New Insights on the Energy Impacts of Telework in Canada

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Quantifier l'impact du télétravail sur la consommation d'énergie a longtemps été difficile en raison du faible recours au télétravail. La pandémie de la COVID-19 et le passage généralisé au télétravail fournit une nouvelle occasion pour étudier l'impact du télétravail sur la consommation d'énergie. Dans les deux mois qui ont suivi les confinements, nous avons interrogé 278 travailleurs ayant des emplois fondés sur le savoir qui ont commencé à travailler principalement de chez eux, afin d'étudier leurs comportements et attitudes quant à la consommation d'énergie. Les thèmes principaux de l'enquête sont les actions prises au travail visant la réduction de consommation d'énergie, l'équipement utilisé pour le télétravail, l'impact sur la consommation résidentielle, et la prise de conscience et la réaction quant au prix de l'électricité. Étant donné la tendance plus accrue au télétravail à l'avenir, ces résultats peuvent éclairer la politique publique en matière de télétravail et d'énergie.

Mots clés : comportement des occupants, consommation d'énergie résidentielle, COVID-19 politique d'électricité, télétravail

Quantifying the energy impact of teleworking has been challenging because of the low prevalence of telework. The coronavirus disease 2019 pandemic and the associated widespread shift to telework provides a new opportunity to study the energy impact of teleworking. Within two months of the lockdowns, we surveyed 278 knowledge-based workers in Canada who started working primarily from home to investigate their energy-related behaviours and attitudes. The survey's major themes are energy-saving actions taken in the office, equipment used for telework, impacts on home energy usage, and both awareness of and response to electricity pricing. Given trends toward increased teleworking in the future, these results can inform public policy related to teleworking and energy.

Keywords: COVID-19, electricity policy, household energy consumption, occupant behaviour, telework

Introduction

For more than 50 years, telework (also known as telecommuting or working from home) has been touted as a major opportunity to reduce societal energy use and greenhouse gas emissions (O'Brien and Yazdani Aliabadi 2020). However, despite aspirations in the 1970s, it saw only modest growth. For example, Zhu and Mason (2014) report that 9.5 percent of working Americans have worked from home at least once per week in recent years. Accordingly, the total energy and emissions impacts of telework up to the present have been estimated to be limited to a few percent at most (O'Brien and Yazdani Aliabadi 2020).

After coronavirus disease 2019 (COVID-19) was declared a global pandemic on 11 March 2020, lockdowns around the world mandated closures of non-essential workplaces and schools and discouraged or restricted travel to limit the spread of the disease (WHO 2020). Many knowledge-based workers started working from home full time (Baert et al. 2020), which has changed energy consumption at the utility level (Armstrong 2020). As a result, these lockdowns offer a new opportunity to investigate the energy impact of teleworking. With many organizations planning to implement widespread teleworking post-pandemic (Baert et al. 2020) and approximately two-fifths of workers being able to work remotely (Gallacher and Hossain 2020), it was important to gain insights about workers' energy-related behaviours, particularly while the shift is fresh in their minds.

Given the energy policy implications in Canada of this potential shift toward teleworking, this article aims to capture how the marked increase in teleworking during COVID-19 has affected workers' self-reported energy-related attitudes and behaviours. We set out to obtain insights into these attitudes and behaviours using the following four research questions:

1. How did the behaviour of teleworkers affect office building energy consumption at the start of COVID-19 restrictions?
2. How have energy demand patterns in teleworkers' households changed during COVID-19 compared with before?
3. What are teleworkers' attitudes toward teleworking in the future?
4. What is the awareness and effect on behaviour of the suspension of time-of-use (TOU) electricity rates during COVID-19?

To answer these questions, we conducted a survey during May and early June 2020, more than a month after COVID-19 restrictions began in most countries (including Canada). The survey received 297 responses, primarily from across Canada, and the household characteristics of our sample are representative of the wider Canadian population, which gives us confidence that our findings may apply to the broader public. Because many people were new to teleworking (Kamouri and Lister 2020), the survey captured the first impressions of many new teleworkers while they were easily recallable. To understand potential effects on home air conditioner use, we conducted a follow-up survey in July 2020 with some of the first survey's participants.

New insights elicited by these questions have the potential to improve current policies and provide a foundation for future guidance on energy demand in buildings. Only half of energy efficiency investments occur in residential buildings despite their accounting for more than three-quarters of total global floor space and 70 percent of building sector energy demand (IEA 2019). Several persistent challenges mitigate the widespread adoption of energy-saving technologies in residential buildings, including market or behavioural barriers that can disincentivize energy conservation investments, such as credit constraints or inattention to energy costs (Gillingham, Keyes, and Palmer 2018; Houde and Myers 2019; Myers 2020). In this context, a shift toward greater rates of telework has implications for the attainment of climate policy goals and the effectiveness of demand response programs, particularly peak shifting (Papineau 2019; Spees and Lave 2007, 2008). The imperative to better understand the dynamics of energy demand in buildings is further bolstered by the Government of Canada's recent announcement of a large-scale energy efficiency retrofit program for buildings as part of post-COVID recovery plans (Canada 2020a).

Our study results indicate an increase in home energy use resulting from the shift to telework as the lockdowns or stay-at-home measures entered into force. This is consistent with Cicala (2020b), who analyzed monthly data from the US EIA by customer class (residential, commercial, and industrial) and hourly data from Innowatts, a utility analytics company. He found a 10 percent increase in residential consumption and 12 percent and 14 percent reductions in commercial and industrial usage, respectively. Such shifts put an additional US$11 expense on monthly customer utility bills per household.

Our survey finds that two-thirds of participants expressed a desire to telework more going forward than before COVID-19, and survey participants used more energy at home during COVID-19 for computers and office equipment, cooking, lighting, and heating or cooling systems, but they used less energy on transportation. Among participants cooking or baking during COVID-19, nearly four-fifths did so between 9:00 a.m. and 5:00 p.m. on weekdays. Similarly, among participants doing laundry, three-fifths did so between 9:00 a.m. and 5:00 p.m. on weekdays. A shift to mid-day electricity use has the benefit of having greater complementarity with solar profiles and the corresponding output of solar energy systems, and the flexibility of the timing of loads (e.g., laundry, electric

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vehicle charging) could be improved with greater daytime presence of occupants (Wood et al. 2018).

The majority of participants (73.1 percent) believed their electricity bills would increase as a result of COVID-19–induced telework but were split on whether it would decrease or increase their total energy usage and monthly costs. Moreover, almost three-quarters of participants were never or rarely willing to sacrifice comfort to save energy costs. There was also low participation in energy-saving actions taken before leaving the office for the last time as a result of COVID-19 restrictions, although participants may not have known they were leaving the office for a period of at least several months.

On one hand, working remotely during a pandemic can be stressful for employees who may experience an increase in their utility bills as they consume energy at home rather than at the office. On the other hand, employers may save money when people telework by reducing expenses such as office space, supplies, and utilities. This shift in energy consumption may imply that employers should consider subsidizing their remote workers' home energy bills. In this regard, employers may want to list the percentage of the relevant costs (if not the entire bill) that it will consider reasonable to compensate using today's smart meters to track energy use by device or TOU (e.g., working hours).

We also found that there is potential to improve the impact of TOU pricing because many Ontarian participants did not know about TOU pricing or its suspension and either never or no longer shifted their electricity consumption away from peak hours. The follow-up survey indicates that among respondents with air conditioning (AC), a plurality were using it more during the day compared with the previous summer.

The rest of the article is organized as follows. In the next section, we provide background information and related literature on teleworking and energy consumption. We then explain the methodology and present and discuss the results. In the final section, we offer conclusions and recommendations for future research.

Teleworking and Energy

For the purposes of this article, *teleworking* is defined as working at home, rather than in a central office, at least one full workday per week. This practice is sometimes also referred to as *telecommuting*. Previously, several dozen articles have attempted to quantify the energy impact of teleworking in the areas of transportation, office energy use, and home energy use (Hook et al. 2020). Most studies have concluded that telework results in a reduction in transportation energy and office building energy and an increase in household energy use. Considering the total of these effects, estimates of the change in an individual's total energy use (from the status quo of commuting to a central workplace) range from a savings of 77 percent (Koenig, Henderson, and Mokhtarian 1996) to an energy increase of 3 percent (Alonso, Monzón, and Wang 2017). Although the studies' results vary widely because each study had different contexts (e.g., methods, assumptions, proportions of teleworking, scope), most studies indicate moderate energy savings, with more empirically rigorous methodologies typically finding more modest savings (Giandomenico, Papineau, and Rivers 2020; Hook et al. 2020; O'Brien and Yazdani Aliabadi 2020).

