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National Survey of Canada's Infrastructure Engineers about Climate Change

**Prepared by
CSA Group
For
Engineers Canada**

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Executive Summary

Professional engineers play a critical role in the development and preservation of built infrastructure. Therefore, it is critical that engineers are prepared to address all of the factors that can affect infrastructure – including climate change. In 2007, CSA Group conducted a national survey of infrastructure engineers about climate change. The survey helped determine engineers' level of knowledge and awareness of the impacts of a changing climate on built infrastructure at the time. In 2012, CSA Group conducted a follow-up survey to understand what changes in attitudes, awareness, and actions have occurred since 2007. The 2012 survey also helps identify what engineers are doing now to adapt infrastructure to the impacts of a changing climate. The survey, conducted between December 2011 and February 2012, was targeted at professional engineers across Canada in five categories of built infrastructure: water, transportation, energy, buildings, and resource extraction/processing. A total of 3362 responses were received.

The overall objective of this project is to identify:

- Engineers' attitudes and level of knowledge and awareness about the impacts of a changing climate on engineering practice;
- To what extent infrastructure engineers consider the changing climate in engineering decision-making;
- How infrastructure engineers address the changing climate in their practice and which climate change adaptation tools/techniques they are using;
- How infrastructure engineers use information on the changing climate and where information is lacking;
- Opportunities to increase engineers' level of awareness of the impacts of a changing climate on the built infrastructure sector;
- What barriers are preventing infrastructure engineers from addressing the impacts of a changing climate in practice; and
- Any changes around infrastructure engineering and climate change since 2007.

The key findings of the survey are summarized as follows:

- The majority of engineers agree that a changing climate affects their practice, although a smaller proportion of engineers somewhat agree with this in 2012 than in 2007.
- The belief that a changing climate affects engineering decisions is profiled more towards water infrastructure engineers and government engineers, as well as engineers in Quebec, the Atlantic provinces, and the North.
- Engineers from Alberta and Saskatchewan report lower than average agreement that a changing climate affects their engineering decisions.

- Three out of four engineers believe that reduction of greenhouse gas (GHG) emissions will mitigate future climate change, however a smaller proportion of engineers believe this in 2012 than in 2007; a greater proportion of engineers in 2012 strongly believe that reduced GHG emissions will mitigate future climate change.
- Three out of four infrastructure engineers feel they need more information to address a changing climate in their practice. This is more or less unchanged from 2007.
- Approximately half of engineers indicate a likelihood of seeking information on a changing climate as it relates to engineering practice over the next 12 months.
- Engineers' most preferred methods of receiving information on a changing climate are through published guidelines/best practices and online resources.
- Engineers have lower confidence about their overall familiarity with the impacts of a changing climate in 2012 than in 2007.
- The rate of consideration for the impacts of a changing climate in engineering practice is significantly above average for engineers from Quebec, the Atlantic provinces, and the North.
- Generally, engineers' familiarity with climate change adaptation tools and techniques has increased since 2007.
- Approximately 3 out of 5 engineers report using one or more climate change adaptation tool/technique in their practice.
- Seven percent of engineers report that they are somewhat or very familiar with the PIEVC Protocol while approximately 4 out of 5 engineers report that they are not at all familiar. Three percent of respondents report that they have already used or intend to use the PIEVC Protocol.
- Respondents indicate that the main barriers preventing engineers from addressing the impacts of a changing climate on infrastructure are:
 - lack of requirements in codes, standards, or policy;
 - the changing climate having no effect on engineering practice; and
 - lack of information and resources.
- Twelve percent of engineers indicate that they are skeptical about climate change.

Introduction

One of the core principles of professional engineering is to make prudent decisions without compromising the engineer's duty of care toward the public. Climate change issues are increasingly factoring into the engineer's decision-making process, and engineers must consider these issues in conjunction with a myriad of other influences on their work. Elements of Canada's built infrastructure are typically intended to have a useful service life of many decades. The service life can either be extended or reduced depending on a multitude of factors such as initial design, proper operations and maintenance, as well as weather and climate. Infrastructure engineers may be lacking the right tools and

information in order to act judiciously and decisively when the effects of a changing climate have the potential to impact their practice.

Regardless of the causes, it is widely acknowledged that the Earth's climate is changing. However, the notion of climate change remains a much-debated topic, and action around climate change tends to be influenced by a host of political and socioeconomic factors. While mitigation of climate change remains a topic at the forefront of engineering development, the changing climate may already be having an effect on built infrastructure in Canada. What is more, historical climatic data is becoming less reliable for predicting future climatic patterns and this raises concern as to the vulnerability of future built infrastructure. Depending on geographic location, different impacts of a changing climate are visible, ranging from changes in prevailing weather patterns (e.g. precipitation, localized storm activity, freeze/thaw cycles, extreme temperatures) to thawing permafrost, increased flooding, and changes in sea level. In Canada, these impacts have the potential to affect a variety of infrastructure networks including water, transportation, energy, buildings, and resource extraction/processing. In order to ensure sustainable practices in the future, it is critical that practising engineers have the right tools and knowledge in order to implement strategies that adapt infrastructure to a changing climate.

In early 2012, CSA Group conducted a survey of Canadian infrastructure engineers about climate change. The goal of the survey was to help determine gaps in knowledge about climate change adaptation amongst infrastructure engineers and to identify opportunities to increase the engineer's level of knowledge and awareness of the impacts of a changing climate on the built infrastructure sector. The survey was developed and implemented by CSA Group with the support of Engineers Canada. The survey was accessed online by a total of 3362 respondents from across Canada.

Background

In 2007, CSA Standards conducted a survey of Canadian infrastructure engineers to determine a baseline for their level of knowledge and awareness of climate change as it relates to their practice of engineering. The 2007 survey generated a significant amount of interest and it provided important information to guide decision-making at the time. Engineers Canada approached CSA in late 2011 to do a follow-up survey of infrastructure engineers about climate change in order to help determine current attitudes as well as the level of awareness of climate change and its perceived impact on infrastructure engineering. The survey also aims to identify what infrastructure engineers are currently doing in their practice to adapt to a changing climate with a focus on whether there have been any significant changes since the survey was conducted in 2007. The survey, launched in early 2012, was targeted at engineers from the following five categories of built infrastructure:

- Water
- Transportation

- Energy
- Buildings
- Resource extraction/processing

Objective

The objective of this project is to explore the following themes:

- Climate change and engineering practice:
 - To what extent does a changing climate factor into engineering decision-making;
 - Awareness of the relationship between climate change issues and infrastructure engineering;
 - Consideration for the impacts of a changing climate in engineering decisions;
 - Mitigation of the impacts of a changing climate;
- Climate change information and infrastructure engineering:
 - Availability of the right information to address a changing climate in engineering practice;
 - Accessing information on the changing climate;
 - Methods to communicate information about a changing climate as it relates to engineering practice;
 - Engineers' familiarity with the impacts of a changing climate;
- Climate change adaptation tools and techniques:
 - Familiarity with available tools and techniques to adapt infrastructure to a changing climate;
 - Application of climate change adaptation tools and techniques in practice;
 - Infrastructure engineers' perspective on needs and priorities for addressing climate change issues;
 - Awareness and application of the PIEVC Protocol (Public Infrastructure Engineering Vulnerability Committee);
- Barriers to addressing a changing climate in engineering practice:
 - Current issues surrounding any lack of action to adapt engineering practice to a changing climate;
 - Attitudes toward the effects of a changing climate and its impacts on infrastructure engineering;

Methodology

Survey Design

The survey was targeted at Canadian infrastructure engineers registered with a provincial or territorial engineering association (i.e. professional engineers). The survey comprised twelve questions in total, including ten questions taken from the 2007 survey and two new questions, one of them being open-ended. In order to have a sufficient basis for comparison of results between the 2007 survey and the 2012 survey, it was necessary to mirror the design of the 2007 survey wherever possible.

Survey Implementation

The survey was hosted by an independent third-party research company (Dufferin Research). Respondents were self-selecting with no limit on the number of responses received from each jurisdiction. The survey was administered electronically and was accessible in both English and French via a link to the survey website. Respondents participated by accessing the survey website and responding to a qualifying question. The survey was launched in English on December 16, 2011 and in French on January 23, 2012. The survey was closed on February 21.

Participating provincial and territorial engineering associations, as well as a limited number of industry associations, notified their members of the survey via an e-Newsletter or dedicated email. A link to the online survey website was provided in each case. Outreach to the engineering groups was championed by Engineers Canada. The following engineering associations participated:

- The Association of Professional Engineers and Geoscientists of B.C. (APEGBC)
- The Association of Professional Engineers and Geoscientists of Alberta (APEGA)
- The Association of Professional Engineers and Geoscientists of Saskatchewan (APEGS)
- The Association of Professional Engineers and Geoscientists of Manitoba (APEGM)
- Professional Engineers Ontario (PEO)
- Ordre des Ingénieurs du Québec (OIQ)
- Engineers Nova Scotia (APENS)
- The Association of Professional Engineers and Geoscientists of New Brunswick (APEGNBE)
- Engineers P.E.I.
- Professional Engineers and Geoscientists of Newfoundland and Labrador (PEGNL)
- The Association of Professional Engineers of Yukon (APEY)
- Northwest Territories and Nunavut Association of Professional Engineers and Geoscientists (NAPEG)



The survey was additionally disseminated through industry associations including the Canadian Water and Wastewater Association (CWWA), the Canadian Public Works Association, Centre D'Expertise et de Recherche en Infrastructures Urbaines (CERIU), members of the Public Infrastructure Engineering Vulnerability Committee (PIEVC), and a limited number of federal and provincial departments.

Sample Group

- National sample group
- All 13 Canadian jurisdictions represented
- 2007 total responses: n = 2060
- 2012 total responses: n = 3362
- Groups with less than 50 responses are not reported separately

Sample group national distribution (Q1)

Jurisdiction	Responses	% Total	
B.C	224	6.7%	
Alberta	565	16.8%	
Saskatchewan*	470	14.0%	
NWT/Nunavut	41	1.2%	} Total North; n = 55
Yukon	14	0.4%	
Manitoba	193	5.7%	
Ontario	1462	43.5%	
Quebec	208	6.2%	
Nova Scotia	33	1.0%	} Total Atlantic; n = 135
New Brunswick	39	1.2%	
P.E.I.	22	0.7%	
Newfoundland/ Labrador	41	1.2%	
Not currently practicing	50	1.5%	
Total	n = 3362	100%	

*Note: Saskatchewan was grouped with the territories in 2007

Sample group composition by industry sector (Q2)

Industry sector	Number of respondents	% Total
Engineering Services	1280	38.1%
Resources (e.g. mining, oil and gas, forestry)	413	12.3%
Utilities (including government utilities)	368	10.9%
Manufacturing	278	8.3%
Municipal Government	226	6.7%
Provincial Government	217	6.5%
Construction	156	4.6%
Federal Government	102	3.0%
Other	322	9.6%
Total	3362	100%

Sample group composition by infrastructure category (Q3)

Infrastructure category	Number of respondents	% Total
Energy	678	20.2%
Buildings	579	17.2%
Resource extraction and processing	574	17.1%
Water	519	15.4%
Transportation	438	13.0%
Other	574	17.1%
Total	3362	100%

Breakdown of regions by infrastructure category (Q1 with Q3)

Infrastructure category	BC (n=224)	AB (n=565)	SK (n=470)	MB (n=193)	ON (n=1462)	QC (n=208)	ATL (n=135)	North (n=55)	% Total (n=3362)
Energy	18%	20%	19%	21%	23%	12%	14%	20%	20%
Buildings	19%	12%	16%	28%	18%	12%	27%	21%	17%
Resources	19%	34%	29%	6%	10%	8%	13%	10%	17%
Water	17%	15%	13%	18%	14%	35%	19%	6%	15%
Transportation	11%	10%	9%	19%	14%	22%	11%	34%	13%
Other	16%	10%	13%	8%	23%*	12%	16%	11%	17%

**Note: The high number of respondents from Ontario that placed themselves in the “other category” for industry sector may be due to the prevalence of manufacturing engineers in that province. Since manufacturing can be in support of any number of the industry sectors listed, the “other” category may have been the most logical choice for these respondents.*

Margin of Error

The national results in aggregate are considered to have a margin of error of approximately 2% at the 95% confidence level. However, the margin of error for various cross-tabulations for infrastructure category, region, and industry sector has more variability and can be upwards of 11% at the 95% confidence level. Margin of error is a function of the sample size and the amount of variability within the sample. For example, the margin of error for a sample size of 100 is greater than for a sample size of 1000. The margin of error for a sample size of 100 where 50% of respondents choose an option is greater than the margin of error for the same sample size where only 5% choose that option.

