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Retraining investment for Alberta's oil and gas workers for green jobs in the solar industry

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Abstract

If oil sands are to be eliminated from the energy market to protect the global environment, human health and long-term economic welfare, a significant number of workers will be displaced in the transition to renewable energy technologies. This study outlines a cost-effective and convenient path for oil and gas workers in Alberta to be retrained in the burgeoning solar photovoltaic (PV) industry. Many oil and gas workers would be able to transfer fields with no additional training required. This study examines retraining options for the remainder of workers using the most closely matching skill equivalent PV job to minimize retraining time. The costs for retraining all oil sands workers are quantified and aggregated. The results show the total costs for retaining all oil sands workers in Alberta for the PV industry ranges between CAD$91.5 m and CAD$276.2 m. Thus, only 2–6% of federal, provincial, and territorial oil and gas subsidies for a single year would need to be reallocated to provide oil and gas workers with a new career of approximately equivalent pay. The results of this study clearly show that a rapid transition to sustainable energy production is feasible as costs of retraining oil and gas workers are far from prohibitive.

Keywords Retraining, Oil sands, Solar energy, Photovoltaic, Workforce education, Green jobs

1 Introduction

The need to radically reduce carbon emissions is clear [1–3]. To take but one example, there is a growing body of literature showing that carbon emissions directly results in human death and can be summarized by the 1000-ton rule – that every 1000 tons of carbon emissions is responsible for the death of a human being [4–8]. One of the core strategies to reach a carbon neutral society is with renewable energy (RE)-based electricity production [9–11], coupled with electrification of transportation and heating [12–15]. The rapid decline in RE costs makes such carbon-free electrification increasingly feasible [16, 17]. Wind and solar are now the fastest growing energy sources [18]. Solar energy from photovoltaic (PV) technology is highly scalable with enormous growth potential [19], has been economically viable for more than a decade [20], and offers a sustainable means to meet future energy needs [21].

The deployment of RE sources is currently somewhat limited by their inherent intermittency [22]. Emerging technical developments, however, offer potential to solve this technical challenge. For example, electric vehicles (EVs) can not only greatly reduce fossil-fuel-based land transport if powered with PV [23]; they can also offer grid support that can help overcome the intermittency challenge [24, 25]. EVs have already more than doubled in 2021 [26] and are positioned to rapidly expand their

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market share, supported by policy mandates in more than 20 countries [27]. Vehicle to grid (V2G) technology using EVs is already developed [28]. This low-cost green electricity coupled with a surge in electric vehicles provides one encouraging signal among others of a possible path to keeping unextractable oil in the ground in a 1.5C world [29]. In addition, immobile electric storage is already an economic way to reduce electricity costs while servicing the grid with intermittent generators [30, 31]. These technologies not only help expand penetration opportunities for renewable energy technologies, but they also electrify transportation, which directly undermines the market for the oil industry [32, 33].[1]Similarly, the market for the gas industry is challenged by the electrification of heating using heat pumps [34]. In North America solar-powered heat pumps have already become economically viable [35] and for the first time in history heat pump sales outperformed conventional natural gas furnaces in the U.S. [36].

These trends suggest that over the long term, the fossil fuel industry will diminish as electrification and renewable energy technologies gain traction [37–40] and governments [41–45], corporations [46] and individuals [47, 48] attempt to curb the effects of climate change. The power plants with the worst carbon emissions will be first [49]. Coal has already suffered declines [50] and bankruptcies [51]. It appears clear that the highly polluting forms of oil (e.g., tar sands [52] would be the next to be eliminated because of the additional costs for processing less pure hydrocarbons [53]. If this is to occur there will be a substantive job loss in the fossil fuel sector.

Canada's oil sands are the most polluting type of oil produced in the world today [54], thus finding ways to feasibly phase them out is a key climate priority. Synthetic crude oil originating from the Athabasca oil sands in Canada has an emission intensity of 729–736 kg of carbon dioxide equivalent (CO_{2e}) per barrel. To determine the most intensive CO_{2e} emitting facilities in order prioritize liability for climate lawsuits, and risk mitigation strategies for identified companies as well as their insurers and investors, a new bottleneck method has been proposed, which considers all emissions that a facility enables rather than only what it emits [55]. Three of the five leading emitters were Canadian oil types [54] and counter intuitively based on greenhouse gas emissions bottlenecks, the emissions in the U.S. are dominated by Canadian-owned Enbridge pipelines [56]. This means that if Canadian companies stopped exporting carbon emissions to the U.S. the American emissions would drop significantly. Canada is also one of the world's worst carbon emitters per capita [57]. The Canadian government has vowed to change this and for example, committed by 2030 to increase the country's share of electricity generation through non-carbon emitting sources to 90% [58]. At the same time, however, the federal government has continued to actively support the expansion of fossil fuel activities [59], demonstrating the political challenge of phasing out an industry that is both economically important and tied to a particular region's cultural identity [60] – in this case, the province of Alberta.

Although it is not a forgone conclusion, it is possible that as the ramifications of climate destabilization become more costly, the pressure to decarbonize will increase and Alberta's oil and gas sector will decline by some mechanism or some combination of mechanisms (e.g., carbon taxes, legislative mandate, lawsuits, simple economics, etc.). If Alberta's oil sands are to be eliminated from the energy market to protect the global climate, a significant number of workers will be displaced in the transition to RE technologies. Having well-paying, stable new positions lined up for them is critical. This issue is already being discussed by scholars in the solar and wind industries [61, 62]. For the first time, this article outlines a cost-effective and convenient path for oil and gas workers to be retrained in the solar industry, including a timeline over which the transition can happen.[2]

To reach these goals a novel methodology was employed. Because many jobs in the solar industry require similar skill sets and training as general construction work [27, 63], many oil and gas workers would be able to transfer fields with no additional training required. For this study, the U.S. Solar Census data was used [27] to examine distributions of workers that would maintain proportionality in the oil and gas industry of Alberta (in terms of type of work). When assumed oil worker skills did not align directly with a position type in the solar field, workers were assigned one of a few different types

[1] It should be noted that some studies (e.g., [15] point out that transport electrification without the replacement of fossil-fuel power plants as the source of electricity leads to increasing emissions instead of achieving a low-carbon transition. Here when discussing electrification of transport, it is in the context of a renewable-energy dominant grid where fossil fuels have been displaced and the oil and gas industry is no longer economically viable.

[2] It should be noted that this article is not attempting to claim that an increase of renewable energy workers is displacing oil and gas workers, because the total energy needs of society could (and is likely to) increase. If, however, climate concerns and economics make the provision of existing energy (and potentially more future energy) from oil and gas no longer viable (which also appears likely), then oil and gas workers will lose their jobs as the industry will be eliminated. If such future is realized, then to provide oil and gas workers with continued employment one method is to retrain them for rapidly expanding solar industry.

of positions that would require the least retraining possible. Multiple different retraining options were outlined (universities, colleges and online courses available in Alberta) to provide cost estimates for each different type of retraining (trades certification, 2-year college degree, 4-year university degree, graduate degree). Finally, the oil and gas industry was also compared to the solar industry through multiple social and economic lenses to examine the overall impact for workers switching between industries. By investigating the feasibility and costs of retraining Alberta's oil sands workers for equivalent positions in an emerging solar industry, this analysis lays out one set of possibilities for a just energy transition that could help meet climate change mitigation goals while reducing risks and harms to wildlife, ecosystems, and human health.

2 Background: Alberta's Oil Sands and gas industry

The oil and gas industry currently accounts for a large portion of Alberta's workforce and economy. About 26% of the GDP and 5.9% of all employment in Alberta relates to the oil and gas industry [64]. The industry employs over 35,000 people in the province [65]. Alberta is also globally known for its production of oil as it ranks third among all countries worldwide for its export [66]. About 97% of all oil stores in Canada are located in Alberta [66]. The oil and gas industry has played a crucial part in Alberta's political structure for decades [67].

