tunisia, Indonesia, Nepal, and Australia.¹⁸⁶

Green jobs are not only those traditional jobs people think of as green — like making solar panels, manufacturing wind turbines, water conservation and sustainable forestry. They also include retrofitting related jobs in the construction and public transport sectors, and making energy efficiency improvements in manufacturing plants, along with services supporting all industries.

The number of jobs created from investment is a key indicator to analyze the impact of the green economy in a group of countries and specific industries. For example, middle income economies including Brazil, Indonesia, South Africa, and Bulgaria could create up to 19 million jobs over five years, while 28 million jobs could be created in developed economies in Australia, Germany, Spain, and the USA over five years. Nepal, Indonesia, and Ghana had the highest ratio of jobs per million dollars of investment with labour intensive economies benefiting from green investments.

The ITUC study developed a green job creation benchmark, which estimates the jobs created in selected industries per million dollars invested, including energy, construction, transport, manufacturing, agriculture, forestry, and water. For example, the construction industry in Brazil could create up to 182 jobs per million dollars of investment. Using this benchmark data, governments and the international community can identify targets on green jobs to be reached in a five to 10-year period.

Characteristics of the Construction Industry

To measure GDP, construction is defined as firms engaged in constructing, repairing, and renovating buildings and engineering works, and in subdividing and developing land. Firms operate on their own or under contract to other firms or property owners. They produce complete projects or just parts of projects. Firms often subcontract

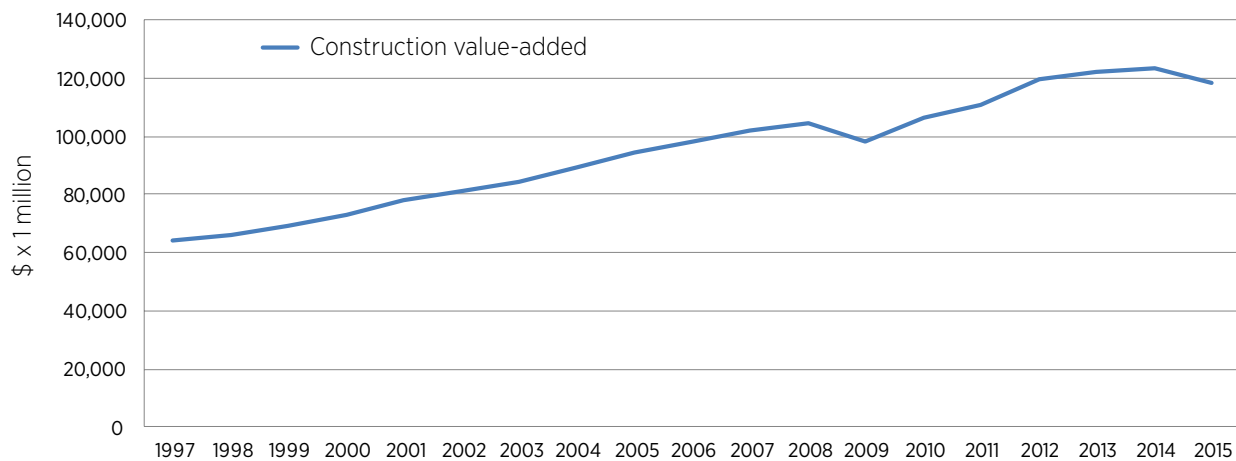
some or all of the work involved in a project, or work in joint ventures.¹⁸⁷

Figure 1 shows that construction value-added was about \$64 billion in 1997 and increased steadily to more than \$100 billion. There is a dip in construction value-added in 2009 to \$98 billion and another period of growth until 2015, when construction declines. To put things in perspective, construction value-added accounted for about 6 per cent of total GDP (\$1.07 trillion) in 1997 and was in the range of 6 to 7 per cent of the total economy between 1997 and 2015.

Since the level of construction output has increased steadily during this period, it would be easy to conclude that one of the main features of the industry is steady growth.

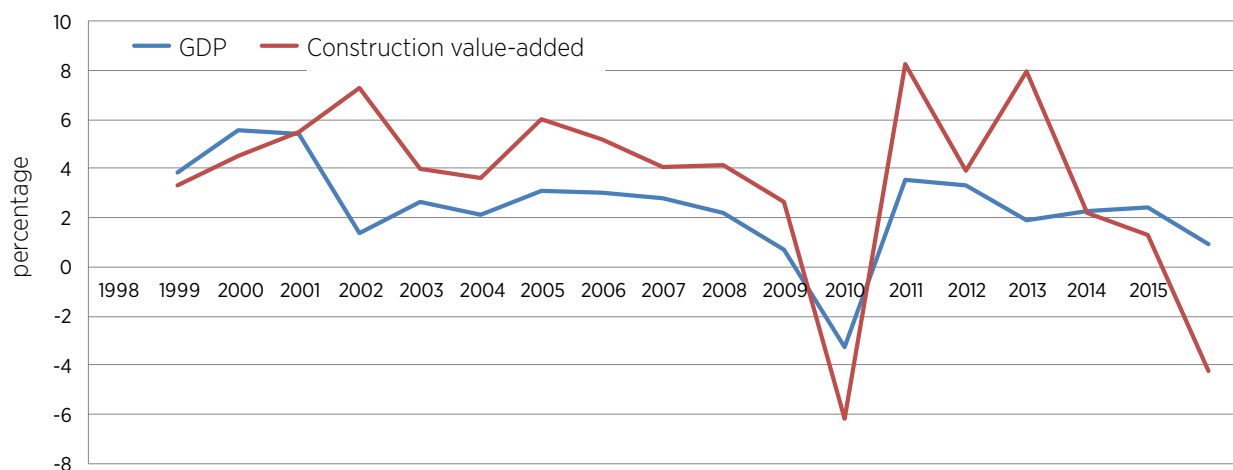
However, Figure 2 shows the construction industry expanded rapidly during the oil boom (2000–2008) in Canada, with rates of 7 per cent in 2001 and 6 per cent in 2004. During the recession in 2009, construction output declined by 6 per cent, and recovered with a growth rate of 8 per cent in 2010 and 2012.

FIGURE 1: CONSTRUCTION VALUE-ADDED 1997–2015 CHAINED (2007) DOLLARS



Source: Statistics Canada – Table 379-0031 GDP at basic prices, by North American Industry Classification System (NAICS), annual (dollars x 1,000,000)

FIGURE 2: RATE OF CHANGE OF GDP AND CONSTRUCTION VALUE-ADDED 1998–2015



Statistics Canada – Table 379-0031 GDP at basic prices, by North American Industry Classification System (NAICS)

In addition, the construction industry has a tendency to grow at a faster rate than the economy during periods of growth (2000–2008 and 2010–2012). It also falls at a faster rate than the economy during a period of economic decline (2008 and 2015).

One of the main characteristics of construction in developing countries is that the industry expands at a faster rate than the economy during periods of growth, and contracts at a faster rate than the economy during periods of decline. Large cyclical fluctuations in construction output are conditioned by several structural features, including: the dependence of the economy on the oil sector; the dependence of the construction industry on public investment, which focuses on large infrastructure projects; and sudden changes in public policy.¹⁸⁸

The construction industry is subject to substantial fluctuations in demand, because the products of the construction industry, such as a factory or office building, are capital or investment goods. This means they are products required in the production of other goods and services. Another economic characteristic of the construction industry is the size of the product, which is large, heavy, and expensive.

Generally, construction products are immovable, so once built they are fixed in location. In addition, most construction output is custom built to unique specification and distributed over a wide geographic area. The product requires a great variety of materials and components supplied by a number of other industries. The products have a long lifetime, which means the stock is large in relation to annual output.¹⁸⁹

The construction contractor responds to site specific demand. This is the opposite of manufacturing, where the product is assembled in a central factory and then distributed for sale in a number of separate geographical markets. This characteristic places limits upon the process



The construction industry has a vital role to play in the transformation to a low-carbon economy, because investment in housing, buildings and factories, and basic infrastructure such as roads, bridges, railways, ports, dams, power stations can reduce CO₂ emissions in all sectors of economic activity.

TORONTO CONSTRUCTION PHOTO COURTESY VIV LYNCH/FICKR

of centralized mass production of component parts or prefabrication, for the economies of scale that may be gained from mass-production must always be balanced against the subsequent costs of transporting component parts or sections of a structure to the construction site.¹⁹⁰

The construction industry has a vital role to play in the transformation to a low-carbon economy, because investment in housing, buildings and factories, and basic infrastructure such as roads, bridges, railways, ports, dams, power stations can reduce CO₂ emissions in all sectors of economic activity. Emissions can also be reduced through the construction of more efficient roads, bridges, railroads, and rapid transit and harbours to transport people, materials, and finished goods.



VANCOUVER CONSTRUCTION PHOTO COURTESY THOMAS MILNE/Flickr

Construction Process

These characteristics have moulded the structure of the construction industry and the process of creating capital goods. The construction industry can be defined as all those parties involved in the construction process, which includes the professions, the contracting industry, and to some extent the suppliers of inputs who jointly respond to the needs of the clients in the industry.¹⁹¹ A more detailed definition of the construction industry includes any or all of the following major participants:¹⁹²

- Client, who commissions the structure but may not be the ultimate user;
- Construction professionals (architects and engineers), who design the project;
- Quantity surveyor, who measures from the drawings in order to arrive at an estimated price;
- Main contractor responsible for the construction of industrial, commercial, institutional and residential buildings;
- Various subcontractors specialised in particular trades or providing labour only;
- Manufacturers and suppliers of building materials, plant, equipment and utilities;

- Building materials merchant, who performs a variety of functions, as an intermediary between the manufacturing industry and contractors and sub-contractors;
- Banking and financial institutions, which provide capital during and after the construction; and
- Suppliers of plant, equipment, utilities transport, insurance and other subsidiary services.