Key Findings

Sample Group

In some cases, the number of responses received within a particular jurisdiction is not commensurate with the number of registered professional engineers in that jurisdiction. This is likely due to the method employed by each jurisdiction’s governing engineering body to disseminate the survey to its members. Experience has shown that the most effective method to solicit responses to a survey of this nature is to send a dedicated email reach-out with a direct URL to the survey page embedded within. Aside from communication methods, other factors that may have affected the rate of response across jurisdictions include the amount of time the French version of the survey was available versus the English version and

the length of time the survey was available in the field. Some of the engineering associations that sent a dedicated email notification to members in 2007 did not do so for the 2012 survey and vice versa.

Climate Change and Engineering Practice

Seventy percent of respondents indicated that a changing climate has already affected or will affect their engineering decisions, with 42% indicating strong agreement with this. While the vast majority of engineers accept that a changing climate affects their practice, fewer engineers in 2012 than in 2007 somewhat or strongly believe this. In 2007, 82% of engineers agreed that a changing climate would affect their engineering decisions. This difference is entirely accounted for in the proportion of respondents who indicated mild agreement (40% in 2007 versus 28% in 2012). In fact, the overall proportion of respondents who indicated strong agreement in 2012 is the same as in 2007 (42%). It is possible that some engineers have done work since 2007 to determine whether or not a changing climate affects their practice, and this group has determined that a changing climate does not actually factor into their engineering decisions. Alternatively, respondents who indicated mild agreement in 2007 may have been unsure or even indifferent towards the effects of a changing climate on their practice, and this group has since fallen off. The range of responses across jurisdictions may be attributed in part to the range of changes to local weather patterns across the country over the past few years.

Engineers working in water infrastructure are significantly more inclined to consider a changing climate in their engineering decisions (82%) as compared to the national average (70%). Indeed, the water cycle has been shown to be extremely sensitive to the impacts of a changing climate, so it follows that water infrastructure engineers may be more cognizant of the impacts of a changing climate on their practice. Engineers in Quebec, the Atlantic provinces, and the North reported relatively high agreement that a changing climate affects their engineering decisions (82%, 86%, and 89%, respectively).

Since the resource extraction/processing category is new in the 2012 survey, the results of this group of respondents was isolated in order to identify its influence on the overall results for the question of whether a changing climate affects engineering decisions. Without the resources category, the overall response is that 30% strongly agree and 43% somewhat agree that a changing climate affects engineering decisions. This does not represent a significant difference from the aggregate results for this question when the resources group is included. Regardless, the resources group has the lowest overall agreement (59% total, 19% strong agreement) of any infrastructure category. One explanation for this is that many resource extraction and processing projects involve short-term contracts and a more transient work force. The resource extraction and processing industry is driven in part by immediate market needs rather than impending factors like a changing climate and its impact on long-term infrastructure. During periods of instability of capital markets, for example, the resource extraction and processing sector may tend to have a more short term focus on infrastructure needs, while when economic factors are favourable, resources companies may shift focus towards sustainability of

infrastructure and adaptation to a changing climate. Engineers from Alberta and Saskatchewan report lower than average agreement that a changing climate affects engineering decisions, which could be attributed to the fact that resources is the dominant industry sector represented by those provinces in the survey.

Engineers in the public sector appear to be more sensitive to the effects of a changing climate on infrastructure than engineers in other industries. Issues around climate change adaptation and mitigation continue to be leading influences for policy makers; 79%, 80%, and 83% of respondents from municipal, provincial, and federal government, respectively, agree that a changing climate affects engineering practice. The 2007 survey showed a similar trend.

While the majority of respondents indicate that a changing climate affects their engineering decisions (70%), only 28% of engineers indicate that they mostly or always consider the impacts of a changing climate in their engineering decisions; only 10% of engineers always consider the impacts of a changing climate in their decisions. Hence, there is high acceptance that a changing climate factors into engineering decision-making, however a smaller proportion of engineers are actually taking action around it. There may be several causes for this, including a lack of general knowledge around the impacts of a changing climate, constraints placed on practitioners by decision-makers, variability in terms of need, and the absence of regulatory requirements. Nevertheless, it is promising that, overall, 74% of engineers consider the impacts of a changing climate to some degree in their practice. The degree to which engineers actually consider a changing climate in their decisions is more or less unchanged since 2007, where the overall rate of consideration was 72%, with 27% always or mostly considering it. In 2007, this was profiled more towards the building sector, while in 2012 it is the water sector that is leading the way, with the overall rate of consideration at 85% compared to 74% for the aggregate group. In 2012, 36% of engineers in the water sector always or mostly consider a changing climate in their engineering decisions (in 2007 it was 24%). This could indicate a possible shift in focus for this sector. The rate of consideration of the impacts of a changing climate in engineering practice is significantly above average for engineers from Quebec (82%), the Atlantic provinces (92%), and the North (92%); the average across all jurisdictions is 74%.

When it comes to climate change mitigation, 3 out of 4 engineers believe that reduction of greenhouse gas emissions will mitigate future climate change, however a smaller proportion of engineers overall believe this in 2012 than in 2007 (76% in 2012 versus 86% in 2007). Despite this, a greater proportion of respondents in 2012 indicate strong agreement that GHG emissions reduction will mitigate future climate change (27% in 2007 versus 38% in 2012). The rate of agreement is higher in Quebec (83%) and the Atlantic provinces (90%), and lower in Alberta (68%). Engineers in the resources sector reported the lowest rate of agreement (63%). Note that the resources category in this survey includes engineers from the fossil fuels extraction and processing sector which may have an economic interest in conflict with efforts to reduce GHG emissions. The overall decline in the rate of agreement that reducing GHG emissions will help to mitigate future climate change could be suggestive of increasing skepticism

around the causes behind a changing climate. The proportion of engineers who strongly agree that reducing GHG emissions will mitigate climate change is significantly lower in 2012 (38% in 2012 down from 58% in 2007).

Climate Change Information and Infrastructure Engineering

The majority (74%) of infrastructure engineers feel they need more information to address the impacts of a changing climate in their practice. This is more or less unchanged since 2007. The need for information is profiled slightly more towards water and transportation infrastructure engineers (80% for both), as well as Manitoba (82%), the Atlantic provinces (83%), and the North (87%). Quebec engineers indicated a lower need for climate change information (64%), perhaps related to the fact that a higher proportion of respondents there are water infrastructure engineers. Manufacturing engineers also report lower need for climate change information (62%).

Respondents were asked how likely they are to seek specific information on a changing climate as it relates to engineering practice in the next 12 months. Less than half (47%) of engineers indicated a likelihood of seeking information. Water infrastructure engineers are well above the national average with 61% indicating likelihood of seeking information, with 27% indicating that they are very likely compared to 17% for the national sample. Resources engineers are the least likely to seek information on a changing climate, with only 35% indicating that they are likely or very likely to seek information (11% indicated that they are very likely). In 2007, engineers were asked how likely they are to seek information on a changing climate over 18 months. Fifty-four percent indicated that they are likely or very likely to seek information. Similar to the 2012 results, this was profiled more towards water infrastructure engineers (65%), but also toward buildings engineers (64%). Resource extraction/processing engineers were not differentiated in the 2007 survey. The reduced overall likelihood of today's engineers to seek information on a changing climate could be partially accounted for in the time interval addressed by the question (12 months in the 2012 survey versus 18 months in the 2007 survey). At the same time, climate change may no longer be the dominant social, political, or economic issue in the mind of the public, and therefore some engineers may be less inclined to take initiative to better understand its impact on their practice. Regardless, there seems to be a prevailing sentiment that additional information is required in order for engineers to fully account for the impacts of a changing climate in engineering practice.

By far, engineers' most preferred methods of receiving information on a changing climate are through published guidelines and best practices (28%) and online resources (including dedicated websites and/or links to websites) (23%). These two categories were also the most popular in 2007*, at 29% and 30% respectively. This implies that engineers prefer to receive information from reference materials, whether online or in print. The least popular method for engineers to receive information on climate change is through classroom continuing education (4%); in 2007 it was e-Learning courses (5%). In 2012,

e-Learning appears to have gained popularity, with 10% of respondents indicating that online continuing education (e-Learning) is their preferred method to receive information on climate change.

***Note:** *The 2012 survey offered eight response choices while the 2007 survey offered six.*

Engineers' overall familiarity with the impacts of a changing climate is lower in 2012 than in 2007. It is important to note, however, that the proportion of engineers who are somewhat familiar with the impacts of a changing climate is only slightly decreased and for some groups unchanged. The majority of the decrease in overall familiarity in 2012 can be mostly accounted for in the decreased proportion of engineers who are very familiar with the impacts, which ranges between 7% and 12%. One would expect familiarity with the impacts of a changing climate to increase over time, however the fact that familiarity has overall decreased by an average of 11% for all the suggested impacts could be an indication that engineers feel they know proportionally less today than they did in 2007. That is, while overall knowledge and understanding of the impacts of a changing climate could have increased since 2007, engineers may now be realizing the complexity of the impacts of a changing climate on infrastructure is much larger than they came to understand in the past. Hence, only relative familiarity of the impacts of a changing climate has decreased over time.

The impacts that were most familiar to engineers in 2007 remain the most familiar in 2012; changes in seasonality and type of precipitation along with more frequent and intense storms top the list in 2012 with 68% of engineers reporting that these are the most familiar impacts to them. In 2007, 75% and 74% of engineers reported familiarity with these same impacts, respectively. It is to be expected that these are the impacts most familiar to engineers since changes in local weather patterns are readily observed on a day-to-day basis and are experienced first-hand by most people across the country. The rate of familiarity is low for sea level rise (38%), thawing permafrost (42%), increased flooding (49%), and water shortages (48%), perhaps because these impacts typically go unobserved by the general population. For these same impacts, the overall decrease in rate of familiarity since 2007 is more severe, with a decrease of 20%, 17%, 13%, and 15% of engineers, respectively, reporting familiarity. Note that the resources group, when isolated from the aggregate results, does not significantly influence the overall level of familiarity with the impacts of a changing climate on infrastructure.

Climate Change Adaptation Tools and Techniques

Generally, engineers' familiarity with climate change adaptation tools and techniques has increased since 2007, albeit marginally in most cases. This result is at odds with the result about engineers' familiarity with the impacts of a changing climate. The tools and techniques that are most familiar to engineers are the ones that are part of standard engineering practice. These are increasing safety factors and performing risk assessment/management (60% of engineers reported familiarity with each of these techniques). More complex techniques, like designing infrastructure that can be modified over time, identifying locations that may be vulnerable to climate change, and considering different climate change scenarios for design are less familiar to engineers likely because these techniques may only be

fully relevant for certain applications. Nevertheless, the increased awareness of adaptation tools and techniques is an indicator that these solutions have developed over time and could penetrate further into mainstream engineering practice in the future.

Fifty-nine percent of engineers reported using one or more tools/techniques to adapt to a changing climate. Not surprisingly, the tools and techniques that engineers use most are the ones with which they are most familiar. Nevertheless, there is a significant disparity between familiarity with each adaptation tool/technique and its rate of application. This ranges between 21% and 35% of respondents for any given tool/technique. The fact that familiarity is relatively high while action is low could represent a call for further education and training of infrastructure engineers in the tools and techniques available to adapt to a changing climate. Still, engineers may be taking more action today to adapt to the changing climate than they were in 2007* thanks to increased understanding and familiarity with adaptation tools and techniques.

***Note:** *The 2007 survey did not ask which tools and techniques engineers use to adapt to a changing climate.*

Engineers Canada developed a procedure known as the PIEVC (Public Infrastructure Engineering Vulnerability Committee) Protocol. This tool evaluates the engineering vulnerability of infrastructure and the risks associated with the impacts of current and future climate change at a screening level. Seven percent of engineers reported that they are somewhat or very familiar with the PIEVC Protocol, while 84% indicated that they are not at all familiar. The main reason why engineers are not using the PIEVC Protocol is lack of awareness or familiarity with the tool (67% reported this), however 14% of engineers indicated that they have no requirement for an engineering vulnerability assessment, and 8% of engineers indicated that they are unsure how the PIEVC Protocol can fit into their practice. Three percent of respondents indicated that they have already used or intend to use the PIEVC Protocol.