The largest deposit, the Athabasca Oil Sands, is located in the Northern portion of Alberta. Other significant oil deposits exist to the West (Peace River Oil Sands) and the South (Cold Lake Oil Sands). Figure 1 shows a map of these deposits along with the educational institutions referenced in this study.

The educational distribution of Alberta oil and gas workers is shown in Fig. 2 [65]. Figure 2 demonstrates that most oil and gas workers have a college education or apprenticeship training, which presents unique opportunities for retraining this industry relatively easily to similar skill-set tasks in the solar industry.

The geographic distribution of all oil and gas-related workers across Alberta is also relatively consistent [65], as shown in Fig. 3. Note that not all of these workers are performing oil and gas extraction and many may work in the management of oil and gas activities.

This makes for an ideal transition to the most rapidly growing energy industry, the solar industry, as well because solar photovoltaics can be highly geographically diverse and applied in virtually all regions of Alberta at the residential, commercial and utility scales. Of the latter, the most promising are agrivoltaics systems, that co-locate PV systems on Alberta's agricultural regions while increasing crop output [68, 69]. The agrivoltaics potential in Alberta alone is phenomenal – only 1.4% of Alberta's farmland would need upgraded to agrivoltaics to eliminate the use of all fossil fuels from the Alberta grid [69]. The PV market is robust (USD$96.5 billion in 2023 and expected to grow at a compounded annual growth rate of 10% for the next 5 years [60]. In addition, the PV industry is relatively labor intensive and thus creates far more jobs per MW than fossil fuel sources [56]. A combination of the growth rate of PV, the potential of PV, and the jobs needed to meet this potential indicate that the PV industry has the capacity to absorb all displaced oil and gas workers in Alberta. The remainder of this study explores how this could occur.

3 Methods

To quantify the retraining costs to move all workers from the oil and gas sector in Alberta to the PV industry, a seven-step method was used, summarized in Fig. 4. The seven steps will be covered in detail in each subsection and include:

1. Obtaining data from the Government of Canada's National Occupational Classification (NOC) [70] for the region and classifying it by job category, job subcategory, region, and required education level.
2. Comparing the oil and gas industry to the solar industry on the basis of skillset, required education, and pay.
3. Reassigning oil and gas workers to the closest or most relevant solar position based on their preexisting skillset.
4. Identifying workers not requiring any retraining and placing them into the most easily transferable solar industry category.
5. Calculating the number of workers requiring retraining and the level of retraining required.
6. Analyzing the cost of appropriate degrees and programs for the retraining at universities and colleges in Alberta.
7. Calculating a cost range for all workers requiring retraining using each educational institution and program option.

Fig. 1 Map of Alberta's oil sands

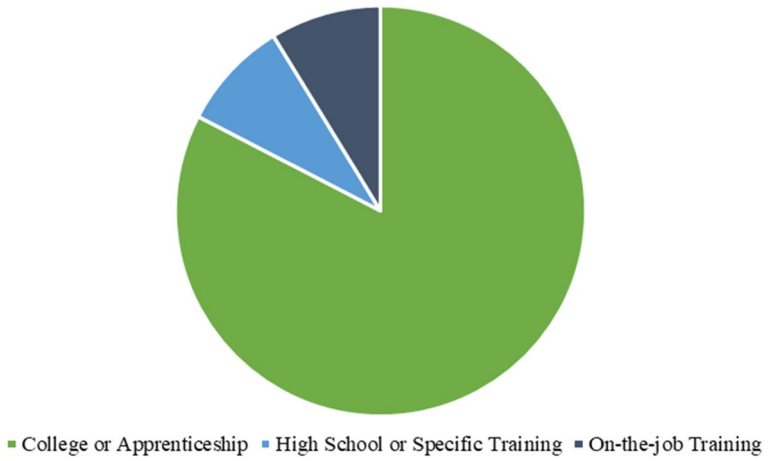

Fig. 2 Level of education and training of all oil and gas workers in Alberta

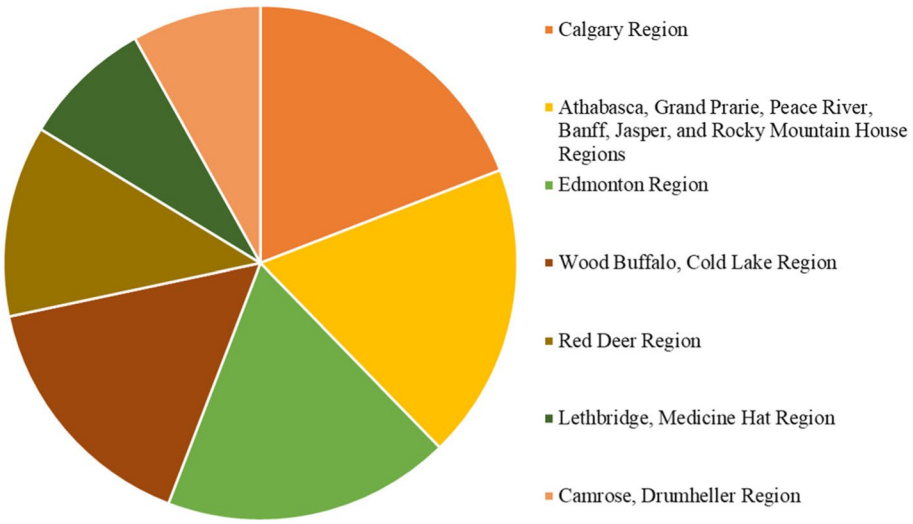

Fig. 3 Proportion of oil and gas workers in each region of Alberta

3.1 Classification

Oil and gas jobs in Alberta are split into four major categories, designated by the NOC [70]: 1) Contractors and Supervisors, Oil and Gas Drilling and Services (8222), 2) Oil and Gas Well Drillers, Servicers, Testers and Related Workers (8232), 3) Oil and Gas Well Drilling and Related Workers and Services Operators (8412), and 4) Oil and Gas Drilling, Servicing and Related Workers (8615). The first two categories (8222 and 8232) have an education level of "College or Apprenticeship" and require completion of secondary school and generally also requires completion of college classes related to oil and gas drilling, an apprenticeship or other extensive training in drilling/other oil field work, significant (3–6 month) on-the-job training and/or a comprehensive college diploma (1–2 years of full-time post-secondary education). The third category (8412) has an education level of "High School or Specific Training" and requires completion of secondary school and generally also requires training of up to 3 months and/or completion of job-specific, industry approved college courses. The last category (8615) has an education level of "On-the-Job Training" and may require completion of secondary school and relevant college courses but will have the majority of training provided on-the-job.

For these four major categories, a total number of people working throughout Alberta is provided, along with the percent of these people who work within more specific job categories (e.g. construction) [65, 70]. Regional information [65] is provided in the same way with a few

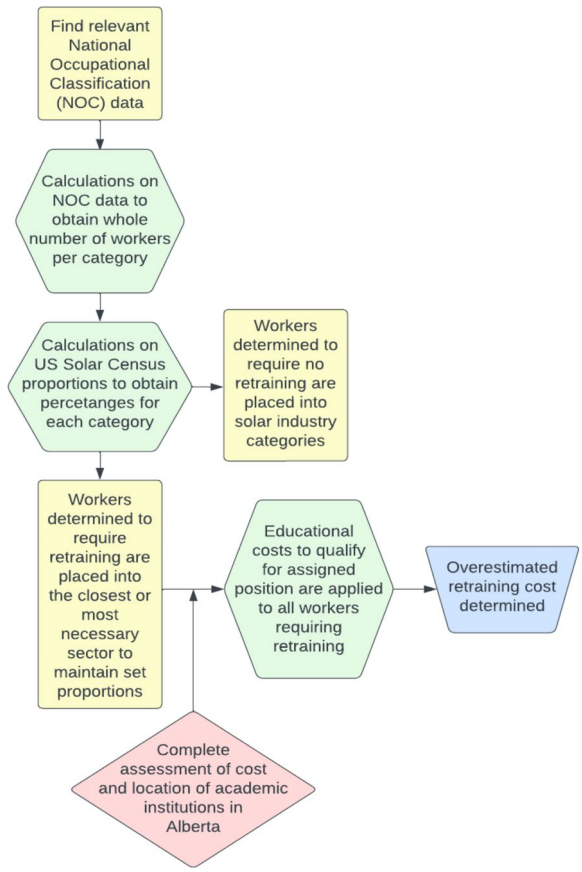

Fig. 4 Flow chart of methodology

more specific job categories (including professional, scientific and technical services). Because there is more detail regarding job position on a region-by-region basis (regions as outlined in Fig. 3), this data is used. All data for job subcategories are presented as a percentage of a total number of workers in the educational category. For ease of future calculation, these percentage values were transformed into numerical values using Eq. 1:

$$W_{job} = W_{total} \times P_{total} \quad (1)$$

where W_{job} represents the number of workers in a given job category (people), W_{total} is the total number of people in that region for a specific level of training (people), and P is the percent of the total workers in each subcategory (construction, etc. see Appendix Table 1A) in each region (%).