Construction Labour Force and the Building Trades

Canada Building Trades Unions are an important stakeholder in the non-residential construction industry, which is made up of firms in industrial, commercial, and institutional (ICI) sectors. These firms are involved in new work, additions and major alterations, as well as on-site assembly of modular or prefabricated commercial and institutional buildings.¹⁹³

Canada's Building Trades Unions also work on commercial construction projects, which include commercial buildings such as offices, hotels, retail malls, and warehouse complexes. The institutional sector involves the construction of schools, hospitals, libraries, and sporting facilities. In

addition, the CBTU is involved in the construction of public infrastructure projects, including highways, bridges, dams, water and sewer lines, and power and communication lines.¹⁹⁴

Figure 3 shows that the total number of industrial, electrical, and construction trades workers was above 700,000 from 1987 to 1990, when the number of workers declined for three years to about 600,000 in 1993. The total number of industrial, electrical, and construction trades began a steady increase in 1994 to a peak of 934,000 at the end of the oil boom in 2008. In this period, the number of workers fell slightly in 1994 and 2000. The construction trades dropped to 870,000 in 2009, but continued to increase to 936,000 in 2014.

The industrial, electrical, and construction trades are broken down into the following subgroups:

- 720 contractors and supervisors, industrial, electrical, and construction trades;
- 723 machining, metal forming, shaping, and erecting trades;
- 724 electrical trades and electrical power line and telecommunications workers;

- 725 plumbers, pipefitters and gas fitters;
- 727 carpenters and cabinetmakers;
- 728 masonry and plastering trades; and
- 729 other construction trades.

The total construction labour force is made up five categories under trades, transport, and equipment operators and related occupations. These are:

- 72 industrial, electrical, and construction trades;
- 73 maintenance and equipment operation trades;
- 74 other installers, repairers and servicers, and material handlers;
- 75 transport and heavy equipment operation and related maintenance occupations; and
- 76 trades helpers, construction labourers, and related occupations.

To put things in perspective, the total labour force increased to about 17.9 million in 2015 from about 12.3 million in 1987.

FIGURE 3: TOTAL NUMBER OF INDUSTRIAL, ELECTRICAL AND CONSTRUCTION TRADES 1987–2015

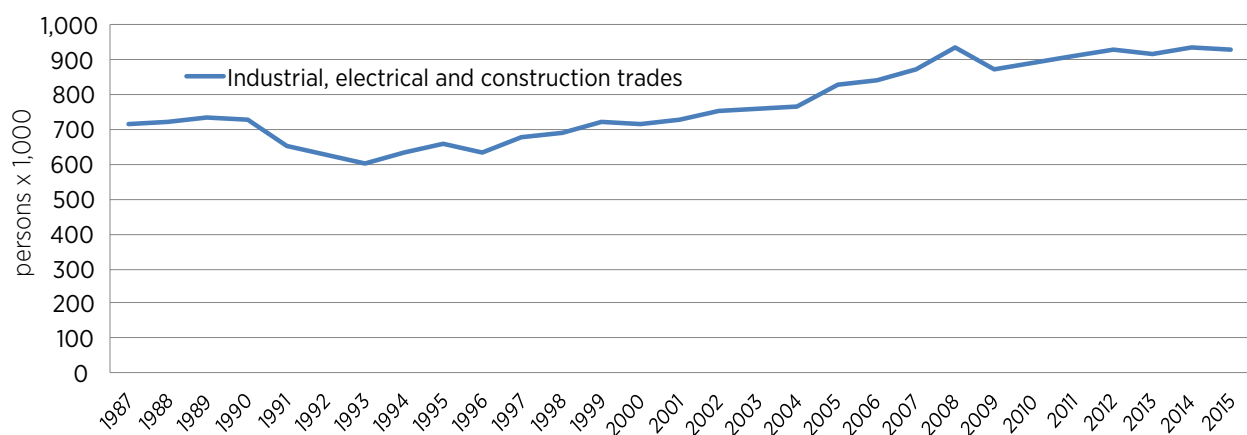


Figure 4 shows the total construction labour force increased steadily from a low of 1.86 million in 1993 to a peak of 2.54 million in 2008. The total construction labour force recovered from recession and increased to about 2.6 million in 2015.

Since 1990, the total construction labour force has been in the range of 14 to 15 per cent of the total labour force in Canada.

Figure 5 shows the relationship between the construction labour force and the total

labour force is similar to the cycles or irregular fluctuations seen in the data on construction value-added and GDP.

There is a tendency for the construction labour force to expand at a faster rate compared to the total labour force during periods of growth. There is also a tendency for the construction labour force to contract at a faster rate than the total labour force, during periods of recession in 1991 and 2008.

FIGURE 4: TRADES, TRANSPORT AND EQUIPMENT OPERATORS 1987–2015

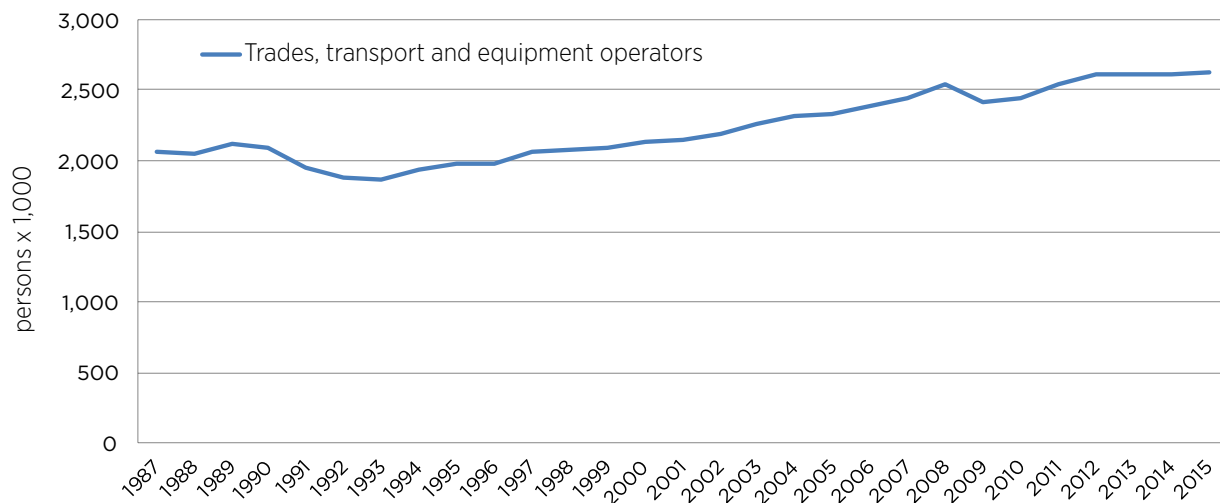
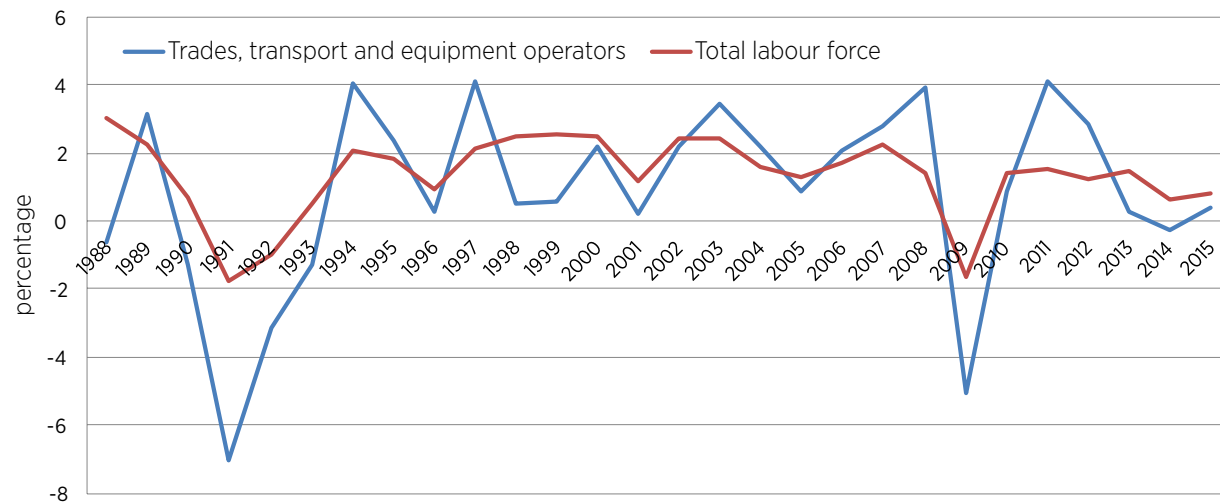


FIGURE 5: CHANGE IN CONSTRUCTION AND TOTAL LABOUR FORCE 1987–2015



Canada's Building Trades Unions

Canada's Building Trades Unions (CBTU) are a major stakeholder in the construction industry, which has a critical role to play in the transformation to a low-carbon economy. The national organization has a membership of more than half a million construction workers, who are employed in more than 60 different trades and occupations. As an umbrella organization for construction unions in Canada, the CBTU is affiliated with the following 15 international unions.

- International Brotherhood of Boilermakers, Iron Ship Builders, Blacksmiths, Forgers and Helpers
- International Association of Bridge, Structural, Ornamental and Reinforcing Ironworkers
- International Association of Heat & Frost Insulators & Allied Workers
- Operative Plasterers' and Cement Masons' International Association of the U.S. and Canada
- International Brotherhood of Electrical Workers
- International Brotherhood of Teamsters
- International Union of Bricklayers & Allied Craftworkers
- International Union of Elevator Constructors
- International Union of Operating Engineers
- International Union of Painters and Allied Trades
- Labourer's International Union of North America
- Sheet Metal, Air, Rail and Transportation Workers
- United Association of Journeymen and Apprentices of the Plumbing and Pipefitting Industry of the U.S. and Canada
- United Brotherhood of Carpenters and Joiners of America
- Unite Here



Canada's Building Trades Unions (CBTU) are a major stakeholder in the construction industry, which has a critical role to play in the transformation to a low-carbon economy. The national organization has a membership of more than half a million construction workers, who are employed in more than 60 different trades and occupations. PHOTO COURTESY CBTU

The CBTU is a department of the American Federation of Labor and Congress of Industrial Organizations (AFL-CIO), which is the largest federation of unions in the United States and is made up of 56 national and international unions. Together these unions represent more than 12 million active and retired workers.¹⁹⁵ Each Canadian province has an umbrella organization. For example, the British Columbia and Yukon Territory Building and Construction Trades Council represents 17 provincial building trade unions in industrial, commercial, and institutional (ICI) construction, as well as road building, pipeline, bridge, utility, and hydro dam sectors. Union workers on residential construction sites are also affiliates of the BC Building Trades Council, which represents about 35 per cent of the ICI construction industry.