Although teleworking generally reduces energy consumption from commuting and office buildings, it is also associated with many phenomena that offset and occasionally overtake these energy savings (O'Brien and Yazdani Aliabadi 2020). For example, teleworkers tend to take longer non-work trips and use more energy at home than non-teleworkers (Chapman 2007; Elldér 2017; Hook et al. 2020; Zhu 2011), and residences may be less energy efficient than commercial buildings (IEA 2019). Previously, quantifying the energy impact of teleworking has been challenging because of the low prevalence and frequency of telework (O'Brien and Yazdani Aliabadi 2020), the small proportion of teleworkers in the workforce, and the low impact of teleworking on total societal energy use. However, with many people working from home full time because of COVID-19 lockdown measures, the energy impact of teleworking has increased (as shown in the next section). The shift to teleworking during the pandemic could also result in a permanent shift to teleworking for some workers (Kamouri and Lister 2020), and it may lead to widespread changes to telework-related energy consumption in the residential sector. These trends highlight the need to accurately assess the energy impact of teleworking to inform policies related to teleworking and energy.

The impact of teleworking on electricity consumption in particular has important environmental and public finance implications (Borenstein 2005; Novan and Smith 2018). Next, we present the electricity market context in which our study takes place.

Effects of COVID-19 on Electricity Consumption

COVID-19 lockdown measures caused the amount and timing of electricity usage across residential, commercial, and industrial sectors to change significantly (Armstrong 2020; EIA 2020; IEA 2020c). After a full month of COVID-19 restrictions, 30 countries experienced an average decrease in electricity consumption of 20 percent, mostly in the commercial building sector (IEA 2020a, 2020b). Within Canada, electricity demand decreased by between 5 and 10 percent across the provinces in the months after COVID-19 lockdowns compared with previous years (Leach, Rivers, and Shaffer 2020). Figure 1 shows the electricity demand profile for one workday in three consecutive years in Ontario. In 2020, the morning peak was smaller and delayed, and the daily profile is generally 20–30 percent

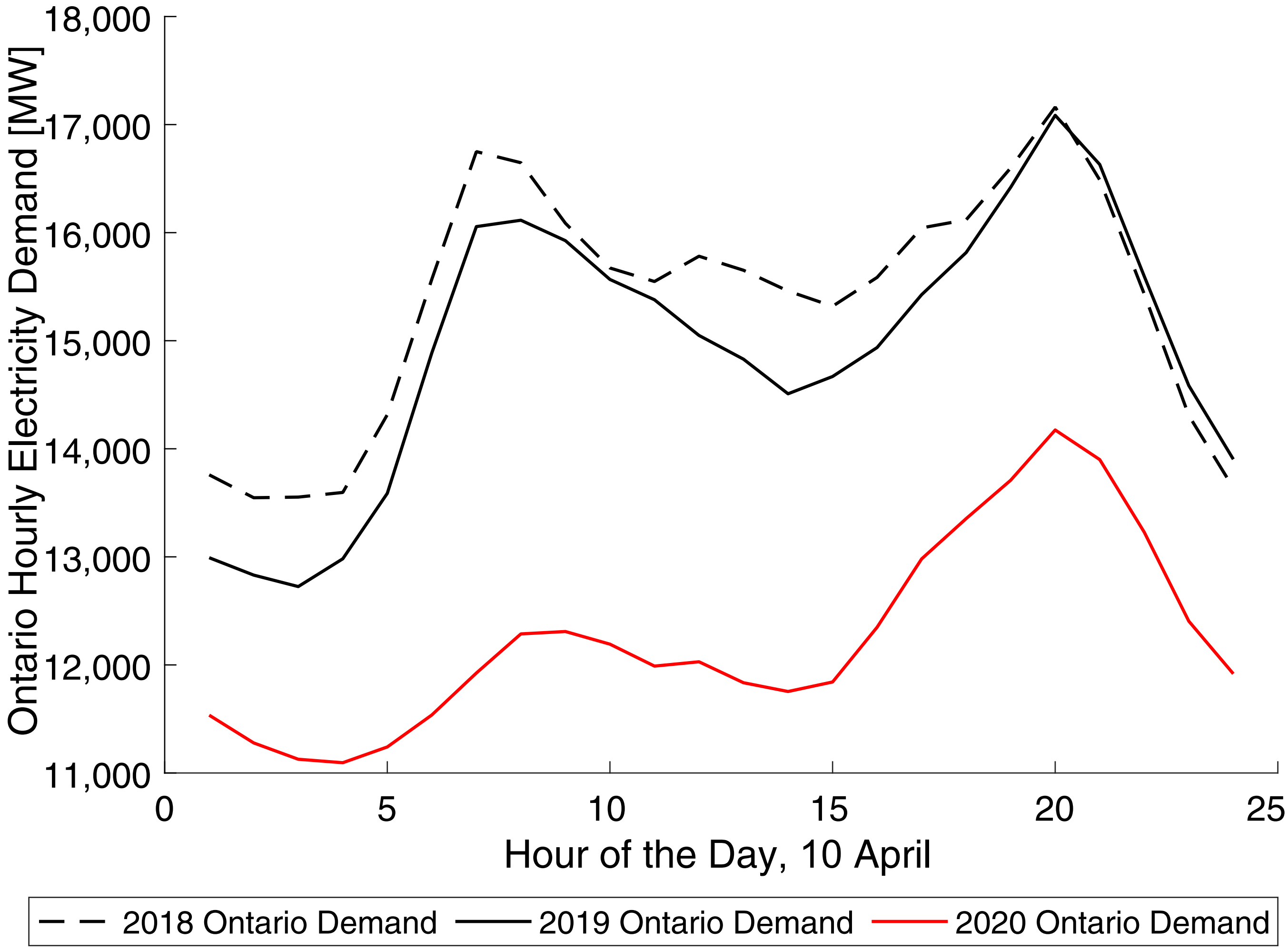

Figure 1: Ontario Electricity Demand Profile on a Typical Day in April (10 April) during COVID-19 Restrictions (2020) and during 2018 and 2019

Note: April 10 was a weekday during each of these years and had very similar outdoor air temperatures.

Sources: Data from IESO (2019, 2020c, 2021) and Canada (2020c).

lower than in past years. Several European countries had similar changes to their electricity demand profiles during COVID-19 (Bahmanyar, Estebsari, and Ernst 2020).

However, many regions experienced increased residential electricity consumption, with the effect particularly significant during peak hours (Armstrong 2020; Lowder, Lee, and Leisch 2020). For example, residential electricity demand in Ontario was, overall and during peak times, respectively, 4 percent and 14 percent higher (IESO 2020a, 2020d). For a recent smaller-scale study of a 40-unit social housing building in Quebec City (Rouleau and Gosselin 2021), detailed measurements were available for energy use. Although electricity use increased by only 2 percent upon lockdown and heating energy use was nearly identical, domestic hot water energy use doubled in the first month (and later returned to normal levels). Grid and building-level statistics are important for informing Canadian policy, but they do not necessarily reveal the behaviours and attitudes of the individuals taking energy-related actions.

Influencing People to Reduce Residential Electricity Usage through Time-of-Use Pricing

Occupant behaviour can have a significant impact on building energy use and the electricity demand profile (Hu et al. 2020; IESO 2020d). TOU pricing is one instrument to encourage people to reduce or shift electricity use to periods when gridwide electricity demand is lower and to avoid carbon-intensive energy sources (Forsberg 2009; Newsham and Bowker 2010; Papineau 2019). TOU pricing can reduce peak electricity consumption by approximately 5 percent (Newsham and Bowker

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2010; Ontario Energy Board 2004). For TOU pricing to be effective at reducing peak residential energy consumption and bearing costs that are more reflective of market electricity prices, it is useful to understand energy-related attitudes, behaviours, and activities of building occupants (Beaman 2020).

Regional Impact on Electricity Demand from COVID-19

To illustrate electricity demand and pricing changes caused by COVID-19 and related events and policies, we focus on Ontario, Canada's most populous province. Although Ontario electricity providers normally charge TOU electricity pricing for residential customers, they temporarily implemented a flat rate from 24 March to 31 October 2020 (Ontario Energy Board 2020). Ontario has warm, humid summers that cause peak electricity loads in the afternoon as a result of AC use (IESO 2020e). Accordingly, electricity demand in the summer is highly dependent on outdoor air temperature (Sahay, Sahu, and Singh 2016) (see Figure 2).[1]

Figure 2 shows that even with the reduction in peak demand expected from the economic slowdown during COVID-19 (Cicala 2020a), there was no substantial change in peak electricity demand compared with the previous two years. The high peak electricity consumption despite the economic slowdown may be a rebound effect of the suspension of TOU pricing, which lowered daytime electricity prices.

As COVID-19 restrictions start to lift, there could continue to be high peak electricity demand as some people continue to stay at home and as commercial buildings re-open and restore their energy consumption to pre-pandemic levels or higher. Figure 3 shows that the highest annual peak electricity demand for 2020, which occurred on 9 July, is higher than that for the preceding six years, which is a change from the downward trend over the past decade.

