ALMOST TWICE AS MANY

Green Jobs in Canada in the Transition to 100% Renewable Energy

By Guy Dauncey

Almost Twice as Many: Green Jobs in Canada in the Transition to 100% Renewable Energy

Guy Dauncey, September 2015

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About the Author
Guy Dauncey is founder of the BC Sustainable Energy Association, co-founder of the Victoria Car Share Cooperative, and the author or co-author of nine books, including the award-winning Cancer: 101 Solutions to a Preventable Epidemic and The Climate Challenge: 101 Solutions to Global Warming. He is currently completing his tenth book titled *Journey to the Future: A Better World Is Possible*. He is an Honorary Member of the Planning Institute of BC and a Fellow of the Findhorn Foundation in Scotland. His websites are www.earthfuture.com and The Practical Utopian.

Website: http://tiny.cc/Almost-Twice-As-Many

Earthfuture Publications
13561 Barney Road,
Ladysmith, BC V9G 1E9
250-924-1445
guydauncey@earthfuture.com

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Before, if we screwed up, we could move on. But now we don't have an exit option. We don't have another planet.
- Tim Flannery, Australian scientist and climate author

Countries that innovate first get the new jobs, developing an economic edge over the laggards that end up having to later import the technology.
- William H. Calvin, University of Washington

Executive Summary

Canada's economy supports 19 million jobs, 4% of which are related to fossil fuel extraction and consumption. From a climate perspective, we need to complete the transition to 100% renewable energy as rapidly as possible, since with each passing year of uncontrolled carbon emissions the prospects for a stable, sustainable future grow dimmer.

As nations accelerate their transition from fossil fuels to renewable energy, new jobs will be generated in four sectors of the economy:

(a) *Electricity*, as the build-up of wind, solar, geothermal and other sources of renewable energy replaces electricity from fossil fuels;
(b) *Buildings*, as work is done to make all buildings more efficient and to convert oil and gas heated buildings to heat pumps, district heat and other forms of renewable heat;
(c) *Transportation*, as travel modes shift and oil is replaced with electricity;
(d) *Farming*, as organic farming replaces conventional methods that depend on fossil fuels to make fertilizer.

The analysis in this report applies to Canada, but a similar approach could be applied to other countries, following the guidelines listed in Appendix 2.

The analysis suggests that over the next 25 years, if Canada were to make a deliberate, organized transition to a 100% renewable energy economy, *during the transition* there would be almost twice as many green jobs created as there would be fossil fuel jobs lost. By the end of the transition the number of ongoing renewable energy jobs will be much the same as the number of fossil fuel jobs that will have ended.

This scenario assumes that within 25 years, or by 2040 if the transition begins immediately:

- 100% of Canada's electricity will be renewable;
- 90% of Canada's buildings will have been upgraded for energy efficiency and converted to renewable heat;
- All Canadian cities will enjoy the benefits of a steady investment in improved transit and/or light rail transit;
- Cycling will have an up to 25% trip share in Canada's towns and cities;
- All cars, buses and light trucks will be electric;
- All of Canada's railways will have been electrified;
- All of Canada's farms will be organic.

Achieving 100% renewable energy status is not yet possible using today's technologies, since renewable energy solutions have not yet been developed for long-distance trucking, shipping and flying. In this report, the term "100% renewable energy" is used only for those sectors of the economy where it is possible using today's technologies.

The challenge is either to build an economy that is sustainable or to stay with our unsustainable economy until it declines. It is not a goal that can be compromised. One way or another, the choice will be made by our generation, but it will affect life on earth for all generations to come.
- Lester Brown, Founder of the Worldwatch Institute

1. Introduction

How many jobs will be lost or gained as we make the switch from fossil fuels to renewable energy? It's a very pressing question. If we successfully phase out coal, oil and gas so that by 2040 there are no more coalmines, tar sands projects, natural gas fracking operations, pipelines or oil tankers, will there be fewer jobs—or more?

Clear analysis, based on peer-reviewed climate science, tells us that if the world is to have a 75% chance of not exceeding the highly dangerous 2°C increase in temperature, all countries will need to make a rapid transition off fossil fuels, and the vast majority of the remaining fossil fuels will need to remain in the ground—a scientific analysis supported by Mark Carney, governor of the Bank of England.[1]

In keeping with this need, analysis shows that Canada will need to complete its transition to a 100% renewable energy economy by 2040, reducing its carbon dioxide emissions by 25 megatonnes a year.[2]

When historians look back on the Age of Fossil Fuels they will conclude that it lasted for around three hundred years, from 1750 to 2050. The Solar Age will last far longer, for when we switch from ancient to real-time solar energy our civilization crosses a critical threshold. Once the equipment to capture the Sun's energy has been installed, the Sun will provide us with free energy for as long as we stay on the planet. After some 1.75 billion years, as the Sun begins its journey to becoming a Red Giant, we will need to relocate to a cooler planet—but not until then.

In the meantime, and for more than a *billion years*, with every passing year renewable energy technologies will improve, and fall further in price. By 2050, Germany's prestigious Fraunhofer Institute for Solar Energy Systems has estimated that solar PV could cost as little as $0.02-0.04 cents/kWh ($20/MWh)[3] compared to $70 to $90/MWh for fossil fuel based generation (without carbon pricing) and $100 to $120/MWh for a typical electrical bill in North America.

Some people worry that without the continued development of its oil and gas resources Canada's economy will cease growing, and they urge approval of new pipelines to allow the export of oil sands bitumen and liquefied natural gas, and new coal exports. Should we be concerned? This is the question that this report explores.

As the shift happens from fossil fuels to renewable energy there will be many changes in Canada's economy and many areas where jobs are impacted. This report considers five major areas where there will be known job impacts during the transition to 100% renewable energy, where it appears that there could be a large change in the numbers of jobs:

1. Fossil fuel activities
2. Electricity
3. Buildings
4. Transportation
5. Farming

We will consider each in turn, sourcing information from a variety of studies.

We have the chance to build this new energy economy in ways that reflect our deepest values of inclusion, diversity, and equal opportunity for everyone.
- Van Jones, The Green Collar Economy

1.1 Methodology

When discussing the phase-out of fossil fuels, four dimensions need to be considered: energy, jobs, government revenues, and the macro-economic implications.
This brief report explores only the jobs and energy implications, using a number of straight-line extrapolations and not any sophisticated economic modeling. The impacts on government costs and revenues and macroeconomic implications are discussed briefly in Section 12, but are otherwise beyond the report's scope.

This is not a detailed project: as reports go it is a relatively quick analysis. If you spot errors in the assumptions or calculations I would value hearing from you. To aid the process, each assumption has been numbered and summarized in Appendix 1.

For each sector, the report's methodology has been to track down a valid study from a trustworthy source that uses a credible job-generating ratio. Those ratios have been used to calculate the number of jobs that will be generated per year in that sector, scaled up or down as needed to match Canada's population, taking care to distinguish between direct, indirect and induced jobs. All numbers have been rounded for ease of comprehension.

Finally, as the new green jobs accumulate over the course of an organized 25-year transition to 100% renewable energy, the numbers have been aggregated and compared to the jobs that would be lost. This indicates how many jobs will be lost or gained each year as Canada makes the transition.

1.2 What is 'a Job'?

First, we need to consider what is meant by 'a job.'

When economists measure the jobs generated by a particular sector of the economy they count three distinct types of job:

- Direct jobs (eg jobs installing solar PV)
- Indirect jobs (eg jobs manufacturing aluminum to make the racking), and
- Induced jobs (eg jobs generated when solar workers spend their earnings in restaurants, bookshops or sports arenas).

All jobs are counted as person-years of employment, so one job means one person working full-time for a year, or two people working part-time. A permanent job is an ongoing, year-to-year job.

The factors by which indirect and induced jobs are generated are called 'multipliers', and Statistics Canada lists multipliers for each sector of the economy. When it comes to induced jobs the multipliers differ, since a fast-food worker who earns $10 an hour will stimulate fewer induced jobs by spending his or her earnings than a lawyer who earns $200 an hour.[4]

When the US government calculates induced jobs from government spending, for example, it assumes that $92,000 of government spending will create 1 job-year, 64% of which is direct and indirect and 36% of which is induced. So each $1 million of US government spending creates 11 jobs, of which 7 are direct or indirect and 4 are induced. [5]

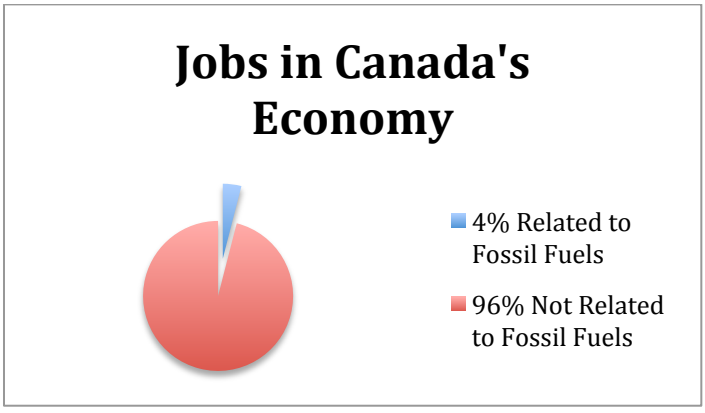
With these complexities in mind we can now explore the shift to 100% renewable energy and estimate how many jobs will be created or lost.[6] The numbers for fossil fuel jobs do not consider the impact of a different scenario in which Canada ignores global concerns about the climate crisis and attempts to become a fossil fuel super-power transected by export pipelines, with oil tankers in all major ports. The numbers for the transition to 100% renewable energy assume a planned, orderly 25-year transition.
This report does not analyze areas of the economy where the switch to renewable energy may not have jobs implications, such as the switch from industrial heat generated by coal or gas to heat generated by biomass, hydrogen from renewables or solar thermal energy, or fuel changes for future long-distance trucking, shipping and flying, where there are far too many unknowns to be able to attempt a meaningful forecast.

It is obviously true that such an orderly transition with its linear projections can only happen in the mind of an idealistic planner or statistician, ignoring the complexities of such a major structural adjustment, but the results do paint an overall picture of the implications if Canada's local, provincial and federal governments were to take urgent and decisive integrated action to address the climate crisis. Far from being gloomy, the jobs outlook if Canada was to accelerate the transition to 100% renewable energy is bright.

1.3 Canada's Economy

Canada's economy is the 14th largest in the world, with a GDP of $1.85 trillion. 30% of its GDP comes from exports, including agricultural, energy, forestry and mining goods (58%), machinery, equipment, automotive products and other manufactures (38%). 73% of Canada's exports are to the United States. In 2010, the energy sector produced 6.8% of Canada's GDP, half of which came from oil and gas and a third from electric power.[7]

In 2015, Canadians worked in some 19 million jobs.[8] Approximately 800,000 jobs are generated by the extraction and delivery of coal, oil and gas, consisting of 257,000 direct, 298,000 indirect and 245,000 induced jobs. *96% of the workforce does not work in jobs related to Canada's fossil fuel industries*.[9]



Statistics Canada lists 1.3 million people as being unemployed in 2015 (6.8% of the labour force). TD Bank's Labour Market Indicator, on the other hand, shows that 15% of Canadian workers aged 24 - 54 are not in the labour market, including those who have become discouraged and those who work part-time involuntarily.[10] 20% of those who are unemployed have been so for the long-term.[11]

Right from the start, therefore, we can see two things: that a switch to 100% renewable energy need not be a heartbreaker for Canada's economy as a whole, and that between one and two million people are seeking work.