To provide more granular details to the types of jobs the provided region-by-region data is shown in Fig. 5.

The total number of workers in oil and gas occupations varies slightly between the provided Alberta total (35,074 workers) and the calculated region-by-region data (38,720 workers) [65]. This inconsistency is attributed to rounding measures and different categorization implemented in the province-wide data. To make a conservative estimate and provide a margin of error when it comes to cost of retraining, the larger number (region-by-region total) is used throughout the remainder of this study. Charts using the less specific (Alberta-wide) data can be found in the Appendices.

A chart combining the data in Fig. 5 to represent all workers regardless of region or education level is shown in Fig. 6 and is used for subsequent job transition analysis.

3.2 Retraining to solar

3.2.1 Primary analysis

The renewable energy industry has grown appreciably in the last two decades, now employs over 430,000 people, and is expected to increase by 50% by 2030 to 639,200 under the Canadian government's new climate plan [71]. Fossil fuels are on track to drop 9% or 125,800 fewer jobs in fossil fuels over the same time period [71]. The solar industry is still relatively small, so the U.S. solar industry job classification was used as an analogue, as the proportion of jobs per MW will be roughly equivalent. Once quantitative data was obtained for oil and gas jobs, a comparison was conducted using data from the 2020 U.S. Solar Census [27] to assess the type and amount of retraining that would be required for oil and gas workers to successfully work in the solar industry.

While the scale of these industries is vastly different, the proportion of workers in each category should be similar. Similar solar industry suppliers, manufacturers, and solar technologies exist in both countries [72]. Slight differences may exist in worker compensation and growth rates between countries, but worker type proportions should not differ significantly. Figure 7 shows the distribution of workers in the solar industry across the U.S. in 2020 [27].

As the majority of the workers in the solar industry are installers and developers (approximately 67%) [27], the process of retraining all oil and gas workers is less costly than may be expected. Solar installation requires little formal training and most of the work is highly comparable to other types of construction work [27]. This means that the average oil and gas worker is, on average, technically over-educated to work in the solar industry. That said, workers who hold a "college and apprenticeship" title may not have a credential that is relevant to the solar industry (e.g. a Petroleum Engineering diploma from an institution such as the Southern Alberta Institute of

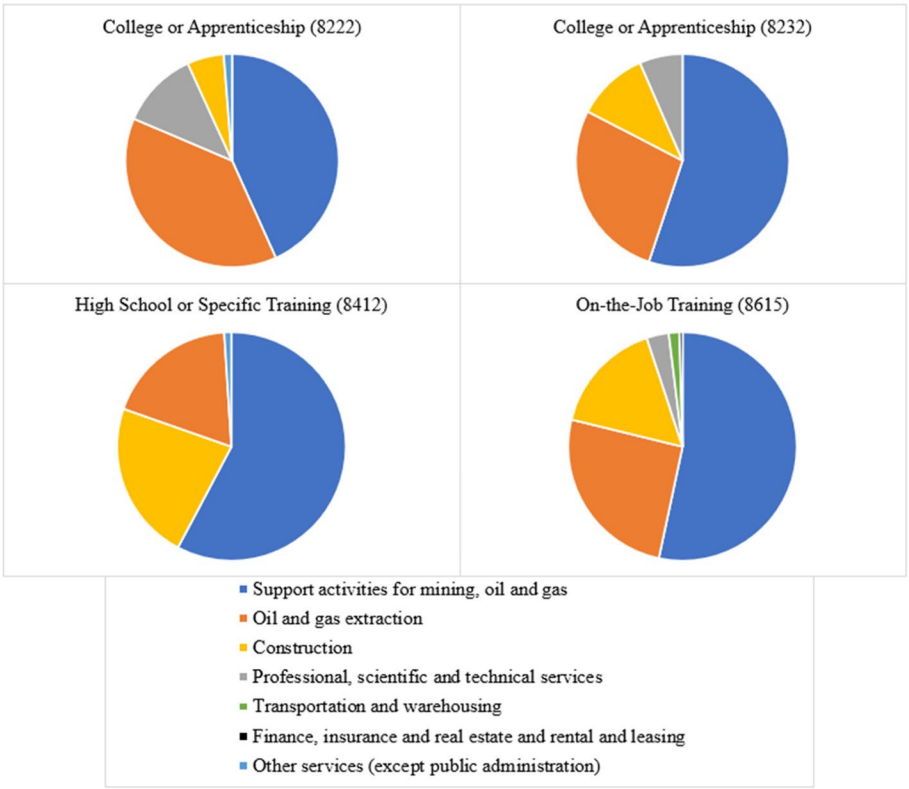

Fig. 5 Distribution of all (province-wide) oil and gas workers in each educational category by job subcategory

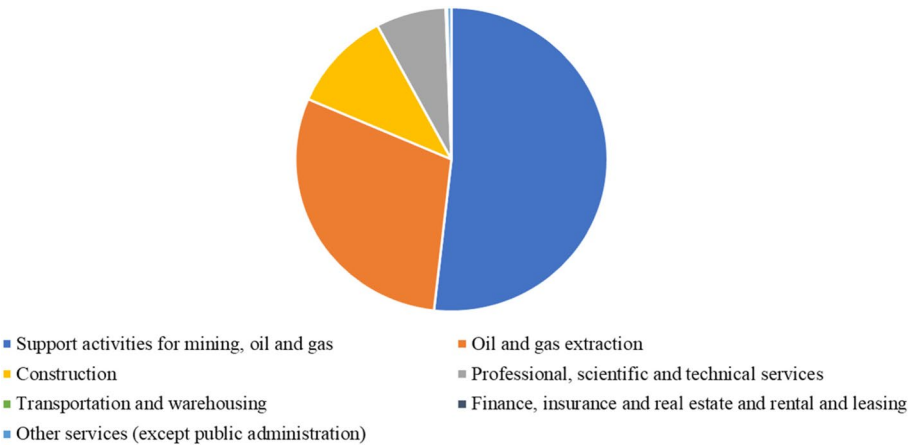

Fig. 6 Distribution of all oil and gas workers (regardless of educational level) in Alberta based on occupational subcategory

Technology (SAIT)) and will require retraining to maintain an equivalent salary and similar work duties (e.g. management position).