Respondents were asked to elaborate on which other tools and techniques they use to adapt to a changing climate. The main themes are summarized below:

- Mitigate climate change through the use of green technologies; design infrastructure for energy efficiency; implement sustainable practices;
- Adjust designs based on increased safety factors; perform risk analysis/risk management and develop contingencies based on specific needs; design infrastructure with increased flexibility;
- Adapt designs based on the newest technical data and research available; consider economic factors when designing infrastructure; use models to predict climate change impacts and adjust designs accordingly; monitor infrastructure continuously and adjust accordingly;
- Expand the scope of planning and preparation;
- Take direction from policy-makers and refer to prevailing codes and regulations; promote information sharing;
- Use an infrastructure vulnerability assessment tool such as the PIEVC Protocol;
- Avoid infrastructure that is vulnerable;

- Do not use tools or techniques to adapt infrastructure to a changing climate due to skeptical attitude towards climate change

Barriers to Addressing Climate Change in Engineering Practice

Sixteen percent of engineers indicate that they are currently addressing the impacts of a changing climate on infrastructure. The main reasons identified for preventing engineers from addressing the impacts of a changing climate on infrastructure are a lack of requirements in codes/standards/policy (18%), climate change having no effect on their practice (17%), and lack of information and resources (13%). The distribution across infrastructure categories of those who are not addressing a changing climate in their practice due to lack of information and resources is more or less even, ranging from 14% of resource extraction/processing engineers to 20% of energy infrastructure engineers. A relatively small proportion of engineers indicated that they do not address the impacts of a changing climate due to lack of support from clients/owners/management (7%), lack of adequate climate data (5%), unjustifiable costs (4%), or lack of available time (1%). Thirteen percent of engineers indicated that they are skeptical towards climate change. Of those who indicated that skepticism is the main barrier to addressing the impacts of a changing climate on infrastructure, 26% are resource extraction and processing engineers, 25% are energy infrastructure engineers, and 16% are buildings engineers.



Appendix A

Survey Questions

Pre-survey screening question

Are you currently licensed as a Professional Engineer with a provincial or territorial association in Canada?

- Yes
- No

Question 1

In which province or territory do you practice professional engineering most often? **Select one answer only;**

- Alberta
- British Columbia
- Manitoba
- New Brunswick
- Newfoundland and Labrador
- Northwest Territories / Nunavut
- Nova Scotia
- Ontario
- Prince Edward Island
- Quebec
- Saskatchewan
- Yukon Territory
- I don't currently practice professional engineering

Question 2

In which industry or sector are you employed? **Select one answer only;**

- Engineering Services
- Resources (e.g. mining, oil and gas, forestry)
- Manufacturing
- Utilities (including government utilities)
- Federal Government
- Provincial Government
- Municipal Government
- Construction
- Other

Question 3

In your day-to-day job, in which area do you most often make engineering decisions affecting design, operations, maintenance, planning, specification, or tendering? **Select one answer only;**

- Water infrastructure (including stormwater, shoreline protection, drinking water, wastewater)
- Transportation infrastructure (including roads, highways, associated drainage structures, seaports, bridges, rail)
- Energy infrastructure (including transmission and distribution systems, pipelines, electricity generation)
- Buildings infrastructure (including structures, HVAC systems, building envelope, foundations)
- Resource extraction and processing (including oil and gas, mining, forestry, pulp and paper)
- Other

Question 4

For each of the following statements, please indicate your level of agreement. If you are not sure, please select the response that is closest to your level of agreement;

Strongly agree

Somewhat agree

Somewhat disagree

Strongly disagree

- A changing climate has already affected or will affect my engineering decisions in the near future.
- Reducing greenhouse gas emissions would lessen the magnitude of future climate change.
- I need more information to enable me to address the impacts of a changing climate in my engineering practice.

Question 5

For each of the following suggested impacts of a changing climate, please indicate your level of familiarity as these relate to infrastructure;

Not at all familiar

Not very familiar

Somewhat familiar

Very familiar

Not applicable to my practice

- More frequent and intense storms
- Changes in seasonality and type of precipitation
- Changes in freeze/thaw cycles depending on region
- Thawing permafrost in northern climates
- More frequent and severe water shortages
- Changes to historical climatic loads such as wind, snow, and ice
- Increased coastal and river flooding
- Changes to peak energy demand magnitudes and seasonality (resulting from extreme temperatures)
- Sea level rise

Question 6

For each of the following tools and techniques that have been suggested for responding or adapting to the impacts of a changing climate, please indicate your level of familiarity;

Not at all familiar

Not very familiar

Somewhat familiar

Very familiar

Not applicable to my practice

- Increase the magnitude of design parameters or safety factors
- Perform a formal risk assessment and carry out risk management
- Review existing practices and use entirely new solutions
- Develop contingency plans for infrastructure failure
- Identify infrastructure that is at risk because of a changing climate, and retrofit priority assets
- Consider increased deterioration rates in design and maintenance plans
- Consider different climate change scenarios or models for design, maintenance, or planning
- Identify locations that may be vulnerable to climate change impacts and avoid them altogether or modify designs accordingly
- Design infrastructure that can be modified over time as the impacts of a changing climate occur



Question 7

To what degree do you consider the impacts of a changing climate in your current engineering decisions?

Always consider

Mostly consider

Sometimes consider

Never consider

Question 8

Which of the following tools and techniques are you presently using in your practice to respond to the impacts of a changing climate? **Select all that apply;**

- I am not currently using any tools or techniques
- Increase the magnitude of design parameters or safety factors
- Perform a formal risk assessment and carry out risk management
- Review existing practices and use entirely new solutions
- Develop contingency plans for infrastructure failure
- Identify infrastructure that is at risk because of a changing climate, and retrofit priority assets
- Consider increased deterioration rates in design and maintenance plans
- Consider different climate change scenarios or models for design, maintenance, or planning
- Identify locations that may be vulnerable to climate change impacts and avoid them altogether or modify designs accordingly
- Design infrastructure that can be modified over time as the impacts of a changing climate occur
- Other (please list): _____

Question 9

How likely are you to seek specific information on a changing climate as it relates to engineering practice in the next 12 months?

Very likely

Somewhat likely

Somewhat unlikely

Not very likely

Question 10

How would you prefer to receive information on a changing climate as it relates to engineering practice?

Select one answer only;

- Classroom continuing education
- Online continuing education (e-Learning)
- Scholarly articles in engineering publications or journals
- Published guidelines and best practices
- Conferences or webinars
- Training workshops
- Online resources (including dedicated websites and/or links to websites)
- Peer interaction

Question 11

Engineers Canada has developed a procedure known as the PIEVC Engineering Protocol that evaluates the engineering vulnerability of infrastructure and the risks associated with the impacts of current and future climate change at a screening level;

a) Please indicate your level of familiarity with this tool;

- Not at all familiar
- Not very familiar
- Somewhat familiar
- Very familiar
- Not applicable to my practice

(PIEVC: Public Infrastructure Engineering Vulnerability Committee)

b) If you have not used the PIEVC Engineering Protocol, please indicate the main reason why.
Select one answer only;

- Lack of awareness or familiarity with this tool
- Unsure of the benefits/value of an engineering vulnerability assessment
- Lack of training for this tool
- Unsure how this tool could fit into my practice/job
- Lack of adequate climate data to use this tool
- No requirement for an engineering vulnerability assessment
- Lack of funds to perform an engineering vulnerability assessment
- Already using other tools and techniques to assess engineering vulnerability
- I intend to use this tool but have not yet had the opportunity
- I have already used the PIEVC Engineering Protocol

Question 12

If you are not already doing so, what is the main reason preventing you from addressing a changing climate and its impact on infrastructure? **Select one answer only;**

- A changing climate has no effect on my practice
- Lack of adequate climate data
- Lack of information and resources
- Lack of support from clients/owners/management
- Skeptical attitude towards climate change
- Lack of requirements in codes, standards, or policy
- Cost cannot be justified
- Lack of available time
- Other
- I am currently addressing the impacts of a changing climate on infrastructure



Appendix B

Detailed Results

Question 1

In which province or territory do you practice professional engineering most often? **Select one answer only;**

Jurisdiction	Responses	% Total
B.C	224	6.7%
Alberta	565	16.8%
Saskatchewan	470	14.0%
NWT/Nunavut	41	1.2%
Yukon	14	0.4%
Manitoba	193	5.7%
Ontario	1462	43.5%
Quebec	208	6.2%
Nova Scotia	33	1.0%
New Brunswick	39	1.2%
P.E.I.	22	0.7%
Newfoundland/ Labrador	41	1.2%
Not currently practicing	50	1.5%
Total	3362	100%

**Total North;
n = 55**

**Total Atlantic;
n = 135**

Question 2

In which industry or sector are you employed? *Select one answer only;*

- Engineering Services
- Resources (e.g. mining, oil and gas, forestry)
- Manufacturing
- Utilities (including government utilities)
- Federal Government
- Provincial Government
- Municipal Government
- Construction
- Other

Industry sector	Number of respondents	% Total
Engineering Services	1280	38.1%
Resources (e.g. mining, oil and gas, forestry)	413	12.3%
Utilities (including government utilities)	368	10.9%
Manufacturing	278	8.3%
Municipal Government	226	6.7%
Provincial Government	217	6.5%
Construction	156	4.6%
Federal Government	102	3.0%
Other	322	9.6%
Total	3362	100%

Question 3

In your day-to-day job, in which area do you most often make engineering decisions affecting design, operations, maintenance, planning, specification, or tendering? **Select one answer only;**

- Water infrastructure (including stormwater, shoreline protection, drinking water, wastewater)
- Transportation infrastructure (including roads, highways, associated drainage structures, seaports, bridges, rail)
- Energy infrastructure (including transmission and distribution systems, pipelines, electricity generation)
- Buildings infrastructure (including structures, HVAC systems, building envelope, foundations)
- Resource extraction and processing (including oil and gas, mining, forestry, pulp and paper)
- Other

Infrastructure category	Number of respondents	% Total
Energy	678	20.2%
Buildings	579	17.2%
Resource extraction and processing	574	17.1%
Water	519	15.4%
Transportation	438	13.0%
Other	574	17.1%
Total	3362	100%



- Breakdown of region by Infrastructure category (Q1 with Q3)**

Infrastructure category	BC (n=224)	AB (n=565)	MB (n=193)	SK (n=470)	ON (n=1462)	QC (n=208)	ATL (n=135)	North (n=55)	% Total (n=3362)
Energy	18%	20%	21%	19%	23%	12%	14%	20%	20%
Buildings	19%	12%	28%	16%	18%	12%	27%	21%	17%
Resources	19%	34%	6%	29%	10%	8%	13%	10%	17%
Water	17%	15%	18%	13%	14%	35%	19%	6%	15%
Transportation	11%	10%	19%	9%	14%	22%	11%	34%	13%
Other	16%	10%	8%	13%	23%	12%	16%	11%	17%

Question 4

For each of the following statements, please indicate your level of agreement. If you are not sure, please select the response that is closest to your level of agreement;

