Talking Transition

Appendix 2

Clean Power PATHWAYS

DAVID SUZUKI FOUNDATION

PERSPECTIVES ON CLEAN POWER PATHWAYS

Results from a survey of energy and electricity system stakeholders

Contents

Clean Power PATHWAYS

DAVID SUZUKI FOUNDATION

EXECUTIVE SUMMARY

More than 150 clean energy experts from across Canada provided their perspectives on reaching net-zero by 2050. The intent of the survey was to ascertain the perspectives of a wide array of energy and electricity system experts and stakeholders from across Canada on a variety of issues across six areas:

- Energy services
- Electricity decarbonization
- Electrification and end-use changes
- Enabling technologies
- Policy options
- Opportunities and challenges

The survey asked stakeholders to identify their own preferences and expert perspectives, as well as what they expected to be the attitudes of Canadians in general on several different issues.

Survey respondents represented a substantial depth of expertise and a wide breadth of organizational and sector affiliations, with particular concentration in the non-profit sector, energy efficiency and conservation. Given that the most highly represented provinces (British Columbia, Ontario and Alberta) possess very different energy/electricity systems, we believe the results of the survey nevertheless offer valuable insights into the diversity of potential clean power pathways to net-zero by 2050 in Canada.

Key findings include:

- Respondents expressed skepticism about the general public's energy literacy, energy system values and preferences, and willingness to engage in energy management, but did see promising changes in concerns and awareness of climate change and the need to address it.
- There is a relatively strong consensus that demand-side measures offer considerable potential to put Canada on a path to net-zero by 2050 in the near term, including energy efficiency and conservation, electrification of personal transportation and building retrofitting
- Where supply-side investments are required, stakeholders tended to prefer smaller-scale, distributed projects and/or renewable generation technologies. Few indicated support for large-scale new hydroelectricity or nuclear power.
- While many stakeholders indicated a preference for renewable energy plus energy storage and smart grids as a desirable pathway to decarbonization and electrification, some (but fewer) stakeholders expressed concern about the viability of these solutions in all sectors and regions, and stressed the importance of integrated energy/electricity solutions (e.g., use of renewable energy to produce hydrogen for use in heavy transport or industry).

Based on the information gathered in the respondent information section of the survey, we believe the results outlined below offer valuable insight into perspectives of the expert energy/electricity system stakeholders who are likely to play important roles in realizing a clean power future in Canada.

INTRODUCTION

Clean Power Pathways is a multi-year collaboration between the David Suzuki Foundation and university research partners aimed at building broad and enduring support for a suite of actions that will transition Canada's energy system at a scope, scale and speed in line with the climate crisis. It couples strategic electricity decarbonization modelling with effective public engagement and policy research to assess how Canada can clean its grid and electrify buildings and mobility.

As part of the Clean Power Pathways project, the David Suzuki Foundation contracted James Gaede (PhD, Carleton University) as an independent consultant in fall 2019 to assist with the design, delivery and analysis of a survey on stakeholder preferences for reaching net-zero by 2050.

This report provides further details on the structure and results of the survey.

The survey received a total of 153 fully complete responses with an additional 38 partial responses. Respondents reported substantial expertise in energy/electricity systems (65 per cent having more than six years' experience). In terms of areas and provinces of expertise, efficiency/conservation and generation were the most highly represented sectors and British Columbia, Alberta and Ontario were the most highly represented provinces.

- Survey respondents were asked a series of questions about their personal preferences (not the position of the organization[s] they were affiliated with) and their beliefs about Canadians' preferences in general with regard to the following six areas:
- **Energy services:** What electricity-system attributes Canadians will most value in a clean power future (e.g., reliability, affordability, non-emitting), and the extent to which Canadians will value opportunities to engage with and manage their energy services.
- **Electricity decarbonization:** Perspectives on future electricity demand, timelines for greater electrification of end-use, personal prioritization and preferences regarding different clean power generation sources, electricity system decentralization and general public acceptability of numerous clean power technologies.
- **Electrification and end-use changes:** Perspectives on the importance of a series of end-use strategies for reaching net-zero by 2050 (e.g., deep energy efficiency building retrofits, electrification of residential and commercial heating, net-zero building codes).
- **Enabling technologies:** Perspectives on the importance of a series of technologies and other public investments that could facilitate reaching net-zero by 2050 (e.g., interprovincial grid connections and trade, smart grids, energy storage, power-to-gas).
- **Policy options:** Perspectives on timelines and policy options (e.g., how Canada's carbon pricing should evolve after 2022) in different sectors (electricity generation, buildings, transportation) to reach net-zero by 2050.
- **Opportunities and challenges:** Perspectives on whether a series of statements pose an opportunity or a challenge for reaching net-zero by 2050 (e.g., The falling cost of renewable energy will facilitate reaching net zero by 2050; Rising ratepayer costs will be a barrier to reaching net-zero by 2050).

In total, 31 subject-matter questions were posed to survey respondents, eight of which were open-ended text response questions. All questions were optional. Because of survey software limitations, questions asking respondents to move a slider to select a target year for policy achievements did not include an option to indicate the respondent lacked adequate information to answer. A copy of the survey is included with this report as Appendix A.

Five additional questions request basic information about the respondent, including organizational affiliation, sector of expertise, years of experience and provinces in which they had expertise. For respondents who indicated expertise in electricity generation, the survey also collected information about the type of generation with which they were familiar. Questions about organizational affiliation, sector of expertise, type of generation technology and provinces in which the respondent had experience were all multi-choice, multi-response questions (meaning respondents could select as many options as applied).

The survey was administered online, via Limesurvey, and distributed to a list of contacts including targeted experts and partnering/pre-identified organizations (per the Clean Power Pathways mailing list) involved in the energy and electricity sectors. Recipients were asked to distribute the survey link to their own contact lists. A link was also posted online via LinkedIn and an invitation to participate in the survey shared with energy stakeholders via Twitter. The survey remained open between November 25 and December 16, 2019.

There was no compensation for completing the survey, and responses were anonymized. The survey instrument was designed such that respondents who indicated they were not based in Canada were not offered the opportunity to complete the survey and thus were not included in the sample.

Respondent characteristics

A total of 310 people viewed the survey and 153 completed it. Of the 310 attempts, 119 respondents exited the survey after completing only the respondent information questions and where thus removed from the final dataset. Consecutively smaller portions of the remaining 191 responses completed each of the subsequent six sections. The total number of included responses per section are shown in Table 1. The information about respondents provide below include the 191 responses that were complete up to the Energy services section.

Table 1. Total valid responses per survey section

Section completed	N
1. Energy services	191
2. Decarbonization	166
3. Electrification and end-uses	163
4. Enabling technologies	162
5. Policy options	157
6. Opportunities and challenges	153

Respondents could choose from a total of 12 different organizational affiliations.[1] In total, 222 organizational affiliations were recorded from 182 respondents (*NA*=9). Approximately 85 per cent (156) of respondents identified a single organizational affiliation. The most common affiliations were non-profit organizations (26 per cent of responses, 32 per cent of respondents), energy services and/or consulting companies (23 per cent of responses, 29 per cent of respondents), and private sector (13 per cent of responses, 16 per cent of respondents). In all, 18 people indicated an affiliation with one level of government, not including three who were affiliated with First Nations/Indigenous government.

It was far more common that respondents identified more than one sector of expertise. Of nine possible options, only 34 per cent (61) of respondents indicated a single area of expertise (*NA*=10). In total, we received 526 responses on this question, and respondents identified 2.7 sectors in which they had experience on average. Generation was the sector with the highest share of respondents indicating expertise (59 per cent) and the highest share of all responses (20 per cent). This was followed by efficiency/conservation (19 per cent of responses, 54 per cent of respondents) and electricity consumer-residential (13 per cent of responses, 37 per cent of respondents).

1 These included federal, provincial or municipal government; First Nations/Indigenous government; regulatory body; utility; electricity system operator; university/college; non-profit organization; industry association; energy services and/or consulting company; private sector.