Oil GHG Emissions and Industrial Construction

International oil companies are major clients for industrial construction services in Canada. This section undertakes a brief macroeconomic analysis, which finds a link between the oil and gas industry and climate change. Time-series data are used to identify a relationship between oil and gas industry value-added and greenhouse gas (GHG) emissions in Canada between 1990 and 2014. This analysis provides a basis for understanding the pathways to a low-carbon economy in Canada.

Sources of GHGs in Canada

There is a growing consensus that the Earth's climate is rapidly changing, due to increases in greenhouse gas (GHG) caused by human activities. An increase in the amount of GHG in the atmosphere is contributing to a warming of the Earth's surface. Human activities are changing the composition of the atmosphere and its properties. The climate is changing, which means sea levels are rising as Arctic ice melts, while storms and heat waves are more severe.

Since pre-industrial times (around 1750), carbon dioxide concentrations have increased by more than one third from 280 parts per million (ppm) to 380 ppm in 2007, as a result of burning fossil fuels, deforestation, and changes in land use. Concentrations of other GHGs such as methane and nitrous oxide have also increased. These rising levels of GHGs are having a warming effect on the climate by increasing the amount of infrared radiation trapped by the atmosphere. In total, the warming effect due to all GHGs emitted by human activities is equivalent to about 430 ppm of carbon dioxide (hereafter, CO₂ equivalent or CO₂e) and rising at around 2.3 ppm¹⁹⁶ per year. The World Meteorological Organization reported in its 2016 Green House Gas Bulletin that the concentration of CO₂ reached 400 ppm in 2015.

Globally averaged concentration of carbon dioxide in the atmosphere reached 400 parts per million for the first time in 2015 and surged again to new records in 2016 on the back of the very powerful El Niño event, according to the World Meteorological Organization's annual Greenhouse Gas Bulletin.

CO₂ levels had previously reached the 400 ppm barrier for certain months of the year and in certain locations, but never before on a global average basis for the entire year. The longest-established greenhouse gas monitoring station at Mauna Loa, Hawaii, predicts that CO₂ concentrations will stay above 400 ppm for the whole of 2016 and not dip below that level for many generations.

The growth spurt in CO₂ was fuelled by the El Niño event, which started in 2015 and had a strong impact well into 2016. This triggered droughts in tropical regions and reduced the capacity of “sinks” like forests, vegetation, and the oceans to absorb CO₂. These sinks currently absorb about half of CO₂ emissions, but there is a risk that they may become saturated, which would increase the fraction of emitted carbon dioxide that stays in the atmosphere.

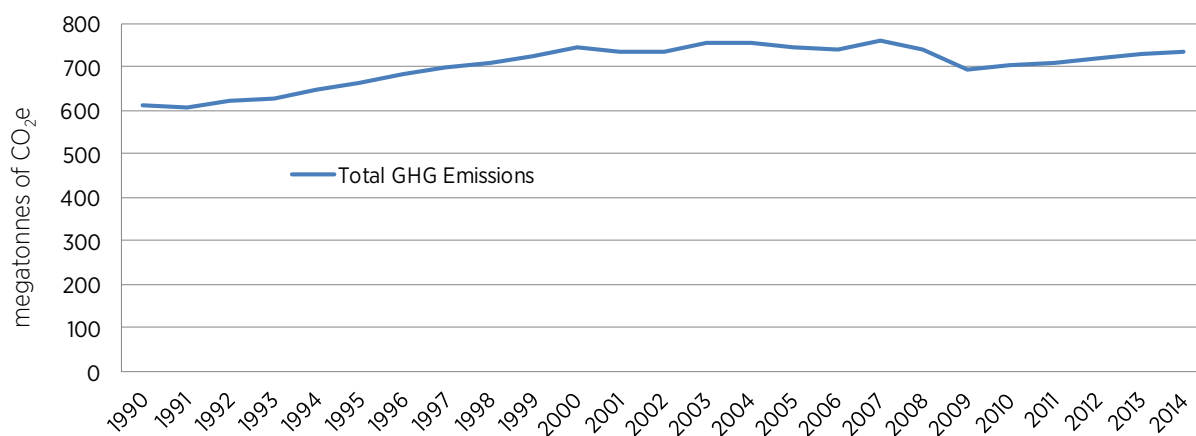
Canada’s domestic GHG emissions have seven main sources, which are listed in the government’s inventory: oil and gas, transportation, electricity, buildings, emissions intensive and trade exposed industries, agriculture, waste, and others. These sources and the dynamics that drive them must be addressed, in order to develop a strategy to achieve the transformation to a low-carbon economy.

Figure 6 shows a steady increase in annual GHG emissions in Canada to 744 megatonnes (Mt) of carbon dioxide equivalent (CO₂e) in 2000, from 606 Mt CO₂e in 1991. This period was followed by fluctuating emission levels between 2000 and 2008, with a peak in 2007 of 758 Mt CO₂e. There was a steep decline in emissions to 696 Mt CO₂e in 2009 and a gradual increase to 732 Mt CO₂e in 2014. This represents a 20 per cent increase (120 Mt CO₂e) above the 1990 emissions of 613 Mt CO₂e.¹⁹⁷

Canada’s total greenhouse gas (GHG) emissions in 2014 were 732 megatonnes (Mt) of carbon dioxide equivalent (CO₂e), or 20 per cent (120 Mt CO₂e) above the 1990 emissions of 613 Mt CO₂e. There is an increase in annual emissions for the first 10 years of this period, followed by fluctuating emission levels between 2000 and 2008. Then there is a steep decline in 2009 due to the global economic recession and a gradual increase thereafter.¹⁹⁸

Canada’s emissions growth between 1990 and 2014 was driven by mining and oil and gas production as well as transport. Emission reductions from 2005 to 2014 were due to reduced emissions from the public electricity and heat production.

FIGURE 6: TOTAL GHG EMISSIONS IN CANADA 1990–2014



Source: Environment and Climate Change Canada. Emissions growth from 1990 to 2014 was driven by mining and oil and gas.

Emissions of GHGs from the oil and gas sector in Canada increased by 79 per cent to 192 Mt CO₂e in 2014, from 107 Mt of CO₂e in 1990. This increase was driven by production of crude oil and the expansion of the oil sands industry.

The oil and gas sector was the largest GHG emitter in Canada in 2014, accounting for 26 per cent of total emissions (192 Mt CO₂e), while the transportation sector emitted 171 Mt CO₂e (23 per cent). The other economic sectors including electricity, *buildings, emissions-intensive and trade-exposed industries, agriculture, and waste, each accounted for between 7 and 12 per cent of total GHG emissions in Canada. The trade exposed industries are mining, smelting and refining, pulp and paper, iron and steel, cement, lime and gypsum, and chemicals and fertilizers. (*When the electricity they use is counted in building emission totals, they account for 25 per cent of GHG emissions in Canada.)

Alberta's emissions increased by 56 per cent in 2014 to 273.8 Mt CO₂e, from 175.2 Mt CO₂e in 1990, primarily because of the increase in the oil and gas industry. Emissions of GHGs from the oil and gas sector in Canada increased by 79 per cent to 192 Mt CO₂e in 2014, from 107 Mt of CO₂e in 1990. This

increase was driven by production of crude oil and the expansion of the oil sands industry.

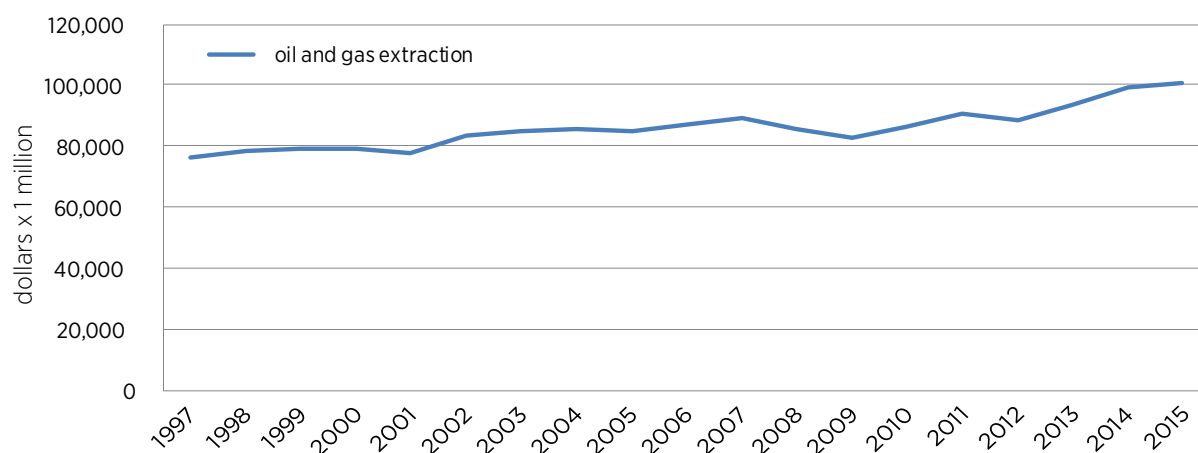
Oil Industry and Greenhouse Gas Emissions

Gross domestic product (GDP) is the total value of the goods and services produced in the economic territory of a country or region during a given period. The level of GDP shows the size of an economy, while the change in GDP from one period to another indicates whether the economy is expanding or contracting. The value added of an industry, also referred to as GDP-by-industry, is the contribution of a private industry or government sector to overall GDP.

The oil and gas sector is defined as firms engaged in operating oil and gas field properties, which includes the production of oil, the mining and extraction of oil from oil shale and oil sands, and the production of gas and hydrocarbon liquids, through gasification and liquefaction.