If Canada and other nations do *not* make the transition, however, the uncontrolled climate crisis will destroy many lives, break many hearts and cost us all dearly, with hundreds of millions of people being made homeless,[12] droughts causing devastating losses to agriculture, and costly extreme weather events such as forest fires happening four to five times more frequently.[13] In June 2015 *New Scientist* magazine reported that a five meter rise in sea-level is already "locked in" due to the melting West Antarctic Ice Sheet, and unavoidable over the next few thousand years, and that unless we act rapidly to reduce our global emissions a 20 metres rise in sea-level will become inevitable.[14]

In 2007, The Stern Review warned the world that "ignoring climate change could reduce global GDP by 20% by the end of the century, and that to avoid this risk the world should spend 1% of global GDP a year, starting immediately." In 2015, Canada's GDP was US $1.825 trillion. 1% of this is US $18 billion a year (CAN $23 billion). Canada's federal government budget is around CAN $290 billion.

In 2014, Stern stated that things had moved on in the eight years since his review, that emissions had gone up faster than anticipated, and that some of the effects of global warming were coming through more quickly, including the melting of the glaciers and the polar ice caps.[15] Section 12.5 describes some of these costs to Canada.

2. Fossil Fuel Extraction and Production Jobs

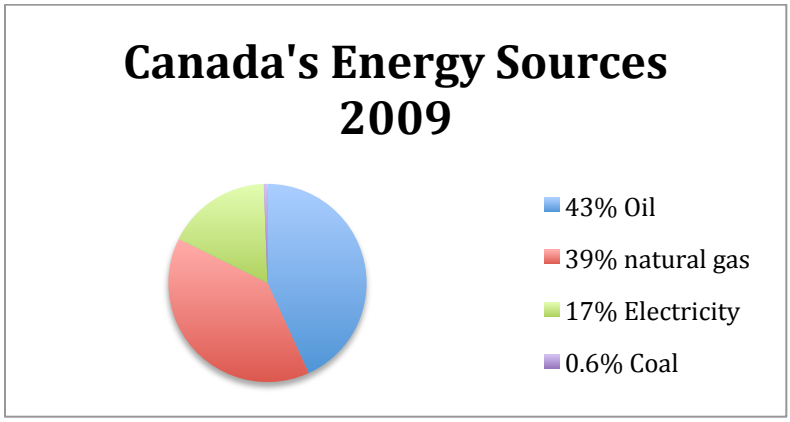
This report uses Statistics Canada's estimate of 257,000 direct, 298,000 indirect and 245,000 induced jobs, for a total of 800,000 jobs relating to fossil fuels. 50,000 jobs will be added for jobs that will be lost in the trucking industry with the switch from road to rail as empty railcar space is created by the end of coal and oil shipments. For the range of fossil fuel jobs estimates and their sources, see Appendix 1.

3. Energy Use in Canada

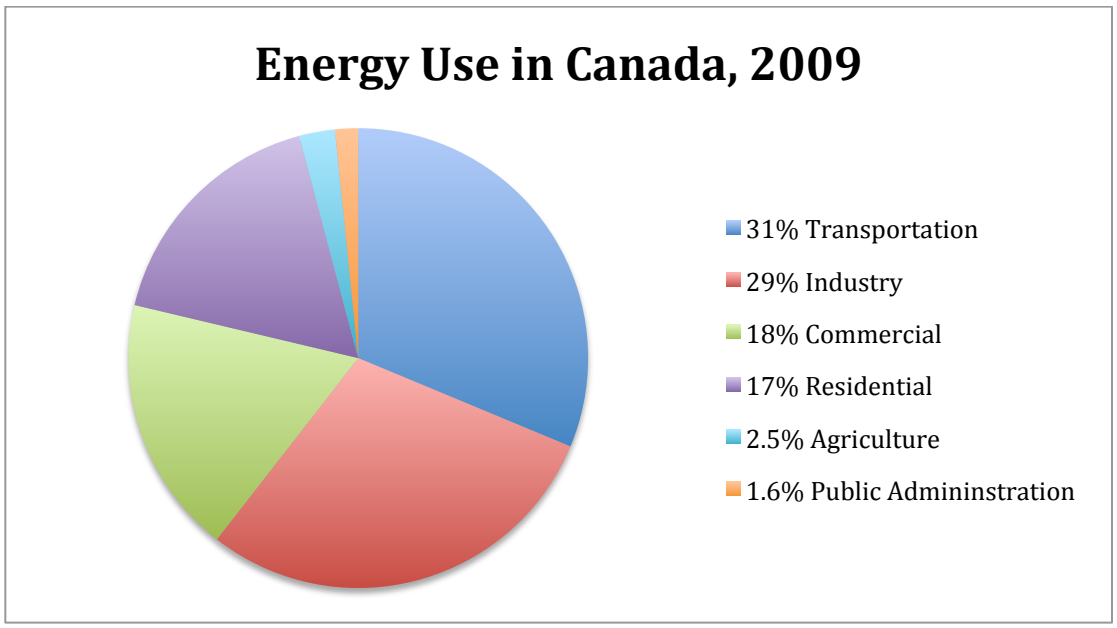
The number of jobs that will be generated during the transition depends in part on the amount of sustainable energy that will be needed. In this analysis, it is assumed that current levels of energy use (plus a growth factor, less an amount for increased energy conservation) will reflect the amount of renewable energy required by 2040.

If Canada was to produce 100% of its electricity from renewables such as hydro, solar, wind and geothermal by 2040, the date chosen in this report for Canada to become a 100% renewable energy economy (Assumption #1), how many jobs would be generated over the 25-year transition period? To understand this we need to estimate how much power Canada will need in 2040.

In 2009, Canada's total energy consumption was 9.2 million terajoules, derived as follows: [16]



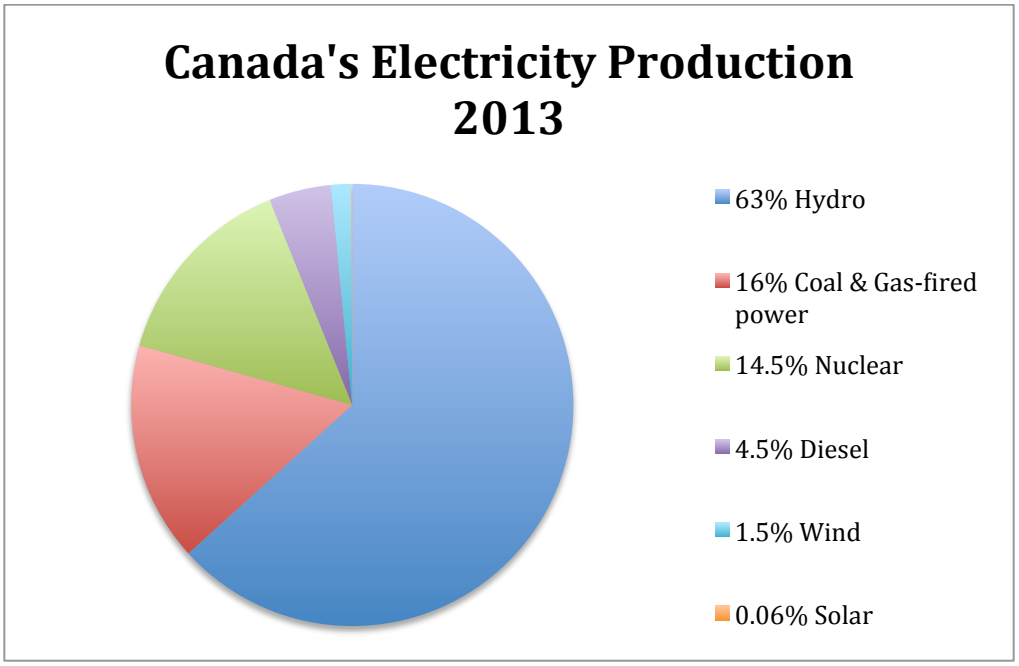
The energy was used as follows: [17]



4. 100% Renewable Electricity

How much renewable electricity will Canada need? In 2013, Canada consumed 511 terawatt hours (TWh) of electricity.[18] If demand continues to grow by 1.6% a year (Assumption #2), it will have risen to 784 TWh a year by 2040.

Our problems are man-made. Therefore, they can be solved by man. And man can be as big as he wants. No problem of human destiny is beyond human beings. Man's reason and spirit have often solved the seemingly unsolvable -- and we believe they can do it again.
- John F. Kennedy, American University Speech June 1963



This needs to be adjusted to account for several factors:

1. Phased out electricity demand by the fossil fuel industry. In 2008, Canada's fossil-fuel industrial activities accounted for 17% of Canada's total energy use, of which 31% was supplied as electricity and 69% as fossil fuels.[19] As Canada makes the transition to 100% renewable energy the electrical demand component will disappear, resulting in a 5% reduction in total demand, reducing the future total to 745 TWh.[20] (Assumption #3)

2. Increased efficiency. If changing social and environmental values combine with smart government policy to inspire every household and business to invest in efficient appliances, fans, motors and lights, we might be able to reduce our power consumption by 25%. (Assumption #4)

3. Increased use of electricity for various purposes. The nation-wide shift to electric vehicles, railways and heat pumps will offset this, however, as electricity replaces the use of oil and gas. (Assumption #5)

In conclusion, by 2040 Canada may need to generate 750 TWh of electricity a year.

Hydro and wind currently generate 330 TWh a year, so to meet the goal we will need to generate an additional 420 TWh a year of renewable energy. In this report, this is assumed to come chiefly from solar, wind and geothermal power, with additional hydro if there is not sufficient geothermal. Smaller contributions may come from tidal energy, wave energy, run-of-river power and bioenergy. Jobs data for these sources are assumed to be covered by the data for solar, wind and geothermal, so additional analysis has not been included.

Nuclear produces 14.5% of Canada's power, but a majority of Canadians have stated a preference not to refurbish Ontario's nuclear plants for a longer life, so we have not assumed a continuation of nuclear power beyond the planned life of the existing plants.[21] Among the reasons for excluding extended nuclear are its high capital cost, the non-sustainability of uranium mining, the health hazards associated with the

nuclear cycle, the nuclear technology proliferation risks to global security, and the heavy opportunity cost that results from the long period of time needed to plan, win approval and build a nuclear plant from concept to production, during which time the same money invested in wind or solar could have been generating power. (Assumption #6)

Table 1. Canada's Electricity Demand and Supply	Terawatt-hours a year
Total demand in 2013	511
Total demand in 2040	750
Supply from renewables in 2013	330
New supply needed from renewables by 2040 • 100 TWh solar PV • 150 TWh wind • 170 TWh geothermal	420

4.1 Future Renewable Energy Supply

For the purposes of making the jobs estimates, this report has made the assumption that the electrical future demand will be provided by 100 TWh of solar, 150 TWh of wind and 170 TWh of geothermal. Clearly, different mixes of renewable energy could be appropriate in different countries. No objective analysis underlies the assumption of this three way split. (Assumption #7)

4.2 How Many Solar Energy Jobs?

The International Renewable Energy Agency (IRENA) estimates that solar PV installation generates 18 direct and indirect jobs per MW during installation and 0.3 jobs per MW per year during operation and maintenance (O&M). [22] The US National Renewable Energy Laboratory 2012 *Jobs and Economic Impacts* analysis estimates 31.6 direct and indirect jobs per MW for installation and 0.3 jobs per MW during operation.[23] In this report we have adopted IRENA's numbers, since the lower estimate is more conservative, and better reflects the improving labour productivity of solar installers. (Assumption #8)

For 100 TWh of Canada's future power to come from solar PV we will need to install 82,000 MW of solar PV or 3,280 MW a year, assuming an average capacity factor of 14%.[24] (Assumption #9) This is equivalent to a 4 kW system on 20 million buildings, or 820 solar farms each averaging 830 acres (3.3 sq. km.) in size. This is 50 TWh less than the upper limit estimated in *The Trottier Energy Futures Project: An Inventory of Low-Carbon Energy for Canada* (David Suzuki Foundation, 2013). [25]

In its report *Vision 2050, The Future of Canada's Electricity System*, the Canadian Electricity Association made a different projection. They estimated that by 2035 natural gas would still provide 15% of Canada's electricity, hydro/wave/tidal 56%, nuclear 11%, coal and coke 3%, coal with carbon capture 3%, wind only 6% and biomass, solar and geothermal only 6%. They also assumed that by 2050 there would only be 700,000 electric vehicles on the road, representing just 3% of Canada's 2014 total of 22 million cars and

light trucks.[26] The assumptions made in the Vision 2050 report make it impossible to prevent the global temperature from rising by more than 2°C.