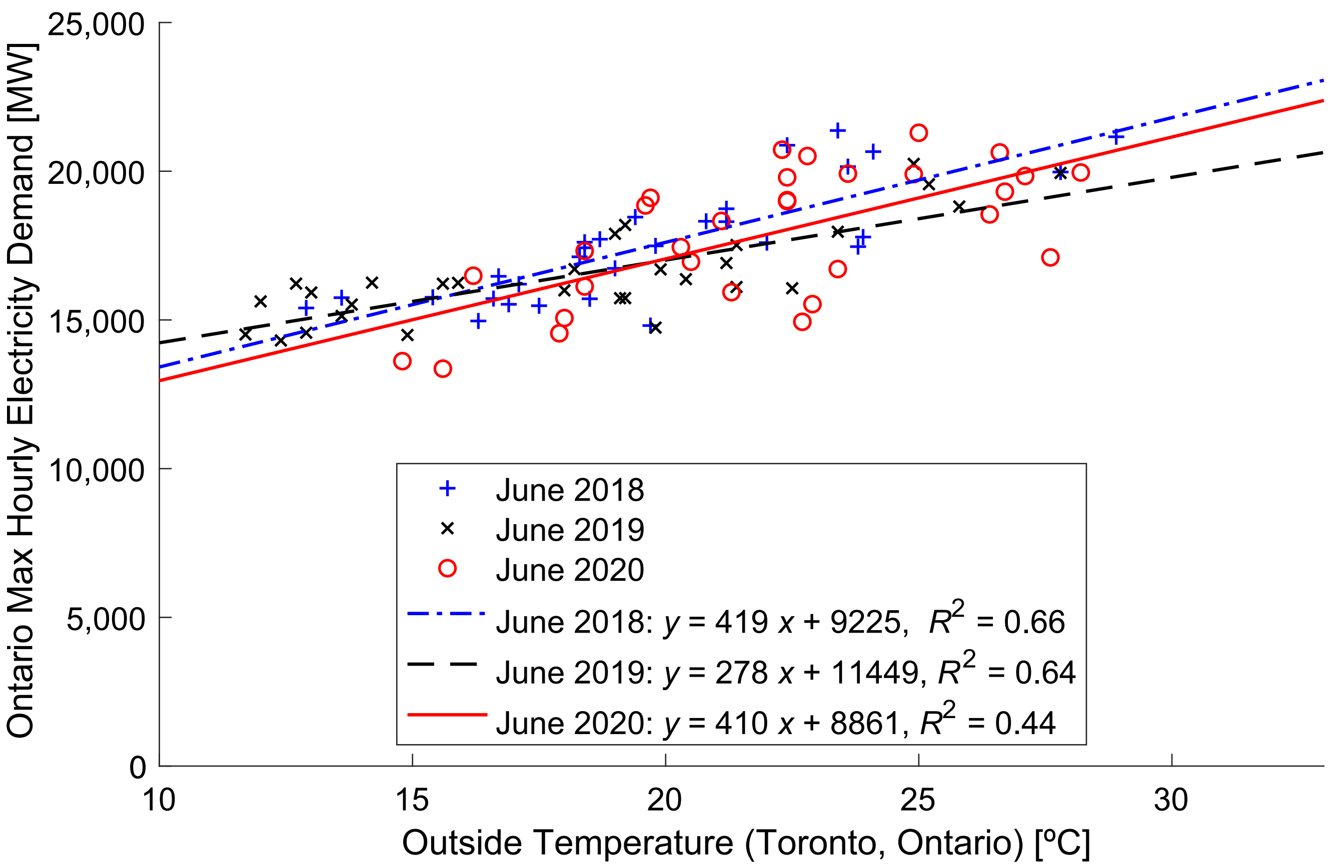

Figure 2: Maximum Hourly Electricity Demand per Day for Ontario and Outdoor Air Temperature during the Peak Load for June 2018, 2019, and 2020

Notes: Temperature is shown for Toronto because this city and the surrounding cities have similar weather and contain approximately two-thirds of Ontario's population (Ontario 2019; IESO 2020b). The lines were fit with linear least-squares regression.

Sources: Data from IESO (2019, 2020c, 2021) and Canada (2020c).

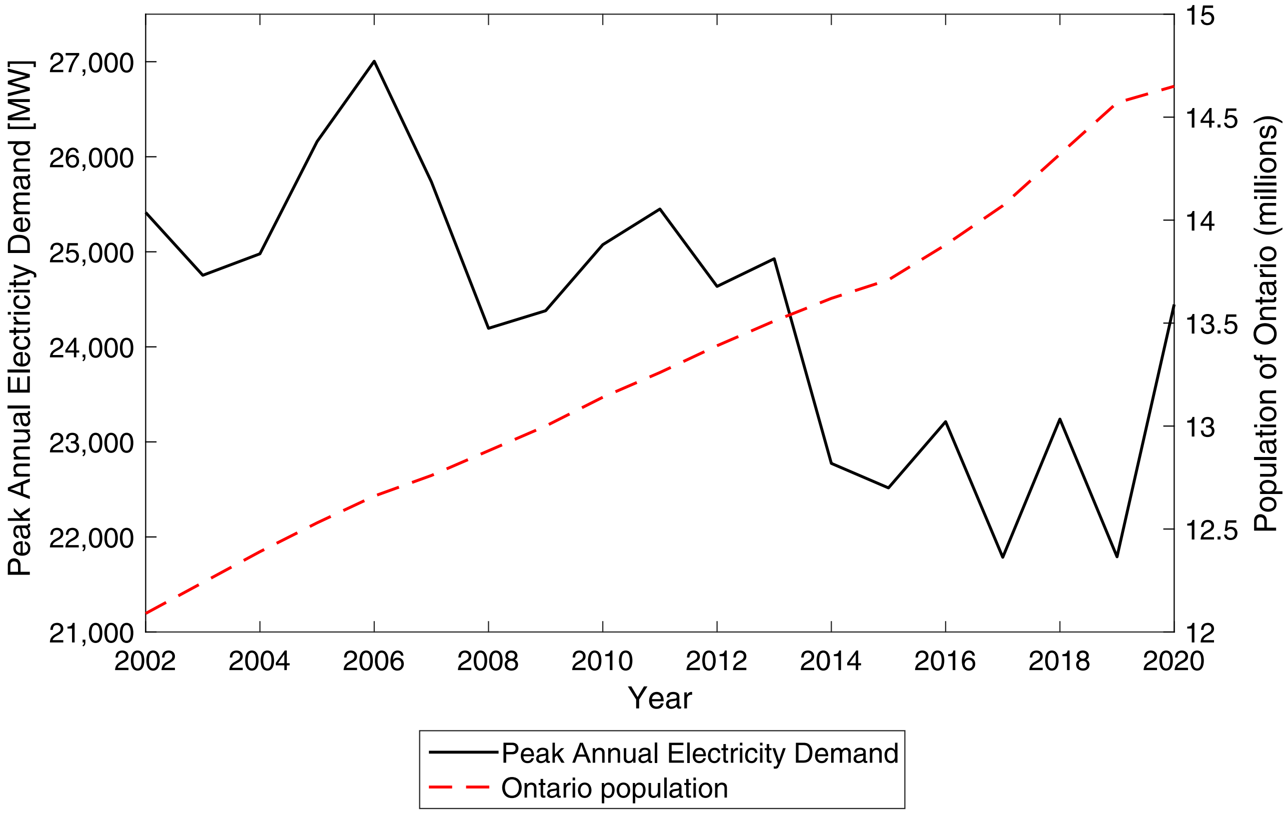

Figure 3: Ontario Peak Annual Electricity Demand and Population, 2002–2020 (as of Mid-December 2020)
Sources: Data from IESO (2019, 2020c, 2021) and Jeudy (2021).

Methodology

To understand the energy-related attitudes and behaviours of teleworkers and their households during COVID-19 restrictions, we designed a survey that took approximately 10–15 minutes to complete. Upon obtaining ethics clearance, participants were recruited via social media and the university alumni email list. Social networks (e.g., Facebook) were prioritized, although LinkedIn was also used, to help target prospective participants who do not have technical or energy-related expertise. Participants had the opportunity to win one of five randomly drawn $100 gift cards. To participate in the survey, participants had to confirm that they were aged 18 years or older, were primarily working from home as a result of COVID-19 restrictions, and performed full-time knowledge-based work (e.g., engineering, design, administration, creative, education, business or accountant, manager, project manager, marketing).

The main questions elicited in the survey were characteristics of the participant's household; energy-saving actions taken at the office before COVID-19; equipment that teleworkers need at home to work; energy costs, consumption, and related behaviour at home; awareness and effects of TOU pricing; and attitudes surrounding teleworking. All response data are self-reported because of the inherent nature of a survey-based approach. The questions used to elicit the responses are presented alongside the results throughout the Results and Discussion section.

