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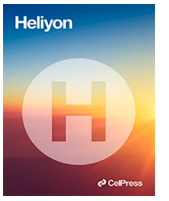

Research article

Sentiments toward use of forest biomass for heat and power in canadian headlines

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ABSTRACT

Replacement of fossil fuels with bioenergy, often in concert with carbon capture and storage, plays an important role in published low-emission pathways from the Intergovernmental Panel on Climate Change (IPCC) and other agencies. National and regional net-zero greenhouse gas emission commitments have caused a dramatic increase in forest biomass consumption globally, and the rise has been accompanied by debates in the scholarly literature and in society at large about the ecological and climate change impacts of forest biomass. This paper presents a quantitative analysis of media headlines about forest bioenergy published in 75 Canadian newspapers from 2010 to 2020. Using a lexicon and rules-based sentiment analysis tool, we explore negative and positive media headlines about forest biomass. Despite our finding that Canadian headlines about forest bioenergy were twice as likely to be positive as negative, media items document reversals away from forest biomass-generated domestic electricity. Our analysis found that increases in electricity costs following the introduction of forest biomass as a fuel type for Canadian electricity generation was a primary cause of these reversals. Headlines also critiqued the expanded production of wood pellets, citing forest ecological impacts and the debate about the net carbon impacts of forest biomass-generated energy. Safety issues, including stories about workplace injuries, and pellet plant fires, and economic issues, such as fiber supply and mill closures, were also featured. This research contributes a social science lens to understand perceptions over time about forest biomass for heat and power.

1. Introduction

Replacement of fossil fuels with bioenergy, often in concert with carbon capture and storage, plays an important part in IPCC and other published low-emission pathways [1–3]. The Energy Roadmap 2050 of the European Commission [4] and the revised renewable energy directive [5] have encouraged growth in wood pellet demand. Various national net-zero emission commitments pledging to balance anthropocentric emissions of greenhouse gases with anthropocentric removals also increased global demand for bioenergy. For instance, the United Kingdom's Climate Change Act of 2008 was followed by a nine hundred percent rise in use of wood pellets to support large scale electricity generation from 2008 to 2016 [7]. In Japan, biomass-generated electricity rose ninety percent between 2015 and 2020, with the sixth Strategic Energy Plan in 2021 calling for a doubling of energy from biomass by 2030 [8]. In Korea, importation of biomass grew fifty-fold after introduction of the Renewable Portfolio Standards policy in 2012 [9].

Along with the surge in international wood pellet markets, social and environmental concerns associated with bioenergy have

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featured prominently in the research literature [2,10,11]. "Land intensive bioenergy", defined as bioenergy cultivated or harvested from terrestrial plants, has been criticized in particular [12–14]. In 2018, published articles challenged the "current assumption of carbon neutrality" of forest biomass [15–18], debating whether an increased bioenergy demand compromises forests' ability to act as a carbon sink [19], and whether different accounting approaches omit emissions, either at global or regional levels [20]. Research has also drawn attention to the effects of rising biomass harvest on forest ecosystem health and biodiversity [12] and the relative greater mitigation potential for forest protection compared to harvest [21].

The discourse about forest biomass is characterized by complexity [22,23], disagreement [24] and sometimes change. Shifts in public opinion, influenced by media coverage, can arguably determine bioenergy project feasibility [25]. For instance, in China, a dramatic rise in negative news articles in 2003 preceded a policy change away from food-based bioenergy/ethanol [26]. Reflective of such criticisms, policy frameworks have moved to discourage bioenergy projects that conflict with food production [14,27].

1.1. Social acceptability of forest-based bioenergy

Social acceptance of bioenergy is multi-faceted. On one hand, leaders in communities dependent on fossil fuels appreciate the potential for energy independence offered by bioenergy [28–30]. However, in England, support for bioenergy was characterized as conditional or "difficult to operationalize in the real world," in part because of a lack of knowledge, but also reflective of ambivalence expressed toward projects [27, p. 6]. German and American studies found that social acceptance of bioenergy was linked to perceptions about energy corporations [31,32].

Besides global concerns, local considerations are also extremely important to deciding whether bioenergy projects can be undertaken [33–36]. For instance, because of the prevalence of direct burning of local waste materials for energy in Africa, small-scale bioenergy technology was proposed to improve respiratory health as well as access to electricity [30]. However, technical aspects such as biomass contamination and raw material unreliability contributed to four failed pellet plants in South Africa [36]. Japan's growing adoption of bioenergy occurred in the shadow of the 2011 Fukushima nuclear reactor disaster [8]; for six pilot projects in Japan, number of media channels and *growth* in public acceptance for bioenergy predicted project success, rather than *initial* community acceptance of bioenergy [37]. In Canada, Indigenous business leaders connected with energy independence offered by biomass energy, but inequity of benefits from forest resources and land use practices were substantial issues documented in the scholarly literature [29, 42].