Because of the minimal prior training required, all workers could theoretically be transferred into the "Installation and Development" sector. All on-the-job training for such positions and any other positions was assumed and the cost for that would be zero. It is true that simple non-institutional training could be used for lower skill jobs, however, to maintain salaries, retraining would be needed for the more skilled workers. The minimum standards/education needed to move into a lateral position was thus included. Oil and gas workers in the "Professional, Scientific and Technical Services" category

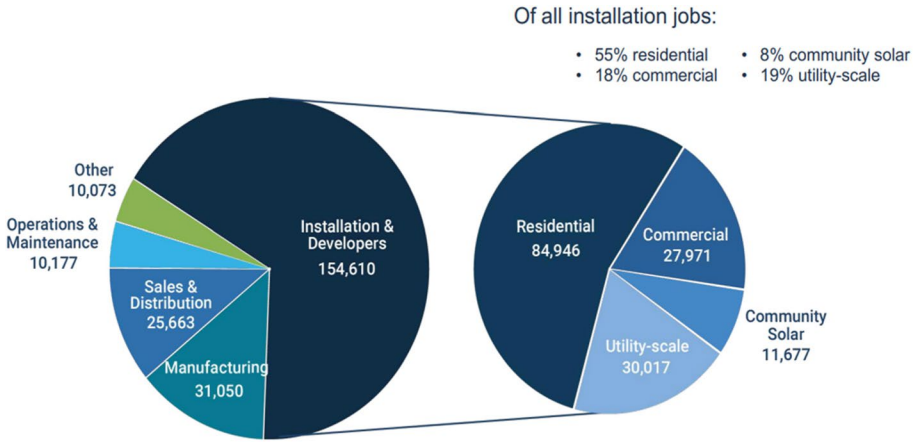

Fig. 7 2020 US Solar Census solar job distribution data [27]. The circle on the right breaks down the installation and developers jobs on the left

may be able to move directly into the "Manufacturing" sector depending on their specific skillset or qualifications. Additionally, oil and gas workers in the "Transportation and Warehousing" and "Finance, Insurance, and Real Estate and Rental and Leasing" sectors may be able to move industries directly by transferring into the "Sales and Distribution" solar industry category.

To streamline the retraining of these workers, the U.S. Solar Census is used to maintain the correct proportions of retrained workers and ensure that workers are retrained using the most efficient pathways possible. Firstly, the data provided in the Solar Census (Fig. 7) is used to determine overall percentages of workers in each category [27]. While the total number of workers in the US and Alberta are vastly different, it is assumed that the proportions of workers will remain relatively constant which is why a percentage-based analysis can be used. Equation 2 shows the conversion from given number of workers in each solar industry category to the percentage that each category makes up.

$$P_{workers} = (N_{workers}/T_{workers}) \times 100 \quad (2)$$

where $P_{workers}$ represents the percentage of total workers in each category (%), $N_{workers}$ represents the number of workers in each category (workers), and $T_{workers}$ represents the total number of workers in the U.S. Solar industry according to U.S. Solar Census (workers). The calculated percentages are shown in Table 1.

For the purpose of placing oil and gas workers into solar industry categories, the "Other" category was eliminated. This allows a 4% margin of error for percentages and allows a more direct placement of workers based on their known skills.

To provide the most direct path for workers to transfer between industries, workers in each oil and gas category are placed into the most similar solar industry category that would require as little retraining as possible for the entire industry, while maintaining the correct proportion of workers in the solar industry. This proportionality is crucial to maintain appropriate growth of the industry and ensure all workers have jobs that most accurately fit their current or desired skill set. For this placement, it is assumed that solar installation requires no formal training (all training will be provided on-the-job). Therefore, all on-the-job workers with no other relevant skills (e.g. financial or transportation skills), all "Construction" workers, and all "Support Activities for Mining, Oil and Gas" workers except those who hold contractor or supervisor status are placed into installation. This exception is made because oil and gas contractors and supervisors will place most directly into solar supervisory and management positions but will likely require retraining (general familiarization with solar installation and industry practices) to do so. All "Other Services (except public administration)" workers are assumed to have a diverse set of skills that fall most closely in line with sales and distribution (as they are not applicable in any trades or manual labor category).

Table 1 Percentage of workers in solar industry given by U.S. Solar Census data

Solar Census Proportions	Number of Workers	Percent of total
Installation & Developers	154,610	66.8
Manufacturing	31,050	13.4
Sales & Distribution	25,663	11.1
Operations & Maintenance	10,177	4.4
Other	10,073	4.3
Total	231,573	100

The process used to determine the number of workers requiring retraining likely produces over-estimated values as similarities in worker skill and training certainly exist between the oil and gas industry and solar industry, but there is not enough information to determine which category they fall into or how many of them there are. Therefore, this analysis was performed using entire categories (or 50% of categories in one case), but it is likely that not all workers within a given category require full retraining.

3.3 Types of retraining and where to acquire retraining

To provide a comprehensive cost analysis for retraining opportunities across Alberta, all colleges and universities that provided relevant programs were identified.

Because of their previous experience as contractors or supervisors, those in the first category of workers requiring retraining likely only need training specific to solar installation and solar systems. This type of education can be obtained in a variety of programs such as the solar photovoltaic continuing education courses through Northern Alberta Institute of Technology (NAIT). Since these workers already have a college diploma or apprenticeship training, they should be able to obtain any additional training within two years of leaving the oil and gas industry.

For those in the second category of workers requiring retraining (professional, scientific and technical workers – 8222), any institution that provides trades education programs will be able to help workers transition to the solar manufacturing sector.

Workers in the third category of workers requiring retraining (professional, scientific and technical workers – 8232) will also be able to attend any institution that provides trades education.

Workers in the last category of workers requiring retraining (oil and gas extraction workers – 8232) may need a variety of different educational experiences depending on their new position. Those moving into the "sales and distribution" sector may need a college diploma in business or management, although oil and gas workers into this category only have on-the-job training. For this assessment, it is assumed that either a certificate or a diploma is required to ensure that all workers are qualified for their new positions. Virtually any college or university in Alberta provides college level business education programs at a similar cost to other programs, so a cost analysis of these programs will not be performed. Workers transitioning into manufacturing from this category will also be able to obtain their training and education from any college that offers trades programs, as listed in Table 2.

Table 2 Universities and colleges in Alberta with programs relevant to the retraining of oil and gas workers to solar industry jobs

Alberta Colleges with Relevant Programs	Alberta Universities with Relevant Programs
Northern Alberta Institute of Technology	University of Alberta
Southern Alberta Institute of Technology	University of Calgary
Red Deer Polytechnic	Athabasca University
Lethbridge College	
Northwestern Polytechnic	
Medicine Hat College	
Olds College	
Keyano College	
Portage College, Lac La Biche Campus	
NorQuest College Edmonton Campus	
Yellowhead Tribal College	

A comprehensive analysis of educational institutions throughout Alberta was performed to determine the cost of retraining all workers who have a need for additional skills or information before being placed into their solar industry positions. Programs offered by each institution were assessed for relevance. Institutions offering no programs that could assist in retraining oil and gas workers were omitted from the study. Although some workers in the field of business administration would be required to facilitate this transition, the number of workers is not significant to the overall total and these workers would likely be fully replaced by those currently working in business administration in the oil and gas industry. Therefore, institutions whose only relevant programs were business related were excluded as well.

3.4 Education/training options and costs

For most workers, a certificate, college diploma, or trades apprenticeship credential is all that is required to facilitate the transition between industries. Some workers, however, will also need a bachelor's degree in a relevant field to act as supervisors and advanced technical workers (engineers, etc.). Every educational institution in Alberta able to be identified using an Internet search was assessed for relevancy to the retraining goals established in this study and those with no relevant programs were eliminated. Institutions in Alberta with relevant programs in 2022 are listed in Table 2.

A full examination of each institution was conducted to identify every potentially relevant program. References for these institutions are not included as links are dynamic and many pages within each institution's

webpage were used. All sites can be found with a general Internet search of the institution name.

The cost to attend each of these colleges and universities for the time required to obtain the most relevant certifications and degrees is detailed in Table A6, A7 And A9.

Equation 3 was used to obtain a total value for attendance.

$$C_{total} = C_{term} \times N_{term} \text{ [CAD]} \quad (3)$$

where C_{term} represents the cost of attendance per term, inclusive of all estimated and actual tuition and required fees (bus passes, required textbooks, etc.) not including the cost of living, per year or other unit of time provided (CAD/term, CAD/year), N_{term} represents the number of terms or years required for completion of an undergraduate degree at full time (15 credits for most universities) (terms, years), and C_{total} represents the total cost of attendance (CAD).