Participants were recruited by broadcasting the survey widely via social media (e.g., LinkedIn and Facebook), where people were encouraged to share the post. Moreover, the survey was distributed via our university's daily newsletter, with the aim of reaching many working people who are not necessarily domain experts (e.g., building engineers). Although participation was not restricted geographically, results from outside of Canada were cut for the analysis in this article. Moreover, the data were cleaned to exclude partial or invalid responses (e.g., provided twice by the same person, based on the email address provided).[2]

The first round of responses was collected between 4 May and 1 June 2020. Eligible response data from 278 participants were analyzed, three-quarters of whom were from Ontario. Open-ended questions were analyzed qualitatively by reading each response, creating categories based on the content and sentiment, and sorting responses into these categories.

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As it became evident that COVID-19–induced telework would continue well into the cooling season, a short survey about AC use was sent to Ontario-based participants in July 2020. This narrow focus was used because of the significant data availability in Ontario and to ensure a relatively consistent (warm, humid) climate. Of the 224 Ontario participants from the first survey, 66 (about 30 percent) completed the second survey. The results and discussion of the second survey are provided later in the Second Survey: Use and Adoption of Air Conditioning Because of Teleworking sub-section.

Results and Discussion

The results are presented and discussed according to the order of research questions given in the introduction. The generalizability and applicability of the results are discussed throughout to inform policies and provide recommendations for future research.

Participant and Household Characteristics

Most participants were new teleworkers who transitioned from working in a central office to working five or more days per week at home. Before COVID-19 restrictions started, the majority of participants worked from central offices (87.4 percent), and the others worked in a co-working space (5.8 percent), at home (4.3 percent), a rotation between different offices (1.8 percent), or in other locations (0.7 percent). Although a few participants said they primarily worked from home before COVID-19, 96.0 percent of all participants have worked more days at home during COVID-19 than before. The vast majority (89.6 percent) of participants live with at least one other adult, and 44.2 percent of participants live with at least one child. Both of these statistics are in line with representative samples of the Canadian population (Statistics Canada 2019a, 2019b).

Energy Use in Teleworkers' Office Buildings Before COVID-19

A significant cause of the teleworking-induced increase in energy consumption may be that workers often leave equipment on in their office when they are absent (Gunay et al. 2016). During COVID-19, many office buildings did not experience decreased energy consumption as much or as quickly as expected, considering that occupancy was virtually zero (St. John 2020). The survey explored how teleworkers affected office energy consumption right before COVID-19 restrictions began. Throughout this section, we present only the responses of participants who primarily worked in a central office (i.e., not a co-working space or rotation between offices) before COVID-19 (n = 243, or 87.4 percent of participants).

Participants who primarily worked in a central office before COVID-19 were asked to select all energy-saving actions that they took in their central office before leaving for the last time as a result of COVID-19 (Table 1).

Table 1: Actions Participants Took to Save Energy Before Leaving the Office for the Last Time Before COVID-19 Restrictions

Action	%
Turn off light	57.6
Turn off computer	46.1
Turn off the printer or other auxiliary equipment	13.6
Open or close blinds	13.6
Close windows	12.3
Unplug equipment	11.9
Turn down thermostat	12.8
None of the above	23.5
I do not remember	3.3

Note: COVID-19 = coronavirus disease 2019.

Source: Authors' survey results.

Turning off lights was the most common action, which other studies have found to be a behaviour that is widely practiced with little education or encouragement (Heydarian et al. 2020). Fewer participants took the other energy-saving actions, possibly because teleworkers did not habitually take these actions or because they were pre-occupied with other concerns. Participants may also have taken fewer actions because they were unaware that they would not be returning to the office for months; many COVID-19 restrictions were implemented indefinitely and with little warning.

These results help to explain the unexpectedly high plug loads in office buildings that remain mostly vacant because of COVID-19 restrictions (St. John 2020). In the future, energy-saving actions may be higher if teleworkers are aware of the length of their absence from the office and if they are educated on and encouraged to take energy-saving actions (Hu et al. 2020). However, access to office computers may still persist if home computers have lower functionality or memory to complete computationally intensive tasks and if teleworking arrangements involve some share of work being completed in the central office.

Effects of Teleworking during COVID-19 on Residential Energy Consumption

Participants were also asked about their home energy use to capture the impact of COVID-19.

Energy Impact of Specific Activities and Systems

Participants were asked how their energy usage from certain activities or systems was affected by COVID-19 restrictions compared with one year ago (Figure 4).

Notably, participants reported using more energy for computers and office equipment, entertainment, cooking, lighting, and heating or cooling systems. Participants may have used more energy for entertainment, such as TV,

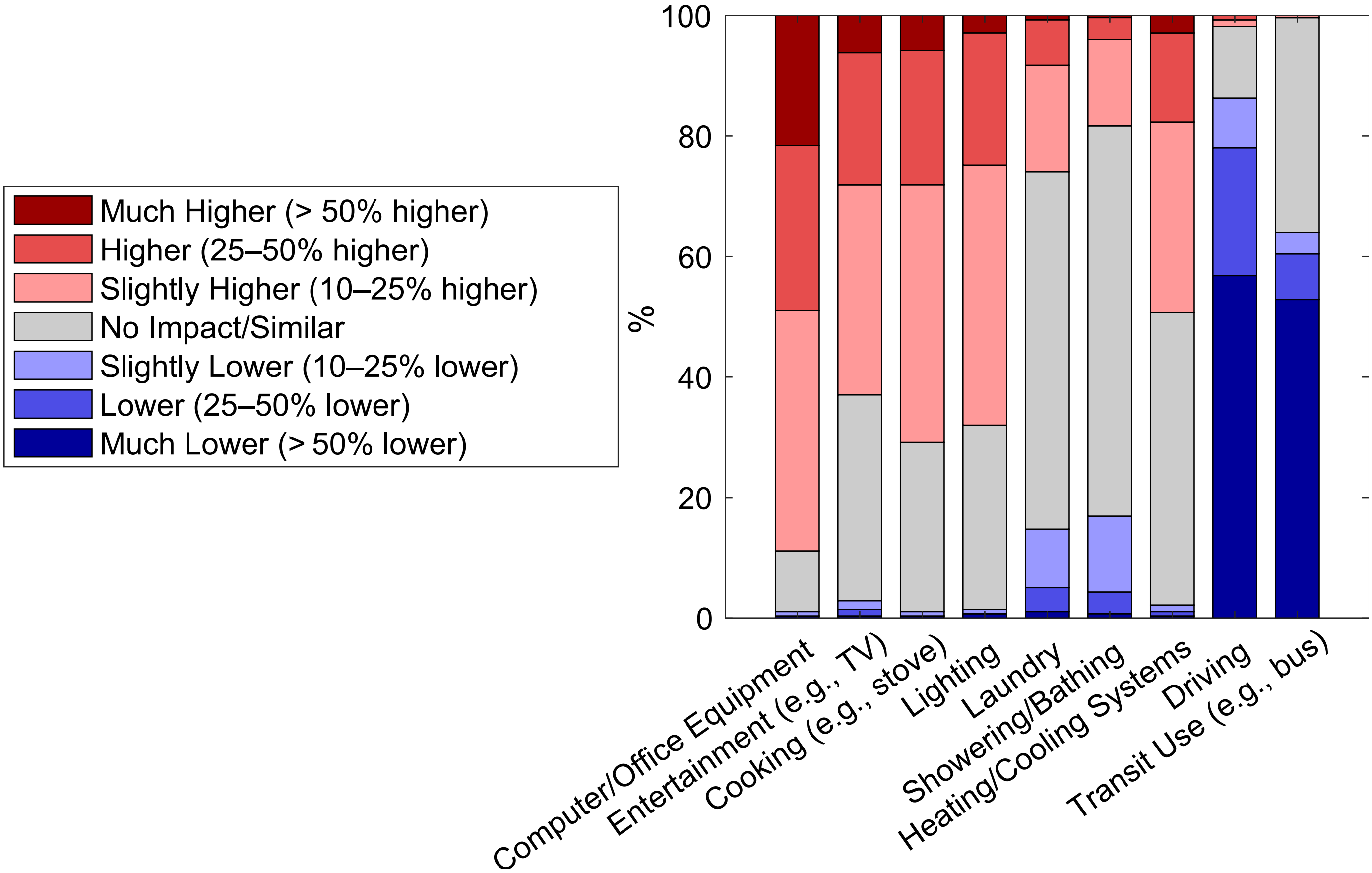

Figure 4: Self-Reported Energy Impact of Certain Activities During COVID-19 Restrictions (May 2020) Compared With May 2019

Source: Authors' survey results.

because they had more time because they were not commuting or because entertainment outside the home was inaccessible as a result of COVID-19 restrictions.