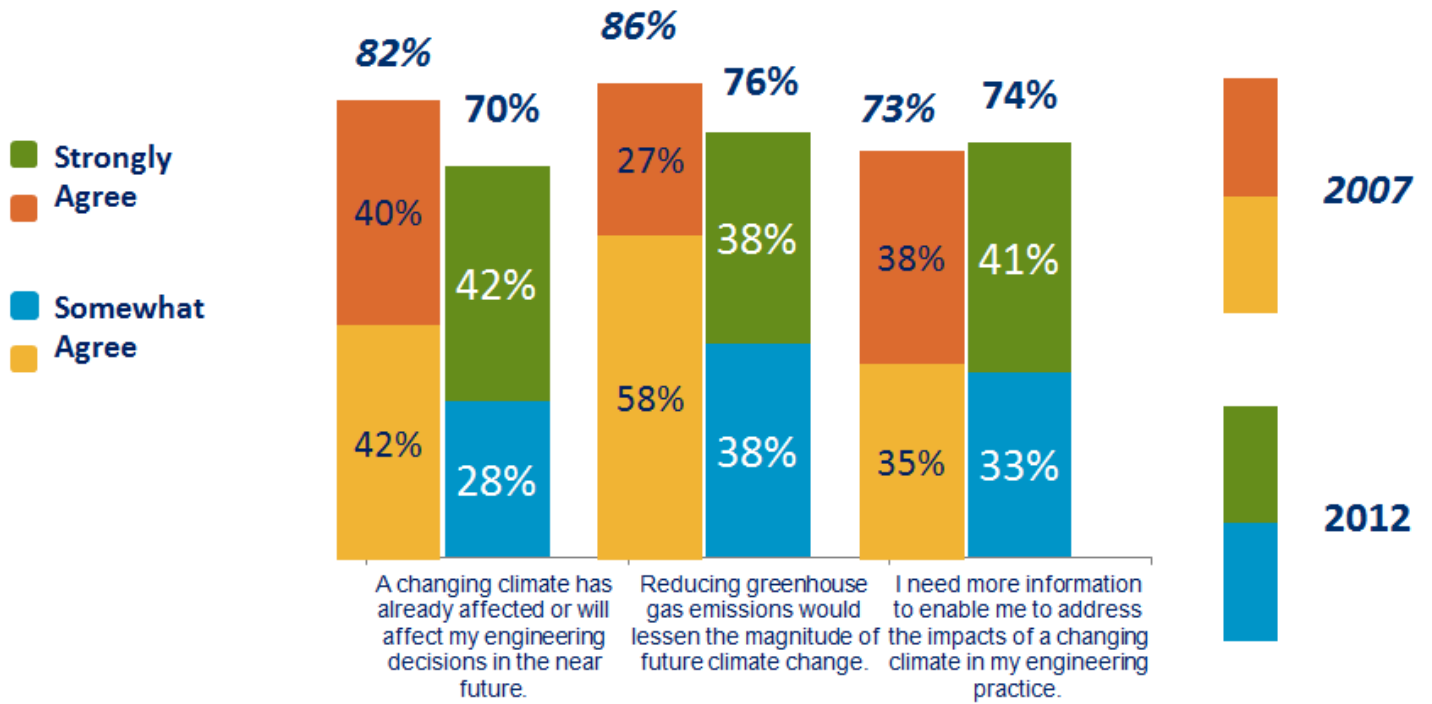
Strongly agree

Somewhat agree

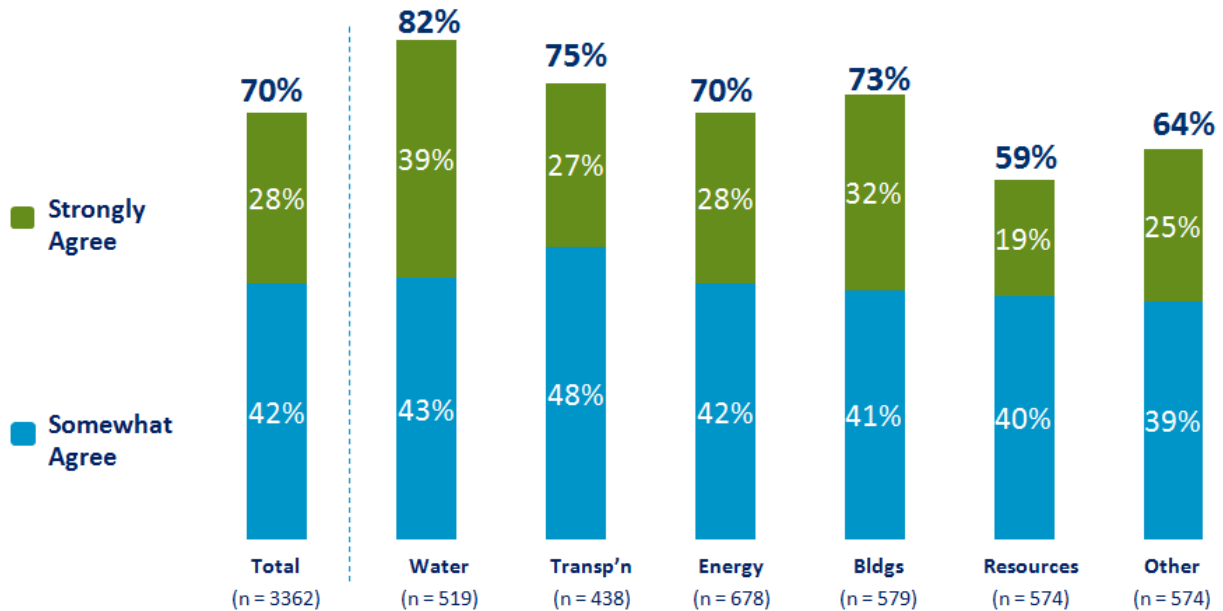
Somewhat disagree

Strongly disagree

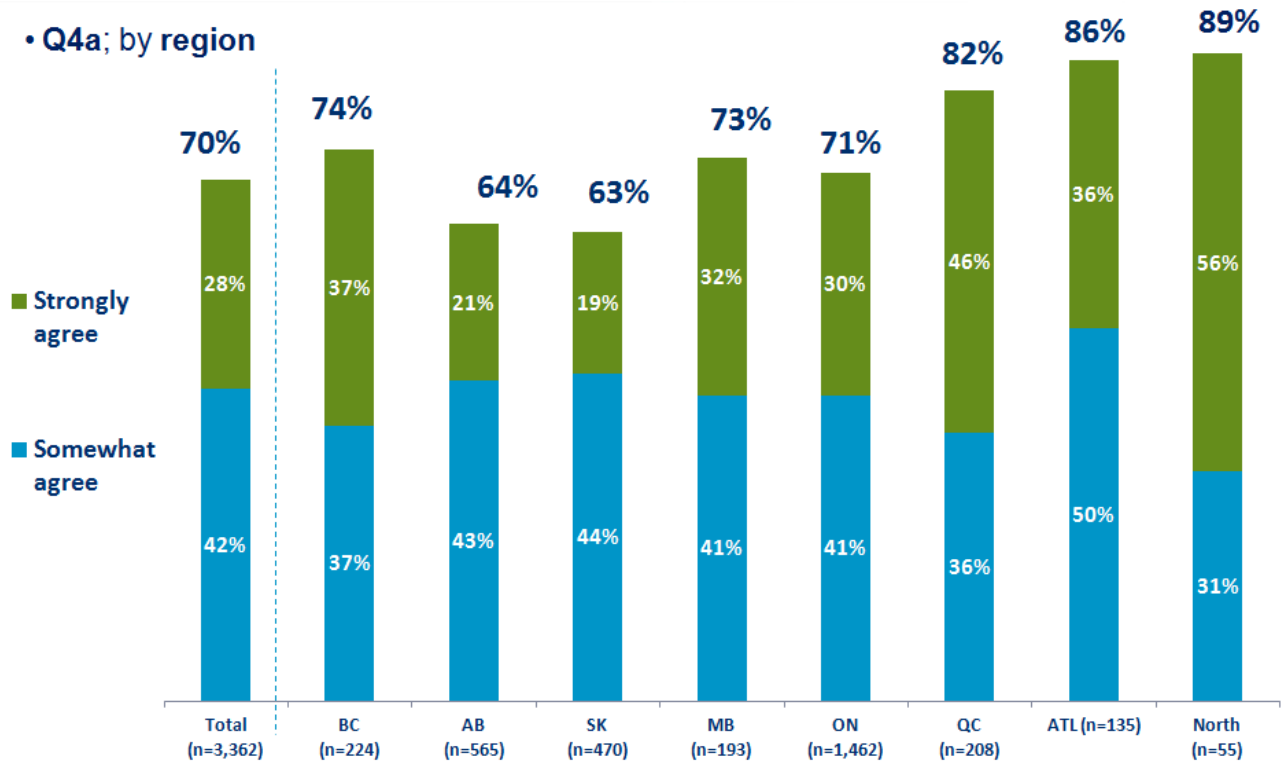
- A changing climate has already affected or will affect my engineering decisions in the near future.
- Reducing greenhouse gas emissions would lessen the magnitude of future climate change.
- I need more information to enable me to address the impacts of a changing climate in my engineering practice.