1.2. Role of media and headlines

Historically, bioenergy has had a lower profile than other fuel sources [38–42]. Particularly when people have low levels of awareness about a topic, media play an important informational role. Reflecting and shaping public perceptions, news media help "with the construction of meaning of artifacts such as biomass energy, and that in order to construct this meaning, the media draws from multiple actors within society such as scientists, policy makers and publics to produce a collective meaning of that technology" [41, p. 3061].

Headlines play an important role in the news ecosystem, influencing interpretation of news stories [43]. Arguably, headlines also "set the tone about the main text body of the article and affect readers' processing of articles' content" [44, p. 1]. As well, given the rise

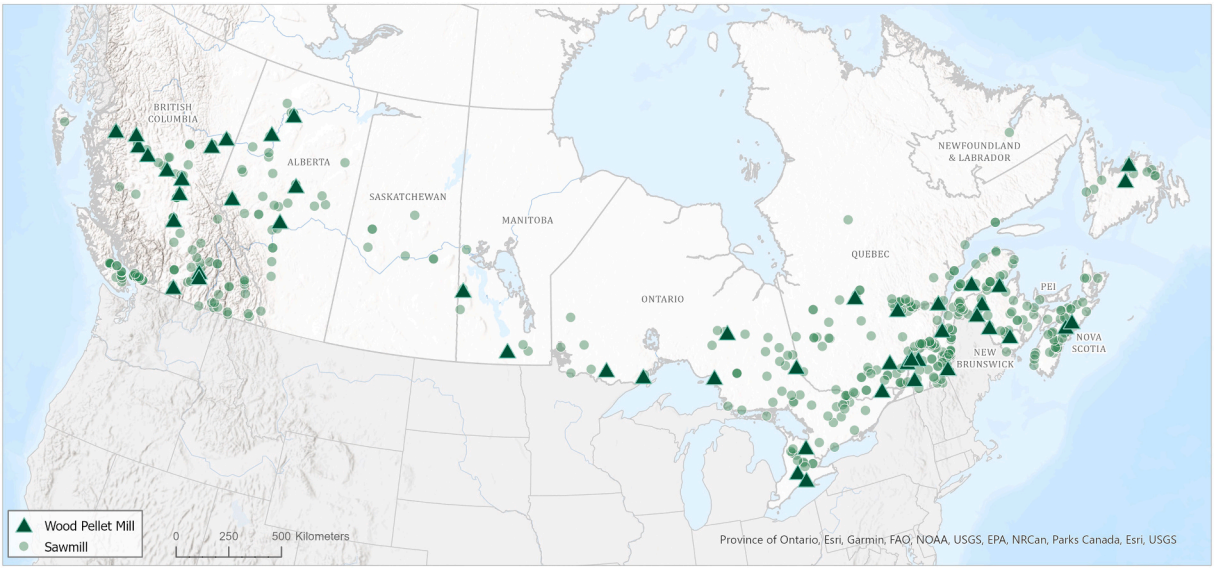

Fig. 1. Location of wood pellet mills and sawmills in Canada.

of news aggregators, headlines are increasingly used in isolation by news consumers [45], rather than consumption of entire news articles.

Research shows that by some measures, negative headlines and media have greater impact than positive news. With respect to bioenergy, negative media and reports about bioenergy were repeated more often than positive stories [46]. In general, a trend toward greater use of negative sentiment in U.S. news coverage conveys greater influence of negative emotion in media communication [44].

1.3. Canadian context

Public perceptions about the use of forest biomass for heat and electricity are important, in part because of Canada's role as a supplier of wood pellets globally. Canada is the third largest pellet producing country in the world, behind the U.S. and Germany. In terms of production, Canadian wood pellet mills are typically located near sawmills (Fig. 1 [47]). In Canada, waste from production of lumber or other forest products is used by sawmills to power their operations [48], sold directly to consumers in some cases, as well as to produce wood pellets. After production, wood pellets are either sold to the domestic market, or stored until transportation to ports before being shipped to international markets.

Despite being a significant producer, Canada is a relatively light user of woody biomass for heat and power [7]. Woody biomass comprises less than ten percent of heat energy and less than two percent of electricity in Canada [29]. Instead, eighty to ninety percent of Canadian pellet production is exported, mostly to Europe and Asia [49–51], rather than consumed domestically. Historically in Canada, multiple efforts have been made to switch electricity generation fuel-types from coal to forest biomass, particularly in provinces with wood pellet capacity. For instance, Ontario's Green Energy and Green Economy Act of 2009 created a feed-in tariff program designed to incent renewable electricity generation via biomass, biogas, wind and solar technologies [52], which was replaced by a bidding system in 2013 [53]. In 2015, Alberta announced plans to transition away from coal-generated electricity completely, which in 2015 supplied over half of the province's domestic electricity [54], but this effort was ultimately not completed as thirty-six percent of Alberta's electricity was still from coal in 2019 [55].