Unsurprisingly, participants reported using much less energy on transportation than a year earlier. Some participants may not have had changes to their driving or transit use if they did not drive or use public transportation beforehand. Several previous studies estimate that teleworking's impact on transportation energy ranges from a 20 percent decrease to a 3.6 percent increase compared with non-teleworking (Balepur, Varma, and Mokhtarian 1998; de Abreu e Silva and Melo 2018). Modern-day work patterns are complex and diverse, so it is more difficult to determine whether teleworking definitively saves transportation energy. Estimates vary because of different proportions of teleworkers, transportation modes, and methodologies. The decrease in transportation energy typically comes from reduced commuting as a result of teleworking (Hook et al. 2020). Teleworkers may have increased use of transportation energy than non-teleworkers because they tend to commute farther on days when they work in the office and may make more non-work trips (Hook et al. 2020). The large self-reported transportation savings of 50 percent or more during COVID-19 result from full-time teleworking and travel restrictions in many places (Kaplan, Frias, and McFall-Johnsen 2020). As COVID-19 restrictions ease, transportation modes are likely to shift from public transportation to private vehicles over fears of COVID-19 infection, which could result in increased short- and medium-term traffic congestion (Honey-Rosés et al. 2020; Tirachini and Cats 2020). Over the longer run, transportation energy use may increase further if the demand to live in lower-density communities increases commuting distances for both work and leisure (Mokhtarian 2009).

One area on which there is particularly little research is home thermostat use (Newsham and Donnelly 2013; Papineau et al. 2020). There is uncertainty about schedules, set points, and whether teleworkers control their home as a single zone or focus on improving comfort in their workspace (O'Brien and Yazdani Aliabadi 2020). When asked how they changed their home thermostat or heating controls since they started teleworking because of COVID-19, 47.5 percent of participants responded that they had made no changes, and 38.1 percent had raised the set point during the day, likely resulting in increased heating usage. Most of Canada was still in the heating season when the participants completed the survey. When asked about their heating bill, more than 90 percent of participants indicated that they had non-electric heating systems.[3] In Canada, the most common non-electric heating system burns fuel and is centralized, meaning the entire house is heated instead of individual rooms (Statistics Canada 2017). Thus, centralized heating increases the teleworker's per capita energy consumption because the entire home is heated when often only the teleworker is home, and there may not be an equivalent reduction in office building energy usage (Hook et al. 2020). Teleworkers with centralized heating, ventilation, and AC (HVAC) could reduce their household energy consumption by lowering the set point during the heating season, raising the set point during the cooling season, and directing heating and cooling to occupied spaces only.

Energy Impact of Home Office Equipment

Previous estimates for the electricity use of equipment and lighting at home to enable telework have ranged by several orders of magnitude (Nakanishi 2015; O'Brien and Yazdani Aliabadi 2020). This is in part due to the fact that previous studies span several decades, during which office equipment evolved significantly. Figure 5 shows the equipment that participants reported having in their home working environment during COVID-19 lockdown measures.

Almost every participant has a laptop and phone, whereas desktop computers are less common. Laptops are more efficient than desktop computers because they tend to be turned off more often when not in use and are associated with lower power consumption (Gunay et al. 2016; Webber et al. 2006). Participants also commonly have peripheral computer monitors. Participants who indicated that they had a computer monitor (other than an integrated laptop monitor) were asked how many they have: 50.3 percent have one monitor, 33.3 percent have two monitors, and 16.4 percent have three or more monitors.

Participants were asked whether they had to start using or had to buy more office equipment to improve the functionality of their home office or workspace since the lockdown started. More than half (52.1 percent) had started more often using electric devices or appliances that they already owned, such as computer monitors, computers, lights, headphones, and tablets. Nearly a third (32.0 percent) bought electric devices and appliances, including computer monitors, headphones, keyboards and mice, computers, laptops, microphones, and speakers.

As a result of COVID-19, participants may have purchased printers and other equipment that is normally available in office spaces but cannot be shared when teleworking (Kitou and Horvath 2007). Equipment needs may vary by area of primary employment. For example, teachers and lawyers may need a printer, but programmers may not. The results on the increased use and purchase of equipment are likely be generalizable to teleworking during post–COVID-19 times because the equipment is necessary for teleworking. Regardless, the energy impact of information and communication technology (ICT) for teleworking is not negligible and should be explored in more detail because teleworkers use a lot of ICT devices and other equipment that consume energy, as illustrated by our survey results and as documented in prior studies (Pohl, Hilty, and Finkbeiner 2019).

Second Survey: Use and Adoption of Air Conditioning Because of Teleworking

The second survey that asked about AC use was completed by 66 of the 224 Ontario participants. Respondents were asked whether their current residence had AC. Most (74 percent) had central AC, 15 percent had at least one portable or window AC unit, and 11 percent did not have any AC.[4] Respondents were asked how often they were using their AC compared with the previous summer. Of the 59 respondents with AC, 47 percent were using their AC more during the day, and 42 percent were using their AC the same amount as the previous summer. These results help explain the trend shown in Figure 2 of continued high summer peak electricity demand during COVID-19. Home AC is relatively inefficient at maintaining a comfortable workspace compared with AC in office buildings as a result of lower occupant density in homes (O'Brien and Yazdani Aliabadi 2020). Consider that worker density in homes may be an order of magnitude lower than in office buildings. Moreover, central AC is common in North American homes, whereby conditioned air is distributed throughout the home rather than targeting the home office.

Respondents were asked what their current daytime thermostat set point was. The most common thermostat set point range was 22°C to 24°C (44 percent of respondents). This is a relatively low set point for the cooling season considering that the National Building Code assumes a cooling set point of 25°C when occupants are present (Abdeen et al. 2020). Respondents also commonly had thermostat set point ranges of 24°C to 26°C (23 percent of respondents) and 20°C to 22°C (18 percent of respondents).

When asked how often they sacrifice comfort at home to try to save energy costs, 74.1 percent of participants said they never or rarely sacrifice comfort. Although this could be viewed negatively as participants not considering saving energy a priority, it is understandable that occupants are priorizing comfort considering its importance to well-being and productivity (O'Brien et al. 2020).

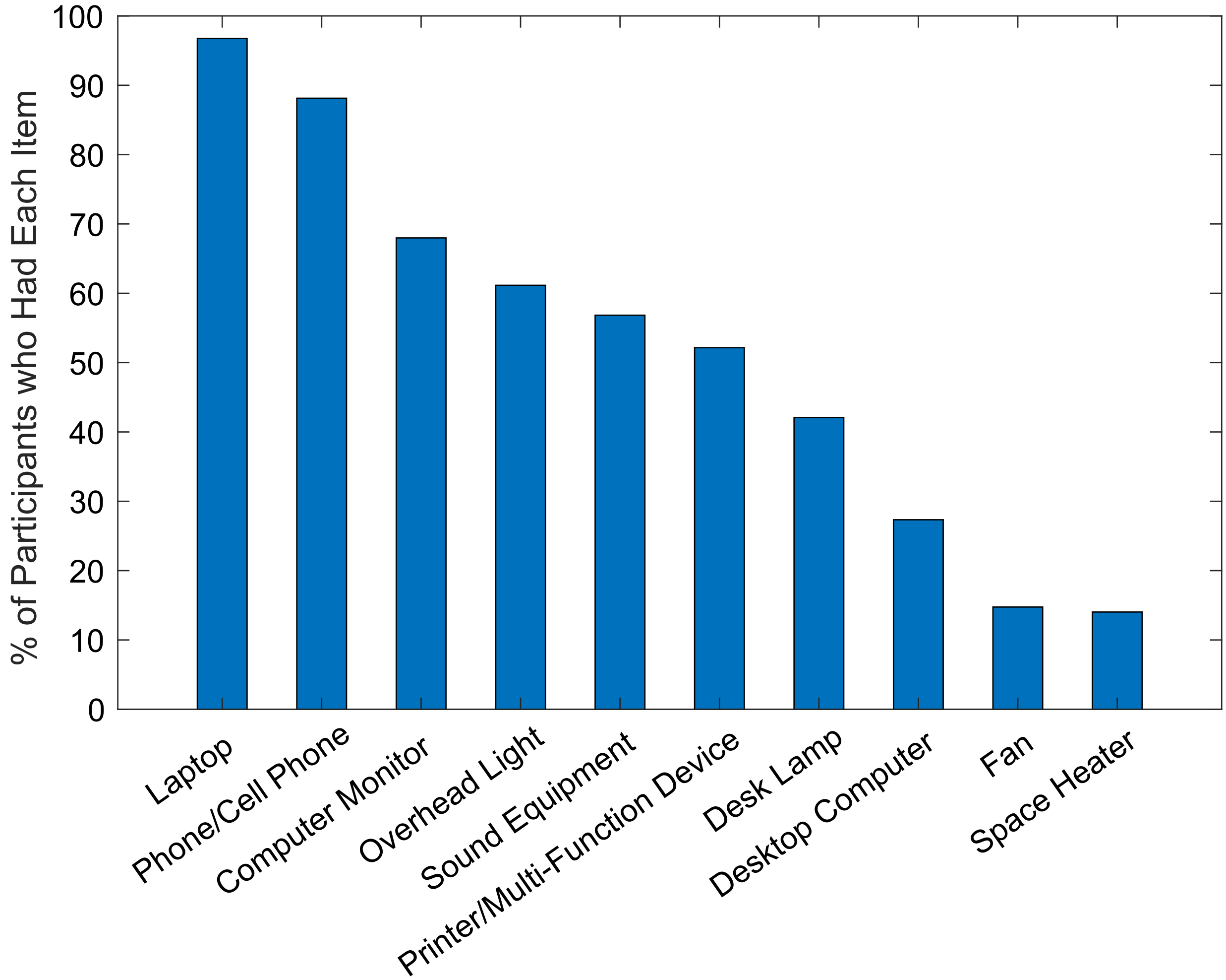

Figure 5: Equipment Respondents Have in Their Home Working Environment

Notes: Sound equipment includes headphones, external microphones, and headphones. Printers or multi-function devices includes fax machines or scanners.