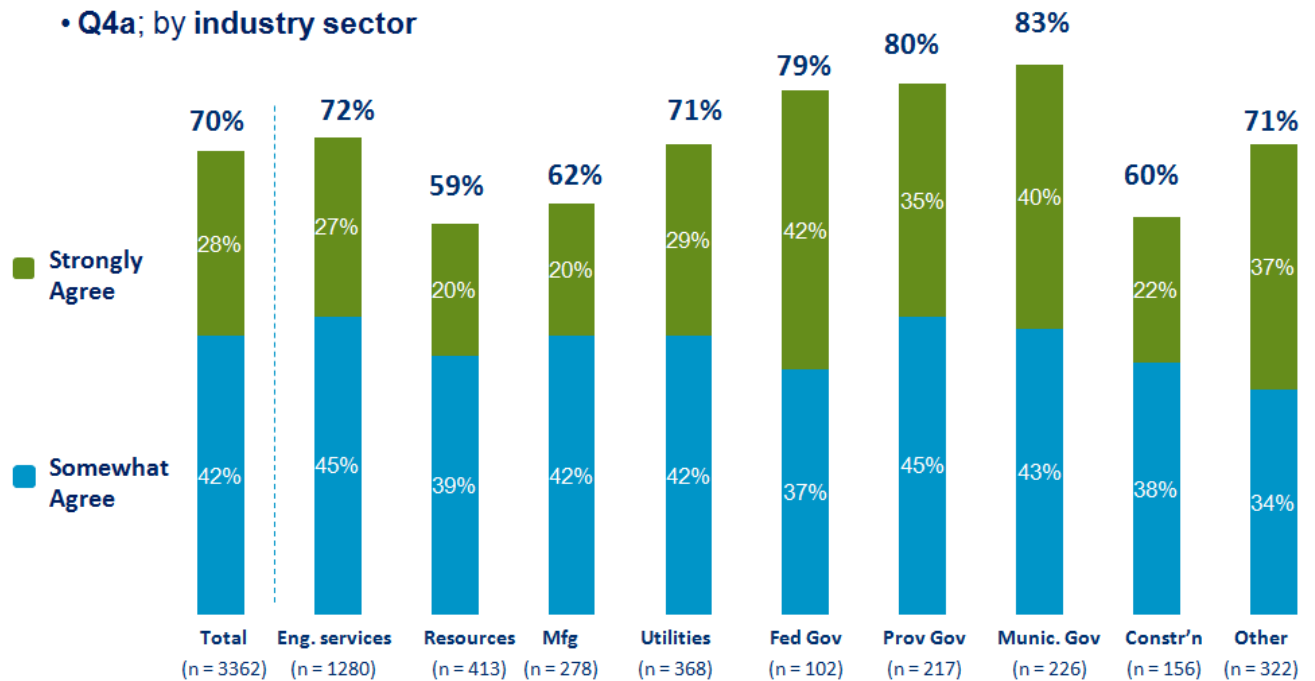
• Q4a; by infrastructure category



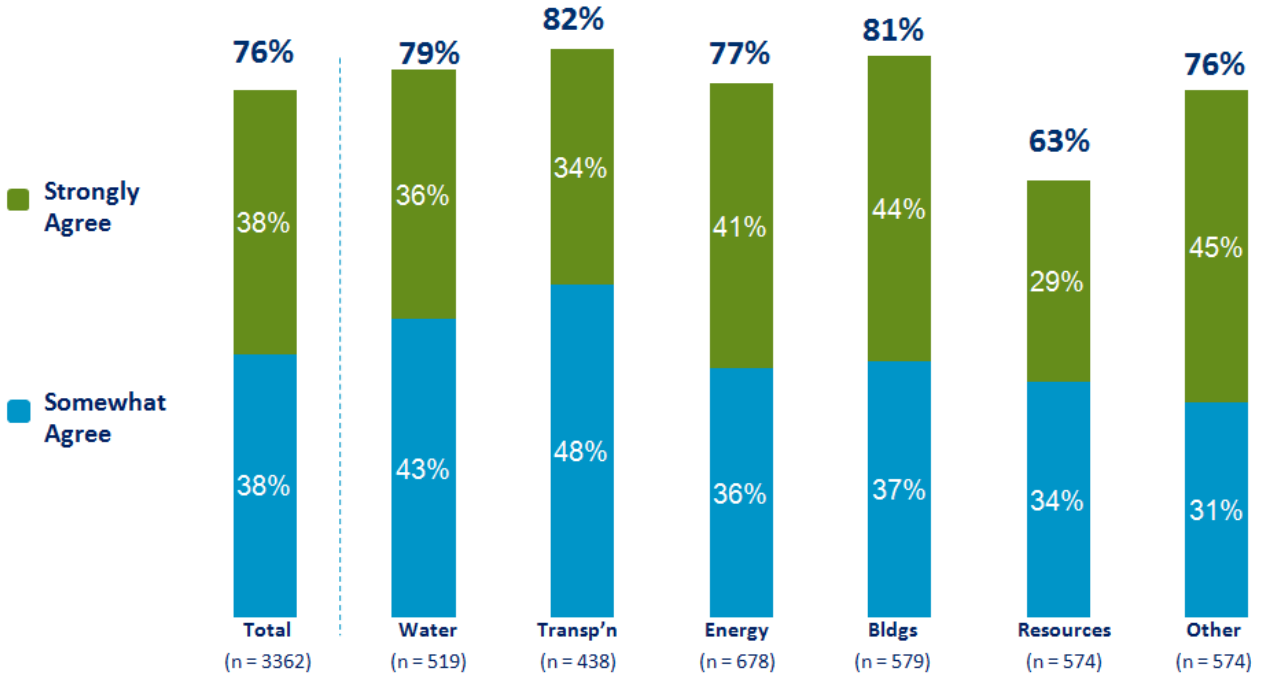
• Q4a; by region



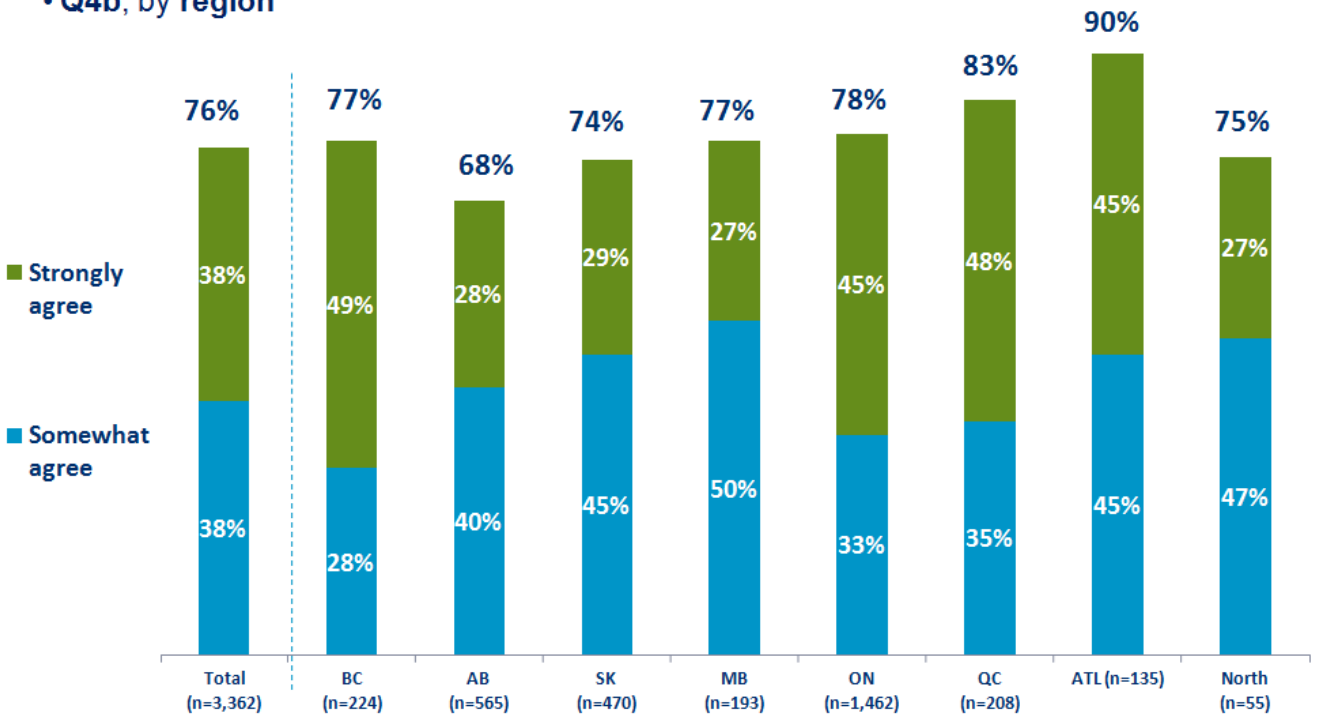
• Q4a; by industry sector



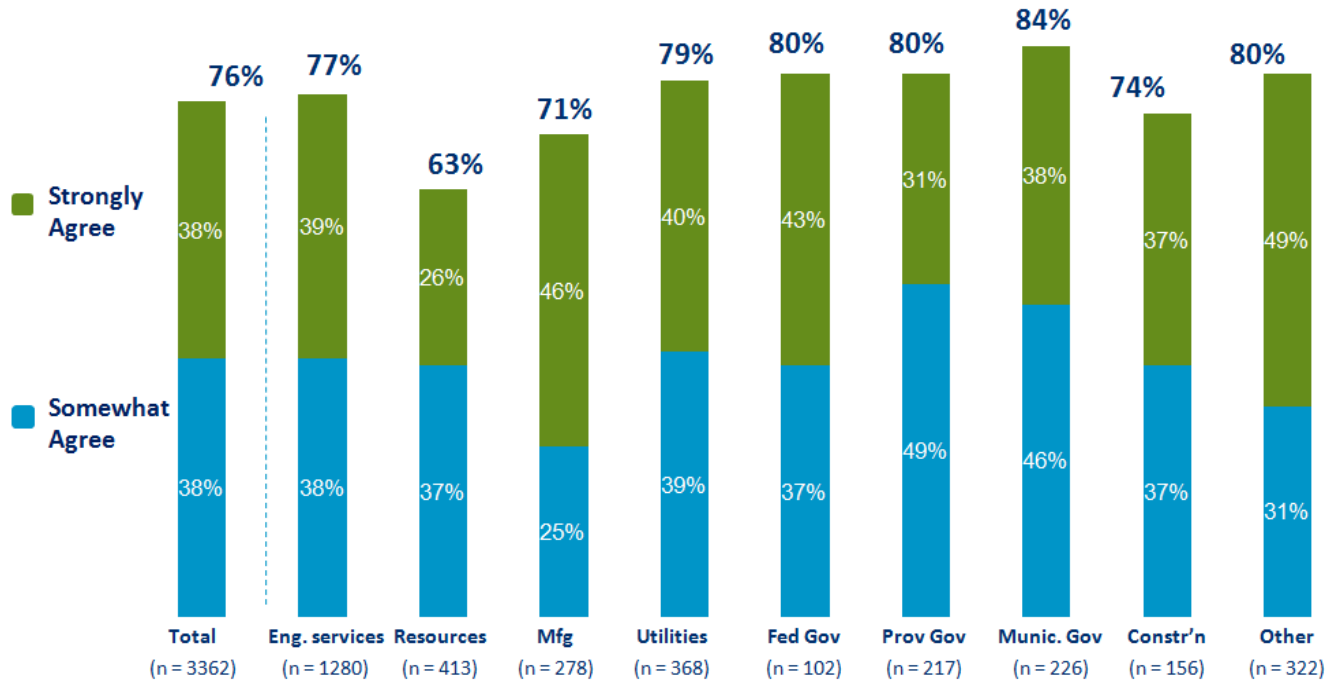
• Q4b; by infrastructure category



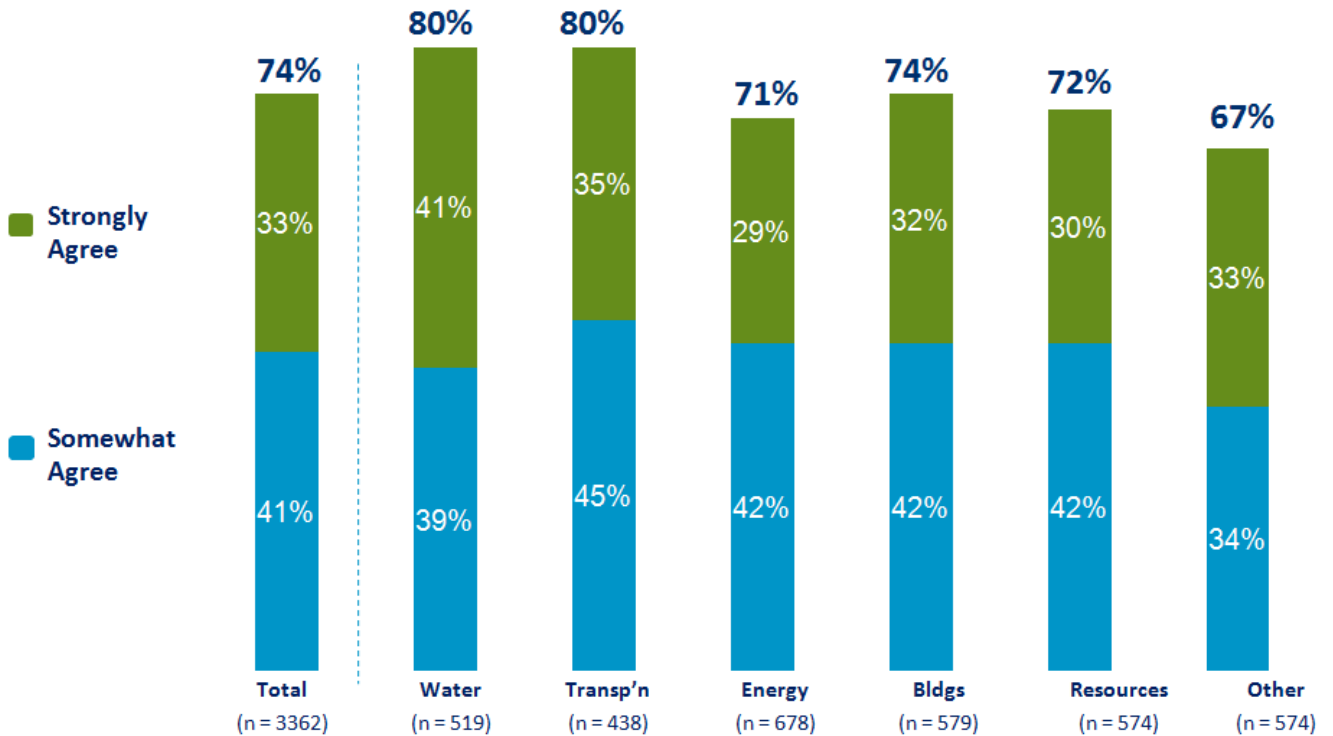
• Q4b; by region



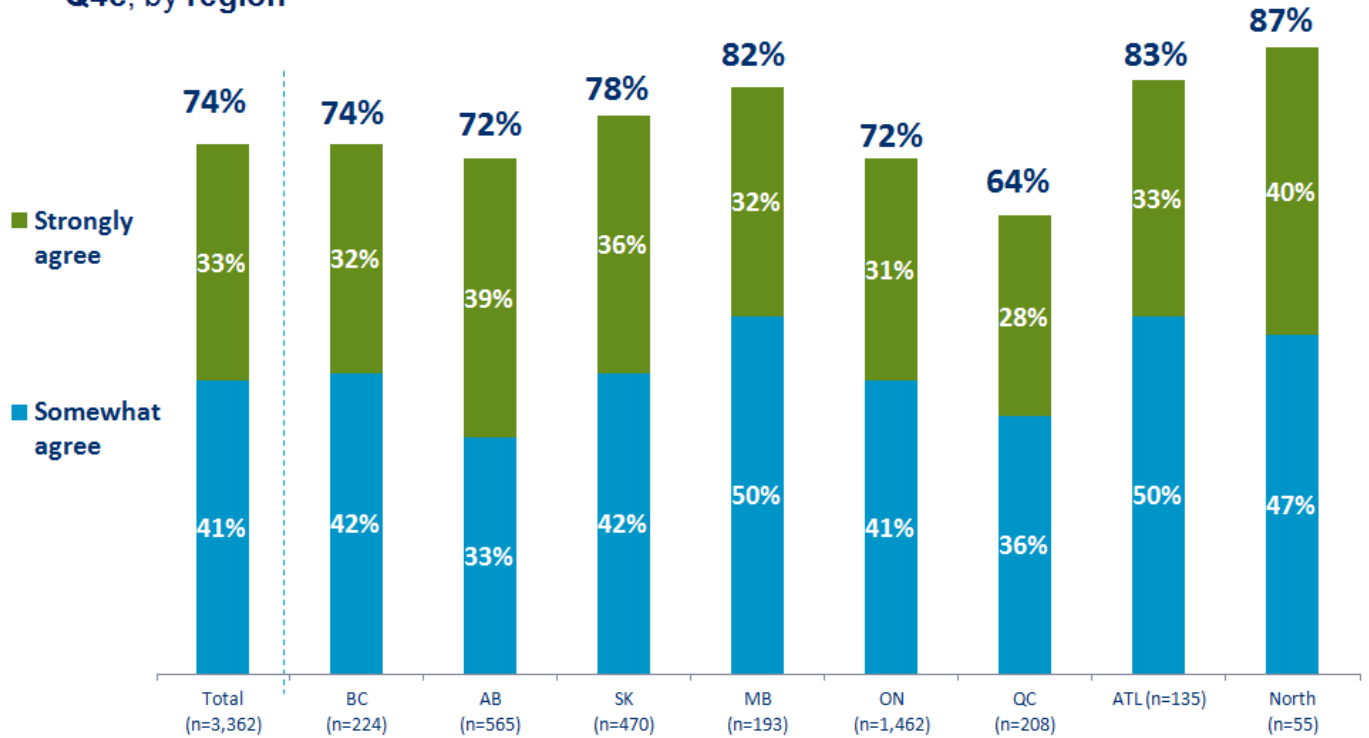
• Q4b; by industry sector



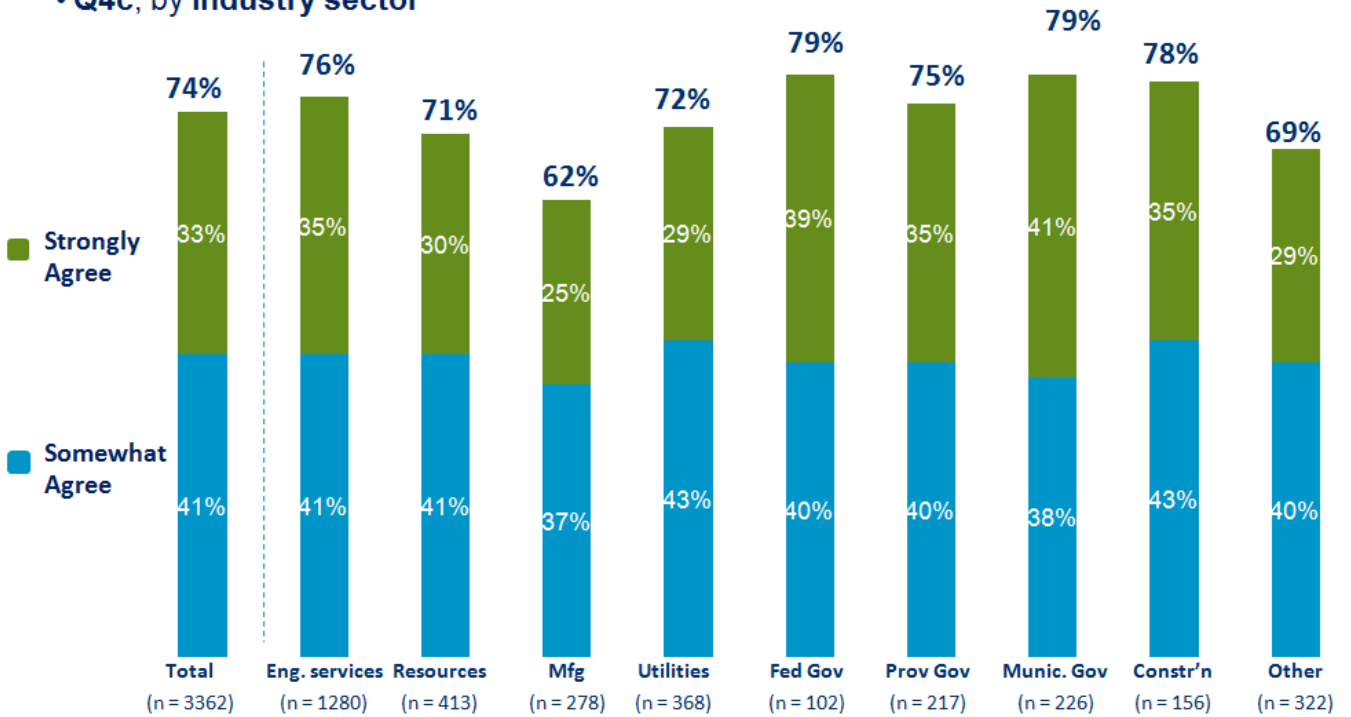
• Q4c; by infrastructure category



• Q4c; by region