In fact, from 2010 to 2020, multiple Canadian provincial policies supported the use of forest bioenergy to generate domestic electricity (Table 1). In 2010, British Columbia began consultations on a feed-in tariff program which would enable supply contracts with small-scale electricity providers producing power from biomass, biogas, geothermal, hydro, solar, ocean, and wind. Ontario's 2010 Long-Term Energy Plan specified that one coal generator (Atikoken in Thunder Bay, Ontario) would be converted to biomass as a fuel source [56](OPA, 2011). In 2012, the Québec government introduced its Climate Change Action Plan, which called for a total of 700 MW of biomass-generated energy [57], and in 2016, the Québec government introduced the 2030 Energy Policy, continuing a focus on residual forest biomass as a fuel in power plants [58]. By 2016, both the provinces of Alberta and British Columbia introduced climate leadership plans which included establishing incentives for biomass-generated electricity.

Despite policy changes regarding bioenergy provincially in Canada from 2010 to 2020, there has been no increase in Canadian use of biomass for electricity generation. Instead, biomass-fueled electricity fell from 1.4 to 1.2% of domestic electricity nationally over this period [59]. Temporal patterns of biomass uptake were distinct provincially (Fig. 2, for provinces with more than 500 Gigawatt hours of biomass generation).

Biomass-generated electricity rose in 2014 in British Columbia and Alberta, before declining in 2015. Québec was a smaller user of biomass as a fuel source for electricity than British Columbia or Alberta from 2010 to 2020, but the share of Québec electricity generated by biomass expanded between 2013 and 2017. Finally, in Ontario, biomass-generated electricity doubled between 2013 and 2016 from 586 GW h to 1444 GW h, although this still represented only one percent of domestic electricity in this province.

1.4. Approach and aims

This paper presents a systematic analysis of sentiments towards the use of forest biomass for heat and electricity as expressed in Canadian news headlines from 2010 to 2020, a decade in which multiple Canadian provinces introduced policies to promote domestic use of forest-based bioenergy. In general, the goal is to assess sentiment expressed in Canadian news headlines about forest bioenergy. More specifically, given little domestic uptake of forest bioenergy currently, Canadian news headlines are explored to identify reasons for continued low use of bioenergy domestically for electricity generation. In particular, we focus a portion of the analysis on British Columbia, Alberta, Ontario and Québec to explore media responses to changes in bioenergy usage for domestic electricity generation documented in these provinces.

Table 1
Canadian provincial legislation relevant to forest bioenergy from 2010 to 2020.

Province	Legislation	Year
Ontario	Long-Term Energy Plan	2010
Québec	Climate Change Action Plan	2012
Alberta	Climate Leadership Plan (CLP)	2015
British Columbia	Climate Leadership Plan	2016
Québec	2030 Energy Policy	2016

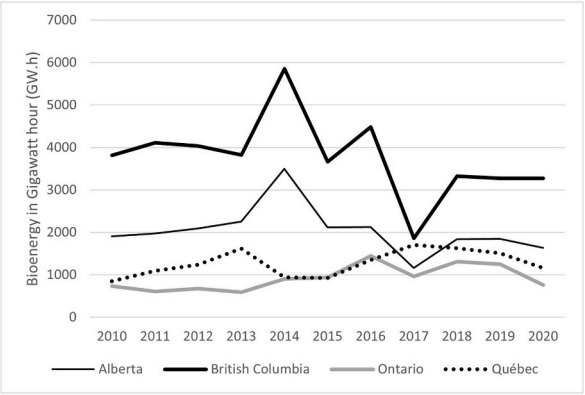

Fig. 2. Biomass-powered electricity, 2010–2020 (data from the Canada Energy Regulator), Alberta, British Columbia, Ontario, and Québec.

2. Material and methods

2.1. Media scan

The analysis was completed on a database of news articles related to forest-derived biomass for heat and electricity, in French and English, from all regions of Canada. Headlines were extracted from 75 Canadian newspapers from 2010 to August 2020 (Appendix A). In addition to local (city-based) newspapers, we also included online news articles from the Canadian Broadcasting Corporation (CBC) and the Canadian Television Network (CTV), which provide free national news coverage. Six industry news publications were included in our sample characterized as forest, biomass or pulp and paper industry publications (Appendix 1).