Figure 7 shows the total value added of the oil and gas industry plateaued around the \$78 billion level between 1998 and 2001, and gradually increased to about \$89 billion in 2007. Oil and gas value-added decreased rapidly to \$85 billion and

FIGURE 7: OIL AND GAS INDUSTRY VALUE-ADDED 1997-2015



Source: Statistics Canada - GDP by Industry at basic prices (by NAICS), annual (dollars x 1,000,000) in current 2007 dollars.

\$83 billion in 2008 and 2009 respectively, due to the international recession and falling oil prices.

In comparison, Canada's estimated GDP in 2015 was \$1.65 trillion or \$1,648 billion, while oil and gas industry value-added was about \$101 billion in 2015. The value of the oil industry as a share of total GDP was 5 to 7 per cent between 1997 and 2014.

Figure 8 shows oil and gas sector value-added and GHG emissions are characterized by short-term cycles, which are driven by changes in the Canadian economy. The relationship is most clearly seen during the recession in 2009, in which oil and gas value-added declined due to falling demand for energy.

During the recession, there was a corresponding decline in GHG emissions. In relative terms, the largest emission reductions occurred in industrial processes due to lower activity by oil sands producers.

A similar pattern is also seen between the value of oil and gas production and GHG emissions during periods of growth in the early and mid-2000s and the economic recovery in 2010. However, this graph also shows a divergence between oil and gas sector value-added and GHG emissions in 2014.

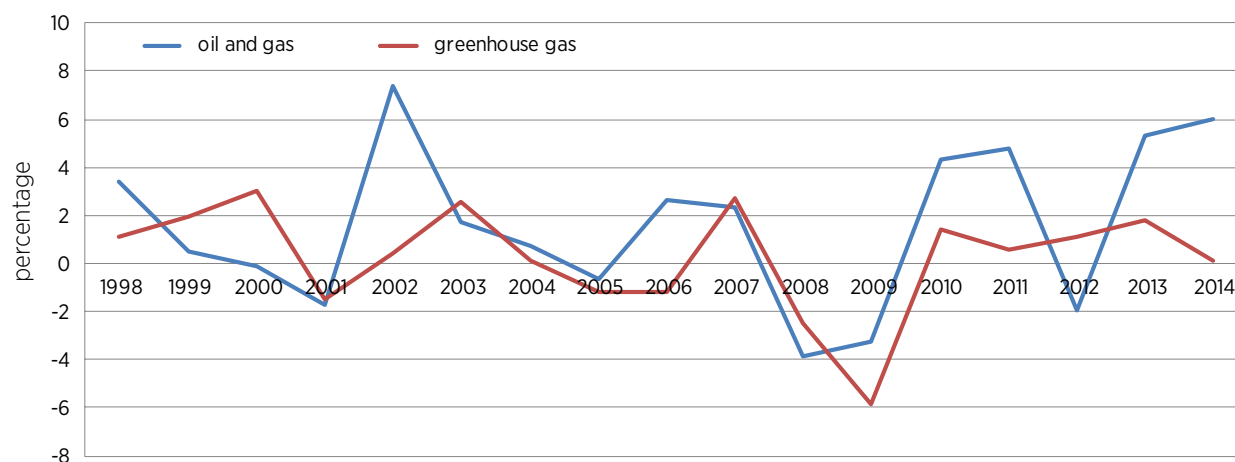


During the recession, there was a corresponding decline in GHG emissions. In relative terms, the largest emission reductions occurred in industrial processes due to lower activity by oil sands producers.

OIL SANDS PHOTO COURTESY JENNIFER GRANT/Flickr

The reduction in GHG emissions since 2013 is related to combustion-based electricity generation, which decreased from 95 Mt of CO₂e in 1990 to 78 Mt CO₂e in 2014. This represents a decrease of 17 per cent over the period. The growing share of electricity generated from hydro and nuclear sources may have contributed to this decline in emissions.

FIGURE 8: RATE OF CHANGE OF OIL AND GAS GDP AND GHG IN CANADA, 1994–2014



Note: short-term fluctuations or changes in oil and gas industry valued-added and GHG emissions move in a similar pattern between 1998 and 2014.



GREEN ACRES SOLAR FARM, ALBERTA, COURTESY DAVID DODGE/Flickr

Construction, Economic Restructuring and Low-Carbon Development

The structure of Canada's economy is the foundation of an ambitious strategy to make the transformation to low-carbon development, through strategic investment in the construction of facilities and infrastructure to reduce CO₂ emissions from the generation of electric power. This section examines the process of economic restructuring and the demand for construction employment in the renewables energy sector, as well as energy efficient buildings.

Construction and Economic Restructuring

Renewable energy is defined as an energy source or fuel type that can regenerate and replenish itself indefinitely. The five renewable sources used most often are biomass, wind, solar, hydro, and geothermal. For this study, restructuring is defined as the reallocation of public and private

investment for the construction of renewable energy infrastructure, while the economy shifts away from fossil fuels. The restructuring of the Canadian economy will take place through the development of decarbonization pathways or roadmaps, which convert existing energy infrastructure. Construction activity will be stimulated by investment in renewable energy and the expansion of the electricity generation system. As a result, the capacity of the renewable energy sector will be increased to power the majority of end users who depend on fossil fuel.

Deep Decarbonization Pathways Project

Released in December 2015, the Deep Decarbonization Pathways Project report outlines how Canada can transition to a low-carbon economy. It aims to support Canada's efforts to

meet the internationally agreed target of limiting the rise in global mean surface temperature to less than 2°C¹⁹⁹ and to work toward 1.5°C. The report identified six pathways to low carbon development in Canada.

The structural transformation of the national economy is one of the most important pathways to low-carbon development. Structural change in the Canadian economy will be driven by federal climate change policy, and the global demand for commodities, such as oil and natural resources.²⁰⁰

Five other pathways to low carbon development were identified by the DDPP report, under the following themes.

The first theme is deepening current trends, which is a group of three pathways. It is a portfolio of technically and economically feasible technologies, including decarbonized electrification, improving energy productivity, and capping or utilizing non-energy emissions. Another two pathways are grouped under the theme next generation technologies. This category includes zero emission transport fuels and the decarbonization of industrial processes.

The study concludes that the implementation of aggressive measures to decarbonize the Canadian economy could cause GHG emissions to steadily decline 78 Mt by 2050 from current levels, which represents a decrease in energy related emissions of 88 per cent.

Almost half of remaining emissions in the decarbonization pathway are from fossil energy extraction by 2050. A further third of emissions are associated with industrial activity. The buildings, transport, and electricity sectors almost completely decarbonize by 2050, accounting for less than a quarter of remaining emissions.

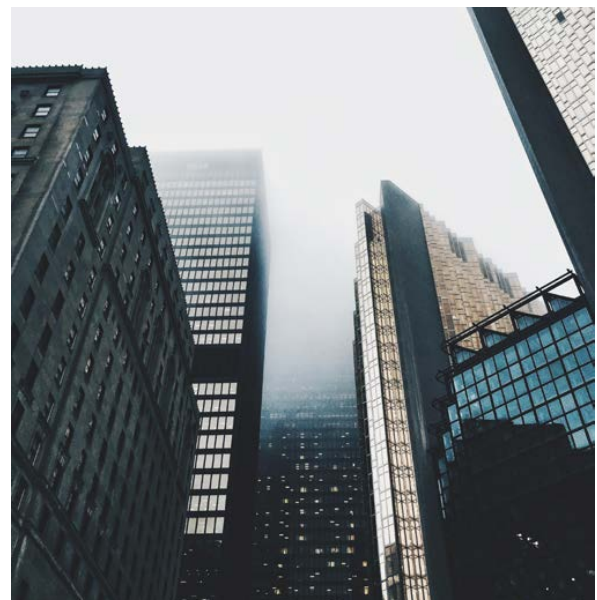
The report estimates total firm level investment will increase by an additional \$16.2 billion annually between 2015 and 2050, which represents an increase of 8 per cent compared to historic levels of private sector investment. The greatest

need for investment is in the electricity sector, which requires about \$13.5 billion annually. This represents an increase of 87 per cent relative to historic levels.

An investment of \$2.9 billion annually is required in the upstream oil and gas sector for the adoption of advanced low emission technologies such as carbon capture and storage (CCS), solvent extraction, and direct contact steam generation in-situ. This is about 6 per cent of historic levels of investment in the sector.

Investment in the commercial buildings sector is estimated to increase by \$700 million annually between 2015 and 2050. These costs are associated with the purchase of lower emission equipment such as heat pumps for space and water heating, more efficient shells, and retrofitting of older shells. Investment in industry also increases by \$600 million annually, representing an increase of 1 per cent over historic levels. This investment is associated with various low-emission technologies, including efficiency, heat pumps, fuel switching, alternative processes, and CCS.

Investment in the commercial buildings sector is estimated to increase by \$700 million annually between 2015 and 2050. PHOTO COURTESY PATRICK TOMASSO/UNSPLASH





Pathways to Deep Decarbonization in Canada is the first national decarbonization study compatible with climate change goals under the Paris Agreement. PARIS AGREEMENT SIGNING CEREMONY PHOTO COURTESY UNITED NATIONS/FLICKR

Climate Change Policy and Decarbonization Pathways

This section examines the link between economic policy in Canada and research from the Institute for Sustainable Development and International Relations (IDDRI) Deep Decarbonization Pathways Project (DDPP).²⁰¹ Elements of the DDPP's macroeconomic research on climate change are emerging in Canadian fiscal policy.

Pathways to Deep Decarbonization in Canada is the first national decarbonization study compatible with climate change goals under the Paris Agreement. The DDPP report brought the link between economic policy and decarbonization into the public debate on climate change in Canada. It provides a vision of economic transformation and low-carbon development

in Canada in the long term. For this reason, the report is being used to inform the design of domestic economic policy packages.²⁰²

IDDRI is a Paris-based, non-governmental organization that undertakes and disseminates research on international economic development issues. The DDPP is a collaborative initiative, which seeks to understand how countries can transition to a low-carbon economy consistent with climate targets. In its first phase (2014–2015), the DDPP developed a research framework to support the adoption of domestic climate actions in 16 countries. These ambitious policies were consistent with national circumstances in each country and the global 2°C limit.