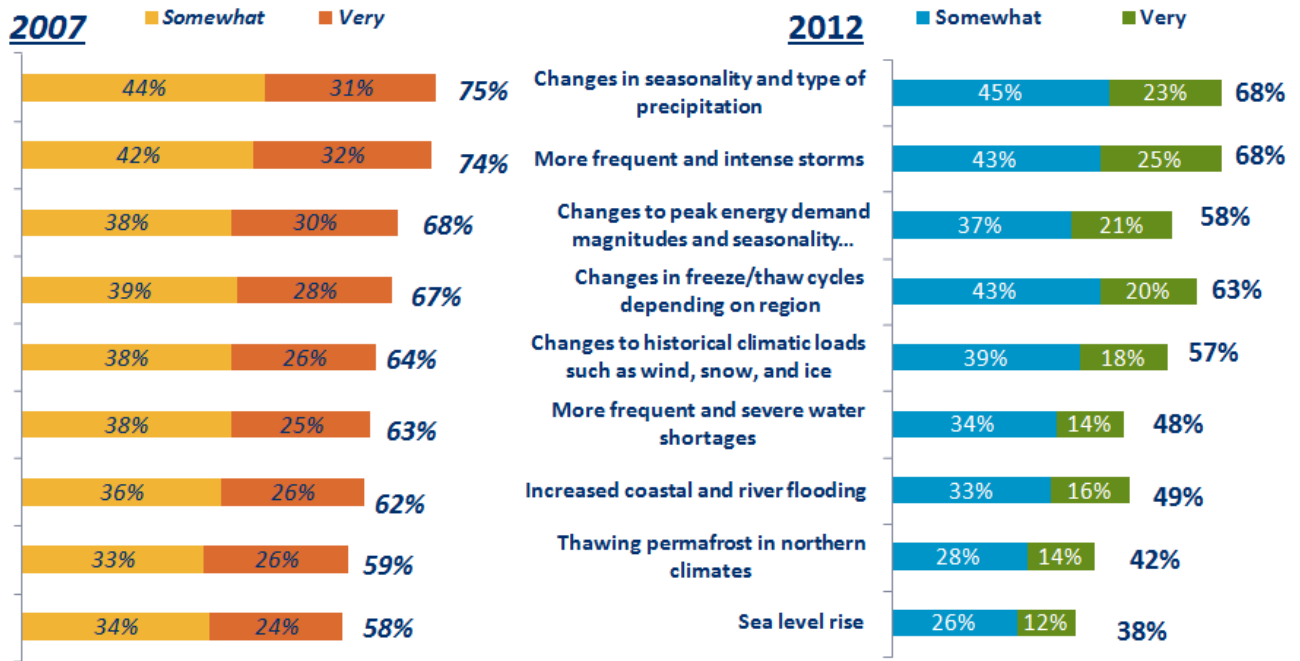


• Q4c; by industry sector



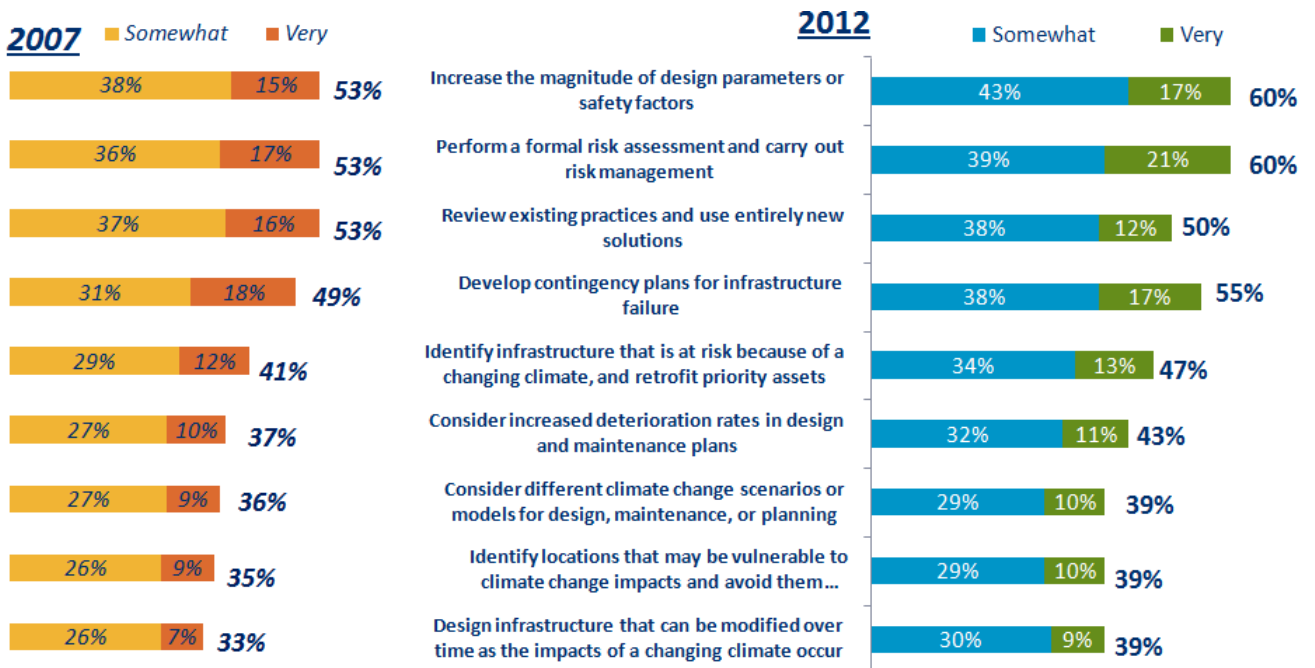
Question 5

For each of the following suggested impacts of a changing climate, please indicate your level of familiarity as these relate to infrastructure;



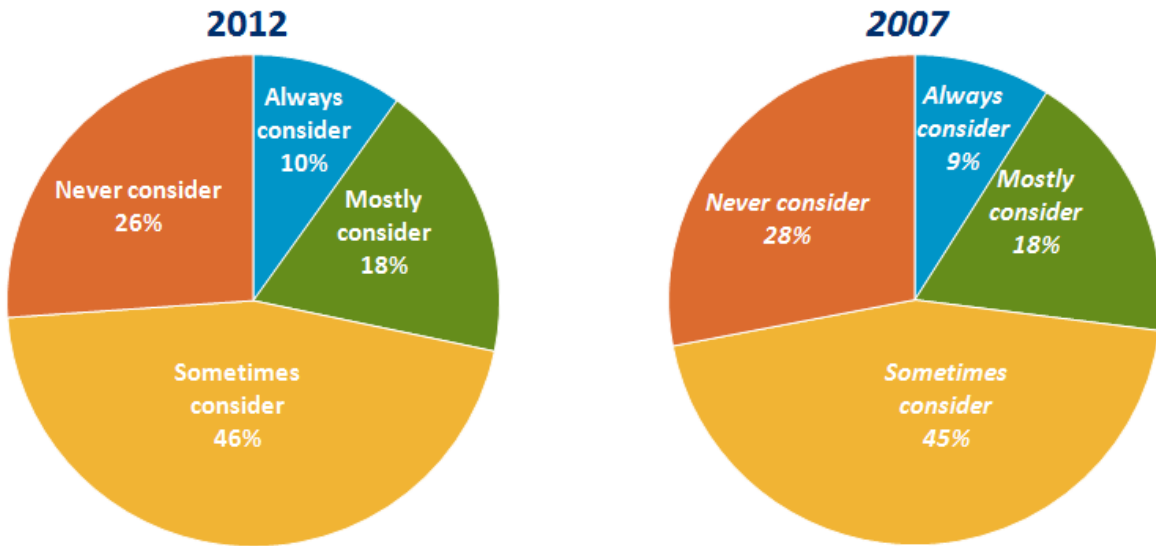
Question 6

For each of the following tools and techniques that have been suggested for responding or adapting to the impacts of a changing climate, please indicate your level of familiarity;