Source: Authors' survey results.

Energy Usage Patterns with Respect to Household Chores

Participants were also asked how often they cooked, baked, and did laundry between 9:00 a.m. and 5:00 p.m. on weekdays (i.e., typical work hours) during COVID-19. About 78 percent reported sometimes, often, or always cooking or baking during the workday, as defined earlier. If participants did laundry, 56.5 percent of participants reported sometimes, often, or always doing laundry during the workday. A poll by Hydro Ottawa found that 72.1 percent of customers baked more during COVID-19 restrictions (Beaman 2020). The increase in cooking and laundry during the day could be because teleworkers have more time to do these tasks as a result of reduced commuting (Hopkinson, James, and Maruyama 2002; Hynes 2013); find it more convenient to do these tasks during the day; eat at home more or eat more overall (Aymerich-Franch 2020); or have no incentive from TOU pricing to avoid these electricity-using activities during the day (see the Awareness and Effect on Behaviour of Time-of-Use Pricing Suspension section for a more detailed discussion of TOU).

Overall Impact of Teleworking and COVID-19 on Costs and Energy Consumption

Participants were asked which home utility bills their household is responsible for paying: 88.9 percent pay for their electricity bill, and 74.1 percent pay for their heating. The remaining participants have utility bills included in rent or maintenance fees or are unsure. Some studies indicate that people who do not pay for their energy bills take energy-saving actions less often and may have higher energy consumption than those who pay for their energy bills (Gunay et al. 2014; Jessoe, Papineau, and Rapson 2020; Levinson and Niemann 2004).

When asked how they expected their electricity bills to change as a result of working from home during COVID-19, some participants (20.9 percent) answered that their electricity bill is 25–50 percent higher because of teleworking. Just more than half (51.4 percent) believed their electricity usage was 10–25 percent higher because of teleworking. The distribution of answers is very similar between participants who had or had not seen their electricity bill since COVID-19 started.

Participants were also asked whether they thought teleworking during COVID-19 saved them energy overall, when taking into account home, office building, and transportation energy use, as shown in Figure 6. The most common response was that that teleworking probably saved them overall energy costs, but the responses were mixed, with a quarter of respondents believing that telework did not save them energy.

Figure 7 indicates wide variability in responses when participants were asked how they expect their total costs to change when considering energy bills and transportation, although participants overall indicate cost savings.

There are many explanations for the wide variation in responses observed in both Figure 6 and Figure 7, especially because participants were asked about combined energy usage or costs from home, office, and transportation. As previously noted, most participants expected higher electricity bills, but their other energy bills may not have changed or may have decreased. Work patterns are complex and variable, and the energy impacts of behaviours and decisions vary in saliency. For example, people may be particularly cognizant of the act of refueling their car but not of energy use in their homes or central office (Giandomenico et al. 2020; Gillingham et al. 2018; O'Brien and Yazdani Aliabadi 2020).

Working remotely during a pandemic can be stressful for employees who may see an increase in their utility bills as they use more energy at home than in the office. However, employers can save money when people telework by reducing expenses such as supplies and utilities and, in the longer term, space. In this regard, we may see a shift toward the cost of working from home being borne by the employer. For example, employers may want to list the percentage of the relevant costs (if not the entire bill) that it will consider reasonable to compensate using today's smart meters to track energy use by device, TOU (e.g., working hours), or both.

Attitudes toward Teleworking Going Forward

Attitudes toward teleworking are important for gauging how COVID-19 may influence the future of teleworking and for informing related policies. On the basis of their current teleworking experience, two-thirds of all participants expressed a preference to work from home more often once the pandemic is over than they did before. This is similar to a previous survey that found that 62.5 percent of Flemish teleworkers wanted to telework more frequently after COVID-19 (Baert et al. 2020); another global survey of teleworkers found a higher percentage of 76 percent (Kamouri and Lister 2020).

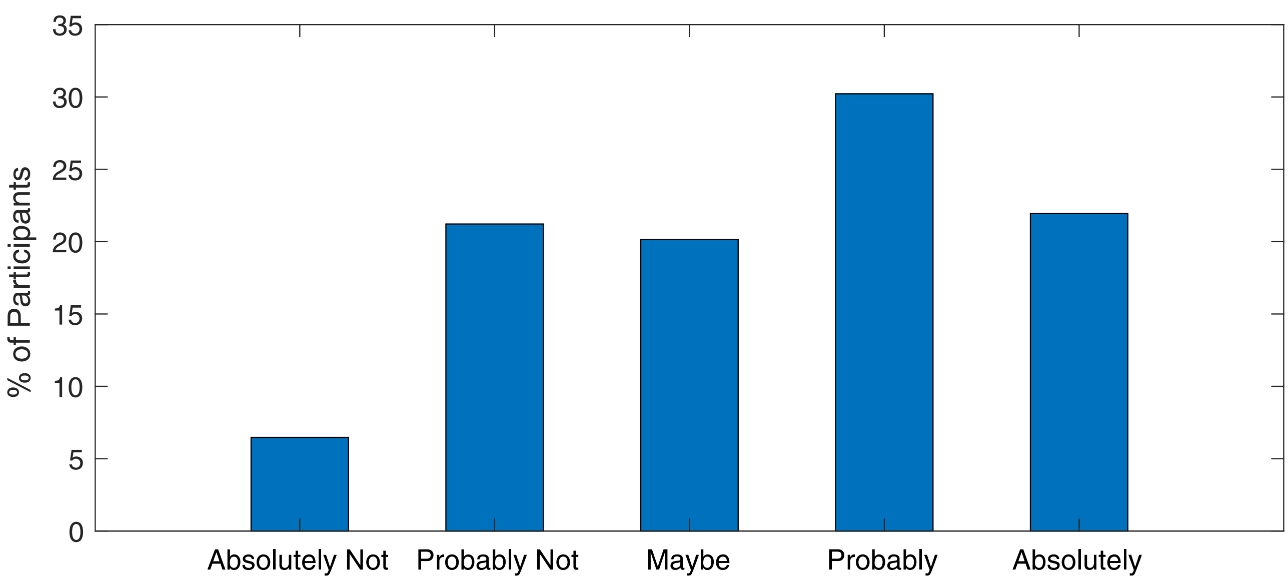

Figure 6: Distribution of Responses to "Do You Think Telework Overall Saves You Energy during COVID-19, Taking into Account Home, Office Building, and Transportation Energy Use?"

Source: Authors' survey results.