For English-language publications, we queried the terms "bioenergy", "biomass", "biofuel", "clean fuel standard", "wood pellet", and "wood store" in the online newspaper search engines. For French language publications, we queried the terms "bioénergie", "biomasse", "bioraffinerie", "granules de bois", and "pellets de bois." The terms used as the basis for the search initially included bioenergy and biomass (consistent with 46 and Uren et al., 2016), but expanded to include "wood pellets" (or granules de bois/pellets de bois in French) after a portion of the data scan completed revealed wood pellets was a common key phrase linked to pertinent news items. The Clean Fuel Standard [60,61], which addresses biofuel content in diesel and gasoline, was also included as search terms, as was the Canadian Wood Store, based on direct relevance to bioenergy, although the focus of this analysis was not on any one policy or program, but rather on social reactions to forest-based biomass. The sample of headlines included news articles and opinion pieces from regular reporters/contributors but excluded letters to the editor from non-staff writers. The database does not include investigative journals with longer textual articles.

2.2. Quality control of headline dataset

Each article was read to confirm that it pertained to forest-based biomass. While the initial search terms included the Clean Fuel Standard and the Canadian Wood Store, headlines resulting from these search criteria were ultimately dropped from this analysis. Specifically, the Clean Fuel Regulations under the Canadian Environmental Protection Act was passed in 2022; therefore, the time period selected for the current analysis was not conducive to a complete analysis of media responses to this regulation. In the case of the Canadian Wood Store, the search did not produce any results for this term.

As each article was read for its content, duplicate headlines were identified and removed from the main analytic dataset (but retained separately for additional analysis). In a small number of cases, duplicate headlines were retained in the database if the duplicate headline contributed distinct information to the database (e.g., regional representation or additional news article information).

2.3. Sentiment analysis

We analyzed the news media titles – headlines – in our database with VADER (Valence Aware Dictionary and sEntiment Reasoner), an open-source, rules-based Python model designed for sentiment analysis. VADER is a lexicon and rules-based analysis which assigns a quantitative score to textual content reflecting both the direction and intensity of the sentiment expressed [63,65]. Here we present a short justification for our use of VADER but interested readers may consult [63] for details of its development and testing. Specifically, our reasons for selecting VADER are two-fold: this method is open-source (and therefore, replicable); second, research has demonstrated that not only does VADER perform well against human raters [63], but VADER also performed best in published multi-class experiments [66].

We analyzed sentiment as quantified by VADER's overall ("compound") score, which ranges from −1 (i.e., very strong negative sentiment) to 1 (i.e., very strong positive sentiment). We focused on article titles, as VADER is designed primarily for short text

communications, although analysis of longer text material also is possible. Sentiment scores were compared statistically in SAS Version 9.4 of the SAS System for Windows. Using a Welch *t*-test for two independent samples, we compared the average sentiment scores between the following groups: a) national media compared to local newspapers; b) industry publications (as listed in Appendix A) compared to all other publications; and c) media by Canadian province. T-tests generated from PROC REG in SAS were used to statistically test the dependence between the proportion of headlines by province on a) the proportion of wood pellet mills; and b) the percentage of Canadians by province, using an alpha of 0.05. Finally, a single sample *t*-test was used to test whether VADER sentiment scores were significantly different from 0 (neutral) overall and by year.

2.4. Keyword analysis

To identify key words, we utilized COUNTW and WORDFREQ in SAS. Using the word counts, we constructed word clouds using Microsoft Publisher focusing on the most common headline words for headlines with a positive versus negative VADER composite score. Words listed in 2.1 which were used in the search (e.g., "biomass", "bioenergy", "pellet") were dropped from the keyword analysis, as well as components of the search terms such as bioenergy, energy, pellet, or wood, non-specific action words such as "says", and proper names such as British Columbia.

3. Results

3.1. Number of articles

Our initial search yielded 1065 media articles from 75 newspapers. Follow-up examination of the list of media titles revealed 56 duplicate titles, which were removed from the following analyses. A further 140 were not primarily related to forest bioenergy and were also removed from the database. The final headline database contained 877 articles, distributed spatially and temporally as illustrated in Table 2.

The percentage of articles by province was statistically predicted by the proportion of pellet mills ($t = 7.21$, $p < 0.05$), but not by the proportion of the Canadian population ($t = 2.11$, $p > 0.05$). News articles about forest biomass were most concentrated in the provinces of British Columbia (33.2%), Québec (22.1%), and Ontario (17.7%), with 10.3% of articles originating in Atlantic Canada and 9.6% of articles published in Alberta. Particularly for pellet producing provinces, the distribution of forest biomass news articles was comparable to the proportion of pellet mills rather than to the proportion of Canadians (Table 3).