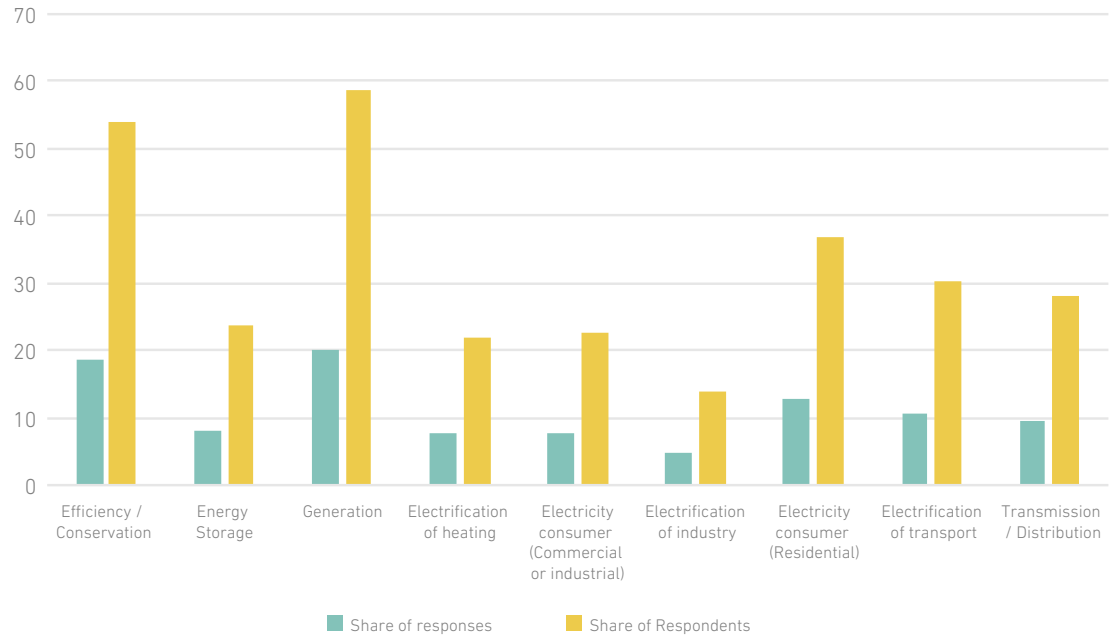

Figure 1. Respondent expertise by sector (n=181)

Of the 106 respondents who indicated expertise in the generation sector, 104 completed a followup question asking about experience and/or knowledge with different types of electricity generation. On this question, renewable electricity was the most frequent response (44 per cent of responses, 84 per cent of respondents indicating expertise), followed by hydroelectricity (28 per cent of responses, 53 per cent of respondents). The respondent pool indicated substantial expertise in their areas, with nearly two-thirds (65 per cent) having six or more years' experience (see Table 2).

Table 2. Respondent years of experience

Experience	n
Less than 1 year	7
1 - 5 years	60
6 -15 years	69
More than 15 years	55

All 191 respondents completed the question on provinces in which they had energy sector experience and/or knowledge, slightly more than half of whom (57 per cent) indicated only a single province. British Columbia, Ontario and Alberta were the most well-represented, with 40 per cent, 33 per cent and 30 per cent of respondents indicating experience or knowledge, respectively. Thirty-eight respondents indicated energy sector experience and/or knowledge Canada-wide.

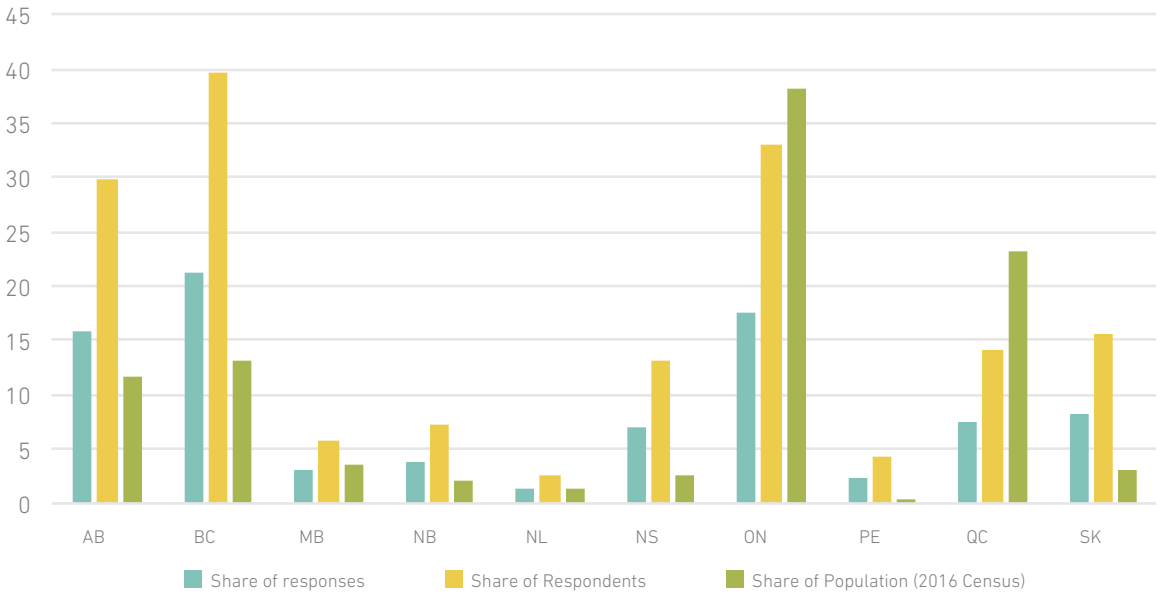

Figure 2. Respondent energy sector expertise and/or knowledge by province (n=191).

As indicated in Figure 1, Alberta and British Columbia were most highly represented, while Ontario and Quebec were comparatively underrepresented, based on provincial share of total Canadian population, 2016 census.[2] In general, however, the share of total responses is more closely in line with shares of total population in Canada.

Limitations

The intent of the survey was to gather perceptions on Canada's energy transition, the role of clean power technologies and enabling solutions, and opportunities and barriers to this energy transition from people with expertise in the energy and electricity sectors in Canada. It is difficult to estimate the total population of people with such expertise, as one could have expertise without being employed in the energy sector itself and, similarly, not all employees in the energy sector possess expertise regarding the policy and governance-related issues the survey sought to investigate. Statistics on employment in energy/electricity sector and sub-sectors are thus not good indicators of the community of stakeholders targeted with this survey. We are thus limited in our ability to assess the representativeness of our sample of the larger energy and electricity system expert stakeholder community.

Furthermore, the online administration and method for delivery of the survey had the potential to result in overrepresentation of people with expertise in specific regions of the country (e.g., Alberta and British Columbia), particular energy/electricity technologies, or sub-sectors of the

2 Statistics Canada, "Table 17-10-0122-01: Census Indicator Profile, Based on the 2016 Census Short-Form Questionnaire, Canada, Provinces and Territories, and Health Regions (2017 Boundaries," Government of Canada, 2016, https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1710012201.

broader energy sector (e.g., efficiency/conservation; generation); or those who are more likely to participate in online activities. However, we believe that, though the share of respondents identifying expertise in select provinces and energy sub-sectors suggests overrepresentation in some areas, the share of total responses is considerably more balanced across these different options. This is suggestive of a breadth of expertise among survey respondents that helps to counter potential effects of overrepresentation in some select areas.

We also sought to improve representativeness by monitoring response rates on regional expertise, organizational affiliation and sector of expertise while the survey was open to ensure no one province, sector or organization appeared to be substantially overrepresented. We restricted responses to those from people in Canada and posted links to the survey publicly on social media and urged participants to invite their colleagues to increase the pool of respondents. Finally, we included many opportunities to provide longer, open-ended responses and comments on the issues contained in the survey, therefore allowing for respondents to register disagreement with the topics and formatting of the survey questions.

This survey should thus be understood as an exploratory look at the perspectives of a self-selected segment of the energy and electricity system stakeholder community, though not necessarily as representative of the broader stakeholder community. Since these respondents have expertise in energy systems, results may not be representative of the views of Canadians in general. Nevertheless, reaching an economy with net-zero carbon pollution by 2050 is an official federal government objective. While realizing this goal will depend ultimately on Canadians' perspectives, beliefs and willingness to modify their behaviours, much of the technical and investment decisions, and implementation, will fall to members of the expert stakeholder community that we sought to survey. Based on the information gathered in the respondent information section of the survey, we believe the results outlined below offer valuable insight into perspectives of the expert energy/electricity system stakeholders who are likely to play important roles in realizing a clean power future in Canada.

RESULTS

Energy services

Energy services refer to the useful things that energy and electricity provide to end-users: light, heat, transportation and so forth. Certainly, people value these services, but there are also characteristics of how these services are provided that may be valued differently, and between which people may be more or less inclined to tolerate trade-offs. To that end, respondents were asked to provide their perspective on the preferences of Canadians in general on different attributes of the provision of energy services in a clean power future.

The first question asked respondents to assess the importance of a series of attributes of electricity provision. All attributes were assessed as highly valued by Canadians in a clean power future, with only the importance of "use of innovative technologies" being indeterminate.

Table 3. Respondent perceptions of value placed by Canadians on attributes of electricity in a clean power future (n=191).