For ease of retraining cost calculation, the cost of different educational programs (bachelor's degree, university transfer program, diploma or certificate, and apprenticeship experience) are shown in every selected institution that provide them. For universities that have different costs for different subjects of the same type of academic program, the lowest possible total cost and the highest possible total cost were calculated using Eq. 3 and are reported in Appendices Tables A6, A8, and A9 (for bachelor's degree, diploma/certificate, and apprenticeship programs respectively). Appendix Table A7 contains the reported cost of university transfer programs which were represented by each institution as a single value cost (no range available).

University transfer programs are generally meant to lower the cost of a bachelor's degree, provide more instructor-student interaction in a student's first year of university or allow those without adequate qualifications to obtain admittance into a larger or more prestigious university by providing an updated academic transcript with higher academic marks than were received in a student's secondary education. These programs could be used by oil and gas workers to lower the cost of their re-training in a competitive field like engineering and provide a more accommodating university experience for the first year of their re-education. It is important to note that transfer programs are always integrated into the completion of a bachelor's degree and cannot be used as a standalone credential.

Bachelor's degree programs generally take 4 full years (8 terms) to complete. Diploma programs generally take 2 years (4 terms) of full-time attendance to complete. Certificate programs are generally 1 year (2 term) programs that consist of training with a more specific focus (more depth, less breadth) than a diploma program. These programs are grouped together for the purpose of this study as most jobs only specify "college education" as a requirement for employment and, depending on the program, one type of program or the other may be more appropriate.

Table 3 Lowest and highest costs for each program type [Athabasca University, University of Calgary, Keyano College, Red Deer Polytechnic, Portage College (LacLaBiche Campus), Medicine Hat College, Southern Alberta Institute of Technology, Northwestern Polytechnic]

Program	Lowest Cost (CAD$)	Highest Cost (CAD$)
Bachelor's Degree (4 years)	29,920	47,834
University Transfer (2 years)	5,239	9,519
Diploma or Certificate (1–2 years)	2,640	21,945
Apprenticeship (3–6 months +)	1,005	7,715

Cost, length of completion, income opportunities, and many other factors vary greatly between apprenticeship programs. Apprenticeship programs, however, generally consist of a few weeks of classroom education per year (6–16 weeks) each year for 3–4 years with the remainder of the time spent working in the chosen field under the direct supervision of a certified professional. In most cases, apprentices are paid for their work which makes apprenticeship training an appealing option for those looking to transfer fields before government or other assistance is available, and who are not able to go without income for a year or longer as would be required with a bachelor's, diploma, or certificate program.

To most easily apply these cost ranges to the required retraining pathway, the lowest cost value and highest cost value was selected to provide a comprehensive cost across all institutions for a given credential. Ranges for each credential are shown in Table 3 and all costs are in $CAD.

3.5 Worker reassignments

Workers requiring re-training are assigned to new solar industry categories based on the preexisting skills and education of the group and the number of workers in the category and these reassignments are summarized in Table 4.

It is assumed that 50% of Operations and Maintenance workers (formerly those in Support Activities for Mining, Oil and Gas from category 8222) will require an undergraduate degree and 50% will require a diploma or certificate. This assumption is supported by the roughly equivalent number of positions in the U.S. solar industry

Table 4 Additional credentials required for each group of workers requiring retraining

Job Class	Function in Oil and Gas	Job Category to Transition to Solar	Additional Credentials Required
8222 (contractors/ supervisors, college/ apprenticeship)	Support activities for mining, oil and gas Professional, scientific and technical services	Operations & Maintenance Manufacturing	Undergraduate Degree or Diploma/Certificate Apprenticeship
8232 (general workers, college/ apprenticeship)	Professional, scientific and technical services Oil and gas extraction	Manufacturing 50% to Sales and Distribution 50% to Manufacturing	Apprenticeship Diploma/Certificate Apprenticeship

Table 5 Wages for oil and gas drilling positions

Job Position	Education/Training Requirements	Average Wage—Alberta (CAD$/hr)	Average Wage—Alberta (Salary, CAD$)
Contractors and supervisors, oil and gas drilling and services (8222)	College or apprenticeship	45.00	90,000
Oil and gas well drillers, servicers, testers and related workers (8232)	College or apprenticeship	40.00	80,000
Oil and gas well drilling and related workers and services operators (8412)	High school or specific training	30.25	60,500
Oil and gas drilling, servicing and related labourers (8615)	On-the-job training	27.88	55,760

between sales and manufacturing (see 2020 US Solar Census solar job distribution data [27]).

3.6 Pay comparisons

To compare positions between the two industries, an income analysis is also performed. The average salary for each overarching oil and gas category is collected from the NOC database [70] and is shown in Table 5.

To have the most relevant, regionally accurate data possible for solar positions, Indeed, a widely used online job board, was used to identify salaries for different kinds of solar industry work. To standardize the job search process, the solar positions from [73], which analyzed converting coal workers in the U.S. to solar positions, were used as search terms.

While some positions provided salary or hourly pay information, many did not. Therefore, all positions were searched using the NOC database and average hourly income values were given for many of the positions. To convert hourly wage values to salaries, the following equation was used.

$$W_{year} = W_{hour} \times H \times K \tag{4}$$

where W_{year} represents the yearly wage (CAD$), W_{hour} represents the provided hourly wage ($CAD), H represents the number of hours per week worked (hours), and K represents the number of weeks per year worked (weeks). In the calculation of these values, it was assumed that employees worked 50 weeks per year [74] and 40 h per week.

3.7 Online job board assessment

In addition to the categorical reassignment, a specific "case study" analysis of available solar photovoltaic industry jobs in Alberta was conducted. Job position titles in the solar industry were taken from "Retraining Investment for U.S. Transition from Coal to Solar Photovoltaic Employment" [73] and were used as search terms on the online job board "Indeed". The complete list of job position tiles is shown in Table A3. in the Appendices. If no results were returned using the search term or similar phrases and keywords, the position was omitted from further analysis. Table A4. in the appendices details the list of omitted positions. Omitted positions were mainly positions that required previous solar experience or specialization in solar technology (e.g., Plumber with Solar Experience). These positions can be easily filled by people with general training in the field (e.g., a standard plumber) with minimal investment.

The positions were then separated based on the education requirements listed in the job posting. All positions required either an undergraduate degree, college education or an apprenticeship/training program, or minimal training (only a recommended number of years of experience in the field or general familiarity with a certain

Table 6 Workers with the most easily transferable skill sets that will require no retraining. All workers go to installation PV jobs

Job Class	Number of Workers
8222 (contractors/supervisors, college/apprenticeship)	
Oil and gas extraction	4224
Construction	615
Other services (except public administration)	138
8232 (general workers, college/apprenticeship)	
Support activities for mining, oil and gas	11,907
Construction	2345
8412 (high school or specific training)	
Support Activities for mining, oil and gas	1711
Construction	670
Oil and gas extraction	551
Other services (except public administration)	30
8615 (on-the-job training)	
Support activities for mining, oil and gas	1642
Oil and gas extraction	785
vConstruction	496
Professional, scientific and technical services	97
Transportation and warehousing	46
Finance, insurance and real estate and rental and leasing	14

workers that were reassigned into solar industry jobs that required no retraining.

Table 6 shows that overall, 25,211 workers in the installation and development category could move directly to PV installation jobs, representing 65.1% of the workforce. Another 60 people (0.2%) could move directly into sales and distribution solar positions. In total, 65.3% of the oil and gas workforce in Alberta could move into the solar industry with no retraining.