For instance, one-third of news articles identified were from British Columbia, similar to the proportion of pellet mills in this province (37.8%), but much higher than the percentage of Canadians in this province (13.1%). Ontario accounted for 17.7% of news articles about forest bioenergy in our sample. This proportion is much lower than Ontario's proportion of the population (38.1%), but more like the percentage of wood pellet mills located in Ontario (13.5%). We identified 79 headlines from four provinces in Atlantic Canada (10.3%), which is lower than the percentage of pellet mills in this region (18.9%). Because of the small number of headlines from this region, as well as from the three territories (Yukon, Northwest Territories, and Nunavut), as well as provinces Saskatchewan and Manitoba, we have restricted more in-depth regional analyses to British Columbia, Alberta, Ontario, and Québec.

In terms of temporal coverage, the dataset of media headlines is concentrated in more recent years, with only 15 articles identified in 2010 and 32 in 2011. Some publications archived older articles in searchable repositories online, but other publications (such as CTV news) retained a more limited online catalogue of historical news articles. Besides general news publications, our sample of headlines includede 55 articles from business or industry news publications (Appendix A).

3.2. Sentiment analysis – general themes

Across all media articles reviewed, the average VADER sentiment score was 0.06, significantly different from zero ($t = 5.99$, $df = 820$, p-value <0.01), indicating that the typical sentiment of media titles was positive. About forty percent of the headlines were

Table 2
Number of news articles by year and by region.

Region	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Count of Headlines (2010–2020)	% of Head-lines by region
National	1	3	12	8	8	15	13	7	6	20	14	107	–
British Columbia	1	12	13	15	24	16	36	28	35	60	16	256	**33.2%**
Territories	0	0	0	1	2	1	5	2	2	4	4	21	**2.7%**
Alberta	8	4	4	4	3	10	15	11	4	11	0	74	**9.6%**
Saskatchewan	0	0	0	1	0	3	4	2	2	7	0	19	**2.5%**
Manitoba	0	0	2	1	0	1	3	4	1	3	0	15	**1.9%**
Ontario	0	5	3	5	14	12	27	21	28	20	1	136	**17.7%**
Québec	2	7	7	17	9	24	16	18	35	34	1	170	**22.1%**
Atlantic[a]	3	1	6	13	8	4	5	6	9	18	6	79	**10.3%**
Total	**15**	**32**	**47**	**65**	**68**	**86**	**124**	**99**	**122**	**177**	**42**	**877**	**100.0%**

[a] Includes Nova Scotia, Newfoundland & Labrador, New Brunswick, and Prince Edward Island (PEI).

Table 3
Proportion of news articles compared to the proportion of wood pellet mills and Canadian population by province.

Province	% News Items in the Sample	% Wood Pellet Mills [32]	% Canadian Population (Census, 2016)
British Columbia	33.2%	37.8%	13.1%
Territories	2.7%	0	0.3%
Alberta	9.6%	10.8%	11.6%
Saskatchewan	2.5%	0	3.1%
Manitoba	1.9%	0	3.7%
Ontario	17.7%	13.5%	38.1%
Québec	22.1%	18.9%	23.3%
Atlantic	10.3%	18.9%	6.5%
Canada Total	100.0%	100.0%	100.0%

assigned a neutral score by VADER (score of zero). Overall, VADER composite sentiment scores were relatively neutral, falling mostly between −0.1 and 0.1.

National news titles were significantly more negative compared to regional headlines, with an average VADER score of −0.03, compared to an average VADER score of +0.06 for local/regional newspaper titles ($t = 3.17$, $df = 111.71$, p-value = 0.002). with respect to regional differences, only ontario newspaper headlines were statistically different from articles from other regions

VADER scores of industry publications were not significantly different from other publications ($t = 0.26$, $df = 61.64$, p-value = 0.796). Negative industry headlines featured wood pellet plant closures, for instance: “High cost, lack of use shutters Thunder Bay Generating Station” [67]. Negative headlines from industry publications also addressed pellet supply: “N.S. firewood supplies down, biomass to blame?” [68].

In total, VADER identified almost twice as many positive news stories about bioenergy compared to negative stories (Table 4). Specifically, one-third of articles were assigned a positive VADER composite score compared to 18.5% of articles with a negative VADER composite score. The largest number of articles about forest biomass were neutral (48.2%).

Across ten years, one in five headlines was negative (162 out of 877 headlines). Nationally, the average VADER score for the last three months of 2014 was −0.15, related to negative headlines in British Columbia (described in the following section). Another peak in negative articles was apparent in 2020, when the percentage of negative articles doubled from 20.3% in 2019 to 45.2% in 2020. In 2020, there were reports of a wood shortage, criticism of forest biomass carbon accounting, and a derailment of a train carrying pellets. The words in Fig. 3 illustrate common words in positive versus negative headlines across all years. Negative themes included biomass shortage, as well as articles about explosions or fires at mill sites. Positive themes included new renewable power projects and plans.