Attribute	n	Mean	SD
Reliability	189	4.8	0.5
Affordability	190	4.4	0.7
Non-emitting	190	4.1	0.8
Low impact on nature	190	3.9	0.9
Renewable	191	3.9	0.9
Local support	186	3.7	0.9
Respects Indigenous rights	190	3.7	1.0
Innovative technology	186	3.0	1.1

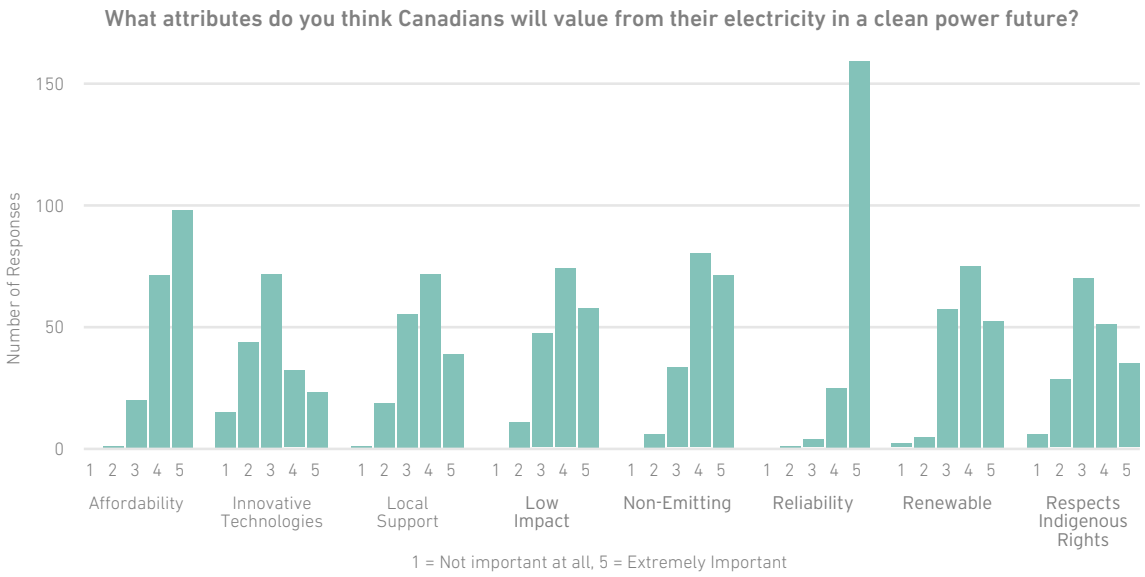

Figure 3. Respondent perceptions of value placed by Canadians on attributes of electricity in a clean power future (n=191).

Reliability and affordability stand out as the most highly valued attributes, followed by non-emitting. In the 38 long-text responses to this question, several respondents (six) raised questions about the willingness of Canadians to sacrifice affordability and reliability for climate change, suggesting these two attributes are "king", and that consumers are generally technologically agnostic. One respondent noted that a technology-agnostic approach should be valued, however, and that regionalized solutions make the most sense.

Yet, preferences for reliability and affordability are not at odds with a clean power future. One respondent noted that cleaner power alternatives could have positive impacts on services and price, and that this will help to spread support for clean power. Alternatively, another respondent noted that, while costs may be important today, there are signs that the "quality" of energy production may eventually matter more (though it is unclear what this respondent meant by the term).

Many respondents noted that general energy illiteracy among Canadians hinders making informed decisions, and that more education is needed for Canadians to appreciate environmental impacts and the political economy of different energy technologies. Many also raised doubts about Canadians' commitments to Indigenous rights. One respondent noted that building local support will be important to counter potential NIMBYism, but that clean power could override the importance of local support, and that it may not be possible to keep everybody happy. History suggests, according to the respondent, that burdens will most likely be shifted to remote communities.

A second question in this section asked respondents to gauge the extent to which Canadians will value options to engage in and manage their energy services through measures such as net-metering, self-generation, load-shifting and time-of-use pricing (1=No value at all, 5=A great deal of value). Responses had a mean value of 3.5 (n=187), indicating that respondents believed Canadians would only moderately value these options. However, in the long-text responses (51), respondents indicated a general skepticism that many Canadians would value these options, most preferring reliability and affordability instead. As one respondent described, "I think the majority wants to have power when called upon, [and] it is up to the sector to provide a comprehensive plan and execute it." Another noted that, though "there will be a sizable minority of Canadians who want to be prosumers and actively manage their energy use…the majority of Canadians just want reliable, available, and affordable energy. Most do not have the time or bandwidth to add energy management to their day to day lives."

Not all agreed. One respondent noted that the options to engage and manage also provide opportunities for cost savings, if implemented correctly, and that they "firmly believe" individuals would optimize their behaviour to save money. Several others noted that people might be more willing to adopt these practices if they are easy to do (e.g., time-of-use rate designs), or if provided by third parties or utility companies. As one respondent noted, "as long as the process is simple, Canadians will value the option to manage their energy services. Complicated energy service options will be under-utilized unless detailed information and processes are outlined to inform all groups of Canadians." One respondent noted recycling programs as a potential analogue, in that widespread participation in recycling programs could be suggestive of the possibilities for greater engagement.

Electricity decarbonization

Canada's electricity system is already relatively decarbonized. According to Natural Resources Canada, almost 82 per cent of electricity in Canada came from non-emitting sources in 2017.[3] Overall, the electricity sector accounted for approximately 10 per cent of Canadian GHG emissions,[4] compared to 33 per cent in the U.S.[5] Given that electricity in Canada is mostly non-emitting, shifting energy end-uses (like space heating in buildings) from fossil fuels to electricity is likely to be an important part of Canada's pathway to net-zero by 2050. In 2018, electricity accounted for about 22 per cent of Canada's final energy demand.[6]

The survey thus asked respondents questions about the trajectory and role of the electricity

3 Natural Resources Canada, "Energy and Greenhouse Gas Emissions (GHGs)," October 6, 2017, https://www.nrcan.gc.ca/science-data/data-analysis/energy-data-analysis/energy-facts/energy-and-greenhouse-gas-emissions-ghgs/20063#L3.

4 Environment and Climate Change Canada, "Greenhouse Gas Emissions," Government of Canada, 2019, https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/greenhouse-gas-emissions.html.

5 U.S. Energy Information Administration, "How Much of U.S. Carbon Dioxide Emissions Are Associated with Electricity Generation?" U.S Department of Energy, 2019, https://www.eia.gov/tools/faqs/faq.php?id=77&t=11.

6 Statistics Canada, "Table 25-10-0029-091: Supply and Demand of Primary and Secondary Energy in Terajoules, Annual," Government of Canada, 2019.

system in reaching net-zero by 2050, including their personal expectations about future electricity demand, timelines for 50 per cent electrification of final energy demand, personal prioritization of different options for decarbonizing electricity systems, preferences regarding the role of hydroelectricity and nuclear, and perspectives on the general social acceptability of a number of electricity system technologies for decarbonization.

On future electricity demand required to meet net-zero by 2050, 70 per cent (116) expected electricity demand to increase over 2019 levels, seven per cent (11) expected it to stay the same or decrease and 23 per cent (38) responded that they did not have enough information to answer the question (*n*=165, *NA*=1). Of the respondents who expected electricity demand to grow, 22 per cent (25) expect it to grow up to 50 per cent, 26 per cent (30) to grow by 50 to 100 per cent, and 53 per cent (61) to grow by more than 100 per cent of 2019 levels by 2050. The mean response for when respondents thought 50 per cent of final energy demand should be electrified if Canada is to meet its 2050 net-zero target was 2036 (*n*=166, *NA*=18).

Respondents were then asked to prioritize five electricity decarbonization options to reach net-zero by 2050, including building new clean electricity, new carbon-emitting electricity with carbon capture and storage, retrofitting existing carbon-emitting generation with CCS, enabling technologies like transmission/distribution/smart grids, and energy efficiency/conservation. Respondents were not required to prioritize all five options if they chose not to.

As indicated in Figure 3, the majority (93, *n*=163) picked efficiency and conservation as the first priority, followed by new clean power (57, *n*=161) and enabling technologies (70, *n*=150) as second and third priorities, respectively. Aggregating the 474 responses from 162 respondents for the top three priorities, efficiency and conservation again ranks highest, with 93 per cent (151) of respondents selecting it as one of their top three priorities, followed again by new clean power (91 per cent, 147), and enabling technologies (84 per cent, 136).