Many of the remaining workers would need some retraining based on their current credentials. Workers were either placed in the category that they would require the least retraining for, or another category close to their current credentials that would help maintain the correct proportionality of workers according to Fig. 7 [27]. In reality, these assignments are highly dependent on personal worker preference and could vary, but the most straightforward reassignments are outlined in Table 7.

All newly reassigned workers (both those that required training and those that did not) were combined to assess the differences in distribution from those in Fig. 7 and Table 7 [27] using Table 8.

To obtain a cost estimate for all retraining required, calculations were performed as detailed in Sect. 3 to

Table 7 Tar Sands workers that will require retraining before being placed into solar jobs

Tar Sands Jobs Category	Number of Workers	Solar Job Category
8222 (contractors/supervisors, college/apprenticeship)		
Support activities for mining, oil and gas	4792	Operations & Maintenance
Professional, scientific and technical services	1304	Manufacturing
8232 (general workers, college/apprenticeship)		
Professional, scientific and technical services	1411	Manufacturing
Oil and gas extraction	5943	50% to Sales and Distribution, 50% to Manufacturing

skill set). Wage information was collected from the individual job postings. If no wage information was provided in the job posting, average wage values were collected from more broad position titles provided by Indeed analytics [75].

4 Results

Using the methods described above, oil and gas workers were reassigned into solar positions that most closely match their skills, with a small portion of workers being reallocated into higher level positions to maintain ideal proportionality within the industry. These examples are shown in Tables 6, 7 and 8 below. Table 6 shows

Table 8 Distribution of oil and gas workers when moved into solar industry categories

Job Category	Number of Workers	Percent of Total
Installation & Development	25,211	65.1
Manufacturing	5687	14.7
Operations & Maintenance	4792	12.4
Sales & Distribution	3031	7.8
Total	38,720	100.0

Table 9 Range of costs for all workers requiring retraining

Worker Class	Credential Required	Workers Requiring Retraining	Lowest Program Cost ($CAD)	Highest Program Cost ($CAD)	Low Total Cost ($CAD)	High Total Cost ($CAD)
8222 Support activities for mining, oil and gas	Undergraduate Degree	2,396	29,920	47,835	7,169,1312	114,616,964
	Diploma/Certificate	2,396	26,41	21,946	6,327,789	52,583,828
8222 Professional, scientific and technical services	Apprenticeship	1,304	1,005	7,716	1,310,822	10,063,353
8232 Professional, scientific and technical services	Apprenticeship	1,411	1,005	7,716	1,417,955	10,885,827
8232 Oil and gas extraction	Diploma/Certificate	2,971	2,641	21,946	7,846,949	65,208,029
	Apprenticeship	2,971	1,005	7,716	2,986,207	22,925,510
				TOTAL COST:	91,581,032	276,283,512

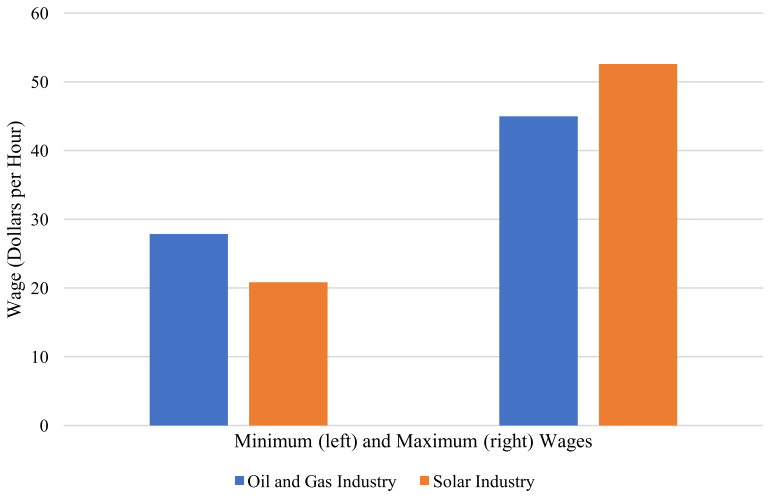

Fig. 8 Minimum and maximum wages in each industry for workers paid on an hourly basis

produce a range of program costs and a range of total costs to retrain all workers who do not have easily transferable skills or who are not placed in the Installation and Development sector of the solar industry. This is shown in Table 9.

To better understand the difference in wages between the two industries, average salaries and hourly wages for the oil and gas industry and the solar industry were compared. These values are shown in Figs. 8 and 9, below.

The oil and gas industry and the solar industry have similar wages depending on the level of training and experience held by a worker. Using the distribution outlined in Methods, the majority of workers will be placed into solar installation and construction which has wages at the low end of the range for solar positions, so workers in higher paid oil and gas positions may wish to complete additional training to raise their income. With the way that reassignment was performed in this study, many of the higher paid workers were the workers that were assigned additional training in order to maintain their supervisory status.

The distribution detailed above is shown in Fig. 10. As is shown, the retrained distribution shown in Table 8 (above) and Fig. 10 (below) matches relatively closely to those taken from Table 7 and Fig. 7.

In summary, the analysis suggests that no oil and gas workers transferring into solar installation would require additional training. These jobs require minimal training outside of on-the-job training. Workers transferring between two relatively unrelated sectors (e.g., from oil and gas extraction to sales and distribution) would need the most retraining.

4.1 Full salary analysis

Analyses of currently available job positions in the solar industry present on Indeed demonstrate that a substantial job market for those wishing to join the solar industry

Fig. 9 Minimum and maximum yearly salary in each industry

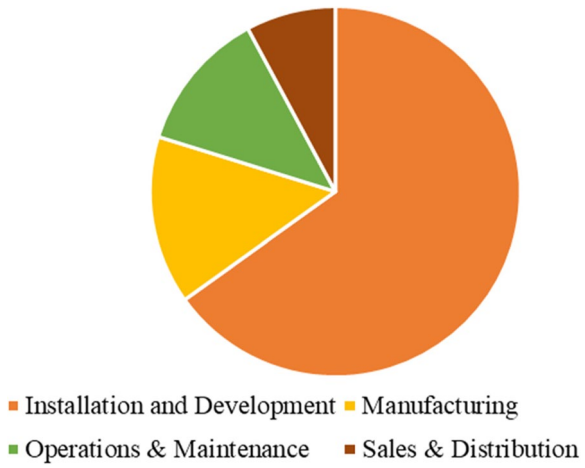

Fig. 10 Distribution of relocated and retrained workers

does exist in Alberta. These jobs are high paying (shown in Table A5 in Appendices), and often provide substantial benefits packages. Additionally, this industry continues to rapidly expand in what the CBC calls a 'Alberta solar power gold rush' [76] which will bring even more diversity and competition to the job market in the coming years, therefore leading to higher wages and more stability for workers.

4.2 Loss of income while retraining

An important consideration for this transition is the opportunity cost of seeking retraining. Workers in the oil fields often provide significant portions of their family's salaries with their jobs and this income is crucial to their comfort, health, and wellbeing. Additionally, certain types of education can be expensive, as outlined above. Multiple options, however, exist to support workers through their reeducation period, including living stipends, scholarships, and other educational funding. Future work is needed in this area to determine the most equitable means to support retraining of Alberta's current oil sands workers.

5 Policy implications

The strikingly low aggregate costs for retraining oil and gas workers in Alberta for a just transition to solar energy employment for roughly equivalent salaries provides for several energy policy options. Overall, the quantitative results of this study show the total costs in aggregate for retaining all oil sands workers in Alberta for new jobs in the PV industry ranges between CAD$91.5 m and CAD$276.2 m. Thus, multiple semi-quantitative options are available to subsidize fund the retraining for these workers which include reallocation of income from top executives of the oil and gas industry and reallocation of government funding to education.