Using IRENA's numbers, installing 3,280 MW of solar a year will generate 59,000 full-time direct and indirect jobs a year during the transition. As the solar productivity of the modules and the labour productivity of the workers rise, these numbers could fall. (Table 3, Column B)

Each 3,280 MW will also generate 984 jobs a year in operations and maintenance. These will accumulate steadily as the solar is installed, starting at 984 jobs in Year 1 and rising to 24,600 jobs in Year 25. These will be ongoing, permanent jobs.

If the solar modules are manufactured in Canada the indirect jobs may be far more than has been estimated. This will depend on future manufacturing costs, and the possible continuation of tariffs against Chinese solar manufacturers.[27]

For the cost of solar PV production, see Section 4.7. For induced jobs, see Section 9. For solar energy jobs from Year 26 onwards, see Section 10.

4.3 How Many Wind Energy Jobs?

For 150 TWh of electricity to be generated by wind, at an assumed 35% capacity factor (Assumption #10), we will need 49,000 MW of new wind capacity, or 1,960 MW a year. This is the amount recommended by the Trottier Project as the upper limit for wind energy in Canada by 2050. [28]

IRENA's estimate for onshore wind is 8.6 direct and indirect jobs per MW during installation (Assumption #11), so building 1,960 MW of wind farms a year will generate 16,800 full-time installation jobs a year during the transition. If the large scale of installation stimulates an increase in Canadian blade and tower manufacturing, the number of jobs will increase.

Once installed, wind energy needs 0.2 jobs per MW for operations and maintenance, so it will generate 392 jobs in Year 1 rising to 9,000 jobs in Year 25. These jobs will be permanent and ongoing.

For the cost of wind energy production, see Section 4.7. For induced jobs, see Section 9. For wind energy jobs after Year 25, see Section 10.

4.4 How Many Geothermal Jobs?

For 170 TWh to be generated from geothermal energy, with plants operating at the 92% capacity factor estimated for new geothermal plants by the US Energy Information Agency (Assumption #12),[29] we will need 21,000 MW of geothermal capacity at an average installation rate of 840 MW a year, utilizing both shallow and deep enhanced geothermal resources.[30]

The Canadian Geothermal Energy Association reports that Canada has more than 5,000 MW in traditional shallow geothermal resources with currently available technology, and a further 10,000 MW or more that may be available in deep geothermal resources, requiring enhanced geothermal technology that is still under development.[31] If only 10,000 MW of geothermal capacity can be developed, 17,000 MW of Canada's hydropower potential (see below) could be developed to fill the gap.

For geothermal energy IRENA estimates 10.7 direct and indirect jobs per MW, so installing 840 MW of new geothermal plants a year will generate 9,000 full time jobs during the transition. (Assumption #13)

Once installed, geothermal supports 0.4 jobs per MW in operations and maintenance, generating 336 jobs in Year 1 rising to 8,400 jobs in Year 25. These jobs will be permanent and ongoing.

For the cost of geothermal energy, see Section 4.7. For induced jobs, see Section 9. For geothermal jobs after Year 25, see Section 10.

4.5 Hydropower

Hydropower produces 63% of Canada's current electricity, generating 355 TWh a year of firm power from 74,000 MW of capacity.

The Canadian Hydropower Association reports that Canada has the technical potential to develop a further 163,000 MW of untapped hydropower potential without considering social or environmental factors, including 44,000 MW in Quebec and 33,000 MW in British Columbia.[32]

At 55% capacity factor, 163,000 MW of new hydropower would generate 785 TWh a year of electricity—almost twice as much as the additional 420 TWh needed to meet Canada's future demand.

IRENA has determined that the installation of hydro projects generates 7.5 direct jobs per MW for large hydro, and 0.3 jobs per MW for operations and maintenance.[33] No jobs have been assigned, however, since this report assumes the use of geothermal power to fill Canada's firm power needs rather than large hydro, due to the many social and environmental concerns and First Nations land claims that arise with large hydro projects.

It is time to start going door to door and convincing our neighbours to vote for a clean-energy future.
- Eban Goodstein, author of *Fighting for Love in the Century of Extinction*

4.6 Other Renewable Electricity Jobs

New jobs will also be created in other areas related to the renewable energy transition, including home, utility and industrial power storage. For example, Tesla is promising big breakthroughs in affordable power storage, both for electric vehicles and for utility, commercial and home energy markets. The Tesla Motors 'gigafactory' in Nevada (right) will produce 500,000 batteries a year, and the newly released Tesla PowerWall has opened the market for power storage.[34] There are too many unknowns, however, to be able to estimate what the future jobs impact might be.

The total direct and indirect renewable electricity jobs created in this scenario come to 87,000 jobs in Year 1, rising to 127,000 jobs in Year 25. (Table 3, Column H). With the induced jobs, the total number of jobs generated comes to 217,000. (Column J)

Table 2. Jobs Relating to the Transition to 100% Renewable Electricity[35]

A	B	C	D	E	F	G		H	I	J
Year	Solar Install	Solar O&M	Wind Install	Wind O&M	Geo Install	Geo O&M		Direct & Indirect Jobs (B-G)	Induced Jobs (H x 0.71)	Total Electricity Jobs (H + I)
1	59,000	984	16,800	392	9,000	336		87,000	62,000	149,000
2	59,000	1968	16,800	784	9,000	672		88,000	62,000	150,000
3	59,000	2952	16,800	1176	9,000	1008		90,000	64,000	154,000
4	59,000	3936	16,800	1568	9,000	1344		92,000	65,000	157,000
5	59,000	4920	16,800	1960	9,000	1680		93,000	66,000	159,000
6	59,000	5904	16,800	2352	9,000	2016		95,000	67,000	162,000
7	59,000	6888	16,800	2744	9,000	2352		97,000	69,000	166,000
8	59,000	7872	16,800	3136	9,000	2688		99,000	70,000	169,000
9	59,000	8856	16,800	3528	9,000	3024		100,000	71,000	171,000
10	59,000	9840	16,800	3920	9,000	3360		102,000	72,000	174,000
11	59,000	10824	16,800	4312	9,000	3696		104,000	74,000	178,000
12	59,000	11808	16,800	4704	9,000	4032		105,000	75,000	180,000
13	59,000	12792	16,800	5096	9,000	4368		107,000	76,000	183,000
14	59,000	13776	16,800	5488	9,000	4704		109,000	77,000	186,000
15	59,000	14760	16,800	5880	9,000	5040		110,000	78,000	188,000
16	59,000	15744	16,800	6272	9,000	5376		112,000	80,000	192,000
17	59,000	16728	16,800	6664	9,000	5712		114,000	81,000	195,000
18	59,000	17712	16,800	7056	9,000	6048		116,000	82,000	198,000
19	59,000	18696	16,800	7448	9,000	6384		117,000	83,000	200,000
20	59,000	19680	16,800	7840	9,000	6720		119,000	84,000	203,000
21	59,000	20664	16,800	8232	9,000	7056		121,000	86,000	207,000
22	59,000	21648	16,800	8624	9,000	7392		122,000	87,000	209,000
23	59,000	22632	16,800	9016	9,000	7728		124,000	88,000	212,000
24	59,000	23616	16,800	9408	9,000	8064		126,000	89,000	215,000
25	59,000	24600	16,800	9088	9,000	8400		127,000	90,000	217,000

4.7 How Can the Transition to 100% Renewable Electricity Be Achieved?

It is not the purpose of this report to make detailed policy recommendations. The fundamentals are relatively simple, however. Each province will need to set a date for the phase-out of coal-fired and then gas-fired power, as relevant, and to stimulate the development of wind, solar and geothermal power by the appropriate support schemes, accompanied by the maximum effort to increase energy conservation and efficiency. As the price of solar and wind continues to fall the need for incentive programs such as feed-in tariffs will disappear.

Geothermal energy is a special case, since the exploratory costs are far higher than they are for wind energy, though long-term production costs are low. When bidding into a competitive utility call for power investors are nervous of spending large sums of money with no guarantee of return. Changes to tax and investment regimes are therefore needed to level the investment playing field, and to give geothermal investors confidence that the risks will be worthwhile.

The greater challenge is less with the scale of what's needed than with the speed of the ramp-up required, and with achieving a relatively smooth year-by-year increase.

The Pembina Institute reports that BC's renewable energy sector currently supports 14,100 direct and indirect renewable energy jobs including hydro.[36] Clean Energy Canada reports that for Canada as a whole the renewable energy sector broadly defined to include energy efficiency technologies, building retrofits and clean transportation supports 23,700 direct jobs.[37]

The scenario in this report calls for 87,000 new jobs in Year 1 in the electrical sector alone, indicating the massive scale of ramp-up required.

All power costs money, but the cost of new wind and geothermal power is equivalent to the cost of new coal- and gas-fired power, even without an assumed carbon price. The cost of solar power is falling rapidly, and by 2020 it may also be equivalent. Energy efficiency investments cost far less per unit of energy saved than all other options.

The standard measure of energy cost is the "levelized cost", although it is difficult to compare sets of numbers due to different assumptions.

Table 3. The Levelized Cost of Power OECD US $/MWh

	IRENA 2014[38]	Lazard 2015[39]	EIA 2019[40]	EIA 2040	Fraunhofer 2050
Coal-fired power		66 - 151	87-114	87	-
Conventional combined cycle gas		61 - 112	61-76	81	-
Integrated coal gasification + CCS		-	137-163	122	-
Solar PV	60-120 Utility scale	60 - 86 Utility scale	101-201 (2012 prices)	110	20-40
Wind onshore	60-70	37 - 81	71-90	73	-
Geothermal	40-100	89 - 142	46-50	67.8	-
Large hydro	20-50				
Energy Conservation		27-125 [41]	-	-	-

Denmark, which has made a national commitment to achieve 100% renewable energy by 2050, has declared that all coal-fired power will be phased out by 2030, and that 50% of its electrical demand will be met by wind by 2020.

Their transition is expected to generate 30-40,000 net new jobs in a population of 5.5 million. The equivalent for Canada's 35 million population would be 190,000 to 250,000 net new jobs, which is comparable to the 217,000 total listed for Year 25 in Table 3.[42]

5. How Many Building Retrofit Jobs?

Next we come to Canada's buildings, and the need to replace oil and gas as the source of heat with improved building envelope efficiency, and with solar hot water, heat pumps, bioheat and district heat, including seasonally stored solar heat. The vast majority of these new jobs will be in the retrofit of buildings. Job estimates linked to the installation of district energy systems were not found, so comparability with a building retrofit has been assumed.