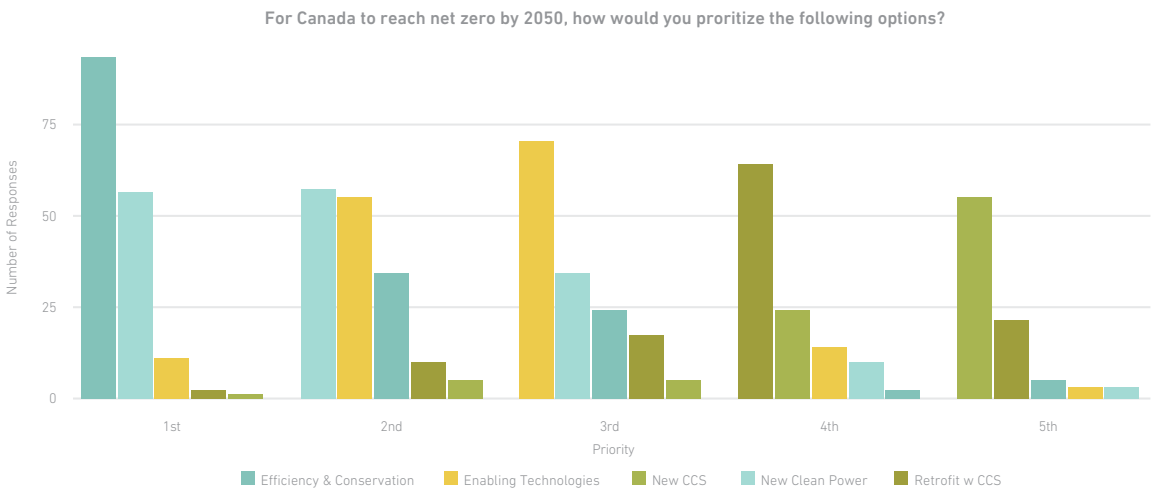

Figure 4. Respondent prioritization of electricity decarbonization options (n=162).

Notably, while the top three priorities did not differ greatly based on sectors that respondents claimed to have expertise in, there was some indication that respondents favoured as their first priority sectors in which they claimed experience. The table below shows first priority preferences for respondents from select sectors. For example, of the 84 respondents indicating expertise in efficiency and conservation, 70 per cent of them choose efficiency and conservation as their first priority, compared to 44 per cent of the 79 respondents that did not indicate expertise in efficiency and conservation.

Table 4. Comparison of respondents decarbonization preference by sector (efficiency and generation)

		Electricity decarbonization options Share of respondents picking as first priority				
Sector of Experience	**Number of respondents**	**Efficiency & conservation**	**New clean power**	**Enabling technologies**	**Retrofit w CCS**	**New CCS**
Efficiency	84	70%	21%	5%	2%	1%
Not efficiency	79	44%	49%	9%	n/a	n/a
Generation	91	51%	43%	5%	n/a	1%
Not generation	72	65%	24%	8%	3%	n/a
Generation (Fossil fuels)	25	44%	48%	8%	n/a	n/a
Generation (Non-fossil fuels)	66	53%	41%	5%	n/a	2%

Table 4 shows that respondents who claimed expertise in the efficiency sector were more likely to pick efficiency and conservation as their first priority than those who did not claim experience in that sector (70 per cent versus 44 per cent of respondents, respectively). Indeed, new clean power was the top-ranked first priority among respondents without expertise in the efficiency sector. Similarly, respondents with expertise in generation were more likely to pick new clean power as their first priority than those without experience in this sector (43 per cent versus 24 per cent), and less likely to pick efficiency than those with experience in the efficiency sector (51 per cent versus 70 per cent). The table also shows figures for respondents with expertise in the generation sector that indicated experience with fossil fuel generation (with or without CCS) on the generation sub-type question, and those without. First priority decarbonization options were similar for both of these groups as for respondents with expertise in the generation sector overall.

Given that respondents were able to indicate expertise in multiple sectors, there is likely some degree of overlap in the respondent pools for each sector given here, but there does appear to be some degree of prioritization of options with which respondents have expertise. Overall though, the combination of expectations of high future electricity demand growth, a mid-2030s target for electrifying 50 per cent of energy end-use and a marked preference for efficiency and conservation as a first priority among the total respondent pool suggests that many energy and electricity system stakeholders believe that reaching net-zero by 2050 may not necessitate the use of all available electricity generation technologies, and that large initial steps can be made through demand-side interventions. New clean power did rank second in the prioritization of options given above, while retrofitting or building new fossil fuel generation with carbon capture and storage ranked lower. Accordingly, stakeholders surveyed here exhibited preferences for meeting additional electricity generation requirements (above what can be addressed by demand-side measures) with non-fossil fuel electricity generation.

Respondents were then asked to assess the role of hydroelectricity in meeting Canada's 2050 net-zero target. Respondents were given a range of options (e.g., build new large capacity plants, build new small capacity plans, refurbish existing plants, etc.,) and asked to select all that they believed should be considered for these technologies (they could also answer "Other" and provide further details). Table 5 below shows the frequency of responses per option.

Table 5. What should be the role of hydro? (Total responses = 405; total respondents = 160).

	Responses	Number of respondents with single preference	Share of total responses	Share of respondents
Refurbish existing	101	10	25%	63%
Build pumped storage hydro	86	4	21%	54%
Build new, small (<50 MW))	84	4	21%	52%
Build new, medium (50-200 MW)	57	2	14%	36%
Build new, large (>200 MW)	50	7	12%	31%
Not enough info to answer	16	15	4%	10%
None — no new hydro	11	7	3%	7%

Responses indicated a preference for refurbishing existing plants, building pumped storage hydro and building new small plants (<50 MW). In the 12 text-based responses, some respondents (five) noted concerns about environmental and social impacts of medium or large hydroelectricity (e.g., "medium and large hydro is preferable to using fossil fuels, but should be done in situations where most of the impacts can be mitigated"), and the need to explore other options (e.g., 'negawatts") before building more electricity capacity. One respondent expressed uncertainty about how much untapped hydroelectricity potential was feasible, and several suggested interprovincial trade as a preferred option.

Table 6. What should be the role of nuclear? (Total responses = 197, total respondents = 158).

	Responses	Number of respondents with single preference	Share of total responses	Share of respondents
None — no new nuclear	59	56	30%	37%
Build new, small modular reactors	49	20	25%	31%
Refurbish existing	48	21	24%	30%
Not enough info to answer	21	20	11%	13%
Build new, mid to large	20	9	10%	13%

Respondents were asked a similar question about the role of nuclear power, though preferences on this question were not as multifaceted. As the above two frequency tables indicate, respondents were much more likely to select multiple options for hydroelectricity than they were for nuclear. For both technologies, refurbishing existing generation assets ranked highly, being the most frequently selected option for hydroelectricity (67 per cent of respondents), and the third for nuclear (30 per cent of respondents). Slightly more than one-third of respondents chose the option of not building any new nuclear. Most of those who selected this option did not choose any other option (56 of 59 responses from respondents choosing no other option). That a large portion of respondents chose only one option for nuclear suggests stakeholders are less flexible in what role they believe nuclear should play in the future.

Eleven text-based responses on the role of nuclear indicated that some respondents (five) were supportive of new, smaller nuclear technologies (e.g., molten salt/thorium), while others expressed similar concerns as with hydroelectricity about environmental implications (e.g., waste) and a preference for limiting additional capacity needs. One respondent suggested that all existing nuclear be decommissioned and dismantled.

On both questions, responses suggest some preference for utilizing existing capacity and smaller-scale projects. This aligns with responses on a question about whether new electricity projects should be more distributed and small-scale, versus large, grid-scale and centralized, which showed a modest preference for smaller, distributed projects (Mean=2.2, SD=1.1, n=157; 1=More distributed, 5=More centralized).

Finally, respondents were presented with a list of many different electricity-system technologies and asked to assess what they perceived to be the general public acceptability of these across Canada (1 = High public resistance, 5 = High public acceptance). Table 3 shows the results. Technologies highlighted in green were considered more highly publicly acceptable, those in yellow more indeterminate and those in orange were considered relatively unfavourably.

Table 7. Respondents assessment of the public acceptability of electricity decarbonization options.

Technology	n	Mean	SD
PV, distributed	162	4.6	0.7
PV, grid scale	161	4.3	0.9
Geothermal	159	4.3	0.8
Hydro, refurb	152	4.2	0.9
Solar thermal	152	4.0	1.0
Ocean energy (tidal/wave)	149	3.9	1.0
Trade with provinces	160	3.9	1.1
Wind, offshore	159	3.7	1.1
Pumped hydro storage	132	3.7	1.0
Hydro, run of river	147	3.6	1.1
Biomass	158	3.4	1.0
Wind, onshore	161	3.4	1.0
Hydro, new small	154	3.2	1.0
Transmission lines	156	3.0	1.1
Fossil w CCS	154	2.2	1.0
Hydro, new large	155	2.2	1.0
Nuclear, small	152	2.1	1
Nuclear, large	160	1.5	0.9

In the 52 open-ended text responses in this section, some respondents qualified how public acceptance should be considered. For instance, one respondent noted that public acceptance may be more salient at the site or project level, rather than for technologies in general. Another noted that acceptance is complicated, writing that "level[s] of public resistance is context specific. Are the projects situated close to existing transmission systems? Is [the] need [for] electricity addressed? Is the region already impacted by prior hydro or electricity generation? What is the effect on wilderness, etc." Other respondents suggested that no technology will

ever by 100 per cent acceptable to the public, though the need to consider local and public concerns is important. According to one respondent:

> "All projects will face local resistance — as not many people want projects visible in their backyard or want to bear the burden of local impact (visual, noise, perceived risk factors, etc.). Resistance will be greatest for those projects with the largest local impact, but these projects tend to be sources of firm supply which will be increasingly important as distributed/intermittent sources grow in generation capacity."