Intended Nationally Determined Contributions

The Liberal government made a commitment under the Paris Agreement in December 2015 to reduce Canada's GHG emissions by 30 per cent below 2005 levels by 2030. The target was set by the former Conservative government in a submission to the United Nations Framework Convention on Climate Change (UNFCCC) in May 2015. Canada's level of mitigation falls behind its peers.

The annual rate of economy-wide emissions reductions from 2020 to 2030 implied by Intended Nationally Determined Contributions (INDC) is a measure of how ambitiously each country plans to move toward the necessary long-term goal.

The World Resources Institute estimates proposals from the European Union and the United States aim to reduce GHG emissions between 2020 and 2030 by about 2.8 per cent per year. Canada's proposal is significantly less ambitious at 1.7 per cent per year.²⁰³

U.S. President Donald Trump's executive order on "Promoting Energy Independence and Economic Growth" sets the U.S. on a path to miss its Paris Agreement commitment for 2025 by a large margin. If the executive order were carried out in full, U.S. emissions in 2025 and 2030 are expected to be roughly similar to today, instead of the 13 per cent decrease from 2014 levels needed to meet its target (Nationally Determined Contribution) submitted to the Paris Agreement.

However, President Trump's executive order can slow, but not reverse, the trends that have driven down U.S. emissions in recent years. Although it begins the process of suspending, revising, and rescinding currently implemented policies, these steps are likely to be followed by legal disputes over the coming years and therefore will have a delayed impact on U.S. emissions.

Canada submitted its INDC to the UNFCCC on May 15, 2015, as part of its preparation for the Paris climate change conference. The INDC outlines a plan to build on a strong base of clean electricity generation, which is being supported by stringent coal-fired electricity standards that ban the construction of traditional coal-fired electricity generation units. The plan will also accelerate the phase-out of existing coal-fired electricity generation units.²⁰⁴

The federal government accelerated the phase-out of coal power in November 2016 by changing regulations to ensure that all traditional coal-fired units are required to meet a stringent performance standard of 420 tonnes of carbon dioxide per gigawatt hour (tCO₂/GWh) by no later than 2030. Traditional units don't use carbon capture.²⁰⁵

Canadian Energy Strategy

The political response to climate change in Canada is a responsibility shared by all levels of government. Canadian provinces and territories have jurisdictional authority over natural resources, energy, and many aspects of the environment. Each has its own legal framework, policies, and measures in place to reduce greenhouse gas emissions. Mechanisms exist for the federal government to engage with Canadian provinces and territories, as well as other key stakeholders, on climate change.

Canadian provincial and territorial leaders launched a new Canadian Energy Strategy (CES) at a Premiers' meeting in July 2015. The strategy assumes the oil and gas industry is crucial to national energy security.

The strategy also focuses on climate change and the transition to a low-carbon economy through public policy initiatives, such as carbon pricing, carbon capture and storage, and technological innovation. The CES promises to enhance the use of cleaner and renewable energy

in electricity generation, industrial processes, heat, and transportation. It also encourages the use of renewable energy through innovative approaches such as energy storage, smart grids, and on-site microgeneration.²⁰⁶

The strategy assumes that the transition to low-carbon economy requires the development of market-based policies that create incentives to reduce greenhouse gas emissions. The CES allows provinces and territories to use a range of carbon management mechanisms, from new technologies that capture and store carbon, to policies that encourage the marketplace to reduce or eliminate emissions, including setting a price on carbon.

Vancouver Declaration

First Ministers signed the Vancouver Declaration on Clean Growth and Climate Change on March 3, 2016 to implement a pan-Canadian framework by early 2017.²⁰⁷ For the first time, they plan to adopt domestic measures, such as carbon pricing, and want the federal government to take the following actions:

1. Supporting climate change mitigation and adaptation through investments in green infrastructure, public transit infrastructure, and energy efficient social infrastructure;
2. Investing in GHG emission reductions by working together on how best to lever federal investments in the Low Carbon Economy Fund to realize incremental reductions;
3. Doubling government investment in clean energy research and development over the next five years, and stimulate private sector investment in clean technology;
4. Advancing the electrification of vehicle transportation, with provinces and territories;

5. Fostering dialogue and development of regional plans for clean electricity transmission; and
6. Investing in clean energy to help Indigenous, remote, and northern communities get off diesel.

Carbon Pricing

Establishing a carbon price is the foundation for developing an economic policy for the mitigation of climate change. In economic terms, GHG emissions are an externality. This means producers of GHG emissions are bringing about climate change, which is imposing costs on future generations of the world. However, these producers of GHG emissions do not face the full consequences of their actions. Putting a price on carbon through tax, trading, and regulation means that people are faced with the full social cost of their actions. This will lead individuals and businesses to switch away from high-carbon goods and services, and to invest in low-carbon alternatives.²⁰⁸

The Liberal government launched its pan-Canadian approach to carbon pricing in October 2016. Under the new plan, provinces and territories can implement:

- (i) an explicit price-based system. For example, a carbon tax like British Columbia's, or a carbon levy and performance-based emissions system like Alberta's; or
- (ii) a cap-and-trade system like Ontario and Quebec. Provinces and territories will retain the revenues raised by carbon pricing and make decisions about investing these funds in their economies, while supporting workers and their families and minimizing impacts on vulnerable groups.²⁰⁹

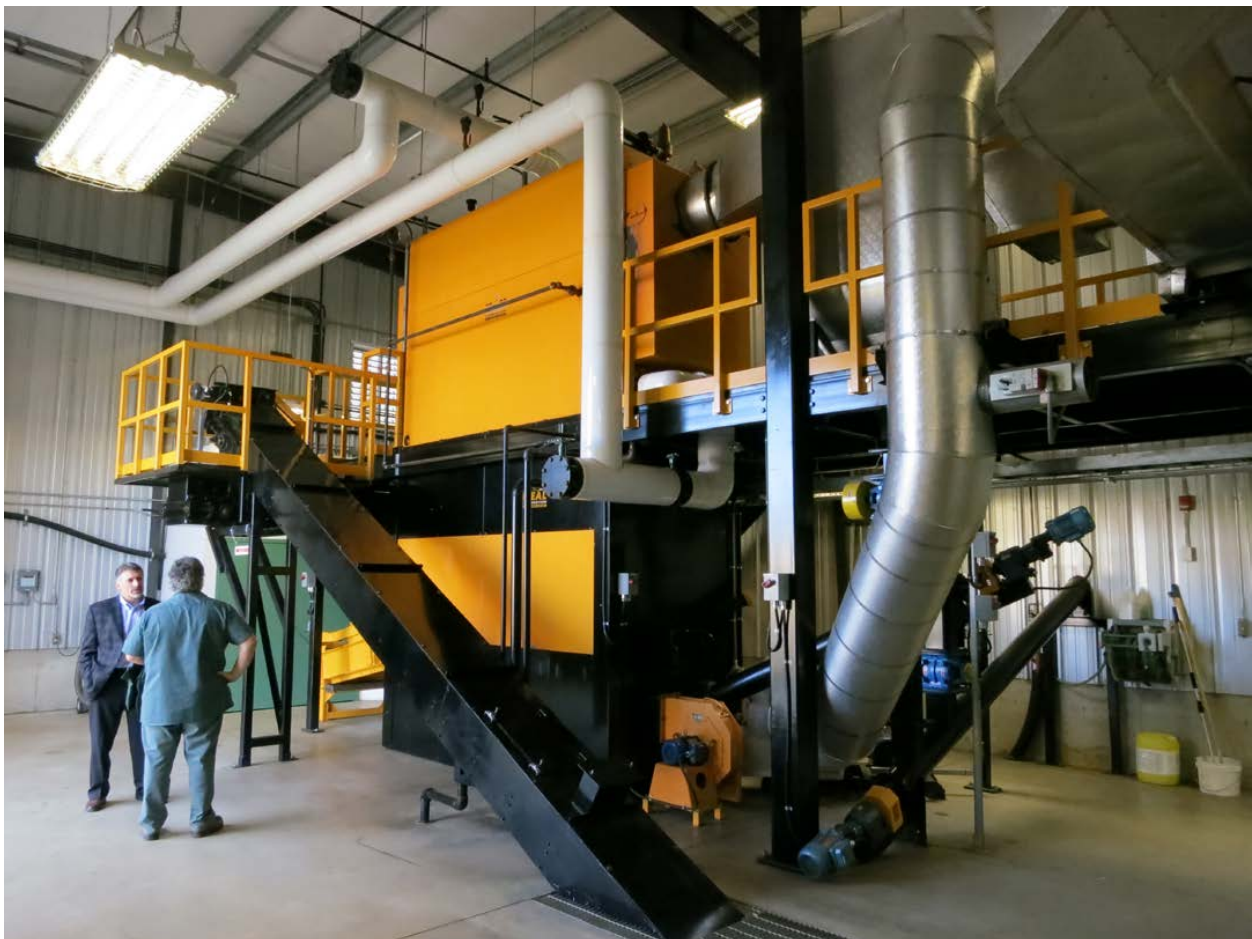
For jurisdictions with an explicit price-based system, the carbon price should start at a minimum of \$10 per tonne in 2018, and rise by \$10 per year to \$50 per tonne in 2022. Provinces with cap-and-trade need:

- a 2030 emissions reduction target equal to or greater than Canada's 30 per cent reduction target; and
- declining (more stringent) annual caps to at least 2022 that correspond, at a minimum, to the projected emissions reductions resulting from the carbon price that year in price-based systems.

BIOMASS HEATING PLANT WITH DISTRICT HEATING AT UNIVERSITÉ ST. ANNE IN NOVA SCOTIA, PHOTO COURTESY DAVID DODGE/FLICKR

Private Investment, Carbon Pricing, and Fossil Fuels

Businesses take uncertainties into account that are likely to evolve over time when making investment decisions. Carbon pricing policy must be based on a framework that gives investors confidence that carbon policy will be maintained. Taking a long-term view on the carbon price is important for businesses investing in assets, such as power stations, industrial plants, and buildings, that last for many decades. If businesses believe carbon prices will rise in the long run to match the damage costs of emissions over time, this should lead them to invest in low-carbon rather than high-carbon assets.²¹⁰



If businesses believe carbon prices will rise in the long run to match the damage costs of emissions over time, this should lead them to invest in low-carbon rather than high-carbon assets.