The European Union, as part of its commitment to carbon reduction, has set a goal that 3% of publicly owned buildings should be retrofitted every year. When the Energy Efficiency Industrial Forum analyzed 35 reports that examined the employment impact of investment in energy efficiency in buildings they found that on average each CAN $1 million invested generated 25.8 jobs (7.6 direct, 18.2 indirect). Induced jobs were not included.[43]

The American Council for an Energy Efficient Economy found that retrofit projects support 20 total jobs per $1 million invested (direct, indirect and induced).[44] GreenJobs BC reports that construction and retrofitting create between 10 and 18 total jobs for every million dollars invested (direct, indirect and induced).[45]

Statistics Canada's multipliers show that each $1 million invested in construction generates 17 jobs (7.6 direct, 4.8 indirect, 4.4 induced). Retrofitting is more labor-intensive than general construction, so we will assume 20 jobs per $1 million (9 direct, 6 indirect, 5 induced.) (Assumption #14)

There are 12,500,000 private dwellings in Canada,[46] 66% of which are heated by a furnace or a boiler burning gas or oil and 27% by electric baseboards.[47] There are also 480,000 commercial and institutional buildings, 50% of which are heated by gas or oil.[48] Electrical baseboard heaters are inherently inefficient and increasingly expensive, so our assumption is that most building owners with baseboards will be inclined to upgrade to heat pumps. (Assumption #15)

We will assume that 90% of Canada's buildings will need an efficiency retrofit and conversion to heat pumps, bioheat or district heat over the next 25 years, to be achieved in a steady progression to maintain a steady flow of work and training. (Assumption #16)

For the 11.25 million residential buildings, at an assumed average investment of $10,000 per building, the expenditure comes to $112 billion, or $4.5 billion a year over 25 years, generating 40,000 direct, 27,000 indirect jobs and 22,500 induced jobs a year (see Table 5). [49] If the investment is $15,000 or $20,000 for a deep retrofit there will be up to twice as many jobs.[50]

For the 432,000 commercial and institutional buildings, at an assumed average investment of $100,000 per building, the expenditure over 25 years comes to $43.2 billion, or $1.728 billion a year, generating 15,500 direct, 10,000 indirect and 8,500 induced jobs a year.[51] (Assumption #17) All of these jobs have the benefit that they can't be shipped offshore: they need local Canadian labour.

Taken together, the work of retrofitting 90% of Canada's buildings over 25 years will generate 124,000 jobs a year.

Table 4. Building Retrofit Jobs

Buildings Retrofit	90% of Buildings in Canada	Investment per building	$ Billion investment per year	Direct jobs per year	Indirect jobs per year	Induced jobs per year
Residential	11,250,000	$10,000	$4.5	40,500	27,000	22,500
Commercial Institutional	432,000	$100,000	$1.728	15,500	10,000	8,500
Total	-	-	-	56,000	37,000	31,000
Total	-	-	-	124,000		

5.1 How Can the Buildings Transition Be Achieved??

The task is undeniably large, since every building will need to be retrofitted to reduce heat-loss, and converted to air-source or ground-source heat or biofuel, or to use pipes under the streets to deliver district heat from a mixture of biomass, biogas, sewer heat, industrial waste heat, refrigeration heat recovery, ground-source heat, ocean-source heat and solar district heat.

To accelerate the change communities will need to partner with provincial and federal governments on an integrated portfolio of solutions, including:

- An increased carbon tax
- Tax-write-offs and financial grants towards the cost of a retrofit
- Low interest loans, backed by municipal finance arrangements and government loan guarantees
- Pay-As-You-Save (on-bill) or Property Assessed Clean Energy (PACE) long-term financing for retrofit loans
- Building energy labeling
- Changes to condo bylaws to require energy efficiency upgrades.[52]
- The requirement that a building must be brought up to code whenever a building permit beyond a certain value is taken out, and also before sale, as San Francisco and Oakland have been doing since 1981.

Communities will need dedicated non-profit organizations able to provide everything a building owner needs. Provincial governments or the federal government could require every new building to be zero-carbon, as Britain had planned to do for all new homes starting in 2016, until the Conservative government that was re-elected in May 2015 decided to scrap the program.[53] They could require every new large building to be 'district energy ready.' Major investments in district energy will be needed, raising the finance from green bonds or the market, helped by municipal finance authorities and government loan guarantees.[54]

The cost of a retrofit would ideally be financed from the energy savings, supported by incentives and facilitated by on-bill or PACE financing. The cost of district energy systems can be financed by contracts for future heat, similar to the way power utility investments are financed.

6. How Many Transportation Jobs?

Next, there are the changes in transportation that will occur as we make the transition to 100% renewable energy, with a modal shift to more walking, cycling, carsharing, transit and rail, and the shift to 100% electric vehicles, and full railway electrification. Some jobs will be gained and some lost, if more use of cycling and transit leads to less demand for cars and light trucks.

The energy that long-distance trucks, planes and ships will use in the future zero-carbon world is a complex matter that is not addressed here. There are experiments underway using biofuel; there's talk of using renewably-sourced hydrogen for long-distance fuel; and there may be a breakthrough in batteries enabling long-distance electric trucking; but these things are nowhere close to market readiness, and no analysis has been done of the employment impact of a shift to renewable energy for long-distance transportation.

If there continues to be no progress, an increasing price on carbon will begin to impact the ease with which we take long-distance transportation and trade for granted, and a global agreement to apply price on carbon to international shipping and aviation will have a similar impact. Further considerations of a future with sharply diminished long-distance travel and trade are beyond the scope of this report.

In its 2014 report *Unlocking New Opportunities: Jobs in Green and Healthy Transport* the World Health Organization surveyed a number of studies from countries around the world, many of which show the potential for increased employment. A German study found that increasing the modal share of public transport by 10% by 2030, for instance, would increase employment in the transport sector by 5.3%.[55]

Increased pedestrian trips are hard to analyze for their job creation potential. It might be assumed that more walking means fewer car trips, but there are too many unknowns to be able to make any reliable jobs estimates.

When Smart Growth America surveyed 37 complete streets projects in America they found a multiplicity of benefits, including job creation. In Orlando, Florida, when 1.6 miles of Edgewater Drive was converted into a pedestrian-friendly commercial district with cafés and shops, researchers found that:

- Collisions dropped by 40%
- Injuries fell by 71%
- Bicycle use rose by 30%
- Pedestrian use rose by 23%
- 77 new businesses opened
- 560 new jobs were created
- On-street parking increased by 41%
- The value of adjacent property rose by 80%

In the Millwork District in Dubuque, Iowa, when a length of the road was reconstructed with the addition of a multi-use trail and streetscaping, the changes brought $34 million in new private investment, with $150 million in the pipeline for new residential units, retail and commercial space, and an incubator for arts and nonprofit organizations.[56]

No job-creation has been assigned to these initiatives, however, because data is lacking for the work of doing the installations, and because the jobs generated by people shopping in the new store-front businesses may be at the expense of jobs in older retail businesses elsewhere.

6.1 How Many Cycling Jobs?

The European Cyclists' Federation reports that with an average 3% share of journeys, 655,000 people work in direct jobs in Europe's cycling economy. This includes 524,000 in cycle tourism (80%) and 80,000 in bicycle retail (12%). As the share doubles to 6%, an additional 400,000 direct jobs will be generated.[57] These are ongoing, multi-year jobs. If a 6% cycling rate generates 955,000 jobs, we can average that out to 159,000 direct jobs per 1% trip rate.

Canada's 2006 census indicated that in 2006, 1.3% of Canadian work-related trips were made by bicycle.[58] The European Union's population is 14 times larger than Canada's, so the numbers suggest that a Canadian cycling economy with a 1% bicycle trip-share might theoretically be generating 12,500 jobs. If 25% of Canadians' trips were made by bike, a rate already being achieved in 40 cities around the world, this would therefore generate 312,500 jobs. Holland may be flat, but the use of electric bikes eliminates the challenge of hills, enabling people even in hilly communities such as North Vancouver to enjoy cycling. [59]

Europe is also dotted with picturesque historic towns and cities, however, making cycle tourism attractive. Canada does not have the same close density of tourist attractions, and many communities are not on any tourist itinerary. Nor do most European cities experience Canadian winters, when cycling is far more challenging. This report therefore assumes a 75% reduction in jobs generated by the cycling sector (Assumption #18), with a 1% trip-share generating 3,000 direct jobs and a 25% trip-share generating 75,000 direct jobs. (Assumption #19)

The employment impact tells only half the story, however. In Britain, a study found that if cycle use increased from less than 2% of trips today to 10% by 2025 and 25% by 2050 it would yield annual benefits by 2050 worth £42 billion (CAN $78 billion) in today's money as the result of increased personal fitness, reduced traffic congestion and decreased casualties from reduced car usage.[60] Applied to Canada's smaller population, the annual economic benefit would be CAN $43 billion a year. Since the savings might reduce jobs in one sector of the economy (eg health care) while increasing them through induced jobs in another, however, no net jobs benefit has been assigned.

Statistics Canada does not list a multiplier for the cycling sector. 80% of the jobs are in cycle tourism, but nor does it list a multiplier for tourism. Fortunately, the University of Michigan does, at 1.66 for indirect and induced jobs combined (1 direct, 0.33 indirect, 0.33 induced).[61]

To achieve a 25% trip-share a large investment will be needed in cycling infrastructure, bringing many health and other benefits. If this is not done, however, a far larger investment will be needed in roads, highways and bridges, costing far more per passenger kilometre.[62]

Table 5. The Cycling Economy

Cycling	Direct Jobs	Indirect Jobs 0.33	Induced Jobs 0.33	Total
1% trip-share	3,000	1,000	1,000	5,000
25% trip-share	75,000	25,000	25,000	125,000

6.2 How Many Transit Jobs?

Fully electric buses already operate in many cities around the world, and over the 12-year life of a bus the savings in operational costs cover the increased cost of purchase, so there are no financial barriers to the full electrification of entire fleets. Hamburg has announced that after 2020 it will only purchase electric buses; Helsinki has announced that it will buy 400 electric buses by 2025; Amsterdam has announced that it will electrify its entire city bus fleet by 2025.[63] This will not generate new jobs, but it will contribute to the elimination of carbon pollution, air pollution and urban noise.

For Canada's urban transportation to become more sustainable, however, and to reduce traffic congestion, a major expansion in transit will be needed.

In British Columbia, the Metro Vancouver Mayors' Transportation and Transit Plan proposed to spend $20 billion in new capital spending and $37 billion in new operational spending over 32 years, averaging $1.78 billion a year to achieve a 2% annual increase in transit services and build a number of major new rapid transit projects in the Lower Mainland. The consulting group InterVISTAS was asked to produce a report on the economic impact and jobs. The proposal was defeated by public plebiscite, but the jobs numbers remain a valuable analysis.

The InterVISTAS report showed that the Metro Vancouver investment would generate 167,000 installation jobs (averaging 5,240 a year) when indirect and induced jobs are included, and 1,102,000 new operating jobs over 32 years,[64] growing from 1,917 jobs in Year 1 to 61,334 jobs in Year 32.[65] For each direct job there would be 0.42 indirect jobs and 0.48 induced jobs.

The Metro Vancouver investment of $57 billion comes to 22 jobs per $1 million, which is close to the British Columbia Treasury Board's 1996 finding that $1 million invested in transit generates 21.4 new jobs,[66] and the Portland-Milwaukie Light Rail project's finding that investing $1 million in transit generates 17 new jobs.[67] The assumption here, echoing the InterVISTAS report, is that $1 million invested in transit will generate 22 new jobs. (Assumption #20)

80% of Canadians live in urban areas where a similar investment is needed, and Metro Vancouver represents 9% of Canadians who live in urban areas, so scaling up the totals eleven-fold covers 100% of Canada's urban areas. An eleven-fold increase on $57 billion comes to a $627 billion multi-year investment. Most urban areas are not as dense or complex as Vancouver, however, and most will not need expensive light rail transit, so a 50% reduction is in order, resulting in a $313 billion multi-year investment. (Assumption #21)

A $313 billion Canada-wide capital investment in public transit over 25 years would generate 918,000 installation jobs, or 37,000 jobs a year (direct, indirect and induced). It would also generate 6 million operational and maintenance jobs, rising from 18,000 jobs in Year 1 to 466,000 jobs in Year 25 (245,000 direct, 102,000 indirect and 116,000 induced). See Table 7. The investment needed would be huge, and require finance from a combination of taxation and green bonds.