Firstly, it should be acknowledged that the salaries of those in top managerial roles of the oil and gas industries make up some of the largest on the planet. Al Monaco, the Director, President, and Chief Executive Officer of Enbridge, received a total cash salary of $6,273,390 in 2021 [77]. His total compensation totaled $19,039,968 the same year [77]. A distribution of his salary could personally offset a substantial portion of the retraining costs for individuals. For example, allowing Monaco a more modest cash salary of $500,000 USD for one year would allow $5,773,390 of his cash salary to be reallocated to supplement the cost of retraining for all of his employees. As stated above, the low end of the range of estimated total retraining costs ($91,581,032) is likely most accurate (Table 9). Thus, if the total of Monaco's income (minus

$500,000) was reinvested into retraining for five years, all retraining costs would be covered for the whole province. Windfall taxes on oil company profits during periods of unusually high prices, as implemented in the UK [78], or higher royalties represent other possible ways to leverage money for retraining from within the oil and gas sector.

Governmental funding and grant programs could also be implemented to cover portions of the retraining cost in the same way that tax rebates and individualized payments are currently available for the purchase of electric vehicles and personal renewable energy investment [64]. One way to raise such funds could be to reduce and redirect federal, provincial, and territorial oil and gas subsidies – conservatively estimated at CAD$4.8 billion per year [79]. Thus, only 2–6% of federal, provincial, and territorial oil and gas subsidies for a single year would need to be reallocated to provide oil and gas workers with new careers.

In addition to governmental support or restructuring, most educational institutions provide support options for part-time or non-traditional students. Utilizing university transfer programs for the first two years of a four-year program (such as those offered by Red Deer Polytechnic) can substantially lower the total cost of attendance. These programs would allow workers to attend classes with more flexibility and lower cost for the first two years of their program to obtain a credential in four-year degree programs that are required in the solar industry such as engineering. Specific cost comparisons can be found in Table A7 (cost of university transfer programs) and A6 (cost of 4-year bachelor's degree programs) in the Appendices. It should be noted that university transfer programs must be followed with 2 additional years of schooling; a total cost comparison should include the cost of the university transfer program and half of the cost of a full bachelor's degree program.

In the wake of the COVID-19 pandemic, many institutions have begun offering different remote and flexible options for degree completion [80]. Because of the remote location of the Athabasca oil sands and the need for workers to continue employment throughout their retraining process, remote courses and degree programs may make the retraining process cheaper and more easily attainable. Athabasca University provides an entirely online experience and other universities such as the University of Calgary also provide options to take large portions of various degree programs remotely. Athabasca University also provides a "credit for work experience" program to allow established workers to skip out of required classes if they can demonstrate that they have obtained the skills from that class elsewhere. This may provide a viable option for trades workers that have no formal academic certifications or post-secondary coursework to more easily demonstrate their skill set to employers in the solar industry.

Although the use of fossil fuels still represents a significant portion of energy usage in the United States, Canada, and globally, renewable energy technologies are gaining traction at increasing rates [18]. Accelerating the transition to renewable energy sources would not only help mitigate climate change,it could also alleviate the impacts of Canada's oil and gas industry on biodiversity, human health, and Indigenous rights – not only in Alberta, but throughout North America. As seen in Fig. 11, oil and gas harvested in Alberta is carried throughout the U.S. For example, Alberta oil endangers thousands of people living and working in the path of the Enbridge Mainline (Line 5), which carries 540,000 barrels per day [81] and has been found in violation of various environmental protection statues over the last few decades [82, 83]. In addition to these environmental and human health risks, Enbridge and other companies have violated treaties with Indigenous peoples across the midwestern United States and Canada [84–86]. While renewable energy sources such as solar are not problem-free, and care must be taken not to replicate existing patterns of social inequity during their implementation, the type of transition envisioned in this analysis offers enormous potential to pursue a more fair and sustainable energy path.

6 Limitations

Focusing this analysis on a relatively simple migration of workers from the oil sands industry to a growing solar industry in Canada represents a first step in demonstrating the feasibility of such a transition. Several issues and questions that lie beyond the scope of this paper deserve further attention.

First, this study assumes that Canada's solar industry is ready to grow quickly enough to accommodate tens of thousands of new workers in less than a decade. This assumption is grounded in the rapid growth of the PV industry observed in other regions globally, Canada and more specifically the growth observed currently in Alberta. Future work is needed to ascertain what limiting factors could exist to throttle that growth rate and what conditions might be necessary to help enable it.

Second, to keep the analysis manageable, this study has focused on one scenario: transferring all oil sands workers into solar energy. Realistically, a just energy transition would likely involve distributing oil and gas into a more diverse set of green jobs (e.g., energy efficiency jobs, jobs focused on electrification of heating with PV providing the power using heat pumps [35, 87] or jobs focused on

Fig. 11 Enbridge Mainline. Carries crude oil, refined petroleum products, and natural gas through 10 states and provinces

electrification of transport with electric vehicles [88]). Further research could explore these nuanced scenarios.

Third, while this study has focused on retraining requirements, the issue of some workers needing to relocate from Alberta to other parts of Canada to do their new jobs is also important and warrants further study.

Fourth, this study focused only on retraining costs and policies to implement them. The reality of fossil fuel workers is more complex than a simple job. Roberts pointed out that coal workers in Appalachia may not be willing to move for even higher paid jobs in solar [8] and Smith, shows the different views of coal workers in different contexts within the U.S. [89]. The same dynamics that limit coal worker mobility in the U.S. may not be as intractable in Canada where the oil and gas workers are more mobile [90, 91] and even willing to suffer long distance commuting for existing fossil fuel employment [92]. Considerable past research on the just energy transition have looked at ways to protect fossil-fuel workers in a range of contexts [93–96] and can be leveraged specifically to help Canadian fossil fuel workers weather the transition. Considerable future work is needed in this area.

Finally, while this analysis has suggested some possibilities for leveraging resources to pay for worker retraining, such an effort would likely require policy commitments and cooperation from federal, provincial/territorial, and private sector actors. The political challenges even in the face of increasing human death toll from carbon-emissions involved in negotiating such an arrangement are considerable and deserve careful research attention.

7 Conclusions

Retraining oil and gas workers in Alberta is both a feasible and necessary step in the transition to clean just energy usage. As the results of this study show the training costs are generally minimal for a transition from oil and gas to solar as the majority of workers in the solar industry require only general trades or site-specific training that is provided by employers. The quantitative results show the total costs in aggregate for retaining all oil sands workers in Alberta for the PV industry

ranges between CAD$91.5 m and CAD$276.2 m. Thus, multiple semi-quantitative options are available to fund the retraining for these workers which include reallocation of government funding to educational subsidies and reallocation of income from top executives of the oil and gas industry. For example, only 2–6% of federal, provincial, and territorial oil and gas subsidies for a single year would need to be reallocated to provide oil and gas workers with a new career of approximately equivalent pay. Similarly, oil CEOs could also directly pay for the retraining of their own workers from a fraction of their total incomes. In addition to the human and environmental safety concerns posed by the oil and gas industry, this industry is a primary driver of global climate destabilization. A rapid transition to cleaner forms of energy production is not only necessary to avoid the detrimental health and environmental effects of Canada's oil and gas sector, but – as this paper demonstrates – increasingly feasible. The analysis presented here shows that the costs of retraining oil and gas workers are far from prohibitive.