Media documented reversals away from forest biomass-fueled domestic electricity was described as hurting the domestic demand for wood pellets for heat, as was competition for wood pellet by exporters [68]. Media coverage also drew attention to the negative social effects of policy reversals and consequent plant closures: “I’ve seen families and businesses leave town. I’ve seen people scared for their livelihoods and those of their neighbours.” [69]. The effect of the change in ownership of the Atikokan, Ontario wood pellet mill was described in 2018: “[Employees] went through a time of uncertainty – there’s no doubt” [70].

Safety-related topics also proved to be a source of numerous headlines which were assigned the most negative scores by VADER. This included national media coverage of accidents at pellet plants, pellet plant fires, and derailments of trains carrying wood pellets, as well as similar coverage by city-based newspapers. Besides safety issues, media covered public complaints about wood pellet facilities, particularly about noise and air quality, as well as related to aesthetic (visual) concerns. For instance, silos built to store wood pellets in Québec were repurposed due to public opposition [71]. Headlines about wood pellet dust and terminal noise were reported as well [72].

Canadian news headlines highlighted social discord related to ecological impacts of forest biomass, including media reporting on old growth forests harvested to feed provincial electricity generators [73], as well as media coverage of scholarly publications about forest biomass carbon neutrality. At the same time, a substantial portion of the positive articles highlighted the environmental benefits of forest biomass [74].

Table 4
Canadian News Articles Assigned a Positive, Neutral, or Negative VADER Score by Year (Count, Percent, Column Percent). Neutral: VADER score of 0.

Sentiment	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Negative	**3**	**6**	**5**	**8**	**15**	**16**	**19**	**14**	**21**	**36**	**19**	**162**
	0.3	0.7	0.6	0.9	1.7	1.8	2.2	1.6	2.4	4.1	2.2	18.5
	20.0	18.8	10.6	12.3	22.1	18.6	15.3	14.1	17.2	20.3	45.2	
Neutral	**8**	**12**	**27**	**39**	**37**	**43**	**58**	**49**	**54**	**79**	**17**	**423**
	0.9	1.4	3.1	4.5	4.2	4.9	6.6	5.6	6.2	9.0	1.9	48.2
	53.3	37.5	57.5	60	54.4	50	46.8	49.5	44.3	44.6	40.5	
Positive	**4**	**14.0**	**15**	**18**	**16**	**27**	**47**	**36**	**47**	**62**	**6**	**292**
	0.5	1.6	1.7	2.1	1.8	3.1	5.4	4.1	5.4	7.1	0.7	33.3
	26.7	43.8	31.9	27.7	23.5	31.4	37.9	36.4	38.5	35.0	14.3	
Total	**15**	**32**	**47**	**65**	**68**	**86**	**124**	**99**	**122**	**177**	**42**	**877**
	1.7	3.7	5.4	7.4	7.8	9.8	14.1	11.3	13.9	20.2	4.8	100

Fig. 3. Word cloud of positive and negative words in Canadian headlines about bioenergy (words from headlines with a positive VADER score in green, and words from headlines with a negative VADER score in red). Words that occurred 5+ times in headlines with both negative and positive VADER scores are presented in black font.

3.3. Sentiment analysis – regional trends

The four provinces with greatest consumption of biomass-generated electricity showed different patterns in terms of headline sentiments (Fig. 4), In 2013, British Columbia news headlines ranged from −0.42 to +0.84. In 2013, British Columbia news articles described a white paper from the Pacific Institute for Climate Solutions which proposed that fossil fuel burned in BC could be replaced by wood waste [75]. By 2014, British Columbia use of bioenergy for electricity peaked, accompanied by increased media coverage, with VADER scores ranging from −0.89 to +0.65. In 2014, protests at a terminal, pellet dust and noise reported by British Columbia residents produced headlines with negative VADER scores.

By 2016, British Columbia use of bioenergy for electricity production dropped by 58% of 2015 levels. In 2017, British Columbia headlines reported provincial spending of $58 billion in independent power producer contracts (including biomass-generated power projects), the province's single largest contractual obligation, according to the British Columbia Auditor General [76]. In 2019, British Columbian 100 Mile House Free Press described "B.C.'s private power vision" as showing up "as big charge to hydro bills" [77].

In Alberta, the introduction of a provincial carbon tax was followed in 2016 b y calls to discontinue provincial support for biomass generated electricity [78]. Albertan consumption of biomass to produce domestic electricity declined from a peak of 3500 GW h in 2014–2120 GW h, in 2016, which in either case represented a small fraction of provincial electricity consumption (80,773 GW h in total). In this province, coal usage declined by 37% in 2020 compared to 2010, but natural gas-generated electricity rose by 62% over