This is by far the largest component of the new renewable energy jobs, and while it is needed for the long-term sustainability of our cities, it is not inherently needed for the transition to 100% renewable energy if people are willing to tolerate much more traffic congestion.

Table 6. Jobs from Transit Investment		
	Metro Vancouver Plan (32 years)	Canada 100% Renewable Energy (25 years)
Investment	$57 billion	$313 billion
Installation jobs	167,000 5,200 jobs a year	918,000 37,000 jobs a year
Operating Jobs	1,102,000 total cumulative	6,061,000 total cumulative 18,640 in Year 1 466,000 in Year 25

6.3 How Many Electric Vehicle Jobs?

The assumption in this report is that by 2040, 100% of Canada's cars and light trucks will be electric, running on 100% renewable electricity. (Assumption #22)

Do electric vehicles create jobs? It is not obvious why they should, since we are assuming the replacement of manufactured gasoline vehicles with manufactured electric vehicles. There are studies that analyze the job creation benefits of EV manufacturing and installing EV charging infrastructure, but they do not consider the loss of conventional auto-manufacturing jobs in factories that fail to make a planned transition. [68]

The shift to electric vehicles may also support fewer vehicle maintenance jobs, since EVs have fewer moving parts and need a third less maintenance than gasoline vehicles. Data on the jobs generated by electric vehicle versus conventional vehicle manufacturing was not found.

Any estimate relating to auto-manufacturing will also be highly subjective, since there is no knowing whether the electric vehicles of the future will be made in Canada, the US, China or elsewhere. Canada's auto-industry employment peaked in Canada in 2000 at 153,000 workers. By 2009 it had fallen to 98,000, and has since recovered to 102,000 jobs.[69]

With this report's assumptions about a shift to more cycling and transit, the level of car-ownership may also fall, reducing the demand for new vehicles and the associated manufacturing jobs. The loss of auto-manufacturing jobs will be partially offset by the increase in jobs making bicycles and buses, but for the purposes of this report we are assuming a 25% loss of 25,000 auto-manufacturing jobs by 2040. (Assumption #23)

In 2015 electric vehicles cost considerably more than regular vehicles, but with the falling price of batteries the price difference is expected to disappear by 2020-2025, by when consumers will be able to choose between similarly priced conventional vehicles and electric vehicles with 300 km range that cost six times less to run. In June 2015, BMW announced that by 2025 it would be selling *only* electric vehicles.[70]

The switch to electric vehicles will be driven by consumer demand as the price of EVs fall. The use of vehicle emission standards could drive the uptake of EVs if there was an EU and North American vehicles emissions regulation requiring that all new vehicles achieve 0 gm CO_2/km from the tailpipe by 2030. With a 10-year average vehicle life, this would mean that most cars and light trucks would be electric by 2040.

The reason why electric vehicles are considered to be job-generators lies with the induced jobs that are generated because EVs are six times cheaper to run, leaving people with more cash to spend into the economy, generating induced jobs, and because instead of imported oil the electricity for electric vehicles will be generated by local utilities, which will spend the income in Canada's domestic economy, creating new induced jobs.

In America, where 33% of the oil consumed is imported, the Electrification Coalition reports that if 75% of future passenger miles are electric, "cumulatively, during the 2010-2030 period, households would experience an increase of $4.6 trillion in aggregate income due to cost savings on fuel if they switched to EVs—money that can be saved or spent on other goods and services," and that this would generate 1.9 million induced jobs.[71]

If 100% of America's future miles were electric this would induce 2.5 million jobs. This is over a 20-year period, so when the induced jobs benefit is extended to 25 years it grows to 3.125 million jobs, averaging 125,000 jobs a year.

Scaled down for Canada's nine-fold smaller population, this comes to 347,000 induced jobs, starting with 1,000 jobs in Year 1 and building to 25,000 jobs in Year 25.[72] (Assumption #24)

The electric vehicles financial benefit is known to work: New Yorkers drive much less than the average U.S. metro resident, keeping $19 billion each year in their local economy, while residents of Portland, Oregon, who drive four miles less per day than the national urban average, keep $2.6 billion dollars a year in their local economy due to the fuel savings.[73]

When the 25,000 jobs gain is set against the 25,000 jobs loss due to reduced vehicle purchasing, however, the gains and losses cancel each other out, leading to no net jobs benefit.

6.4 How Many Railway Electrification Jobs?

The end of coal and oil shipments will allow Canada's railways to carry much more general freight, so we won't assume any job creation from the increased use of rail.

300,000 men and women work in Canada as truck drivers, so some of these jobs may be lost as more goods are transported by rail.[74] (See Section 11.)

It is the electrification of rail to replace the use of diesel that is the job-creator. In Ontario, Metrolinx studied the electrification of the 1,200 kilometres GO Rail network, at a cost of $4 billion. Their analysis showed that full electrification would generate 9,700 to 14,800 jobs. At an average 12,250 jobs this is 10 jobs per kilometre—4 direct, 3 indirect and 3 induced.[75] (Assumption #25)

Canada has 50,000 km of railways, of which only 129 km are electrified, so full electrification would generate 500,000 jobs. Spread over a 25-year period, this comes 20,000 jobs a year, assumed to be 8,000 direct, 6,000 indirect and 6,000 induced.

Electrified railways are also a good location for the installation of solar PV. In the UK, which has 17,700 km of railway track, calculations by the consultancy group WSP Global indicate that a series of solar arrays along 50% of the trackside would create 2,440 MW of capacity, generating 1,950 GWh a year. In Canada, with three times more track and 40% better solar exposure, solar along the railway tracks could contribute 6,000 GWh (6 TWh) to the 100 TWh of solar energy that will be needed.[76]

Railway electrification would cost $6 billion a year (scaled up from the Ontario GO Rail example). The investment could be partially financed by the savings on energy costs as trains switch from diesel to electricity, prompted by the increasing price on carbon, but it is beyond the scope of this report to compare the savings to the cost.

7. How Many Farming Jobs?

Conventional farming requires the use of natural gas to make fertilizer, so farming without fossil fuels means organic farming. Organic farming also stores more carbon in the soil, which is an important contribution to tackling the climate crisis through the ecosequestration of atmospheric carbon. Data collected from field experiments conducted by the Rodale Institute over 30 years shows that there is no loss of yield from organic farming methods, and a slight increase in drought years.[77]

In Britain, where 68% of the land is farmed, the Soil Association reports that organic farming creates 32% more jobs per farm than conventional farming. On average, organic farms in Britain provide 2.77 jobs per farm compared to 2.09 jobs for a commercial non-organic farm. If all UK farmers adopted organic farming, the change would generate an additional 93,000 permanent farm jobs. [78]

Canada has 305,000 jobs in farming, so a full shift to organic methods that employ 32% more people would generate 100,000 new jobs, gradually accumulating at 4,000 jobs a year.[79] (Table 11, Column G) (Assumption #26)

Statistics Canada's multipliers show a 1.76 multiplier for indirect jobs associated with crop and animal production and a 0.28 multiplier for induced jobs. The increased labour needed for organic practices will not increase the volume of food being produced or the area of land being farmed, however, so no increase in indirect jobs is assumed. The 4,000 jobs a year will generate induced jobs as the new farm workers spend their wages, but the loss of expenditures on pesticides and fertilizers will remove induced jobs, so there may be no net gain in induced jobs.

It is also possible that our future food will cost more if the droughts in California and elsewhere continue, or that it will cost less due to increased organic farming efficiency and competition. It is also possible that as the temperature rises due to the climate crisis, and the growing season increases, Canada will produce and export more food, increasing the number of farmers. There are many factors here that depend on unknowns, however, so no additional increase in jobs has been assumed.

7.1 How Can the Farming Transition Be Achieved?

This is outside the scope of this report, but conventional farming imposes many hidden costs, including the loss of habitat and species, herbicide-resistant super-weeds, aquatic nitrogen pollution from fertilizers, soil erosion, the impact of pesticides on bees, the abuse of antibiotics, and negative health impacts caused by the use of pesticides and fertilizers and the loss of essential nutrients from the soil, including cancer and dementia, which have been linked to the use of pesticides and nitrogen fertilizers.

The application of a tax on fertilizers and pesticides, with all of the revenue being used to help farmers make the transition to organic methods, would speed the transition.

8.0 Other Fossil Fuel Substitution Jobs

There are other areas that will be impacted by a transition to 100% renewable energy. The US plastics industry uses 2.7% of US petroleum production; globally, 3 to 4% of oil goes into plastics manufacturing. In 2010 the US healthcare industry used 1.5 million tonnes of plastics, as well as many pharmaceuticals that use oil in their manufacture.[80]

10% of the crude oil supply is used by the chemical industry, including "80% of raw materials for cosmetics, including the majority of components for all waxes, perfumes, dyes, shaving creams, shampoos and conditioners."[81] A transition to bioplastics or other plastics substitutes will probably happen in the long run, but there is no reason to assume any change in jobs.

Road repairs also require the use of asphalt, which is made from oil. Asphalt recycling is becoming more common, but this report does not assume any change in jobs.

9.0 Induced Jobs

Induced jobs are generated when people spend their earnings, enabling others to work in stores, restaurants and holiday resorts.

An industry such as the oil sands that pays high wages has a much higher induced jobs multiplier than one that pays lower wages, such as agriculture.

For mining, quarrying, oil and gas, Statistics Canada reports that for each direct job there are 1.16 indirect and 0.95 induced jobs. [82]

Railway electrification generates 0.75 induced jobs for each direct job, using statistics from the GO Rail report.

In the electricity sector, IRENA reports that for every direct and indirect job there are 0.71 induced jobs.[83]

For building retrofits, for each direct job there are 0.55 induced jobs. Since investments in building retrofits result in reduced energy bills, some people have suggested that there will be an additional induced jobs benefit, since people saving money on their energy bills will be able spend the savings into the economy.

Table 7. Induced Jobs Multipliers	
Industry	Multiplier
Oil and gas	0.95
Railway electrification	0.75
Electricity	0.71
Retrofits	0.55
Transit	0.48
Cycling	0.33
Farming	0.28

The US Energy Information Agency reported in its 2011 Annual Energy Review that reducing energy use in buildings by 20% has the potential to save consumers $80 billion a year.[84] Scaled down nine-fold for Canada's smaller population, this would indicate an annual saving for consumers of $9 billion. At 5 jobs per $1 million for induced jobs, this could in theory generate 45,000 jobs a year.

There is no reason to believe that these will be new jobs, however, since the money saved by a future building owner is currently being paid to Canada's utilities, which presumably already spend it, generating induced jobs. It's an undoubted consumer benefit, but it may not generate new induced jobs.

Investments in transit produce 0.48 induced jobs for each direct job, based on data from the InterVISTAS report.

Cycling investments produce 0.33 induced jobs for each direct job, based on data from the University of Michigan.

Farming produces 0.28 induced jobs per direct job, based on Statistics Canada data.

10. Year 26: When the Transition is Complete

When the transition is complete, how will the job creation estimates change? Jobs such as those in farming and the cycling economy will continue, while those relating to capital installation will end. Capital stock needs renewal, however, so once the installations are complete the cycle of renewal begins.