Some (four) respondents noted opposition to transmission lines is a barrier, and that the need for such infrastructure is "greatly undervalued" due to lack of knowledge. One respondent noted that more interprovincial and international transmission capacity meant that less natural gas would be required.

Several (eight) respondents advocated strongly that too much focus on electrification alone is not ideal, and that integrated energy-electricity options should play an important role. Some other options these respondents mentioned included continued reliance on natural gas in some regions, and production and use of hydrogen in some sectors. According to one respondent:

> "We need to be looking at the production of blue (from fossil fuels with CCS) and green (from renewables) hydrogen that will fuel the transportation and industry/heating demands where direct electrification does not work well. By incorporating hydrogen infrastructure into future energy systems, we create an opportunity to greatly expand low cost intermittent renewables, like wind and solar, that can feed the grid when needed and make hydrogen when not needed."

Another respondent suggested that co-generation could also play an important role, and that full electrification should itself not be a goal.

Electrification and end-use changes

The next section of the survey dealt with electrification and end-use changes, asking respondents to register the importance of a series of options for reaching net-zero by 2050 (1=Not important at all, 5=Extremely important). Significant positive responses were received for all options, with deep retrofits, net-zero building codes and electrification of light-duty vehicles ranking as the most important end-use changes.

Table 8. Respondent assessments of the importance of electrification and end-use change options.

Options	n	Mean	SD
Deep retrofits	159	4.6	0.8
Net-zero building codes	159	4.5	0.8
Electrification, light duty vehicles	159	4.5	0.8
Demand-response	152	4.3	0.8
Electrification, medium-duty vehicles	158	4.3	0.8
Electrification, industry	154	4.3	0.8
Consumer behaviour change	160	4.3	0.9
Electrification, heating	160	4.2	1.0
Appliances	156	4.2	0.8
Electrification of heavy-duty vehicles	157	4.1	1.0

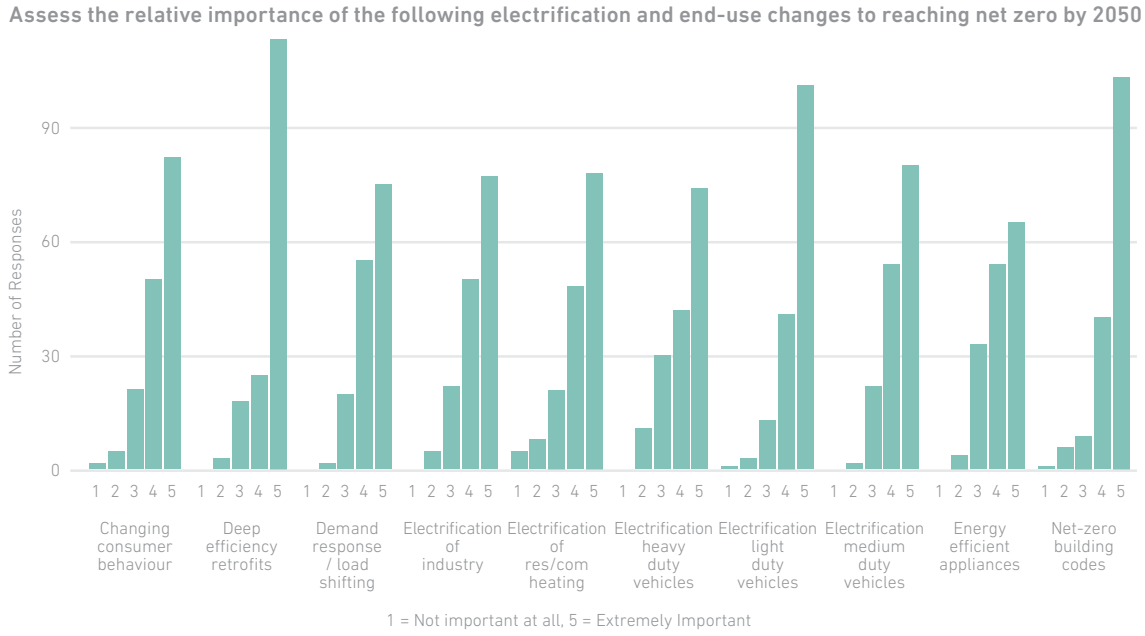

Figure 5. Respondent assessments of the importance of electrification and end-use change options.

Though all options were considered important, positive sentiments were most strongly expressed for deep energy retrofits, net-zero building codes and electrification of light-duty vehicles. That respondents considered the first two options the most important aligns with findings in the electricity decarbonization section, which indicated preferences for lower-

impact, demand-side measures (as opposed to new electricity generation capacity). Responses (39) to the open-ended text question in this section reinforced this finding and reiterated some concerns about widespread electrification. According to one respondent, efficiency must come before electrification:

> "It will be extremely difficult/not possible to electrify certain end use applications such as heavy-duty vehicles/shipping and certain industrial processes such as cement. Also, unless and until marginal electricity is non-emitting it does not make sense to try to electrify highly efficient heating loads that can be served by other fuels such as natural gas and eventually non emitting gasses such as hydrogen. The passenger vehicle market is probably the best electrification market to focus on due to the state of the technology and the benefits of fuel switching which include both emissions and efficiency gains."

As in the previous section, other respondents (eight) echoed this view, suggesting electrification in some climates or in some sectors was not feasible, and that hydrogen (e.g., in natural gas heating networks) was a potential alternative. Another respondent argued that "hydrogen needs to be the vector to enable medium to heavy duty vehicle, heating and industrial sector carbon reduction. Electricity alone cannot reach these sectors." Another pointed to the potential role of biogas and biofuels in industry.

Not all respondents agreed that efficiency should be prioritized over electrification, however. For instance, one respondent noted:

> "In large parts of Canada, the electricity supply is almost entirely decarbonized outside of the peak hours. As Net Zero Energy construction focuses on annual energy consumption and typically is optimized for solar thermal heat gain, it does little to mitigate peaking (which drives carbon generation)."

Another, making a distinction between deep-energy and deep-carbon retrofitting, wrote:

> "Deep-energy retrofits are rarely economical. Rather, deep-carbon retrofits should be the priority, by combining economical building envelope retrofits with electrification of heating and hot water using heat pumps, or replacement by low-carbon district heating systems in urban centres."

A possible implication of the results in this section is that, while stakeholder preferences support improvements to building efficiency and electrification of some end uses, some feel these should not be undertaken in isolation, and efforts should instead be taken to develop integrative energy-electricity solutions where they are applicable.

Enabling technologies

The enabling technologies section was similar in structure to the electrification and end-use section, asking respondents to rate the importance of a series of options for reaching net-zero 2050 (1=Not important at all, 5=Extremely important).

Table 9. Respondent assessment of the importance of enabling technologies.

	n	Mean	SD
Smart grids	146	4.4	0.8
Batteries, non-hydro storage	154	4.2	0.9
Interprovincial grid / trade	150	4.2	0.9
Community energy / microgrids	147	4.1	1.0
Transmission/distribution infrastructure	152	4.1	0.9
Pumped hydro storage	141	3.9	0.9
International grid / trade	148	3.6	1.0
Power-to-gas	102	2.9	1.2