The next 10 to 20 years will be a period of transition, from a world where carbon-pricing schemes are in their infancy, to one where carbon pricing is more widespread and is automatically factored into decision making. However, while the worldwide carbon pricing system is being established there is a risk that future carbon prices are not properly factored into business decision-making. If this happens, businesses may continue to invest in high-carbon assets and lock economies into a high-carbon trajectory.

Currently, HSBC Global Research and other international financial institutions are warning investors about the growing risk that their fossil-fuel assets may become stranded. The main idea is that burning available fossil fuels would mean breaching the 2°C globally-agreed



SHEERNESS GENERATING STATION, ALBERTA PHOTO TONYGLEN14/FLICKR

temperature goal. As a result, regulation to tackle CO₂ emissions would cause fossil fuel assets to be stranded and lose value, or turn into liabilities before the end of their expected economic life. In the context of fossil fuels, the assets would be stranded in the ground.²¹¹

HSBC noted that the concept was initially applied to coal assets, but falling oil prices in 2015

widened the debate from coal to oil and gas. Oil types such as oil sands and shale oil break even at US\$80 per barrel or higher, although it should be noted that costs are likely lower in a mature facility. Crude oil prices ended 2015 below \$40 per barrel, which means some oil sands facilities have become loss-making. The risk of fossil fuel assets being stranded is also driven by energy efficiency and advancements in renewables, battery storage, and enhanced oil recovery, which impact demand for fossil fuels. The timing of structural changes in the economy is difficult to predict, which is why it is such a challenge for international financial investors.

The Bank of England is conducting an enquiry into the risk of fossil fuel companies causing an economic crash if future climate change rules render their coal, oil, and gas assets less valuable. Bank of England governor Mark Carney said in December 2014 that insurers' losses from weather-related events have grown to US\$50 billion a year, from US\$10 billion a year in the 1980s. Carney said market-based mechanisms can reduce emissions and keep global temperatures from rising more than 2°C. But, this would require a full accounting of carbon emissions in economies around the world.²¹²

The stranded assets debate was fueled by a study in *Nature*, which found the GHG emissions contained in present estimates of global fossil fuel reserves are three times higher than the globally-agreed limit of about 1,100 gigatonnes of cumulative CO₂ emissions between 2011 and 2050. The limit is needed to keep global temperatures 2°C above pre-industrial times. The study found a third of oil reserves, half of gas reserves, and more than 80 per cent of current coal reserves should remain unused from 2010 to 2050 to meet the target of 2°C. Implementation of this policy is expected to cause a decline in oil sands production after 2020, because it is more expensive than other methods of production.

Construction, Fossil Fuels, and Renewable Energy

Coalition Calls for National Climate Strategy

Canadian business, labour, and environmental groups called on the federal government in November 2016 to finalize plans for a national climate change strategy. The coalition representing more than 60 organizations encouraged First Ministers to put a rising price on carbon, while using the revenues to advance climate goals. The letter, signed by more than 60 organizations, made a commitment to lead and accelerate the transition to a low-carbon economy. Representatives from the construction, oil, and renewable energy industries included:

- Neil Bruce, President and CEO, SNC-Lavalin;
- Michael McSweeney, President and CEO, Cement Association of Canada;
- Chris Buckley, President, Ontario Federation of Labour;
- Ken Neumann, Canadian National Director, United Steelworkers;
- Robert Hornung, President, Canadian Wind Energy Association;
- Jacob Irving, President, Canadian Hydropower Association;
- Michael Crothers, President and Canada Country Chair, Shell Canada;
- Brian Ferguson, President and CEO, Cenovus Energy;
- Ian MacGregor, Chairman and CEO, North West Refining Inc.; and
- Steve Williams, President and CEO, Suncor.

Public Sector Investment and Renewable Energy Infrastructure

Putting a price on carbon pollution presents an opportunity for economic transformation by providing a new source of government revenue. One option is to use the revenues to offset other taxes, such as those on income earned or business profits. Another is to support government spending in chronically underfunded areas such as health, education, and infrastructure. And a third is to use the funds to support clean technology development.²¹³ More importantly, it is critical for the Canadian government to consider how to avoid the risks of locking into a high-carbon infrastructure.

Public Investment and Decarbonization

A Canadian government report submitted to the UNFCCC in November 2016 said public infrastructure investment is critical to support deep decarbonization and reshaping the economy along low-carbon pathways. Public investment can address GHG emissions and enhance resilience to the impacts of climate change. The report said the following key factors link decision-making, decarbonisation, and infrastructure development in the long term:

- Investments are influential in setting long-term GHG pathways as the lifespan of infrastructure assets are long-lived, often ranging from 25 to 60 years;
- Once infrastructure investments are made, the associated behaviours and carbon emissions are more or less 'locked-in' and the shift to a new pathway can become very costly;

- Strategic public sector investment can attract private low-carbon infrastructure investments, and generate funding for future low-carbon investments; and
- The transformative nature of infrastructure projects plays a complementary and enabling role to support the transition to a low-carbon economy.
- \$5.0 billion over five years for water, wastewater, and green infrastructure projects; and
- \$3.4 billion over five years for social infrastructure, including affordable housing, early learning and child care, as well as cultural, recreational, and community health care facilities on reserve.²¹⁴

Federal Budget 2016

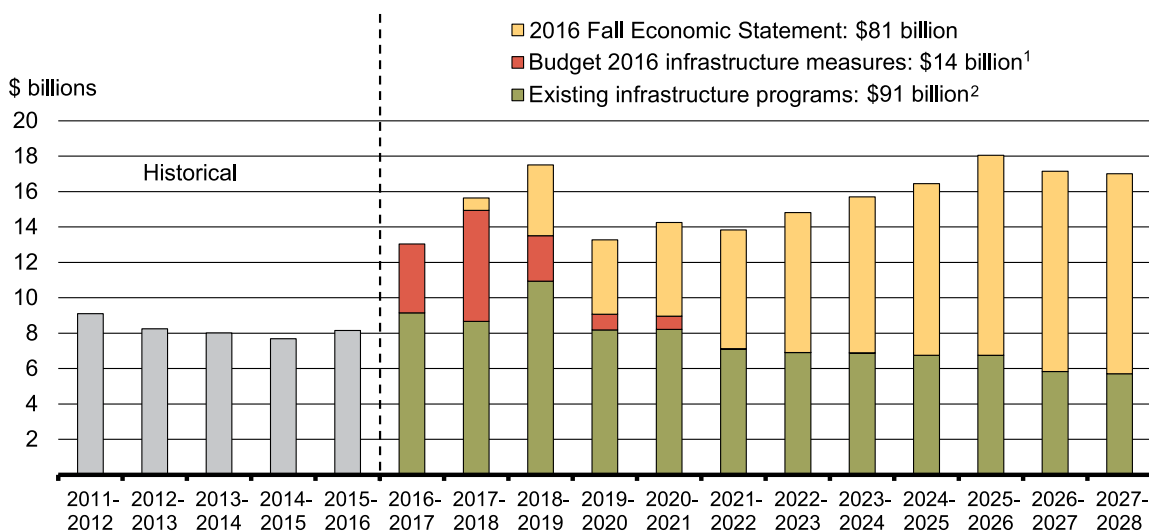
Finance Minister Bill Morneau tabled the new Liberal government's first federal budget in Parliament on March 22, 2016. The centrepiece of the budget was a two-phase plan to invest more than \$120 billion for the construction of infrastructure over a 10-year period. Phase 1 of the plan was launched with an investment of \$11.9 billion over five years, which included:

- \$3.4 billion over three years to upgrade and improve public transit systems;

It is estimated that Phase 1 investments and other measures in Budget 2016 will help create or maintain 100,000 jobs, including project planning and management, engineering, and construction.

The Fall Economic Statement 2016 provides a federal government forecast for spending on the Long-Term Infrastructure Plan between 2016–2017 and 2027–2028. The yellow segment in Figure 9 outlines a proposal to invest \$81 billion over an 11 year period, starting in 2017–18. The red segment represents \$14 billion of infrastructure investment in Budget 2016, which includes \$11.9 billion for Phase 1.

FIGURE 9: LONG-TERM INFRASTRUCTURE PLAN



¹ Includes Phase 1 (\$11.9 billion), strategic investments in post-secondary infrastructure (\$2.0 billion) and rural broadband (\$500 million). See Table 2.1 for details.

² Includes Infrastructure Canada programs, Indigenous infrastructure programs and social infrastructure programs.

Source: Fall Economic Statement 2016, Nov. 1, 2016.

The green segment represents \$91 billion for existing programs. The total federal infrastructure investment in the Fall Economic Statement is more than \$180 billion, which is the largest investment in public infrastructure in Canadian history.

Phase 2 of the plan will make strategic investments in the construction of infrastructure in the long term, which will support the transformation to low-carbon development. The government is creating a Low Carbon Economy Fund, which will invest \$2 billion over two years. The Fund will support provincial and territorial actions that reduce greenhouse gas emissions and achieve reductions within the period of Canada's nationally determined target. Resources will be allocated toward those projects that yield the greatest absolute greenhouse gas reductions for the lowest cost per tonne.²¹⁵

Alternative Energy Strategy Proposals

The second phase of the federal infrastructure plan has implications for the development of the renewable energy sector, which is represented by CanCORE. This organization includes the Canadian Hydropower Association (CHA), Canadian Solar Industries Association (CanSIA), Canadian Wind Energy Association (Can-WEA), and Marine Renewables Canada. For this reason, CanCORE sent a letter to the Minister of Infrastructure and Communities in September 2016.