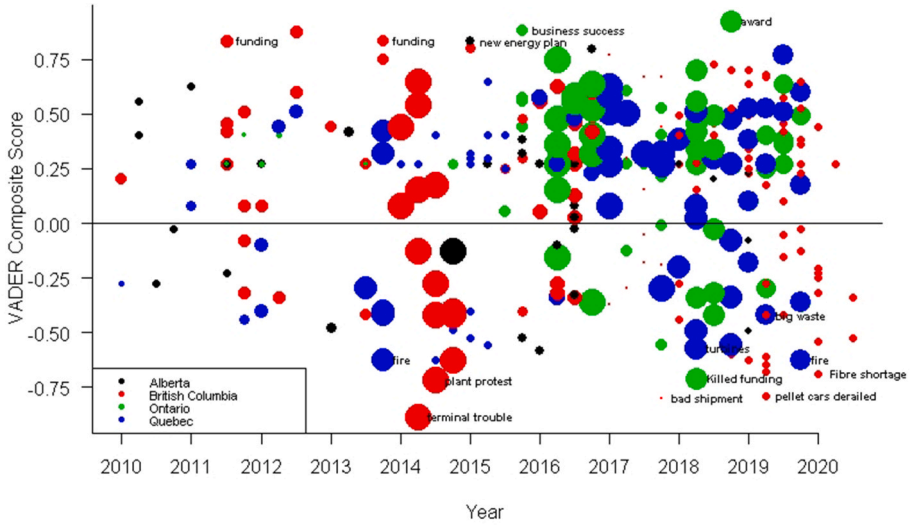

Fig. 4. Scatterplot of headlines with non-zero VADER composite score (Alberta, British Columbia, Ontario, and Québec), size of symbol indicates share of bioenergy usage as a percentage of the maximum bioenergy usage from 2010 to 2020 (data from the Canada Energy Regulator), size of symbol is derived from Fig. 2.

the same period to almost 60% of Alberta electricity consumption [79].

In Ontario, the move to renewables (and specifically electricity from forest biomass) was criticized in 2016 as costing millions more than 'market price' [80]. Ontario media reported on a suggested "course correction" published by Canada's Ecofiscal Commission which described the years 2006–2011 in Canada as corresponding with "a period of aggressive support from federal and provincial governments" [81] which were costly relative to a carbon tax. Ontario headlines in 2016 also urged Canadian provinces to learn from Ontario's mistakes when transitioning away from coal-powered electricity, and "never take their eye off the affordability ball" [82]. By 2018, negative headlines also conveyed negative effects of policy changes on communities [83].

Of 89 headlines from Québec, sixteen were assigned a negative VADER score. In 2013, a fire at a pellet mill caused a negative headline. By 2014, a year after Québec usage of bioenergy rose to over 1600 GW h, Le Journal de Montréal reported that grants to generate electricity from biomass (among other investments) amounted to throwing money out of the window. After bioenergy peaked again in 2018 to over 1700 GW h, Le Journal de Montréal reported on "Billions wasted for nothing" (May 23, 2018) and "Big waste at Hydro-Quebec" (April 23, 2019).

In summary, we registered negative headlines related to bioenergy for electricity in the four profiled provinces. Notably, these four provinces have very different energy profiles. British Columbia and Québec both rely primarily on hydroelectric power (89.1% and 95.2% of provincial electricity generation respectively, CER, 2022). In Alberta, natural gas-generated electricity grew from 39.2% of the provincial total in 2010 to 58.8% in 2020; conversely, coal-generated electricity diminished from 53.4% of electricity in 2010 to 30.8% but was still substantial at 23,500 GW h of electricity in 2020 (CER, 2022). Finally, most Ontario electricity generation over the study period was fueled by nuclear power (56.3% in 2010 and 53.8% in 2020, CER, 2022).

3.4. Study limitations

Despite our best efforts, there were some shortcomings associated with our sample. For example, several pay-to-access publications (e.g., Globe and Mail) were not included in our initial analysis due to budget limitations. To measure the effect of omitting paywalled publications on our analysis, we developed a separate dataset of headlines from one major pay-to-access publication, the Globe and Mail, and completed a qualitative analysis to determine whether stories in the Globe and Mail were picked up by other publications in the database. Twenty of 28 stories covered by the Globe and Mail were picked up by other publishers. Articles that were unique to the Globe and Mail (Table 5) tended to be opinion pieces such as "There's a role for biomass energy in Ontario" (June 14, 2011) or "The long journey of a Canadian wood pellet" (February 11, 2013) which were similar to other headlines (e.g., "Biomass is the next obvious source of energy", the Record, August 15, 2011).

Besides the Globe and Mail, the majority of other paywalled publications were Postmedia serials (e.g., British Columbia Province, Toronto Sun - Ontario). Arguably, the ability to track headline trends in our study was mitigated because of representation of other serials from this publisher in the same province (e.g., Vancouver Sun – British Columbia, 30 articles; Ottawa Citizen - Ontario, 14 articles) by this publisher. There was at least some evidence that serials from the same publisher ran similar stories; 39 of 56 duplicate headlines originated from publishers that had representation from other serials in the database.