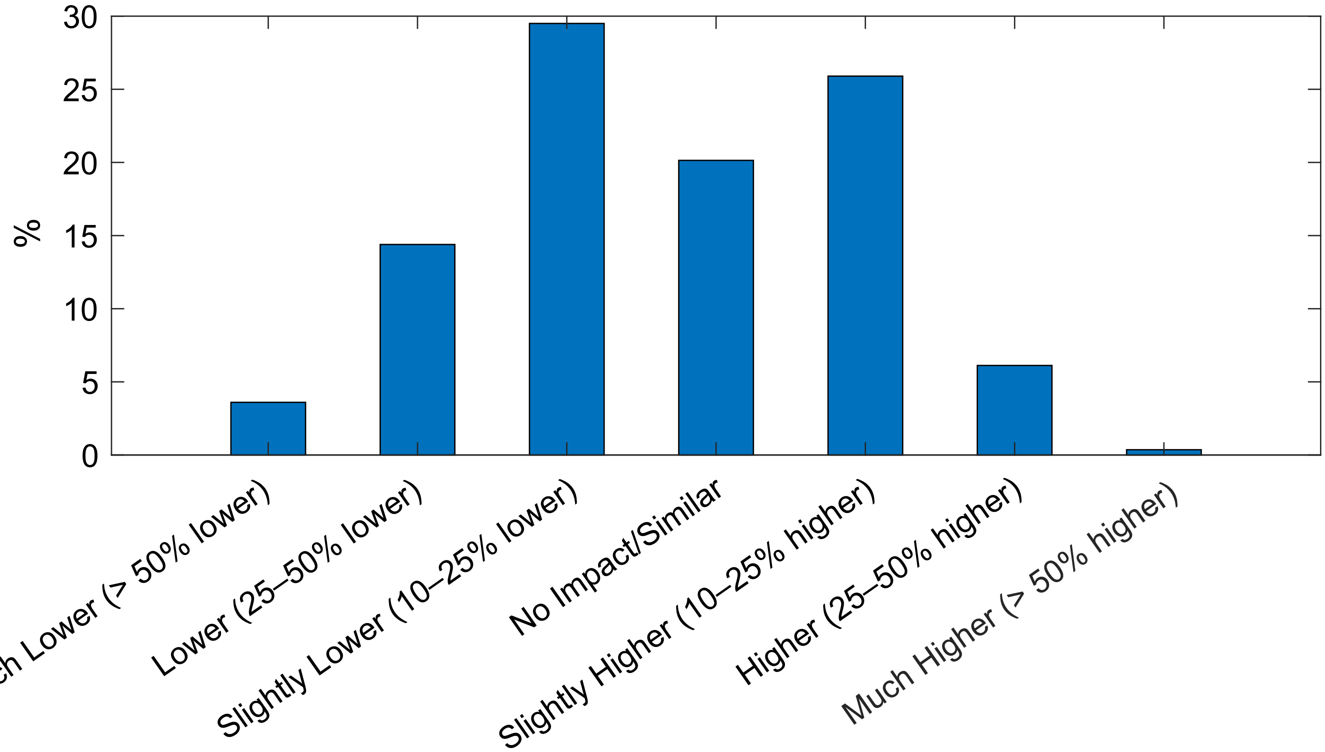

Figure 7: Distribution of Responses to "Considering All Household Energy Bills and Transportation Costs, How Do You Expect Your Total Monthly Costs to Change, as a Result of COVID-19 Restrictions?"

Note: COVID-19 = coronavirus disease 2019.

Source: Authors' survey results.

Awareness and Effect on Behaviour of Time-of-Use Pricing Suspension

As mentioned previously, Ontario has had TOU electricity rates since 2012 for residential consumers but temporarily implemented a flat rate from 24 March to 31 October 2020 (Ontario Energy Board 2020; Lessem et al. 2017). Basic TOU electricity pricing can reduce on-peak electricity demand by 5 percent, although the effect is smaller in Ontario (Lessem et al. 2017; Newsham and Bowker 2010).

Because 224 participants were from Ontario, we investigated the effects of the temporary suspension of TOU electricity pricing in the province. Participants were asked, "Has the company that supplies your home with electricity started charging a flat/constant rate for electricity used during COVID-19, rather than TOU pricing where you pay different rates at different times of day?" Figure 8 presents the responses of Ontario participants, based on whether they pay for their electricity bill given the agency problems that can arise from not paying energy bills (Gunay et al. 2016; Jessoe et al. 2020).

Just more than half of Ontario participants (53.6 percent) correctly knew about Ontario's changes to electricity pricing. As expected, Ontario participants who did not pay their electricity bill because it was included in rent or condo fees were less certain about electricity pricing.

Even after a month under the new flat rate structure, the results from Figure 8 indicate that there was significant confusion about electricity pricing, with about 50 percent of respondents either unaware of or unsure about the electricity pricing changes, despite the fact that the suspension was widely disseminated via the media during the survey period.

Those who answered "yes" regarding knowledge of the changes to TOU pricing were asked an open-ended follow-up question on how TOU electricity pricing affected their energy-related behaviour. Figure 9 shows the answers for these Ontario participants.

Of these participants, 39.2 percent said TOU never affected their behaviour. One participant in this category wrote, "My house is electrically efficient and the TOU price premiums are minimal"; another participant said that energy is required to do work regardless. Some participants (38.3 percent) used to avoid doing laundry, cooking, running the dishwasher, or using other energy-intensive appliances during peak hours but no longer shift activities away from peak hours because of the flat

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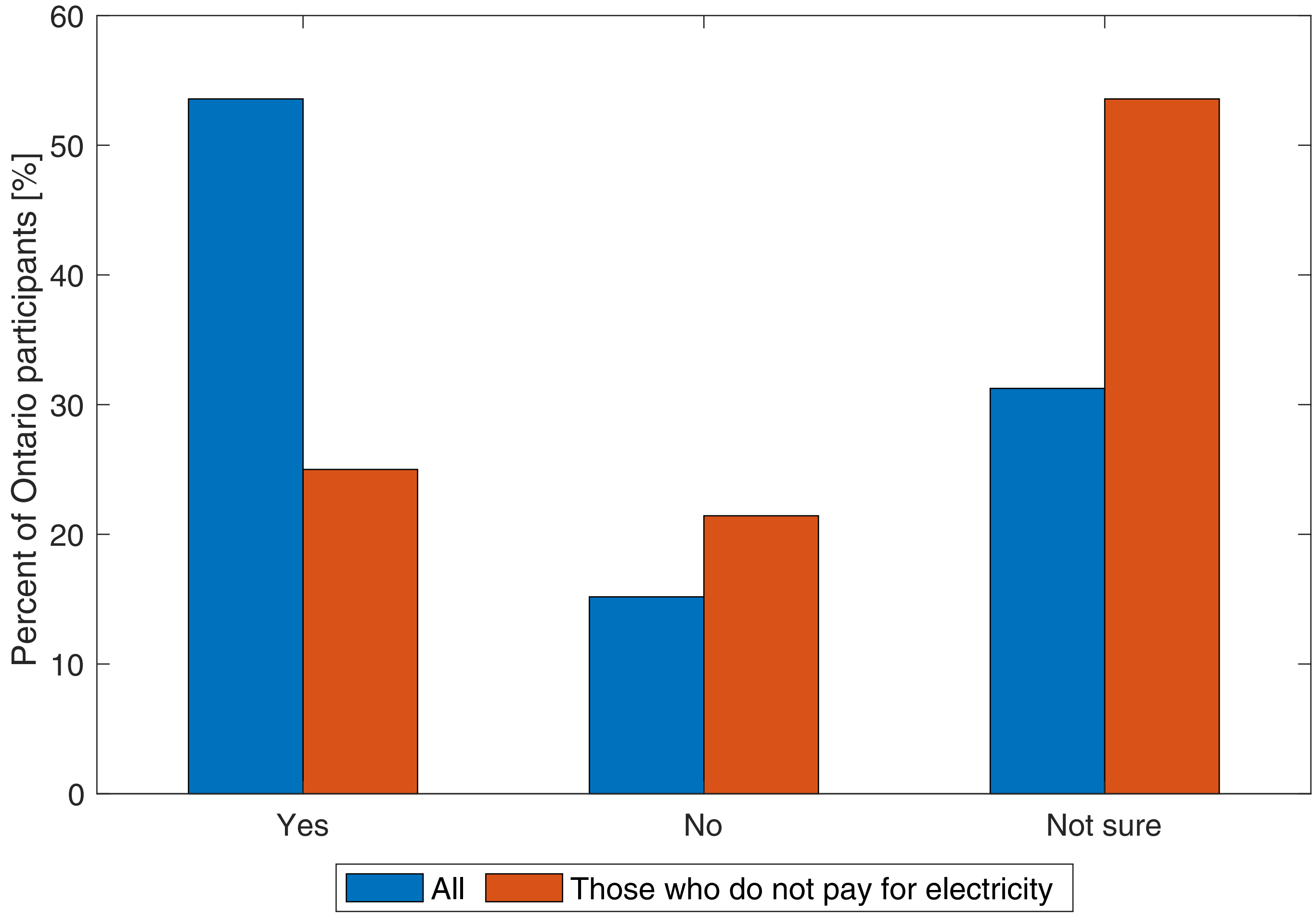

Figure 8: Percentages of All Ontario Participants (*N* = 224) and Ontario Participants Who Do Not Pay for Their Electricity Bill (*n* = 28) Who Answered "Yes," "No," or "Not Sure" When Asked Whether Their Electricity Provider Started Charging a Flat or Constant Rate during COVID-19, Rather Than TOU Pricing

Notes: COVID-19 = coronavirus disease 2019; TOU = time of use.

Source: Authors' survey results.

rate. A participant in this category wrote, "I feel more free to change my routines that involve consuming energy." Relatively few of these participants (17.5 percent) continue to minimize electricity usage during peak hours as they had before COVID-19.