The letter said the national climate change plan should be based on the decarbonization of electricity generation. This means replacing existing fossil fuel generation with zero-carbon power over time, and producing all electricity with non-emitting sources of generation. In addition, the energy system must increase its reliance on electricity, by switching away from fossil fuel sources to renewable power.²¹⁶

The government should invest a minimum amount of total revenues in GHG reducing initiatives



The Low Carbon Economy Fund will invest \$2 billion over two years to support provincial and territorial actions that reduce GHGs and achieve reductions within the period of Canada's nationally determined target. Resources will be allocated toward those projects that yield the greatest absolute GHGs for the lowest cost per tonne.

SOUTHERN ALBERTA FOOTHILLS PHOTO COURTESY GORD MCKENNA/FICKR

such as renewable energy projects. In particular, CanCORE recommends the government prioritize and grant preference to proposed infrastructure projects that achieve the following objectives:

1. Enhancing energy productivity.
2. Enabling and facilitating achievement of national targets for electricity generation that move us close to 100 per cent zero-carbon electricity by 2050.
3. Supporting clean electrification in northern Indigenous communities and industrial facilities.
4. Enabling increased use of electricity in the energy system to achieve a target more than 50 per cent of all energy used in Canada by 2050. These projects facilitate fuel-switching from fossil fuels to electricity for transportation, industry, and buildings, with the following sectoral targets:

- a) Transportation: Increasing the use of electricity for transportation to meet 10 per cent of energy needs in 2030, and more than 30 per cent of energy needs in 2050.
- b) Industry: Increasing industrial use of electricity to meet 45 per cent of energy needs in 2030, and more than 50 per cent of energy needs in 2050.
- c) Buildings: Increasing the use of electricity in residential and commercial buildings to meet 80 per cent of energy needs in 2030, and 100 per cent of energy needs in 2050.

As part of the 2017 pre-budgetary consultations, CanWEA and CanSIA made a submission to the Federal Standing Committee on Finance in August 2016. They argued the transition to a low-carbon economy requires a public policy and investment regime that stimulates private sector investment in renewable energy projects. The associations made the following recommendations:

- 1. Pricing carbon to level the playing field between low-carbon and carbon intensive energy;
- 2. Improving the investment case for low-carbon infrastructure by increasing returns and reducing the cost of capital;
- 3. Broadening the investor base to deepening the capital pool to enable social participation; and
- 4. Enhancing existing measures to maximize their impact.

Renewable energy projects are capital intensive, which means construction requires long-term financing. For this reason, CanSIA and CanWEA argue that tax policy is a key enabler for renewable energy projects globally. In particular, they understand that pricing carbon will give Canadian businesses a clear and predictable basis for decision-making in relation to the renewable energy industry.

Currently, construction projects must meet the following financial requirements to obtain private financing:

- (i) a fixed, long-term contract or revenue which supports operating demands as well as the principal and interest payments on the debt;
- (ii) proven and supported technologies; and
- (iii) a minimum \$10,000,000 to perform due diligence, structure the debt and other transaction costs.

Unfortunately, many renewable energy projects do not meet these criteria.

Therefore, residential, commercial, and community-scale projects that are too small relative to the transaction and diligence costs are constrained by a lack of financing. This also applies for energy efficiency, solar heating and cooling, and energy storage projects where long-term fixed price contracts may not be available. As a result, there is a financial gap that acts to prevent investors from pursuing these projects and supporting the pan-Canadian Framework on Clean Growth and Climate Change.

Federal tax policies that improve the investment case for low carbon infrastructure by increasing returns and reducing the cost of capital enhance the capability of Canadian renewable energy projects to compete for capital with investments in other jurisdictions and the fossil fuel industry. However, the renewable energy sector is very concerned that Canada's tax code currently offers a number of incentives to Canada's oil, gas and mining sectors offset development expenses and capital costs. These types of economic incentive for capital costs and development expenses are very weak in the renewable energy sector.²¹⁷



This study makes a unique contribution to the international development literature by undertaking original macroeconomic research on the construction industry, economic restructuring, and low-carbon development in Canada. PHOTO COURTESY BC BUILDING TRADES

Environmental Scan Conclusion

CANADA IS A SIGNATORY to the Paris Agreement, adopted at the 21st Conference of the Parties (COP21) to the United Nations Framework Convention on Climate Change (UNFCCC). It represents the first time in history that all the world's nations agreed to combat climate change under a common framework. Under the Paris Agreement, 197 countries representing 97 per cent of global greenhouse gas (GHG) emissions agreed to take measures that hold the increase in the global average temperature to below 2°C above pre-industrial levels and to work toward 1.5°C. There is an urgent need²¹⁸ for Canada to develop

plans for the rapid economic transformation to low-carbon development.

Canada's ability to meet this challenge will be based on the construction of new infrastructure and facilities for the generation of electricity using renewable sources, including hydro, wind, solar, and tidal energy. Members of the Building Trades are central to this transition. This study makes a unique contribution to the international development literature by undertaking original macroeconomic research on the construction industry, economic restructuring, and low-carbon development in Canada.

Glossary

ADAPTATION	Climate adaptation indicates actions and strategies taken by communities and ecosystems to cope with the consequences of global warming.
AFL-CIO	The American Federation of Labor and Congress of Industrial Organizations is the parent organization of Canada's Building Trades Unions (CBTU).
CARBON PRICING	A government policy that charges those who emit carbon dioxide for their emissions. A carbon price is the amount that must be paid for the right to emit one tonne of CO ₂ into the atmosphere. This method is the foundation for developing an economic policy to mitigate climate change.
CBTU	Canada's Building Trades Unions represents more than half a million Canadian construction workers working in more than 60 trades and occupations, and is affiliated with 15 international unions.
CHAINED DOLLARS	A method of adjusting a series of economic data such as gross domestic product (GDP) for inflation over successive years, which puts this data in real or constant terms. Statistics Canada presents GDP at basic prices or constant prices by industry in chained dollars.
CONSTRUCTION	Construction as used in this study refers to building trades, labour, and managerial/white-collar construction employees directly involved in construction of buildings, infrastructure, industrial facilities, and other projects.
CONSTRUCTION VALUE-ADDED	Also referred to as construction gross domestic product (GDP), this is the monetary contribution of the construction industry to the total economy or overall GDP.
DECARBONIZATION	Carbon dioxide (CO ₂) is one of the primary greenhouse gases (GHGs) causing global warming, and GHGs like methane and nitrous oxide are generally measured in a single unit called a carbon dioxide equivalent (CO ₂ e). Because of this, movement in that direction is called “decarbonization” by many agencies.
GDP	Gross domestic product (GDP) is the total monetary value of the goods and services produced in the economic territory of a country or region during a given period. As the broadest quantitative measure of a nation's total economic activity, GDP reveals information about the size of an economy and indicates whether the economy is expanding or contracting.
GHGs	Greenhouse gases (GHGs) such as carbon dioxide, methane, chlorofluorocarbons (CFCs), and nitrous oxide absorb and trap infrared radiation in the atmosphere.
GLOBAL WARMING	The increase of Earth's average surface temperature due to effects of greenhouse gases, such as carbon dioxide emissions from burning fossil fuels or from deforestation, which trap heat that would otherwise escape from Earth. It is one measure of climate change.
INDC	Intended Nationally Determined Contributions (INDC) is a term used by the United Nations Framework Convention on Climate Change (UNFCCC) for reductions in greenhouse gas emissions. All countries that signed the Paris Agreement were asked to publish targets for the reduction of CO ₂ emissions in the lead-up to the 2015 United Nations Climate Change Conference in Paris, France in December 2015.

JOB	Jobs are person-years of employment, calculated at 1,500 hours per year. This is based on the number of hours required for a year's credit in most building trades pension plans, and the amount needed to qualify for a year of apprenticeship.
JOB CALCULATION METHODOLOGY	A full-time construction job is deemed to be one year of employment totaling 1,500 hours. This is the number of hours required for a year's credit in most building trades pension plans, and is the same number necessary to receive credit for a year of apprenticeship.
LOW CARBON DEVELOPMENT	Used in this study to describe forward-looking national economic development plans or strategies that encompass low-emission and/or climate-resilient economic growth.
MACROECONOMICS	A branch of economics dealing with the study of the performance, structure, behaviour, and decision-making of an economy as a whole. Economists working in this field study aggregated indicators such as employment rates, GDP, and inflation, in order to analyze how different sectors of the economy relate to one another or understand how the economy functions.
MITIGATION	Climate change mitigation refers to efforts to reduce or prevent human-made GHG emissions.
NET ZERO	The state in an industrial economy where any greenhouse gas (GHG) emissions — such as carbon dioxide, methane, and nitrous oxide — are absorbed by natural and/or human-made means.
NEX-GEN	Pertaining to the next generation or stage of development of a product, service, or technology.
PPM	Parts per million is a measurement used to monitor and analyze changes in the concentration of carbon dioxide (CO ₂) in the Earth's atmosphere. CO ₂ is the primary driver of climate change. Since the beginning of the Industrial Revolution (1750), human activities have produced a 40 per cent increase in the atmospheric concentration of carbon dioxide, from 280 ppm in 1750 to 400 ppm in 2015.
RENEWABLE ENERGY	An energy source or fuel type that can regenerate and replenish itself indefinitely. The five renewable sources used most often are biomass, wind, solar, hydro, and geothermal.
TIME SERIES DATA	A collection of observations of well-defined data items obtained through repeated measurements over time. For example, measuring the level of unemployment each month of the year would comprise a time series. This data allows economists to identify change within specific indicators over time, such as the impact of cyclical, seasonal, and irregular events on the data item being measured.
UNFCCC	The United Nations Framework Convention on Climate Change is an international environmental treaty negotiated at the Earth Summit in Rio de Janeiro in June 1992 that came into force in March 1994. The objective of the treaty is to stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous human impact on the environment such as climate change.