Solar PV
By Year 26 the process of solar renewal will have begun, with the older, less efficient and declining value solar systems being replaced by new more efficient ones that generate more power.

The rate of solar yield decline has been analyzed at 0.5% a year, so after 25 years a PV system will generate 12.5% less power than when it was new.[85] This might mean that the solar yield numbers in Section 4.2 above are off, but the performance efficiency of new solar PV is improving by 0.3% a year, reducing the overall loss to 0.2% a year, sufficiently small to ignore for the purposes of this paper.[86]

How soon after Year 25 will consumers begin replacing their systems? The answer is probably fairly immediately, since the older systems will have earned their keep and the newer systems will be half the price and 8% more efficient. By Year 50 we can be sure that every system will have been replaced and upgraded, so for the purposes of this paper we will assume that older systems are replaced at the same rate that new systems were installed, replacing 3,280 MW of solar a year. (Assumption #27)

In 25 years, however, it is reasonable to assume that labour productivity will have doubled, so instead of 18 jobs per MW the work of replacement will generate 9 jobs per MW, supporting 30,000 permanent direct and indirect jobs. (Assumption #28). The solar operations and maintenance jobs will continue at 24,600 jobs a year.

Wind Energy
The expected life of a wind turbine is 25 years, so after 25 years the process of renewal will also begin, refitting and upgrading 1,960 MW of wind farms a year. Labour productivity will have likewise improved, but probably by 25%, not the 50% assumed above, given the far more complex nature of a wind turbine, falling from 8.6 to 6.45 jobs per MW. (Assumption #29) At 1960 MW a year, this will generate 12,500 jobs a year. The operations and maintenance jobs will continue at 9,000 jobs a year.[87]

Geothermal Energy
On average, the yield of a geothermal well begins to decline by year 25-30, and it becomes cost-effective for a utility or owner to drill a new well nearby. So after 25 years the process of geothermal replacement will begin, just as it will for wind and solar. If 840 MW of geothermal is replaced every year, in keeping with the rate of installation, and if labour productivity is 25% higher than today, instead of 10.7 jobs per MW it will create 8 jobs per MW, generating 6,720 jobs a year (6,500 when rounded). (Assumption #30) For operations and maintenance, the 8,400 jobs a year will continue.

Table 8. Renewable Electricity Jobs after Year 25

A	B	C	D	E	F	G	H	I	J
Year	Solar Install	Solar O&M	Wind Install	Wind O&M	Geo Install	Geo O&M	Direct & Indirect Jobs (B-G)	Induced Jobs (H x 0.71)	Total Electricity Jobs (H + I)
26	30,000	24,500	12,500	9,000	6,500	8,400	91,000	65,000	156,000

Building Retrofits
By Year 26, in this statistical model, the work of retrofitting Canada's buildings will be complete, and all new buildings will be passive, zero carbon houses. The 93,000 retrofit jobs will therefore cease.

Cycling
The jobs generated are mostly in tourism, with the rest being in cycle manufacturing and maintenance. These are ongoing, permanent jobs, so the 125,000 direct, indirect and induced jobs will continue.

Transit
The average bus has a life of 12 years, after which it will need replacing. The work of building new installations for bus rapid transit and light rail transit will be complete, however, so those jobs will end. As an estimate, therefore, we will assume that half the installation jobs continue for stock replacement (Assumption #31), supporting 18,500 permanent jobs. The 466,000 operational and maintenance jobs will continue, totaling 484,500 jobs.

Railway Electrification
By Year 25 track maintenance will require more work than before, due to the added overhead electric lines. Instead of the 14,000 direct and indirect installation jobs, therefore, we will assume a 75% reduction to 3,500 permanent jobs. (Assumption #32)

Organic Farming
The 100,000 new jobs in organic farming will continue after Year 25. Taken together, there will be 867,000 jobs a year once the transition to 100% renewable energy is complete, from a combination of ongoing operations and maintenance, capital stock renewal, and permanent ongoing jobs.

Table 9. Ongoing Jobs after Year 25	
Electricity	156,000
Building Retrofits	0
Cycling economy	125,000
Transit capital stock renewal	18,500
Transit operations and maintenance	466,000
Railway Electrification	3,500
Organic farming	98,000
Total	**867,000**

11. Fossil Fuel and Trucking Jobs Lost

The transition to 100% renewable energy will see the phasing out of 800,00 jobs in coal, oil and gas at the rate of 32,000 jobs a year (direct, indirect and induced). The number of induced jobs will decrease as the stimulus from fossil fuel workers spending their wages decreases.

In reality, until there are renewable energy solutions for long-distance trucking, marine shipping and aviation, the use of oil will continue, being constrained by an increasing price on carbon and a possible carbon cap, and by increasing expectations for greater transportation demand management for both freight and passengers.

As less coal and oil is shipped by rail, general freight may fill the gap. This report does not have data to estimate the change, but we will assume a 10% reduction in trucking jobs from the current 225,000 direct jobs to maybe 200,000. (Assumption #33)

Trucking jobs have a 2.03 multiplier (1 direct, 0.6 indirect, 0.43 induced), causing 51,000 jobs to be lost over 25 years at an average 2,000 jobs a year. Combined with the 32,000 fossil fuel jobs lost per year, this comes to 34,000 jobs lost a year.

In Table 12, Column A, the 800,000 jobs in fossil fuels have been joined by 50,000 jobs lost as trucking moves to rail, taking up the space vacated by fossil fuels.

12. Results and Final Considerations

The results of all these estimates are assembled in Table 10. Tables 10 and 11 show that in Year 1 there will be almost ten times as many new jobs created as there will be jobs lost due to the intensive nature of the work installing solar, wind and geothermal plants, retrofitting buildings and electrifying the railways, etc. By Year 25 there will be as many new jobs created as there will have been jobs lost.

Over the 25 years in total, as Table 12 shows, there will be almost twice as many jobs created as lost - 18 million compared to 11 million, where a job is defined as full-time work for one year.

By Year 26, in this statistically utopian model, stock renewal takes over from installation. In total, there will be 867,000 ongoing jobs, effectively equivalent to the 850,000 jobs in fossil fuels and trucking that will have been lost. There will also be new jobs in power storage and other new renewable energy derivatives, although it has not been possible to assume any data.

Table 10. Summary of Jobs Created: Direct, Indirect and Induced

Year		A Renewable Electricity Jobs	B Building Retrofit Jobs	C Cycling Economy Jobs	D Transit capital spending Jobs	E Transit operational Jobs	F Railway electrification Jobs	G Farming Jobs	H Total
0		0	0	0	0	0	0	0	0
1		149,000	124,000	5,000	37,000	18,500	20,000	4,000	357,500
2		150,000	124,000	10,000	37,000	37,000	20,000	8,000	386,000
3		154,000	124,000	15,000	37,000	55,500	20,000	12,000	417,500
4		157,000	124,000	20,000	37,000	74,000	20,000	16,000	448,000
5		159,000	124,000	25,000	37,000	92,500	20,000	20,000	477,500
6		162,000	124,000	30,000	37,000	111,000	20,000	24,000	508,000
7		166,000	124,000	35,000	37,000	129,500	20,000	28,000	539,500
8		169,000	124,000	40,000	37,000	148,000	20,000	32,000	570,000
9		171,000	124,000	45,000	37,000	166,500	20,000	36,000	599,500
10		174,000	124,000	50,000	37,000	185,000	20,000	40,000	630,000
11		178,000	124,000	55,000	37,000	203,500	20,000	44,000	661,500
12		180,000	124,000	60,000	37,000	222,000	20,000	48,000	691,000
13		183,000	124,000	65,000	37,000	240,500	20,000	52,000	721,500
14		186,000	124,000	70,000	37,000	259,000	20,000	56,000	752,000
15		188,000	124,000	75,000	37,000	277,500	20,000	60,000	781,500
16		192,000	124,000	80,000	37,000	296,000	20,000	64,000	813,000
17		195,000	124,000	85,000	37,000	314,500	20,000	68,000	843,500
18		198,000	124,000	90,000	37,000	333,000	20,000	72,000	874,000
19		200,000	124,000	95,000	37,000	351,500	20,000	76,000	903,500
20		203,000	124,000	100,000	37,000	370,000	20,000	80,000	934,000
21		207,000	124,000	105,000	37,000	388,500	20,000	84,000	965,500
22		209,000	124,000	110,000	37,000	407,000	20,000	88,000	995,500
23		212,000	124,000	115,000	37,000	425,500	20,000	92,000	1,025,500
24		215,000	124,000	120,000	37,000	444,000	20,000	96,000	1,056,000
25		217,000	124,000	125,000	37,000	462,500	20,000	100,000	1,085,500
26		156,000	0	125,000	18,500	466,000	3,500	100,000	869,000

Table 11. Net Gain in Jobs Resulting from the Transition

Year	A Cumulative Total of Fossil Fuel & Trucking Jobs Lost	B Annual Loss of Fossil Fuel and Trucking Jobs	C Cumulative Total of Renewable Energy Jobs Created	D Difference Factor (Col C divided by Col A)	E Net Cumulative Job Gain (Col C minus Col B)
0	0	0	0	0	0
1	34,000	34,000	357,500	10.5	323,500
2	68,000	34,000	386,000	5.7	352,000
3	102,000	34,000	417,500	4.1	383,500
4	136,000	34,000	448,000	3.3	414,000
5	170,000	34,000	477,500	2.8	443,500
6	204,000	34,000	508,000	2.5	474,000
7	238,000	34,000	539,500	2.3	505,500
8	272,000	34,000	570,000	2.1	536,000
9	306,000	34,000	599,500	2.0	561,500
10	340,000	34,000	630,000	1.9	596,000
11	374,000	34,000	661,500	1.8	627,500
12	408,000	34,000	691,000	1.7	657,000
13	442,000	34,000	721,500	1.7	687,500
14	476,000	34,000	752,000	1.6	718,000
15	510,000	34,000	781,500	1.6	747,500

16	544,000	34,000	813,000	1.5	779,000
17	578,000	34,000	843,500	1.5	809,500
18	612,000	34,000	874,000	1.4	840,000
19	646,000	34,000	903,500	1.4	869,500
20	680,000	34,000	934,000	1.4	900,000
21	714,000	34,000	965,500	1.4	931,500
22	748,000	34,000	995,500	1.4	961,500
23	782,000	34,000	1,025,500	1.3	991,500
24	816,000	34,000	1,056,000	1.3	1,022,000
25	850,000	34,000	1,085,500	1.3	1,051,500
Total	11,050,000		18,037,000		
26	850,000	0	867,000 See Table 11	1.0	17,000

12.1 A Just Transition

As Canada embarks on the transition to a 100% renewable energy future the jobs related to the extraction and distribution of fossil fuels will disappear. New jobs will be created to take their place, but while some will require similar skills others will be in different sectors of the economy and different areas of the country, and require different skills. Oil-related jobs will decrease in Alberta, Saskatchewan and Newfoundland while renewable electricity jobs will increase in the same provinces as they move to replace coal-fired power with wind, solar and geothermal power.

Likewise, British Columbia may not generate many new jobs in renewable electricity, since its electricity is already 95% zero carbon, but if a BC-Alberta grid connection was built BC could see a boom in wind production, with new jobs in the northeast of the province. Alberta and Saskatchewan, by contrast, will see many new renewable electricity jobs as coal-fired power is phased out.

In some instances entire communities will be affected, such as Fort McMurray in Alberta, in the heart of the oil sands, and Tumbler Ridge in northeastern BC, which was intentionally built to enable the exploitation of local coal deposits.