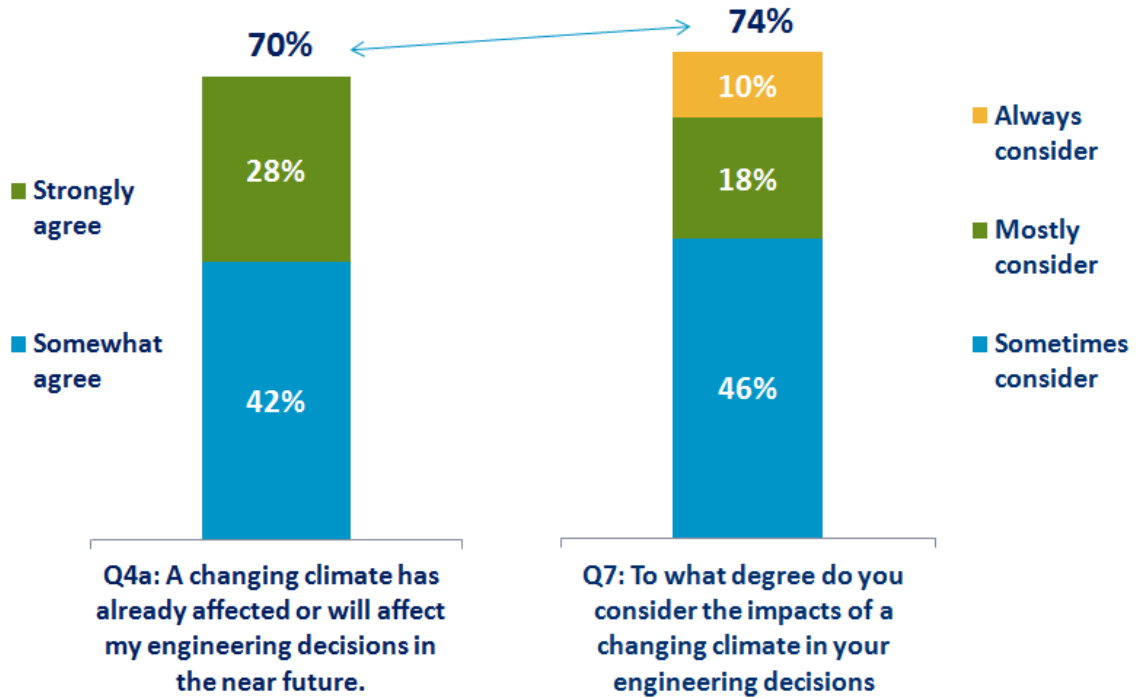


Question 7

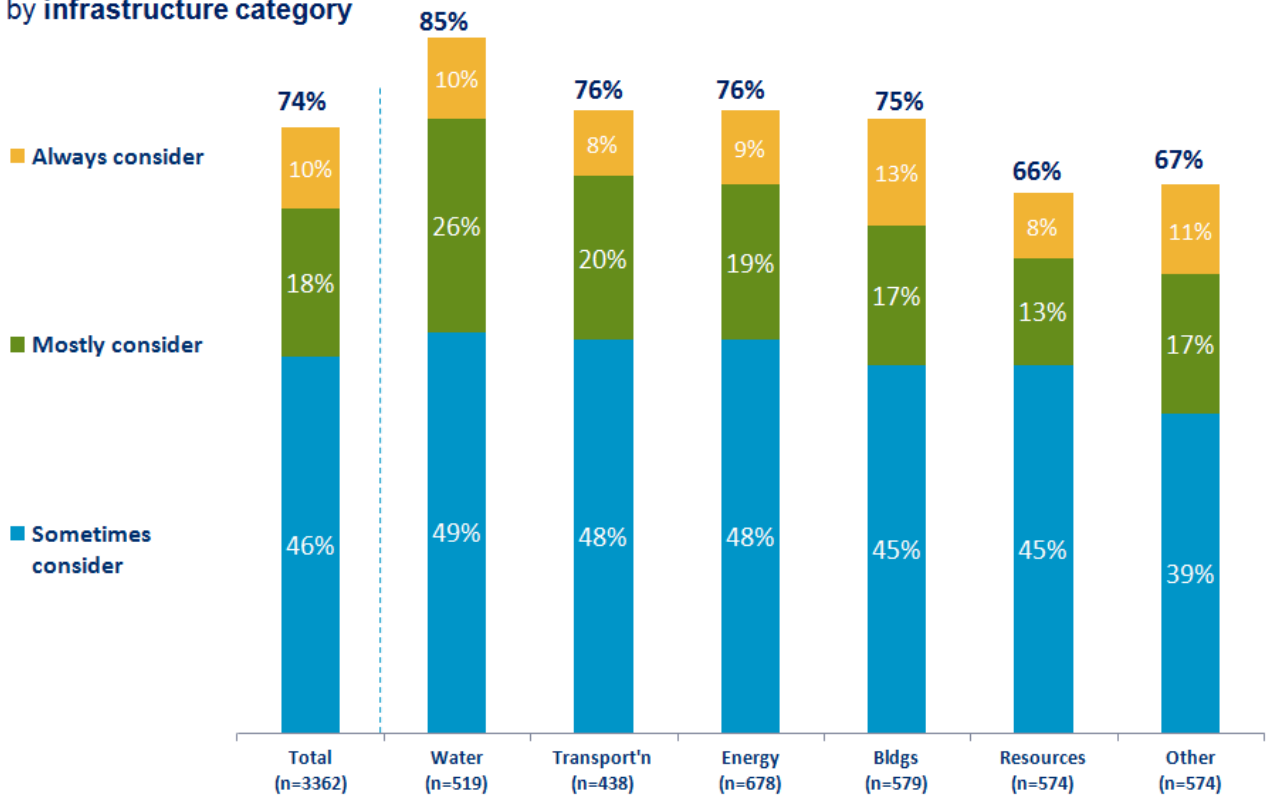
To what degree do you consider the impacts of a changing climate in your current engineering decisions?



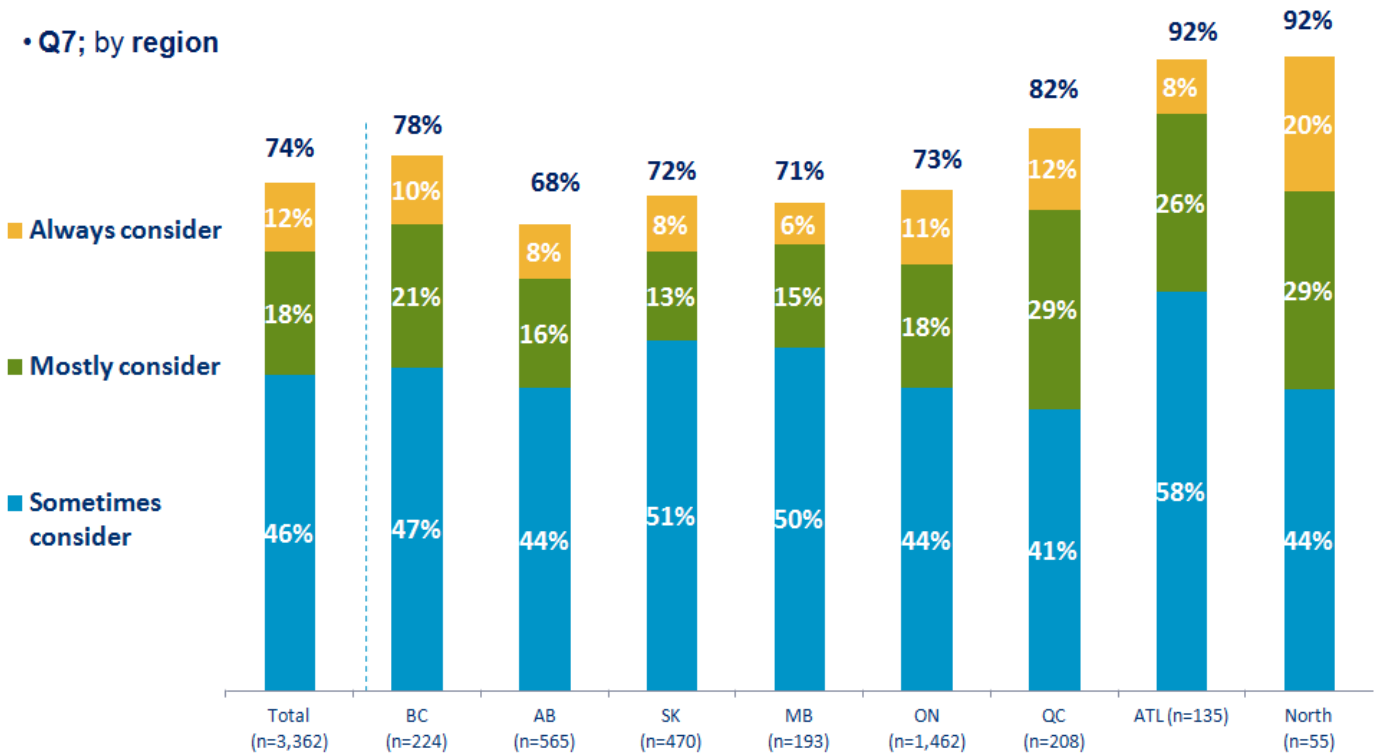
• Q4 vs. Q7



• Q7; by infrastructure category

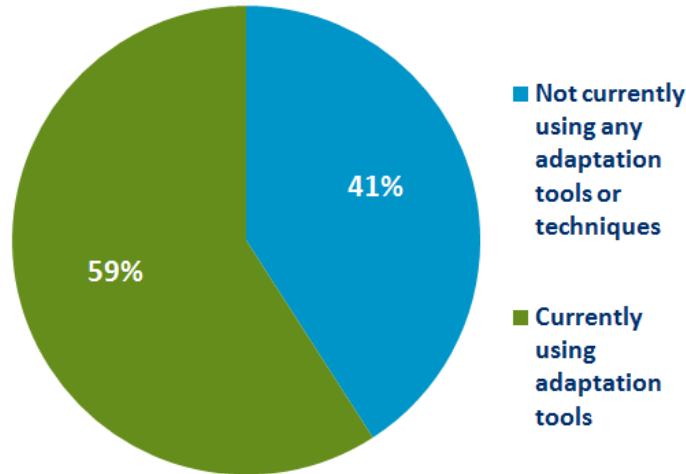


• Q7; by region

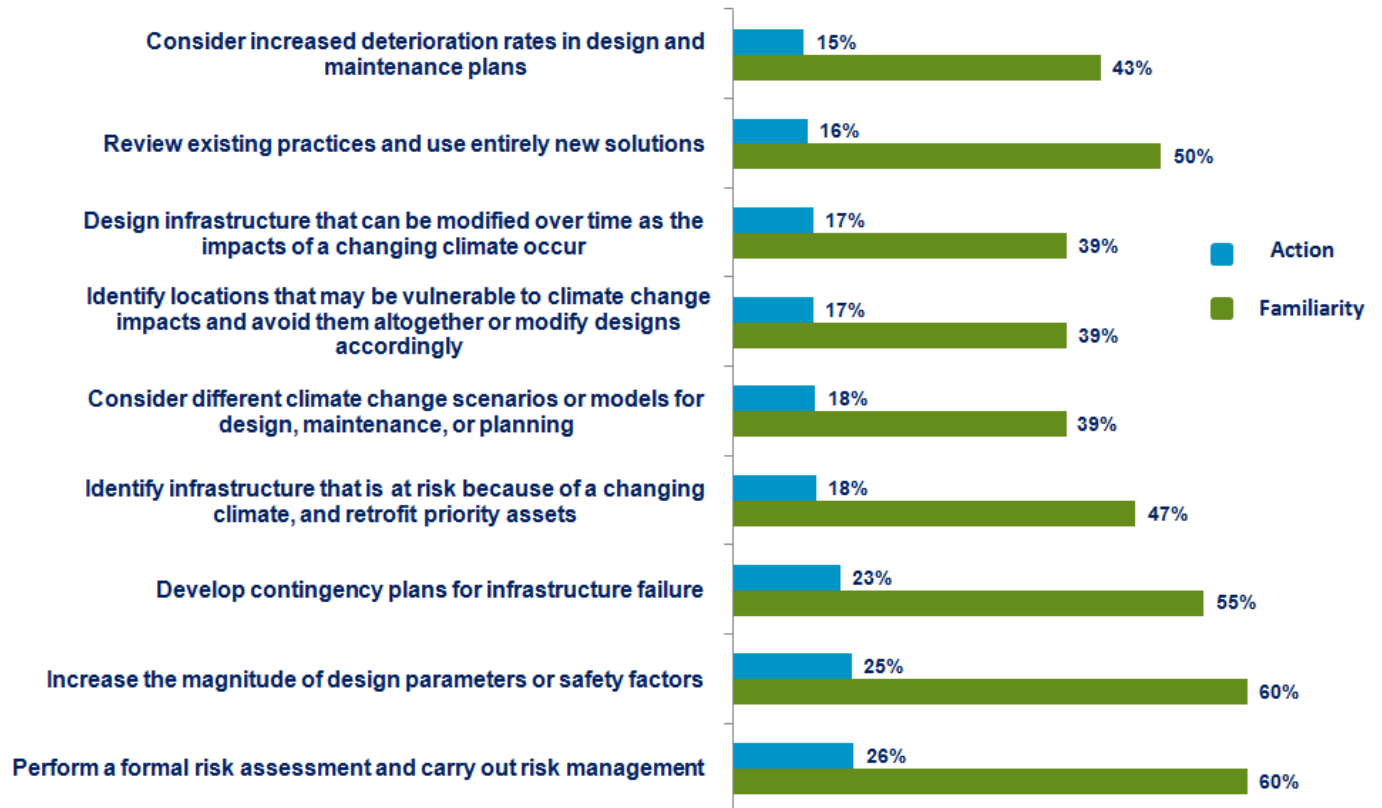


Question 8

Which of the following tools and techniques are you presently using in your practice to respond to the impacts of a changing climate? *Select all that apply*;