Notes

- 1 Calculations derive from 19,899 “green” non-residential building construction jobs in 2014, noted in CaGBC’s report “Green Building in Canada: Assessing the Market Impacts & Opportunities,” p. 84, http://www.cagbc.org/CAGBC/Advocacy/Green_Building_in_Canada_Assessing_the_Market_Impacts_Opportunities.aspx. This is proposed as a 30% figure of the total non-residential building construction jobs, based on polling of contractors, architects, building owners and engineers by McGraw Hill Construction for CaGBC (See “Canada Green Building Trends: Benefits Driving the New and Retrofit Market,” p. 6, <https://www.cagbc.org/cagbcdocs/resources/CaGBC%20McGraw%20Hill%20Cdn%20Market%20Study.pdf>), giving a calculation of: $19,899/x = 30/100$; $x = 66,330$. This estimate is likely low, as there are approximately 600,000 Canadians working on non-residential building construction. (See BuildForce report titled “Labour Market Assessments for the Residential Construction Industry,” graph p. 14, <http://www.buildforce.ca/en/system/files/products/Labour-Market-Assessments-Residential-Construction-Industry-2015.pdf>). In total, about 1,385,000 Canadians worked in construction in 2016, per StatsCan data here: <http://www.statcan.gc.ca/tables-tableaux/sum-som/101/cst01/econ40-eng.htm>. It is doubtful that only 66,000 Canadians are working to build commercial, industrial and institutional buildings; however, using this low figure, we project green saturation of the sector from 2014 to 2050 (achieving 100% saturation by 2049) proportional to projected population growth (from 36M to 48M): $36/48 = 66,330/x$; $x = 88,440$ as a 2050 figure of ongoing jobs, giving 1,997,640 for total job-years.
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- 4 Environment and Climate Change Canada (2016) “Canada’s Mid-Century Long-Term Low-Greenhouse Gas Development Strategy,” http://unfccc.int/files/focus/long-term_strategies/application/pdf/canadas_mid-century_long-term_strategy.pdf?utm_source=All+Media&utm_campaign=517babec61 EMAIL_CAMPAIGN_2016_11_18-2050+strategy&utm_medium=email&utm_term=0_135bfb50a9-517babec61-347670097
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- 6 “Paying the Price: The Economic Impacts of Climate Change for Canada,” *ibid*, p.16.
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- 13 *Ibid*.

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- 21 CIA World Factbook, Crude Oil - Production page, <https://www.cia.gov/library/publications/the-world-factbook/rankorder/2241rank.html>
- 22 CIA World Factbook, Natural Gas - Production page <https://www.cia.gov/library/publications/the-world-factbook/rankorder/2249rank.html>
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- 41 Canadian Electricity Association (2014) Key Canadian Electricity Statistics. Slightly different stats from NRCAN here, showing 620 TWh instead of 611, and different percentages, but not broken down as specifically: 2015-16 Energy Fact Book, https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/files/pdf/EnergyFactBook2015-Eng_Web.pdf
- 42 Statistics Canada (2016) "Canadian Demographics at a Glance," February 19, 2016, p. 4: 52.6 million by 2061, <http://www.statcan.gc.ca/pub/91-003-x/91-003-x2014001-eng.pdf>
- 43 Sustainable Development Solutions Network (SDSN) and Institute for Sustainable Development and International Relations (IDDRI) (2015). "Pathways to Deep Decarbonization in Canada," Figure 17, p. 25. The report predicts electricity providing 43% of Canada's power in 2050, versus a business-as-usual scenario of 25%.
- 44 Ibid, p. 25.
- 45 See chart on p. 25 of "100% Clean and Renewable Wind, Water, and Sunlight (WWS) All-Sector Energy Roadmaps for 139 Countries," Mark Jacobson (2017) Stanford study; and clarification via personal communication of the meaning of Total 2050 End-Use Load: "That is end use load in GW (not installed capacity). Multiply by 8760 hrs/yr to get end use energy consumption per year among all sectors (residential, commercial, industry, transportation, ag/forestry/fishing). Multiply further by the percent in each subsequent column to get the energy consumption in each sector."
- 46 In this context, note the Canadian District Energy Association's 2012 estimate by that by 2020, Canada's demand for power will be 593 TWh. https://www1.toronto.ca/static_files/economic_development_and_culture/docs/Sectors_Reports/fiscalbenefits_localgeneration.pdf
- 47 Canadian Electricity Association (2014), "Vision 2050: The Future of Canada's Electricity System," <https://electricity.ca/wp-content/uploads/2014/03/Vision2050.pdf>
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- 50 Canadian Wind Energy Association, (2015) "Powering Canada's Future," December 2015, http://canwea.ca/wp-content/uploads/2016/02/Canada-Current-Installed-Capacity_e.pdf
- 51 Suncor (2016) "Suncor and our partners are involved in five operational wind power facilities. These wind power facilities have a generating capacity of 187 megawatts (MW), enough to power about 65,000 Canadian homes." www.suncor.com/about-us/wind-power
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 - 55 JEDI estimates put direct blue and white construction jobs at .6 per MW of installed power. (See Betony Jones, Peter Philips, and Carol Zabin, (2016) "The Link Between Good Jobs and a Low Carbon Future: Evidence from California's Renewables Portfolio Standard, 2002 – 2015," July 2016, P. 5-6, <http://laborcenter.berkeley.edu/pdf/2016/Link-Between-Good-Jobs-and-a-Low-Carbon-Future.pdf>) Using the the 1500-hr year instead of 2080 gives: $2080/1500 = 1.38$; $.6 \times 1.38 = .83$; $.83 \times 228,750$ (see previous footnote for MW calculation) = 189,862. Wind towers need to be replaced after 25 years, resulting in 47,000 MW at minimum that need to be replaced by 2050 in this scenario. We calculate replacement at 1/2 the original construction job rate per MW ($.5 \times .83 = .415$) as there may be no need to re-grade sites or create new footings, and some infrastructure will have already been replaced before the 25 yr mark. This gives an additional $47,000 \times .415 = 19,505$. $189,862 + 19,505 = 209,367$
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 - 57 Based on calculation of average .06 operations jobs per MW of wind. See Sandra Reategui and Stephen Hendrickson "Economic Development Impact of 1,000 MW of Wind Energy in Texas" Report, NREL, August 2011, p. 8, www.nrel.gov/docs/fy11osti/50400.pdf. Taking the 2080 hr year and converting to 1500 hrs gives $2080/1500 = 1.38$; $1.38 \times .06 = .082$; $.082 \times 228,750 = 18,757.5$. Note that this is low relative to other estimates that put the total at .09 operations jobs per MW. See: James Conca, "What Do Energy Sector Jobs Do For Us?" Article, Forbes, August 21, 12, www.forbes.com/sites/jamesconca/2012/08/21/what-do-energy-sector-jobs-do-for-us/#49c675905e67. Wind energy buildout and person-years of operations jobs to 2050 calculations available on CI spreadsheets.
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 - 64 Dr. Harry Wirth, (2017) "Recent Facts about Photovoltaics in Germany" published by Fraunhofer Institute for Solar Energy Systems ISE, updated January 2017 <https://www.ise.fraunhofer.de/en/publications/>

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- 65 In 2015, solar was .04% of the national grid. (Numbers derived from StatsCan data, with a total 2015 electricity generation figure of 592755750 MWh and a total solar generation figure of 251444 MWh. That is about .042%.) CanSIA projects solar growing to 1% of the grid by 2020, so a ten-percent share of the Canadian grid by 2050 seems reasonable.
- 66 571 MW of installed solar PV capacity is estimated to produce 692 GWh/year. Based on NRCAN data from p. 67 here: <https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/canmetenergy/files/pubs/2012-063-eng.pdf>. So the multiplier is 1.21. To get 91 TWh or 91,000 GWh would require the installation of 75,200 MW (91000/1.21).
- 67 Betony Jones, Peter Philips, and Carol Zabin, (2016) "The Link Between Good Jobs and a Low Carbon Future: Evidence from California's Renewables Portfolio Standard, 2002 – 2015," July 2016, P. 5-6, <http://laborcenter.berkeley.edu/pdf/2016/Link-Between-Good-Jobs-and-a-Low-Carbon-Future.pdf>. Without including the higher job ratio for concentrated solar facilities, and using only the more conservative numbers for standard photovoltaic, JEDI estimates put direct blue collar construction jobs at an average of 3 per MW of installed power, plus .9 for white-collar (3.9 total per MW). Using a 1500-hour years instead of 2080, gives: $2080/1500 = 1.38$; $1.38 \times 3.9 = 5.38$. $5.38 \times 75,200$ (see previous footnote for MW calculation) = 404,726. Additionally, 12,500 MW will need to be installed as 25-year old panels are replaced. We calculate replacement at 1/2 the original construction job rate ($.5 \times 5.38 = 2.69$) per MW. This gives an additional $12,500 \times 2.69 = 33,625$ jobs $404,726 + 33,625 = 438,351$
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- backgrounder to their clean energy jobs map (www.pembina.org/reports/bc-clean-jobs-map-methodology-backgrounder-27042015.pdf); JEDI gives 7.1 jobs per MW of small hydro power. (See p. 5-6 here: <http://laborcenter.berkeley.edu/pdf/2016/Link-Between-Good-Jobs-and-a-Low-Carbon-Future.pdf>). We have gone with the Pembina estimate, and adjusted it to the 1,500 hr job-year. $2080 \text{ hrs}/1500 \text{ hrs} = 1.38$. $1.38 \times 7 = 9.66$; $9.66 \text{ jobs} \times 7750 \text{ MW} = 74,865 \text{ jobs}$.
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- 180 American Public Transportation Association (2014) “Economic Impact of Public Transportation Investment” Exhibit 4-9, p. 44. Given the meaning of direct, indirect and induced for the report, it would seem reasonable to take some percentage very close to 30% as the portion of the 5,063 – 5,822 direct jobs created by \$1B of investment (1519 - 1747) that are in construction; the rationale for this being that the “indirect” jobs are not construction jobs, and for the “induced” category only a small percentage of construction workers will go on to use their wages to build new homes from the ground up, or renovate in such a way that would require hiring more construction labor. Naomi Stein, a senior analyst at EDRG who helped author the APTA report, noted that 30% is a reasonable approximation. We have opted for

- median of the two numbers (1519 and 1747): 1633 jobs per \$1 billion, giving a calculation of $150 \times 1633 = 227,850$.
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