Consistent with previous research, these findings indicate that it may be beneficial to improve feedback and education to make residential consumers not only better aware of TOU pricing but also how and why to save energy, because education can help consumers shift electricity use away from peak hours (Delmas, Fischlein, and Asensio 2013; Faruqui, Sergici, and Sharif 2010).

Study Limitations

The survey method and results have some limitations. Given the sample size and under-represented provinces, combined with some differences in provincial policies on COVID-19 restrictions, we did not assess survey results at the provincial level.[5] We also acknowledge that although the participants' household composition statistics cited in the Participant and Household Characteristics section are in line with those of the general Canadian population, the survey sample is self-selected (e.g., respondents may be particularly concerned about or aware of energy issues); also, our professional networks were one of the means of recruitment.

The survey took place during the first months in which the repercussions of COVID-19 were being felt. At the time, some participants may not have received energy bills that reflected the impact of their consumption, and consumers may ultimately be more concerned with energy bills (in dollars) than with their energy use (kilowatt hours consumed).

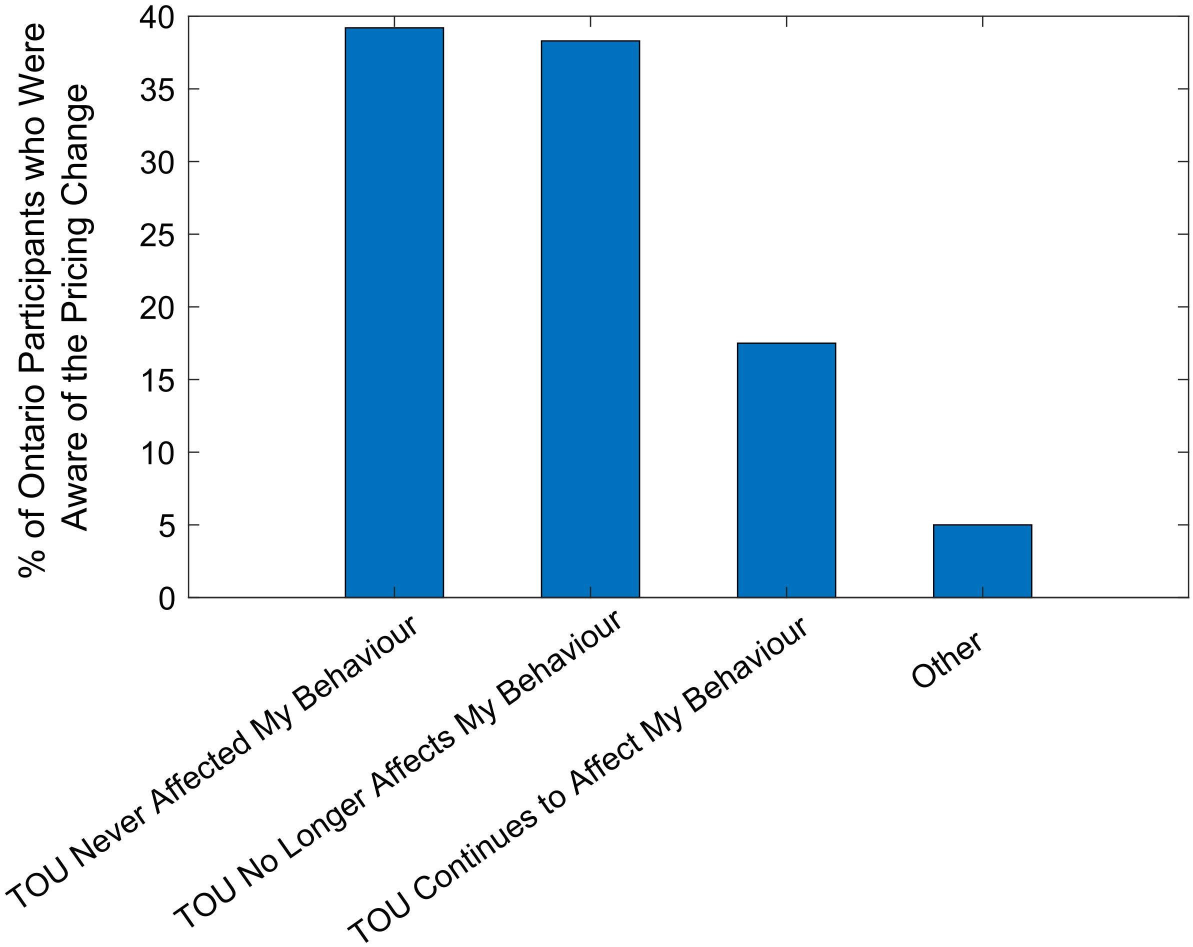

Figure 9: Responses among Ontario Participants to a Question Asking Whether the TOU Pricing Suspension Affected Their Behaviour, for Respondents Who Were Aware of the Pricing Change

Note: TOU = time of use.

Source: Authors' survey results.

Most participants live in regions where COVID-19 restrictions started during the transition between winter and spring (CBC News 2020), so seasonal changes may have influenced occupant behaviour (e.g., thermostat set point, amount of lighting), which in turn affects energy consumption. However, we mitigated the influence of seasonal effects by framing most survey questions as changes resulting from teleworking during COVID-19 or changes compared with the previous year. We also note that a reduction in worked hours occurred in at least the month after COVID-19 lockdowns in Canada (Lemieux et al. 2020); thus, the short-term transitional effects may have influenced survey results.

Although the large shift toward teleworking resulting from COVID-19 restrictions presents an opportunity to study the energy-related consequences of teleworking, the nature of the shift necessarily includes unique characteristics. Namely, people were forced to abruptly transition to telework, potentially without adequate equipment or preparation. It is likely that participants had greater concerns than their energy consumption during COVID-19, such as anxiety over their health and finances. In addition, some participants had to undertake extra responsibilities, such as childcare and educating their children because day cares and schools were closed. Even so, anecdotal evidence in late 2020 suggests a permanent change in the way organizations function and where their employees work. It is important to understand the energy impacts of COVID-19–induced telework to inform public and private policy. With this goal in mind, our approach can help evaluate these impacts by capturing teleworkers' energy-related behaviours two months after the shift began, when most jurisdictions still had strict restrictions in place and therefore workers' preferences were more easily recallable.

Conclusions and Future Work

This article evaluates how Canadian teleworkers' energy-related attitudes and behaviours may influence utility-level changes to energy consumption. Post–COVID-19 electricity usage patterns clearly indicate a change in the magnitude and timing of consumption. As COVID-19 restrictions ease, commercial buildings will consume more energy to meet HVAC guidelines (e.g., increased ventilation rates) that lessen the possible transmission of COVID-19 (Rastogi et al. 2020). At the same time, teleworkers may continue working from home and maintain their current (or close to their current) energy consumption patterns. This could lead to overall increased energy consumption and peak loads, and it may make it difficult and costly for electricity system operators to match supply and demand. Accordingly, new policies and technologies may be needed to reduce peak residential electricity demand, such as different TOU structures for electricity rates.

Teleworking is expected to increase in the future, so there is an urgent need for employers to develop policies related to teleworking and its energy impact. When deciding on compensation or stipends for work-from-home expenses, employers need to keep in mind that teleworkers may have increased energy bills. Government policy-makers may want to consider incentivizing occupancy adaptability of all buildings, considering the lack of energy savings in response to low or variable occupancy (Ouf, O'Brien, and Gunay 2019). On a broader scale, a telework-enabled migration from dense urban areas with small homes to larger suburban homes has the potential to cause much more significant increases in energy use, considering larger homes result in higher energy use per person (Larson and Zhao 2017; O'Brien and Yazdani Aliabadi 2020; Whitaker 2021).

Income and other socioeconomic factors were not explored in this survey but could be considered in future work because they may affect household electricity demand response and thereby can both improve grid operators' and policy-makers' forecasts and enable the evaluation of distributional impacts resulting from telework policies (Gyamfi, Krumdieck, and Urmee 2013). More generally, the energy impact of ICT equipment should not be neglected in future studies on teleworking and energy. Last, there is currently great potential for larger longitudinal studies or studies on the long-term energy impacts of teleworking as those who were new to teleworking continue to telework.

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Notes

1 Ontario winters are cold, but most homes rely on natural gas for heating, which results in lower peak load in the non-summer months (Natural Resources Canada 2019).

2 The Participant and Household Characteristics section provides details on the representativeness of our sample compared with the Canadian population on the basis of Statistics Canada data.

3 This is similar to the Ontario average fuel usage for heating (Natural Resources Canada 2019), which indicates that 85 percent of households use non-electric heating systems.

4 One respondent had both central AC and a portable AC unit.

5 The breakdown by province is as follows: Alberta, 9; British Columbia, 18; Manitoba, 1; Newfoundland and Labrador, 2; Northwest Territories, 4; Nova Scotia, 3; Ontario, 224; Quebec, 16; and Saskatchewan, 1.

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