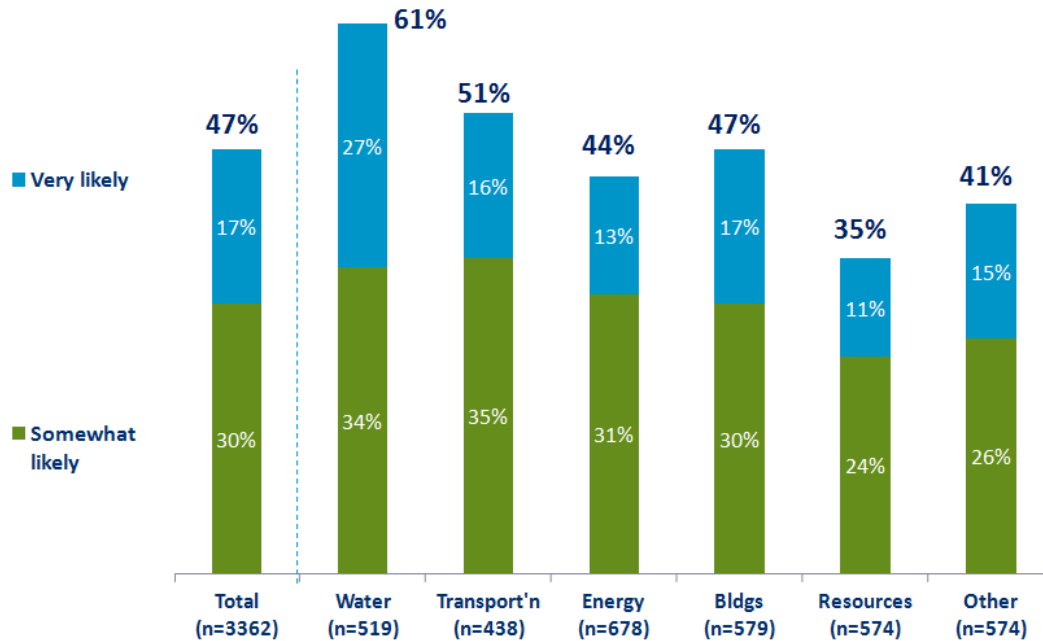


• Q8 vs. Q6



Question 9

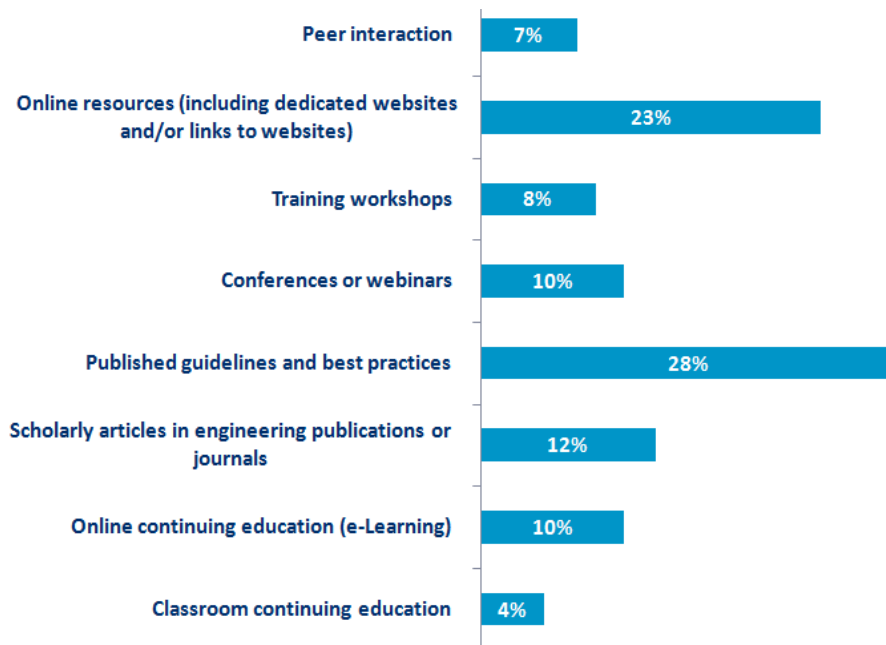
How likely are you to seek specific information on a changing climate as it relates to engineering practice in the next 12 months?



Question 10

How would you prefer to receive information on a changing climate as it relates to engineering practice?

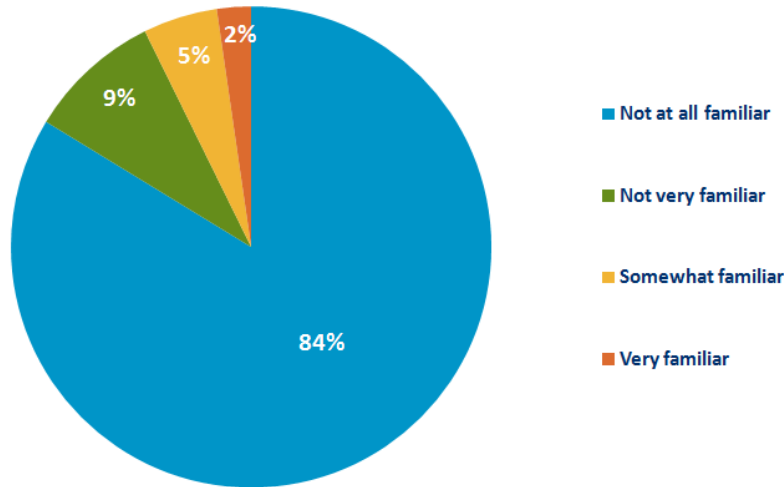
Select one answer only;



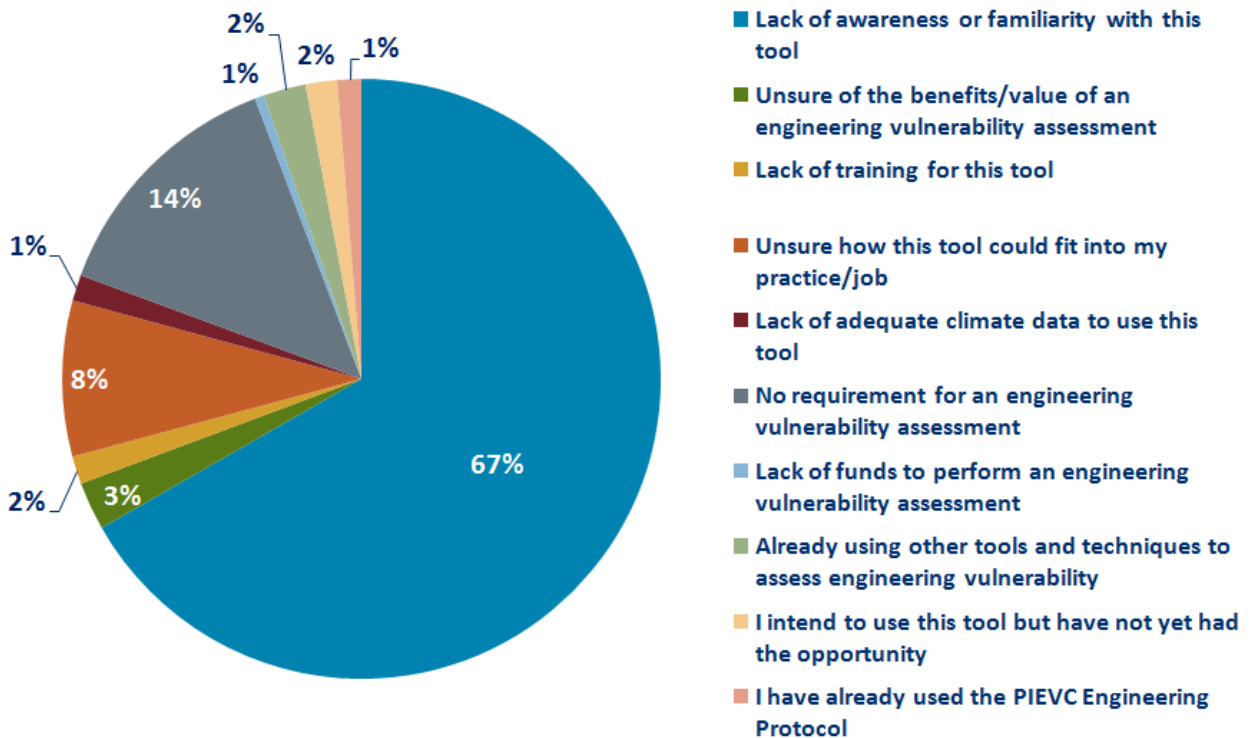
Question 11

Engineers Canada has developed a procedure known as the PIEVC Engineering Protocol that evaluates the engineering vulnerability of infrastructure and the risks associated with the impacts of current and future climate change at a screening level;

a) Please indicate your level of familiarity with this tool;

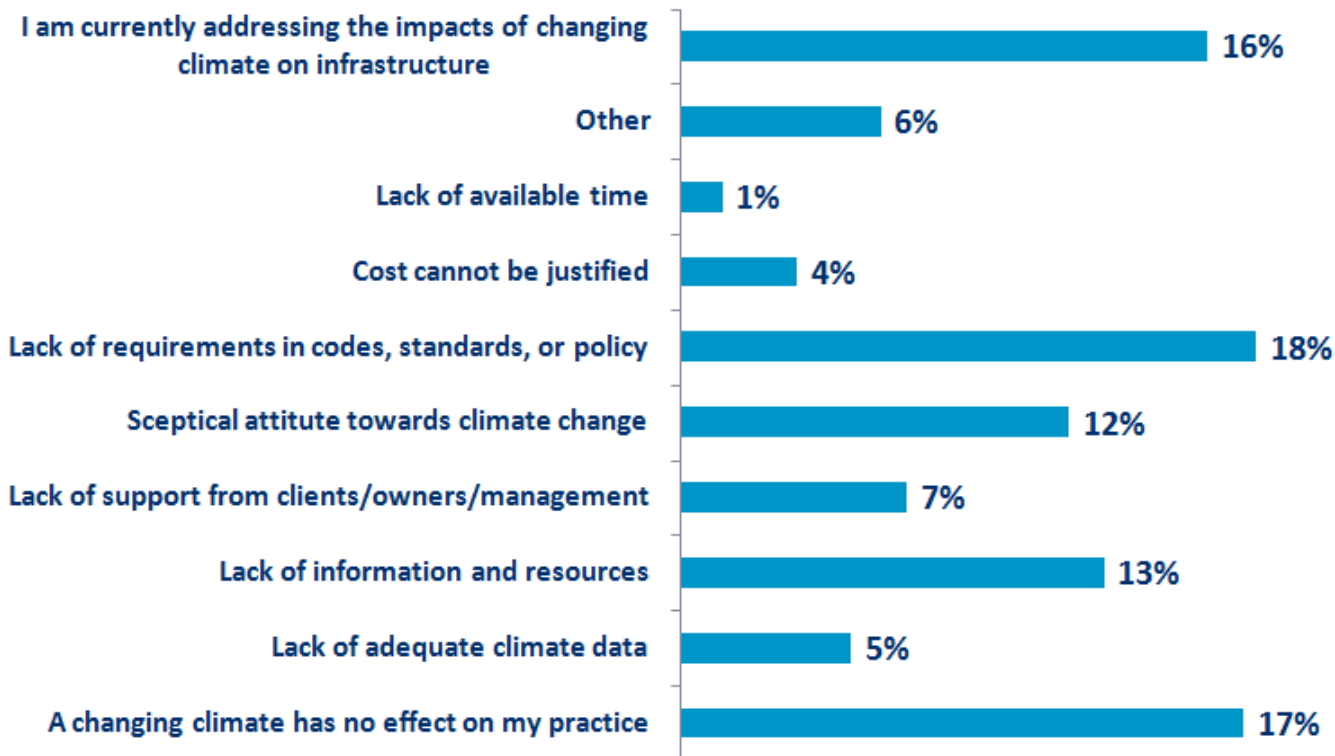


b) If you have not used the PIEVC Engineering Protocol, please indicate the main reason why. Select one answer only;



Question 12

If you are not already doing so, what is the main reason preventing you from addressing a changing climate and its impact on infrastructure? **Select one answer only;**



Breakdown of respondents who chose “lack of information and resources” and “skeptical attitude towards climate change”

	Water	Transportation	Energy	Buildings	Resources
Lack of information and resources	37%	21%	19%	32%	30%
Skeptical attitude towards climate change	37%	43%	44%	41%	41%