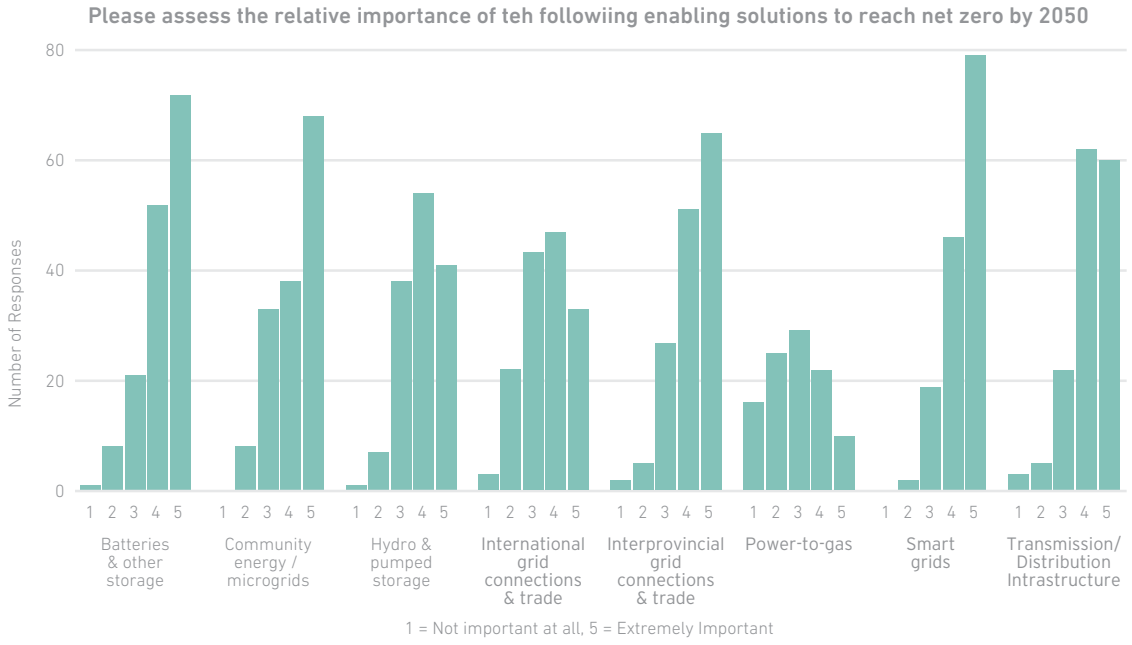

Figure 6. Respondent assessment of the importance of enabling technologies.

As in the electrification section, all options (except for power-to-gas) were considered important for achieving net-zero by 2050. Importance was particularly pronounced for smart grids and batteries and non-hydro energy storage, suggesting a possible modest preference for distributed energy solutions.

Responses (29) to the open-ended text question tended to reinforce the importance of energy storage, particularly for integration of renewable electricity courses and in communities powered by diesel generators. Several respondents (seven) noted that hydrogen can play an important role as well, including a storage role (as noted by two respondents). Several respondents (six) expressed some skepticism about the role of increased grid connections and trade, both within Canada and between Canada and the U.S., noting politics as a barrier. Two others suggested that hydro and pumped storage should not be included together, as they are different technologies that may play different roles in reaching net-zero by 2050.

Policy options

The policy option section of the survey was intended to gather respondents' perspectives on the requisite targets for electricity decarbonization to meet Canada's net-zero goals, targets for electrification of transportation and views about the trajectory of carbon pricing.

Canada's present target is for 90 per cent of electricity generation to be non-emitting by 2030. We asked respondents if they believed this target should be accelerated. Results were mixed — 54 per cent (85) of respondents believed it should be accelerated, while 39 per cent (61) did not. Eleven respondents selected 'not enough information to answer" (n=157). Of the respondents who believed the target should be accelerated, 53 per cent (45) believed it should be moved to 2025.

Table 10. Respondent perspectives on acceleration of Canada's 90 per cent non-emitting electricity generation target year.

		n	% of total responses
Not enough info to answer		11	7%
Should not be accelerated		61	39%
Should be accelerated		85	54%
Which year?	2025	45	29%
	2026	11	7%
	2027	18	11%
	2028	9	6%
	2029	2	1%

The survey followed up with two questions about what timelines Canada should set for a) all new electricity generation to be non-emitting, and b) what target Canada should set for "nearly 100%" of electricity to be non-emitting. The mean responses for these questions were 2026 and 2037, respectively (n=157). As might be expected, the mean target years for these questions differed between those who thought Canada's 90 per cent by 2030 target should be accelerated and those who did not. Nevertheless, as indicated in the chart below, respondents that thought Canada's 90 per cent target should not be accelerated still indicated a preference for new generation to be non-emitting prior to 2030, and nearly 100 per cent of electricity to be non-emitting prior to 2050.

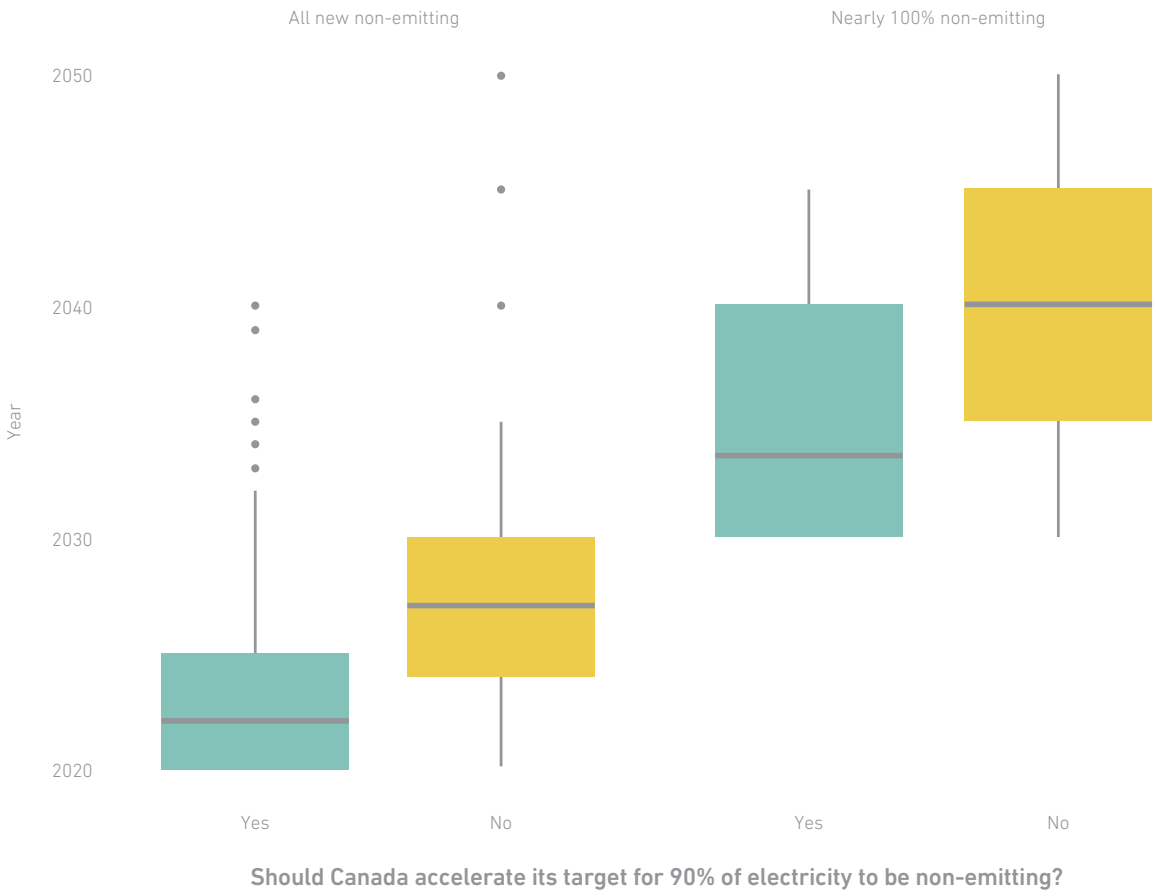

Figure 7. Perspectives on target years for all new generation non-emitting and nearly 100% generation non-emitting (N=146).

When asked how Canada's carbon price should evolve after 2022, 69 per cent (101) suggested it should increase significantly, 21 per cent (31) said it should increase moderately, five per cent (seven) that it should not increase at all, and five per cent (eight) responded they did not have enough information to answer the question. Of the 10 respondents that answered "Other" to this question, only two expressed strongly negative perspectives on the carbon tax; the rest supported gradual but consistent increases.

The next five questions dealt with electrification in the end-use sector, specifically policy options for light-duty and heavy-duty vehicles, heating and cooling for new construction, and deep-energy building retrofits.

Canada's present target requiring all light-duty vehicles for sale to be zero-emissions is 2040. Asked if this target should be accelerated, 71 per cent (112) believed it should, 24 per cent (38) believed it should not, and four per cent (seven) did not have enough information to answer the question (n=157). Of those that believed it should be accelerated, there was a strong preference for earlier target years (Mean=2032, SD=2.3, n=157). When asked about a target for medium- and heavy-duty vehicles, respondents gave more mixed responses (Mean=2036, SD=5.6, n=157).