Another weakness of our study is that is does not consider Atlantic Canada headlines. Although the number of headlines for Atlantic provinces (Nova Scotia, New Brunswick, Prince Edward Island, and Newfoundland and Labrador) was small (79), these headlines may nevertheless support a qualitative analysis. In particular, analysis of Nova Scotian headlines (43) may be possible.

4. Discussion

Little work has been done to systematically study sentiments towards forest bioenergy within Canada. This is an oversight, because Canada is one of the top three producers of wood pellets internationally. Further, the market for biomass is expected to grow, with some estimates suggesting that the market for biomass is larger than coal or natural gas [84]. The IPCC 6th Assessment Report on Mitigation points out that bioenergy has the potential to meet net-zero goals in Germany, the Netherlands, France, and other countries, and that additional imports may be needed to meet European demand [1].

Despite being a significant producer of forest biomass, Canadian use of forest biomass for electricity and heat is described as underdeveloped [85]. This paper provides a cautionary tale about why uptake of forest biomass for electricity, at least, was not popular during multiple attempts in Canada to increase forest biomass for domestic electricity generation. While general media coverage about forest biomass in Canada was relatively neutral (or slightly positive), the headlines also reveal a repeated pattern as Canadian jurisdictions shift away from the domestic use of forest biomass for bioenergy production due to cost.

Our analysis also highlights the existence of a wide range of issues which produced negative media coverage. Negative sentiments scores were identified for headlines covering the ecological impacts on forests due to biomass harvesting, fires or explosions at wood pellet plants, noise and air quality issues related to pellet plants, concern about forest harvest sustainability, and fiber supply. Scholarly articles about disputed carbon neutrality of forest biomass also generated negative headlines.

Our review of historic public acceptance of biomass as reflected in the media will remind technical practitioners that the social response to the use of forest biomass is a credible factor influencing the implementation of biomass pathways. Not only will a mix of different pathways will be needed to achieve net-zero commitments [86], but those pathways must continue to adapt in response to socio-economic responses. Our analysis contributes evidence of "socio-economic constraints" [87], which together with other factors, characterized the efforts covered in this study to increase bioenergy usage. Of course, this does not mean that successful adoption of bioenergy in other forms and contexts are not possible and occurring. As with any case study, our conclusions are limited to the particularities of our context.

Table 5
Stories/headlines from the globe and mail on forest-based biomass not picked up in other headlines.

Headline	Date
There's a role for biomass energy in Ontario	14-Jun-11
Europe is hot for this form of renewable energy	11-Feb-13
The long journey of a Canadian wood pellet	11-Feb-13
How wood pellet boilers work	14-Jan-14
Wood pellets help the North break its diesel habit	14-Jan-14
Renewable fuel from forest-based biomass	21-May-19
Alberta has its economic answer in front of them. Will they see the forest for the trees?	04-Dec-19

From a methodological perspective, one benefit of the VADER approach was its replicability. Our experience with this approach was that application of a rules-based sentiment analyzer, coupled with qualitative, in-depth analysis, was useful to highlight commonalities in policy moves away from forest-based biomass for Canadian domestic electricity generation. A potential drawback of the methodological approach is the possibility that headlines do not faithfully represent the content of the article, and instead, sentiments expressed in headlines may be more extreme (positive or negative) to attract readers. On the other hand, headlines are themselves an important form of communication, and particularly in the age of news aggregators, news consumers are increasingly exposed to headlines as opposed to full articles.

5. Conclusions

This research presents a portrait of forest biomass as published by Canadian news media from 2010 to 2020. The database of over 800 headlines tells the story of how multiple provinces in Canada engineered a transition away from coal-based domestic electricity, in part reliant on forest biomass. In the decade from 2010 to 2020, however, several reversals occurred, which are documented in the media headlines analyzed for this study. Despite positive sentiment scores linked to bioenergy-related economic opportunities throughout the decade covered by the study, newspapers across the country reported on a mix of reactions to forest-based bioenergy, in particular for domestic electricity generation. Methodologically, this paper contributes a novel case study application of a rules-based sentiment coding approach to media data, in this case headlines about forest-based bioenergy, accompanied by a publicly available dataset.

Author contribution statement

Heather MacDonald, Ph.D.; Emily Hope; Kaitlin de Boer: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Daniel W. McKenney, Ph.D. Conceived and designed the experiments; Wrote the paper.

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Data availability statement

Data associated with this study has been deposited at Open Science Framework https://doi.org/10.17605/OSF.IO/J4FAW [88].

Declaration of interest's statement

The authors declare the following conflict of interests: Member of Bioeconomy Technical Working Group, which is composed of members of the Canadian Forest Service and the Ontario Forestry Institute.

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