Appendix

Table A1 All job categories of oil and gas workers across all education levels on a regional basis (expanded data)

Job Category Across All Education Levels and Regions	Number of People
Support activities for mining, oil and gas	20,052
Oil and gas extraction	11,503
Construction	4126
Professional, scientific and technical services	2812
Other services (except public administration)	168
Transportation and warehousing	46
Finance, insurance and Real estate and rental and leasing	14
TOTAL	38,720

Table A2 Job categories in province-wide data with combined and rounded data

Job Categories Across All Education Levels and Regions	Number of People
Support activities for mining, oil and gas	23,808
Oil and gas extraction	8934
Construction	1562
Architectural, engineering and design services	771
TOTAL	35,074

Table A3 Complete list of solar industry positions [73]

Quality Assurance Specialist
Process Control Technician
Industrial Engineer
Environmental Engineer
Mechanical Engineer
Electrical Engineer
Computer Numerical Control (CNC) Operator
Advanced Manufacturing Technician
Instrumentation and Electronics Technician
Materials Scientist
Plumber with Solar Expertise
Electrician with Solar Expertise
Solar PV Installer (residential/small commercial)
Solar Installation Contractor
Solar PV Technician (commercial/utility)
Solar Installation Helper
Mechanical Assembler
Solar Sales Representative (Retail)
Solar Marketing Specialist
Building Inspector with Solar Expertise
Solar Project Developer/Sales Representative (Wholesale)
Solar Site Assessor
Code Official with Solar Expertise
Lawyer with Solar Expertise
Electrical Inspector with Solar Expertise
Utility Interconnection Engineer
Residential PV System Designer
Structural Engineer
Solar Utility Procurement Specialist
Power Systems Engineer
Solar Energy Systems Designer
Engineering Technician

Table A4 Solar positions not used in Indeed analysis

Plumber with Solar Expertise
Solar Installation Helper
Solar Marketing Specialist
Code Official with Solar Expertise
Lawyer with Solar Expertise
Electrical Inspector with Solar Expertise
Residential PV System Designer
Solar Utility Procurement Specialist

Table A5 Hourly and salaried pay for solar positions from Indeed search and Government of Canada database [65]

Job Position	Education/Training Requirements	Pay for Specific Position if Provided (CAD/hr)	Pay for Specific Position if Provided (salary)	Average Pay for Position in Alberta (CAD/hr)	Average Pay for Position in Alberta (salary)	Average Pay Position Titles
Quality Assurance Specialist	Undergraduate degree	NA	NA	46.15	92,300	Manufacturing Manager
Industrial Engineer	Undergraduate degree	NA	NA	45.67	91,340	Industrial and Manufacturing Engineering
Environmental Engineer	Undergraduate degree	NA	NA	45	90,000	Civil Engineering
Mechanical Engineer	Undergraduate degree	NA	NA	48.72	97,440	Mechanical Engineering
Electrical Engineer	Undergraduate degree	NA	NA	52	104,000	Technical Services Electrical Engineering
Materials Scientist	Undergraduate degree	19.5–50	39,000–100000	52.59	105,180	Research Scientist—Composite Materials
Utility Interconnection Engineer	Undergraduate degree	NA	NA	46	92,000	Power Engineer and Power Systems Operator
Structural Engineer	Undergraduate degree	NA	NA	45	90,000	Civil Engineering
Power Systems Engineer	Undergraduate degree	NA	NA	46	92,000	Power Engineer and Power Systems Operator
Solar Energy Systems Designer	Undergraduate degree	NA	NA	46	92,000	Power Engineer and Power Systems Operator
Engineering Technician	Undergraduate degree	NA	NA	36	72,000	Mechanical Engineering Design Technologist
Electrician with Solar Expertise	College/apprenticeship/certificates	NA	NA	41.72	83,440	Power System Electrician
Advanced Manufacturing Technician	College/apprenticeship/certificates	NA	NA	30	60,000	Manufacturing Technician—Industrial Engineering
Instrumentation and Electronics Technician	College/apprenticeship/certificates	19.84–66.48	39,680–132956	37.5	75,000	Design Technologist, Electrical and Electronics
Process Control Technician	On-the-job training	22	44,000	46.15	92,300	Manufacturing Manager
Computer Numerical Control (CNC) Operator	On-the-job training	22–25	44,000–50000	21	42,000	Machine Operators and Inspectors—Electrical Apparatus Manufacturing
Solar PV Installer (residential/small commercial)	On-the-job training	19–29	38,000–58000	27	54,000	Residential and Commerical Installers and Servicers
Solar Installation Contractor	On-the-job training	25–37.50	50,000–75000	35	70,000	Contractors and Supervisors, Other Construction Trades, Installers, Repairers and Servicers
Solar PV Technician (commercial/utility)	On-the-job training	16/20	32,000–40000	27	54,000	Residential and Commercial Installers and Servicers

Job Position	Education/Training Requirements	Pay for Specific Position if Provided (CAD/hr)	Pay for Specific Position if Provided (salary)	Average Pay for Position in Alberta (CAD/hr)	Average Pay for Position in Alberta (salary)	Average Pay Position Titles
Mechanical Assembler	On-the-job training	NA	NA	22.15	44,300	Mechanical Assemblers and Inspectors
Solar Sales Representative (Retail)	On-the-job training	17.64–52.95	35,272–105,893	20.84	41,680	Retail Sales Supervisors
Solar Site Assessor	On-the-job training	19–29	38,000–58000	48.56	97,120	Assessors, Valuators, Appraisers

Table A6 Cost of bachelor's degrees from all universities with relevant programs in Alberta

Institution	Low Cost of Bachelor's Degree	High Cost of Bachelor's Degree
University of Alberta	45,783.04	NA
University of Calgary	46,560.24	47,834.80
Athabasca University	29,920.00	NA
Southern Alberta Institute of Technology	32,738.50	NA

Table A7 Cost of a university transfer credential at all universities and colleges that hold relevant university transfer programs. Single cost values provided for each program

Institution	Cost of University Transfer
Red Deer Polytechnic	9,519.00
Keyano College	5,239.84
Northwestern Polytechnic	8,462.04

Table A8 Cost of a diploma or certificate from relevant colleges in Alberta. Colleges that only offer diploma programs are indicated

Institution	Low Cost of Diploma or Certificate	High Cost of Diploma or Certificate
Northern Alberta Institute of Technology[a]	10,584.00	17,280.00
Southern Alberta Institute of Technology	5,130.00	13,440.00
Red Deer Polytechnic[a]	9,117.00	9,546.00
Lethbridge College[a]	16,850.00	18,073.00
Northwestern Polytechnic	3,866.75	10,648.07
Medicine Hat College	5,450.00	21,945.59
Olds College	7,025.65	13,719.10
Keyano College	6,705.92	7,970.84
Portage College, Lac La Biche Campus	2,640.87	NA
NorQuest College, Edmonton Campus	16,197.62	16,462.00
Yellowhead Tribal College	9,460.00	NA

[a] Only diploma (2 year) programs offered

Table A9 Cost of an apprenticeship program from all colleges with relevant programs in Alberta

Institution	Low Cost of Apprenticeship	High Cost of Apprenticeship
Northern Alberta Institute of Technology	2,880.00	5,760.00
Southern Alberta Institute of Technology	1,005.00	5,568.00
Red Deer Polytechnic	NA	NA
Lethbridge College	3,487.2	6,005.08
Northwestern Polytechnic	3,309.12	7,715.52
Medicine Hat College	2,700.35	5,643.10
Olds College	4,895.13	6,526.84
Keyano College	3,683.88	4,911.84
Portage College, Lac La Biche Campus	3,409.47	5,025.96

Abbreviations

CAD	Canadian dollars ($)
CO_{2e}	Carbon dioxide equivalent
C_{term}	cost of attendance per term, inclusive of all estimated and actual tuition and required fees (bus passes, required textbooks, etc.) not including the cost of living, per year or other unit of time provided (CAD/term, CAD/year)
C_{total}	total cost of attendance (CAD)
EV	electric vehicle
H	number of hours per week worked (hours)
K	number of weeks per year worked (weeks)
N_{term}	number of terms or years required for completion of an undergraduate degree at full time (15 credits for most universities) (terms, years)
$N_{workers}$	number of workers in each category (workers)
P	percent of the total workers in each subcategory
$P_{workers}$	percentage of total workers in each category (%)
PV	photovoltaic
$T_{workers}$	total number of workers in the U.S. Solar industry according to U.S. Solar Census (workers)
RE	renewable energy
V2G	vehicle to grid
W_{job}	number of workers in a given job category (people)
W_{total}	total number of people in that region for a specific level of training (people)
W_{year}	yearly wage ($CAD)
W_{hour}	provided hourly wage ($CAD)

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