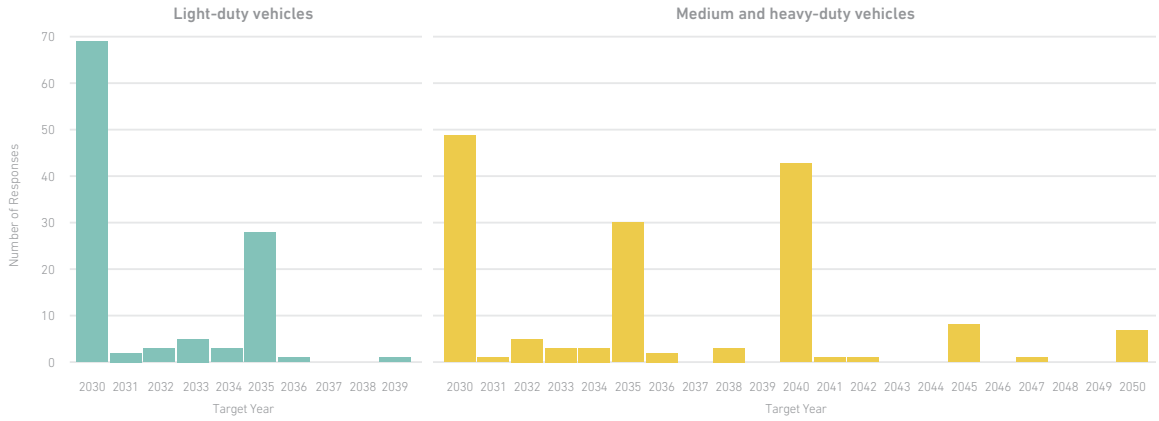

Figure 8. Respondents' preferred target years for requirements for zero-emission light and medium/heavy-duty vehicles for sale

Next, the survey asked respondents about timelines for requirements for zero-emission heating and cooling for new building construction (Mean=2032, SD=3.9, n=157), and what percentage of existing residential and commercial buildings should undergo deep-energy retrofits by 2030. Results are displayed in the following two figures.

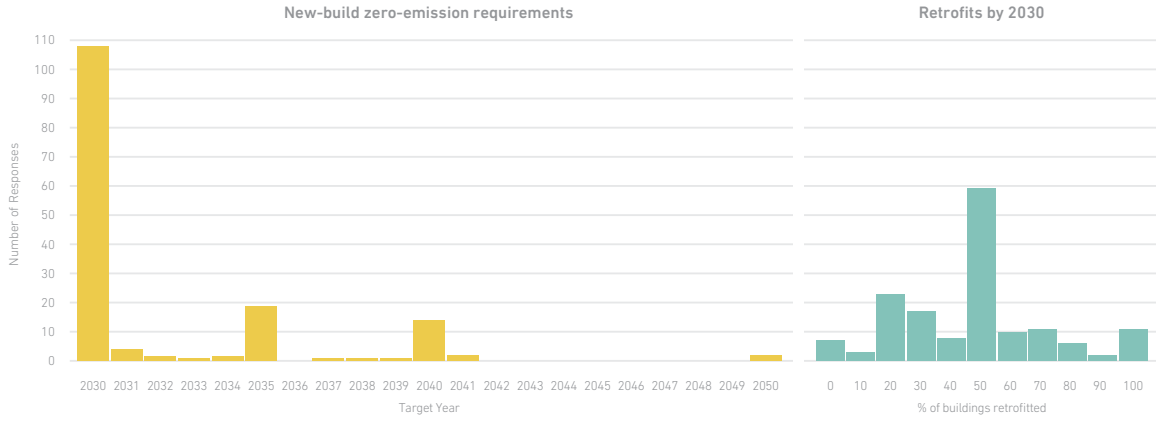

Figure 9. Respondents' preferred target year for new building zero-emission requirements and share of existing buildings retrofitted by 2030

The 56 open-ended text responses in this section offered a wide range of policy ideas. Several respondents (eight) noted the importance of increasing public transit and building intercity transit infrastructure to reaching net-zero by 2050, topics that were not dealt with in the survey. Some respondents expressed concern about expending political capital on policy targets or technologies that may not yet be feasible (e.g., complete electrificiation, heat pumps in northern communities). Two respondents suggested carbon pricing should be seen as supplementary to other governmental measures, such as regulation, stricter building codes and targeted subsidies.

Some respondents (seven) noted concerns about electrification and a goal of zero-emissions (though the survey defined clean power as inclusive of fossil fuel–based generation with carbon capture and storage). One respondent suggesed that 'non-emitting suggests a binary distinction between assets that generate power with no carbon versus anything more than zero carbon," and that this was a "false choice [since] driving anything to zero is often inefficienct and costly." Rather, according to this respondent, the goal should be the "fastest economical pathway to carbon neutrality." Others noted the role that integrative energy-electricity solutions could play, particularly hydrogen. One respondent wrote, "there needs to be a focus on how to move from the three disconnected energy systems we have today (electricity, thermo-chemical and motion) to one, more resilient energy system in a net-zero Canada."

a) Opportunities and challenges

The final section asked respondents to register their agreement with a series of statements about potential opportunities and challenges to reaching net-zero by 2050. Responses were positive for the four statements about opportunities and mixed for two of the three statements on challenges (see Figure 7 and Figure 8 below).

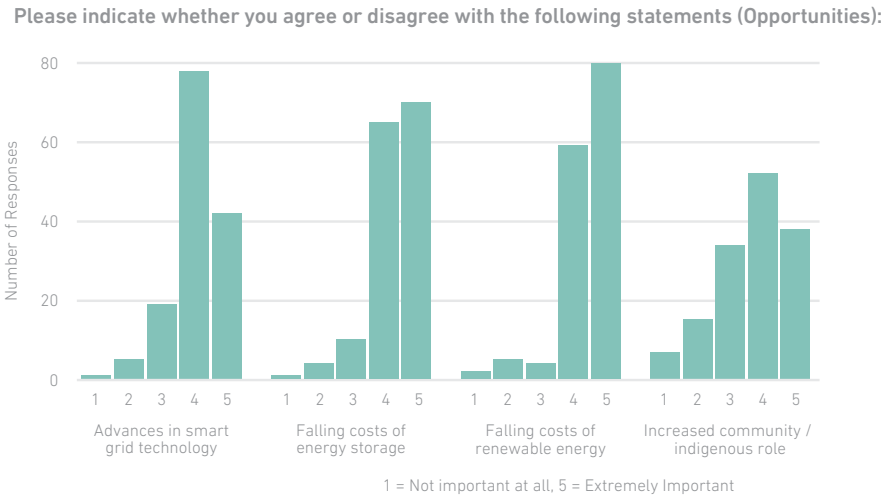

Figure 10. Respondent agreement with statements of opportunities (n=153).

Notably, respondents strongly tended to agree that current market and regulatory frameworks were a challenge to reaching net-zero by 2050. In fact, this question registered the strongest level of agreement of all statements posed to respondents in this section (Mean=4.42, n=144, NA=9). Opinions about the challenge of a skilled worker shortage were mixed.

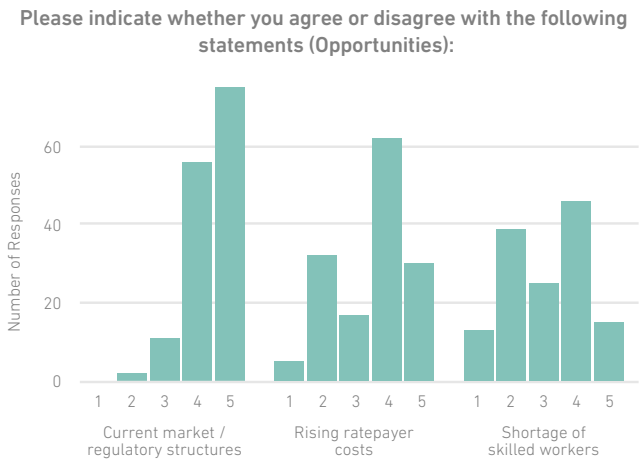

Figure 11. Respondent agreement with statements of challenges (n=153).

Respondents were also asked two open-ended text questions in this section: what they considered to be the biggest clean power opportunity or factor that will faciliate Canada reaching net-zero by 2050, and what they saw as the biggest clean power challenge or barrier to reaching this target.

The question about opportunities drew a wide range of responses from nearly all respondents (113/153) who completed the survey to this point.[7] Topics that respondents identified as opportunities (in rough order of frequency, higher to lower, with which they where mentioned) included renewables, particularly solar (34 mentions); public policy and governance, e.g., policy stability (20 mentions); energy storage, often in conjunction with renewables (18 mentions); smart grids and distributed energy resources (14 mentions); electrification of end uses (11 mentions); public opinion and awareness, e.g., greater concern about climate change (10 mentions); energy efficiency (nine mentions); hydroelectricity, e.g., existing resources and ability to balance intermittent renewable generation (nine mentions); and interprovincial trade and grid connections (nine mentions). Other opportunities that were mentioned (albeit less frequently) included hydrogen (five mentions), nuclear (five mentions), geothermal (three mentions), energy recovery, e.g., from sewers (one mention), and carbon capture and storage (one mention).