The advantage of a planned 25-year transition, in contrast to an unplanned drift, is that plans can be made to ensure that the affected communities are provided with participatory planning services, that individuals are provided with the appropriate career change counseling, and that training programs are established in local colleges. New provincial organizations will be needed to coordinate activities, and to ensure that people with the appropriate skills are available to take up the new jobs, and that those whose jobs are phased out receive the support and training they need to make a smooth transition to the new jobs.

12.2 The Process of Job Creation

There are several schools of thought on what causes jobs to be created:

(a) 'Trickle down' theory holds that if people have more money to spend through lower taxation, more jobs will be created;
(b) The use of tax breaks and incentives and public bank lending can be used to stimulate specific sectors of the economy;
(c) Local or community economic development emphasizes the role of entrepreneurial education and support to encourage business and cooperative start-ups.

All three approaches contribute to job creation, but when specific communities are impacted by the closure of a traditional industry, bringing the possible departure of local entrepreneurial leadership, the second and third approaches become more important. Community-based economic development has been shown to generate success, especially in relatively isolated communities, by bringing people together to form cooperatives and community economic development corporations.[88]

12.3 Skills and Training for the Transition

- The transition to 100% renewable electricity will require engineering, electrical, planning, construction and financial skills.[89]
- The building retrofit work will require building skills, and training in energy-saving techniques not currently taught in construction trades courses.
- The cycling economy jobs will be mostly in tourism, requiring entrepreneurial training to create and operate new businesses.
- The transit installation jobs will require skills in transportation planning, road repairs and civil engineering. The operating jobs will require transit management and operating skills.
- The work of railway electrification will require planning, civil and electrical engineering, and other electrical skills.
- The organic farming jobs will require training in organic farming in addition to courses provided at agricultural colleges today.
- The new induced jobs will be spread throughout the economy. It is not possible to plan for specific jobs, since changing consumer preferences will determine how people spend their money.

If the transition proceeded in a smooth orderly manner, in Year 1 there would be almost ten times as many new jobs created as there would be fossil fuel and trucking jobs lost. By Year 25 there will be as many new jobs created as lost, and by Year 26, when the transition is complete, there would be 867,000 new permanent jobs. See Table 12.

These jobs will be filled in the normal competitive manner, in which people find and change jobs in keeping with their skills and aspirations. Some will be filled by people who are currently unemployed, while others will by filled by people moving from one job to another.
The net effect of more skilled jobs opening up will be to create more job openings, which will benefit those without work.

Statistics Canada reports that in March 2013 1.3 million people were unemployed in Canada, representing 6.8% of the working population aged 24-54.[90] When those who have been discouraged or who are struggling on part-time work are included, TD Bank estimates that the unemployment and underemployment rate could be as high as 15%, totaling three million people.[91] Canada also has 1% annual population growth, adding 350,000 people a year, half of whom enter the labour force.

The important point here concerns the skills of those who are unemployed, and the training needed to equip them for the new jobs as they arise.

A comparison between the job training needs for the transition and the scope and scale of existing college and university training courses, and delving any further into the dynamics of Canada's future labour market, is beyond the scope of this report.

12.4 Fossil Fuel Revenues and Subsidies

How would Canada's government revenues and expenditures be affected by the transition to a 100% renewable energy? The oil sands (as a subset of fossil fuels in general) generate 2% of Canada's GDP.[92] The federal government states that it receives an average $23.3 billion a year in revenues from the oil and gas industry, representing 8% of the government's revenues.[93]

In December 2014, CIBC reported that the government would lose $5 billion due to the low price of oil. Compared to the government's $290 billion budget, this is a 1.7% impact.[94]

Where might the government obtain the equivalent revenues as Canada's fossil fuel industries are phased out? Canada is currently releasing 500 million tonnes of CO_2 emissions a year. If these emissions were taxed at $50 a tonne this would generate an initial $25 billion a year, rising for ten years as the carbon tax increased, then falling to zero as fossil fuels were phased out, requiring revenue adjustments.

In 2014, The Pembina Institute produced a report on Fossil Fuel Subsidies. [95] In this, they quoted the IISD's Global Subsidies Initiative, which showed that Canada's federal and provincial governments gave $2.8 billion in direct fossil fuel subsidies in 2008/9. Progress in phasing out the subsidies had reduced them to $711 million by 2010, and the government has a long-term plan to phase out the remaining subsidies too.[96]

In its 2015 global study of the full direct and indirect fossil fuel subsidies, the IMF estimated that the world's nations give away $5.3 trillion a year in direct and indirect post-tax subsidies to fossil fuels, at the astonishing rate of $10 million a minute. 6% of these come from pre-tax subsidies, 24% from the costs of global warming, 52% from air pollution costs, 12% from vehicle externalities, and 6% in foregone revenues.[97]

In a 2013 report, the IMF found that Canada gave an effective $27 billion a year in subsidies to fossil fuels, $19.4 billion of which stemmed from uncollected taxes on the externalized costs of burning gasoline and diesel, including carbon emissions, air pollution, traffic accidents and road congestion. These last two categories should not really apply, since electric cars also cause road accidents and congestion.[98] The figure is derived from the IMF data assuming inherent subsidies at the level of 1.52% of Canada's GDP in 2011.

For natural gas, the IMF estimated untaxed costs in Canada of $7.3 billion per year, plus $440 million in direct producer support and $360 million in other untaxed externalities. Canada's coal industry receives $4.5 billion in annual subsides, mostly from unpriced carbon and sulfur dioxide emissions.

12.5 Climate Costs

Our use of fossil fuels imposes heavy social, health and environmental costs, due chiefly to the damage that the climate crisis is already causing, and health care costs caused by air pollution and smog, which are a contributing cause of heart disease, lung disease and cancer.

In 2008, the Canadian Medical Association found that Canada's air pollution was responsible for 2,700 acute premature deaths, 92,000 emergency-room visits and 620,000 visits to a doctor's office a year, and that the full economic cost of air pollution-related illness and death in Canada, including lost productivity, reduced quality of life and loss of life came to $8 billion a year, including $438 million in direct healthcare costs.[99] With the transition to 100% renewable energy, all of these costs will disappear.

In BC, the mountain pine beetle outbreak, which has been directly linked to rising temperatures caused by climate change, has cost BC an estimated $65 billion in lost timber and $890 million in direct government expenditures to fight the outbreak. By 2017, it is estimated that 788 million cubic metres of pine forest will have been killed by the beetles, creating a huge fuel source for future forest fires. [100]

The increase in climate-change induced forest fires is a source of both concern and rising cost. In 2014 BC's Wildfire Management Branch reported that by 2080, in BC's southern interior the average fire size is expected to double, summer fire severity to increase by 95%, the fire season length and frequency to increase by 30%, and the annual area burned in the boreal forest to increase by 50% to 300% by 2115.[101]

In Calgary, the floods of 2013 cost the province an estimated $5-6 billion, including a record $1.7 billion in insurable losses. No individual flood can be directly attributed to climate change, but the increase in extreme downpours and floods is directly in line with what climate models predict.

There is only one rational conclusion that can be made when the future costs of the climate crisis are considered, knowing that they will continue to grow, year by year. It is that the transition to 100% renewable energy is not just a policy option. It is an urgent necessity for every economy in the world.

12.6 Macroeconomic Considerations

This report is a bottom-up, micro-economic consideration of the jobs impact of the transition to 100% renewable energy. As such, it does not consider questions of capital productivity, labour productivity, the end of fossil fuels export earnings, the increase in domestic income resulting from the Canadian nature of renewable energy, the impact on the Canadian dollar, the role of government borrowing to finance renewable energy development, the opportunity costs of such investments, or the impact on long-term GDP and economic growth.

The weakness of many macro-economic analyses, however, is their tendency to ignore natural capital, which includes the inherent and essential value to the economy of nature's services including the soil, the forests, the oceans, the atmosphere, clean water, pollination, our immune systems, and a stable climate. When such considerations are ignored it becomes easy to treat natural capital as an externality, and to argue that the high labour productivity of fossil fuels compared to renewables makes them a more productive investment for Canada's economy.

This discussion goes to the heart of conventional economics, where labour and capital are seen as the main components of economic growth, and the depletion of natural capital is not considered because it can always be substituted with human-made capital.

This view is increasingly difficult to sustain, since it requires either denial that the climate crisis is a real and present danger, or the assumption that technology can control future carbon emissions from fossil fuels, mechanically extracting the surplus carbon from the atmosphere.

In an eco-macroeconomic analysis, the weakening of natural capital through the rising level of CO_2 in the atmosphere would be balanced by taxation on the destruction of natural capital.

In an eco-democratic analysis, the urgency of the need to prevent extreme climate danger would call for governmental initiative to override the market and initiate the planned transition to 100% renewable energy as rapidly as possible.

13. Conclusion

This analysis, while brief, suggests that over the next 25 years, if Canada chose to make an orderly transition to 100% renewable energy, there would 18 million total new jobs created and 11 million total fossil fuel jobs lost, where one job equals one job-year.

By Year 26, when the transition was complete, there would be 876,000 new permanent jobs, compared to 850,000 jobs that would have ended, without counting additional new jobs in renewable energy storage and other derivative fields.

The complete transition to 100% renewable energy will require either rapid technological progress in the use of renewable hydrogen, biofuel or electricity to power trucking, shipping and aviation, or a major reduction in our expectations with regard to global trade and travel.

If the rapid technological breakthroughs occur, the jobs implications may be few, since the same number of trucks, ships and planes may operate, using renewable energy instead of diesel, bunker fuel and kerosene.

If the breakthroughs do not occur, and as the climate crisis grows in intensity, there will be increasing political pressure to reduce the world's greenhouse emissions, causing the relative cheapness of long-distance travel and transportation to be impacted by the elimination of fossil fuel subsidies and a steadily increasing price on carbon. This may increase local manufacturing and tourism, so the jobs lost in long-distance transportation may—or may not—be balanced by jobs gained in these sectors. The unknowns are such that statistical analysis is not yet possible.

At the end of the transition, Canada will still have a flourishing economy supporting just as many jobs as it had before. Most air pollution will have vanished, health care costs will have fallen, and the prospects for a long-term sustainable future will be bright.

If such a transition is *not* achieved, however, not just in Canada but in every major economy, the increasing cost of extreme weather events, with increasing damage and loss of life, and the increasing cost of adapting to the climate crisis, including the rising sea level, will have consequences that will grow more severe, costly and deadly with every passing year.

The primary purpose of this report has been to demonstrate that the shift to a 100% renewable energy economy will not be the job-killer some people imagine it to be. On the contrary, the outlook for job-creation resulting from the shift appears to be very bright.

We have to do what we have to do. Miracles happen. The life force of this planet is very strong. Dandelions poke through sidewalks. We don't know enough to give up. We only know enough to know that we have to try to change the course of human events.
- Elizabeth May, MP, Leader of Canada's Green Party

Appendix 1. Fossil Fuel Jobs

Statistics Canada reports that 307,000 people (2% of Canadians) have jobs in mining, quarrying, oil and gas.[102] Metal mining employs 27,000 people, and non-metal mining (rock, sand and gravel) employs 23,000 people, so that leaves 257,000 people in coal, oil and gas. Canada's coal industry employs 7,000 people, and oil and gas employ 250,000 people.[103]

The Petroleum Human Resources Council estimated petroleum industry employment in 2011 at 186,600 jobs, including oil and gas services (87,000), conventional exploration and production (73,000), oil sands (20,000) and pipelines (6,500).[104] [105]

The Canadian Energy Research Institute reports that there are 514,000 jobs in oil sands-related total employment. This includes 1.0 indirect job and 1.5 induced jobs for each direct job, so their estimate of direct jobs in the oil sands is 146,000.[106]

In 2014, Clean Energy Canada reported that there are 23,000 direct jobs in the oil sands.[107]

Estimates of Direct Jobs in Fossil Fuels

Source	Sector	Direct Jobs
Statistics Canada and Natural Resources Canada	Mining, quarrying, oil and gas less metal and non-metal mining	257,000
Petroleum Human Resources Council	Petroleum industry	186,600
Canadian Energy Research Institute	Oil sands-related employment	146,000
Clean Energy Canada	Oil sands	23,000

Appendix 2: Assumptions

1. A 25-Year Transition to 100% renewable energy, 2015-2040.
2. Electricity demand will grow by 1.6% a year.
3. As Canada makes the transition to 100% renewable energy, electrical consumption by fossil fuel industry will end, resulting in a 5% reduction in demand.
4. There will be an overall 25% reduction in demand due to energy efficiency measures and investments.
5. The nation-wide shift to electric vehicles, railways and heat pumps will offset a 25% increase in energy efficiency.
6. Nuclear plants will continue their useful life, but not be renewed.
7. The renewable energy split for Canada's future energy.
8. Solar PV installation generates 18 direct and indirect jobs per MW during installation and 0.3 jobs per MW per year during operation and maintenance.
9. Solar PV 14% capacity factor
10. Wind energy 35% capacity factor
11. Onshore wind energy generates 8.6 direct and indirect jobs per MW during installation and 0.2 jobs per MW during operations and maintenance.
12. Geothermal energy 92% capacity factor
13. Geothermal energy generates 10.7 direct and indirect jobs per MW and 0.4 jobs per MW in operations and maintenance
14. Retrofitting buildings generates 20 jobs per $1 million
15. Most building owners with electric baseboard heaters will upgrade to heat pumps
16. 90% of Canada's residential buildings, assumed average investment of $10,000.
17. 90% of Canada's Commercial buildings, assumed average investment of $100,000.
18. For the cycling economy, a 75% reduction in the jobs generated compared to Europe
19. A 25% cycling trip-share in Canada's cities and towns.
20. $1 million invested in transit generates 22 new jobs (MetroVancouver Inter VISTAS numbers)
21. A 50% reduction in transit investment for Canada's cities and towns, compared to the proposed MetroVancouver investment.
22. 100% of Canada's cars and light trucks will be electric, running on 100% renewable electricity
23. Auto manufacturing: a 25% loss of 25,000 jobs by 2040 due to increased cycling and transit ridership
24. Electric vehicles: a 25,000 induced jobs gain due to domestic economy spending of renewable energy
25. Railway electrification generates 10 jobs per kilometre—4 direct, 3 indirect and 3 induced.
26. Organic farming creates 32% more jobs per farm than conventional farming.
27. After Year 25, older solar PV systems are replaced at the same rate that they were installed.
28. By Year 25 solar labour productivity will have doubled, generating 9 jobs per MW instead of 18.
29. By Year 25 wind energy labour productivity will have increased by 25%, generating 6.45 jobs per MW instead of 8.6.
30. By Year 25 geothermal labour productivity will have increased by 25%, generating 8 jobs per MW instead of 10.7.
31. After Year 25 half the transit installation jobs will continue due to transit and LRT stock replacement.
32. After Year 25 ongoing electrified railway track maintenance will support 25% of the jobs required for electrification.
33. A 10% reduction in trucking jobs as freight shifts to rail.

Appendix 3: Application to Other Countries

1. Use government statistics to research the total number of jobs in fossil fuel industries in your country, including direct, indirect and induced.

Electricity

2. Research how much electricity your country uses per year, and the share that comes from existing renewables.
3. Research an estimate of future electricity demand by 2040, and the assumed annual growth rate.
4. Accept or reject the assumption that 25% of the electricity demand can be reduced by energy efficiency investments, balanced by a 25% increase in demand from electric vehicles, heat pumps and railways.
5. Calculate how much new renewable energy needs to be generated to meet anticipated demand in 2040.
6. Estimate the solar portion in TWh, and research the local capacity factor for solar PV, ranging from 12% in rainy grey countries to 24% in hot sunny countries.
7. Use the capacity factor to calculate how many MW of solar PV will be needed.
8. Choose an appropriate job generation number for direct and indirect solar installation jobs, or use the one referenced in this paper to calculate the total installation jobs. Divide by 25 for a yearly estimate.
9. Do the same for the solar operations and maintenance jobs. To convert the total to the annual jobs created, divide by 325. (Eg 10,000 total jobs starts with 31 jobs in Year 1 and accumulates to 775 jobs (31 x 25) in Year 25. 325 comes from the addition of 1 job-unit in Year 1, 2 in Year 2, etc. to 25 in Year 25.
10. Follow the same procedure for wind energy.
11. Follow the same procedure for geothermal energy.
12. Start a 25-year Table. Place the aggregated renewable electricity numbers in Col 1. (see Table 3), and add them horizontally to obtain the total direct and indirect jobs per year. In MS Word, under Table-Formula use =SUM(LEFT).
13. Use a multiplier of 0.71 for induced jobs, and apply it to the totals to derive the annual induced jobs.
14. Add the direct, indirect and induced jobs for a final total. In MS Word, you'll need to retype each number to remove the addition function.

Buildings

15. Use government statistics to research the total number of residential and institutional/commercial buildings in your country.
16. Apply a retrofit investment factor of $10,000 per building for homes and $100,000 for commercial and institutional properties, and calculate the total jobs generated assuming 20 jobs per year per $1 million (direct, indirect and induced).

Cycling

17. Take Europe's cycling economy estimate (159,000 jobs per 1% cycling trip-rate) and scale it up or down to your country's population. Europe's population is 500 million.
18. Make an assumed cycling trip-rate for 2040, and multiply up.
19. Compare your country to Europe, and consider whether the total needs be decreased for cultural or other reasons to reach a total.
20. Apply the 0.33 + 0.33 multipliers for indirect and induced jobs.

Transit

21. Use the $313 billion Canada-wide estimate for planned investment in future transit over 25 years (derived from the InterVISTAS MetroVancouver report), and scale it up or down for your country. Canada has a population of 35 million.
22. Assume 22 jobs per $1 million invested, 14% in installation and 86% in operations and maintenance.
23. Divide the installation jobs by 25, and assume the same number each year.
24. Divide the O&M jobs by 325, and accumulate them steadily from Year 1..

Electric Vehicles

25. Assume no jobs gain, on the basis that the induced jobs benefit is neutralized by the vehicle purchase decrease that results from increased cycling and transit, and by decreased electric vehicles servicing.

Railway Electrification

26. Research the total length of your country's railway system.
27. Research how much has been electrified, and how many kilometres remain to be electrified.
28. Assume job generation of 10 jobs per kilometre (GoRail, Toronto): 4 direct, 3 indirect and 3 induced.
29. Divide the total over 25 years, assuming the same number of jobs each year.

Farming

30. Research the total number of farm jobs in your country.
31. Increase the number by 32% for the shift to organic methods, and divide the total of new farming jobs by 25 to obtain job creation numbers in a steady year-by-year increase. Assume no additional indirect or induced jobs.

Aggregation

32. Assemble all your numbers in a single table (see Table 9).
33. For Year 26 onwards, assume full solar, wind and geothermal replacement, but with solar labour productivity being 50% better and wind and geothermal labour productivity being 25% better. Assume no further building retrofit jobs, ongoing cycling economy jobs, ongoing transit installation jobs at 50% the rate of installation and railway electrification jobs at 25% the rate of installation.

Trucking Jobs Lost

34. Research the number of trucking jobs in your country.
35. If your country's railway system carries coal and oil, assume a 10% reduction in trucking jobs as freight takes up the rail capacity vacated by coal and oil.
36. Use a 2.0 multiplier to estimate indirect and induced jobs. (1 direct job becomes 2 total jobs)
37. Add this number to the fossil fuel total jobs established in #1.

Change in Jobs Resulting from the Transition

38. Create a Table to capture all the results (Table 12).
39. List the annual loss of fossil fuel and trucking jobs in Column A.
40. Add the accumulating new jobs in Col C
41. Subtract Col A from Col C for each year to obtain the annual net jobs gained. (Col D)

Endnotes

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To convert total jobs over 25 years to annual increments, assume that the total jobs in Year 1 are one job unit, so 1 + 2 + 3…+25 equals 325 total job units after 25 years. Divide the total jobs over 25 years by 325 to arrive at the unit increase for Year 1, which then grows incrementally year-by-year.

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Food for Thought

The vast majority of reserves are unburnable
- Mark Carney governor of the Bank of England

Do politicians understand just how difficult it could be,
just how devastating rises of 4C, 5C or 6C could be? I think, not yet.
- Nicholas Stern, UK economist

Each and every one of us should stop playing small and license ourselves to become one of the giants of the new century. We will need champions by the truckload.
- Van Jones, author of *The Green Collar Economy*

How is it that we have created an economic system that tells us it is cheaper to destroy the earth and exhaust its people than to nurture them both? How did we create an economic system that confused capital liquidation with income?
- Paul Hawken, Amory Lovins and L. Hunter Lovins, in *Natural Capitalism*

I'd put my money on the sun and solar energy. What a source of power!
I hope we don't have to wait 'til oil and coal run out before we tackle that.
- Thomas Edison

If global warming is not contained, the West will face a choice of a refugee crisis of unimaginable proportions, or direct complicity in crimes against humanity.
- George Monbiot, UK journalist and author

Most green-collar jobs are middle-skill jobs. That means they require more education that a high-school diploma, but less than a four-year degree.
- *Van Jones, author of* The Green Collar Economy

No generation before us has faced a decade of choices that will so profoundly impact the course of life on this planet as those we now face. And no generation before us has had the opportunity to enrich the future so vastly.
- Eban Goodstein, author of *Fighting for Love in the Century of Extinction*

No problem of human destiny is beyond human beings. Man's reason and spirit have often solved the seemingly unsolvable – and we believe they can do it again.
- President John F. Kennedy, American University, June 1963.

Now is not the time to shrink from the challenge of saving our only home in the universe. Now is not the time to pull into ourselves, retreating into either survivalist or escapist mode. To the contrary, this is the time for titans, not turtles. Now is the time to open our arms, expand our horizons, and dream big. Big problems require big solutions.
- *Van Jones, author of* The Green Collar Economy

There is no science on how we are going to adapt to 4 degrees warming. It is actually pretty alarming.
- Prof Neil Adger, Tyndall Centre for Climate Change Research, UK

Trusting your energy policy to the fossil fuel lobby
is like trusting your health care system to the tobacco lobby.
William H. Calvin, University of Washington

Only in the last few years did the science crystallize, revealing the urgency – our planet really is in peril. If we do not change course soon, we will hand our children a situation that is out of their control.
– James Hansen, former chief NASA climate scientist

We must start... rebuilding our cities around energy efficiency and human needs,
rather than around the car and wasted energy.
- Washington state Governor Jay Inslee & Bracken Hendricks, in *Apollo's Fire*

We need to design transportation solutions that overcome our reliance on fossil fuels.
- Toyota, 2007

What a great time to be born, what a great time to be alive,
because this generation gets to completely change this world.
- Paul Hawken

You may never know what results from your action. But, if you do nothing, there will be no results.
- Mahatma Gandhi

It is a civilizational wake-up call.
A powerful message—spoken in the language of fires, floods, droughts, and extinctions—telling us that we need an entirely new economic model and a new way of sharing this planet.
- Naomi Klein, This Changes Everything: Capitalism vs. The Climate

You should never even ask if a campaign is winnable, because the question is not answerable.
No-one can predict the course of the future. Time and time again I have seen completely unforeseeable shifts in the tide of events that result in campaign victory.
- Elizabeth May, MP, Leader of Canada's Green Party

Earthfuture Publications, 2015