More respondents (124) answered the question about barriers, raising a range of issues that are harder to classify than opportunities. Broadly speaking, concerns about politics, lack of political will, ineffective or incomplete policy and the need for leadership and/or strong planning were the most frequently mentioned category of barriers (27). This was followed by mentions of institutional and regulatory barriers, including criticisms of provincial utilities (23 mentions). Concerns about "special interests" (mainly the oil and gas industry) were closely associated (21 mentions) with regional politics (eight mentions). The perceptions and behaviour

7 Total mentions may not equal the number of responses for both the opportunities and barriers questions, as not all responses are categorized (e.g., some responses did not really address the question) and some responses are categorized in multiple categories (respondents often mentioned a slew of barriers).

of Canadians, as well as our complacency in acting on climate change, were another frequently mentioned barrier (14 mentions). Other categories of barries included climate change denial, opposition to infrastrucutre and resistance to action (10 mentions); costs (nine mentions); challenges associated with electrification (seven mentions); and challenges associated with firming intermittent renewable electricity sources (six mentions).

DISCUSSION

Broadly speaking, respondents did not hold highly optimistic views on the general public's understanding of energy/electricity system issues, their willingness to change behaviour or accept trade-offs for realizing climate goals, or for respecting and engaging Indigenous rights and communities. Several expressed hope that the trajectory of public opinion was toward greater concern and understanding of these issues, but many noted a need for education and improved energy literacy among Canadians.

It is notable that respondents considered reliability to be the most valued attribute of energy services by Canadians, and not affordability (though this was ranked second-most important), as this suggests stakeholders believe consumers may be willing to accept some trade-offs in affordability to receive (or continue receiving) reliable energy services. As discussed above, the longer-text answers from some respondents noted that a preference for reliability and affordability is not at odds with a clean power future, however. The presumed preference for reliability and affordability aligns with the modest assessment of Canadians' interest in engaging with and managing their own energy services, suggesting Canadians would generally prefer to avoid large departures from the status quo in terms of their relationship with energy services.

On electricity decarbonization, respondents indicated a clear preference for efficiency/conservation as a "first fuel," followed by new clean power and enabling technologies. Though respondents demonstrated some preference for decarbonization options with which they had expertise, the combined results for the top three priorities nevertheless followed this same ranking. In both the quantitative and qualitative responses, stakeholders expressed a belief that large initial steps could be made through demand-side interventions, and refurbishment of existing assets and small-scale new projects are preferable on the supply side. Nevertheless, in this section and others, a small number of respondents consistently registered concern that pursuit of electrification of all end uses was not ideal, and that technologically agnostic solutions should be pursued.

Respondents tended to prefer smaller-scale approaches (at least, at the project level) regarding the role of hydroelectricity and nuclear power in a clean power future. As noted, respondents were more likely to select multiple options for hydroelectricity than for nuclear, suggesting that preferences for the latter technology are perhaps less flexible. If you believe no new nuclear should be built, that is essentially your only position on the future

role of nuclear. In the text-based responses, some respondents were more supportive of newer nuclear technologies in reaching Canada's net-zero goals, though these perspectives were not widespread. Furthermore, a preference for technologically agnostic solutions for achieving clean power could also be taken as a perspective supportive of new, larger-scale, hydroelectricity and/or nuclear power investments.

Assessments of the public acceptability of various electricity decarbonization technologies generally held most renewable sources to be more publicly acceptable, though within that category there are some contrasts. Solar power technologies (e.g., grid and distributed photovoltaics, solar thermal), along with geothermal, were considered the most publicly acceptable, while wind power, new hydroelectricity and biomass were seen as less so (though still considered acceptable). This finding aligns with the preference for smaller-scale options noted previously, suggesting stakeholders consider public acceptance to hinge substantially on project scale and visibility. Indeed, one stakeholder suggested that acceptance depends more on project and site specifics than it does technology. That distributed solar photovoltaics were considered most acceptable might also suggest energy stakeholders believe that decarbonization strategies in which Canadians can directly participate may be more socially acceptable.

Regarding electrification in general, some stakeholders were less enthusiastic. A somewhat frequent opinion was that too much reliance on extensive electrification does not accord well with the particularities of different regions and sectors, and that proponents of a net-zero future should also seek integrated energy-electricity solutions, where they may exist. In particular, a small number (about five) of stakeholders frequently pointed to the role hydrogen could play in bridging gaps between the energy and electricity sectors, and in industry and heavy-duty transportation as well. Similarly, some stakeholders rejected goals of 100 per cent decarbonization as well, preferring carbon neutrality as a target, rather than zero-carbon (though it should be noted net-zero does not imply zero carbon).

Several implications can be taken from these perspectives. For one, proponents of net-zero or decarbonization efforts should be careful in their use of terms, not equating decarbonization with net-zero where the goal is the latter, not the former. Second, it is important to consider whether the perfect can at times be the enemy of the good, in regard to target-setting for decarbonization and/or electrification, as well as to what technologies are considered viable or acceptable options. Third, the most appropriate solutions for reaching net-zero may differ by region and by sector, and universal solutions are not ideal. While sentiments such as these were not widespread in the survey results, they were mentioned frequently enough to merit consideration.

Respondents were split on whether to accelerate Canada's 2030 target for 90 per cent of electricity to be non-emitting, and there were some differences between stakeholders who did or did not wish for the goal to be accelerated on when all new electricity generation should be non-emitting and when nearly 100 per cent of generation should be non-emitting.

Nevertheless, it is worth noting that even stakeholders who did not wish for the 90 per cent target to be accelerated indicated some support for new and existing electricity to be non-emitting before the latest date offered in the survey (2030 and 2050, respectively). This suggests that, though there is some variance in preferences regarding the pace of change, there is nonetheless support for regulation to put Canada on a path toward non-emitting electricity systems.

In transportation and buildings, there was considerable support for accelerating Canada's targets for zero-emission light-duty vehicles and zero-emission new building requirements, though less so for medium- and heavy-duty vehicles. Text-based responses on the latter question showed some concern that electrification was not the best path forward to decarbonizing the sector, and several respondents noted the absence of public transportation as a strategy in the survey. Stakeholders also demonstrated substantial belief that 50 per cent or more of the building stock could and should be retrofitted by 2030. These results are suggestive that stakeholders see the most potential for decarbonization in the consumer choices and behavioural change of individuals, and a perception that there are few remaining market or technical barriers to widespread adoption of personal electric vehicles. Concern about the exclusion of public transportation indicates that there is a social/equity dimension to addressing carbon emissions in personal transportation, however, as not all Canadian consumers are able or willing to purchase electric personal vehicles.

Finally, on opportunities and challenges, the strongest agreement among stakeholders was that current markets and regulations are barriers to greater change in the energy and electricity sectors. Text-based responses in this section did not appear to link these barriers to costs of clean power but more to subsidies to non-clean energy sources, vested interests in maintaining the status quo and other forms of "lock-in" to existing institutional and market structures. Many stakeholders agreed that the falling costs of renewable energy sources, along with energy storage, distributed energy resources and existing hydroelectricity assets, offered the greatest opportunity for a clean power pathway, often noting Canada's considerable resources in these areas, and space in which to build them.

Stakeholders surveyed here did not demonstrate strong consensus on all the issues raised, however, and a frequent point of contention concerned electrification of end uses and regional/sectoral/technical considerations that may require more bespoke solutions. Stakeholders who expressed such views also tended to stress the importance of integrative energy/electricity solutions, though it should be noted that such perspectives were not widespread among respondents. Overall, responses to this survey lend themselves to the understanding that many energy and electricity system stakeholders see considerable near-term potential in substantial change on the demand side (through energy efficiency, non-emitting personal vehicles, and building retrofitting), while changes on the supply side should be generally low-impact, addressing the margins first, and striving to make the best use of the existing clean power capacity Canadians already enjoy.

REFERENCES

Meyer, Carl. "Liberals Commit to Carbon-Pollution Target of Net-Zero by 2050." National Observer, December 5, 2019. https://www.nationalobserver.com/2019/12/05/news/liberals-commit-carbon-pollution-target-net-zero-2050.

Natural Resources Canada. "Energy and Greenhouse Gas Emissions (GHGs)," October 6, 2017. https://www.nrcan.gc.ca/science-data/data-analysis/energy-data-analysis/energy-facts/energy-and-greenhouse-gas-emissions-ghgs/20063#L3.

Statistics Canada. "Table 17-10-0122-01: Census Indicator Profile, Based on the 2016 Census Short-Form Questionnaire, Canada, Provinces and Territories, and Health Regions (2017) Boundaries." Government of Canada, 2016. https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1710012201.

Statistics Canada. "Table 25-10-0029-091: Supply and Demand of Primary and Secondary Energy in Terajoules, Annual." Government of Canada, 2019.

U.S. Energy Information Administration. "How Much of U.S. Carbon Dioxide Emissions Are Associated with Electricity Generation?" U.S Department of Energy, 2019. https://www.eia.gov/tools/faqs/faq.php?id=77&t=11.