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New insights on the energy impacts of telework

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Abstract

Quantifying the energy impact of teleworking has been challenging due to the low prevalence of telework. The COVID-19 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 297 knowledge-based workers who started primarily working 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 towards increased teleworking in the future, these results can inform public policy related to teleworking and energy.

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

JEL: Q41, Q48, H31, L94

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1. Introduction

For over 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 COVID-19 was declared a global pandemic on March 11, 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), it is important to gain insights about workers' energy-related behaviours – particularly while the shift is fresh in their minds.

Given the energy policy implications of this potential shift towards teleworking, this paper aims to capture how the marked increase of teleworking during COVID-19 has affected workers' self-reported energy-related attitudes and behaviours. We set out to obtain insights on 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 to before?
3. What are teleworkers' attitudes towards 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, over a month after COVID-19 restrictions began in most countries. 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 the impacts were easily recallable. To understand potential effects on home air-conditioning use, we conducted a follow-up survey in July 2020 on some of the first survey's participants.

New insights on 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 them accounting for over 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 behavioral barriers that can disincentivize energy

conservation investments, such as credit constraints or inattention to energy costs (Gillingham, Keyes, and Palmer 2018; Myers 2020; Houde and Myers 2019). In this context, a shift towards greater rates of telework has implications for the attainment of climate policy goals and the effectiveness of demand response programs, particularly peak-shifting (Spees and Lave 2007; 2008; Papineau 2019). 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 (Government of Canada 2020a).

Our study results indicate that a shift towards telework may heighten the challenge of meeting energy policy goals in residential buildings. Two-thirds of participants expressed a desire to telework more than before going forward, and survey participants used more energy at home during COVID-19 for computers and office equipment, cooking, lighting, heating or cooling systems, but used less energy on transportation. Among participants cooking or baking during COVID-19, nearly four-fifths did so between 9 a.m. and 5 p.m. on weekdays. Similarly, among participants doing laundry, three-fifths did so between 9 a.m. and 5 p.m. on weekdays. These are periods when electricity demand is high, and if these trends persist they could pose difficulties for grid operators and existing demand-response policies (Borenstein 2005).

The majority of participants (73.1 percent) believed their electricity bills would increase as a result of COVID-induced telework but were split on whether it would decrease or increase their total energy usage and monthly costs. Further, 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, though participants may not have known they were leaving the office for a period of at least several months.

We also found there is potential for improving the impact of TOU pricing since many Ontarian participants did not know about TOU pricing nor 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 an air conditioner, a plurality were using it more during the day compared to the previous summer, and the rate of new air-conditioning system installation was four times higher compared to previous years.

The rest of the paper is organized as follows. Section 2 provides background information and related literature on teleworking and energy consumption; Section 3 explains the methodology; Section 4 presents and discusses the results; and Section 5 offers conclusions and recommendations for future research.

2. Teleworking and energy

For the purposes of this paper, 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, thirty-nine papers have attempted to quantify the energy impact of teleworking in the areas of transportation, office energy use, and/or home energy use (Hook et al. 2020). Most studies have concluded that telework results in a reduction of transportation energy

and office building energy, while household energy use increases. Considering the total of these effects, estimates of the energy impact of teleworking ranges from energy savings of 77 percent (Koenig, Henderson, and Mokhtarian 1996) to an energy increase of 3 percent (Alonso, Monzón, and Wang 2017). While the studies' results vary widely because each study had different contexts (e.g., methods, assumptions, proportions of teleworking, scope, etc.), most studies indicate moderate energy savings, with more empirically rigorous methodologies typically finding more modest savings (O'Brien and Yazdani Aliabadi 2020; Hook et al. 2020; Giandomenico, Papineau, and Rivers 2020).

While 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 compared to non-teleworkers (Chapman 2007; Elldér 2017; Hook et al. 2020; Pengyu Zhu 2011), and residences may be less energy efficient than commercial buildings (IEA 2019). Previously, quantifying the energy impact of teleworking has been challenging due to 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 towards teleworking for some workers (Kamouri and Lister 2020), and 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). The rest of this section presents the electricity market context in which our study takes place.

2.2 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, thirty countries experienced an average decrease in electricity consumption of 20 percent, mostly from the commercial building sector (IEA 2020a; 2020b). Fig. 1 shows the three consecutive weekdays' electricity demand profile in Ontario. In 2020, the morning peak was smaller and delayed and the daily profile is generally 20 to 30 percent lower than past years. Several European countries had similar changes to their electricity demand profiles during COVID-19 (Bahmanyar, Estebarsari, and Ernst 2020).

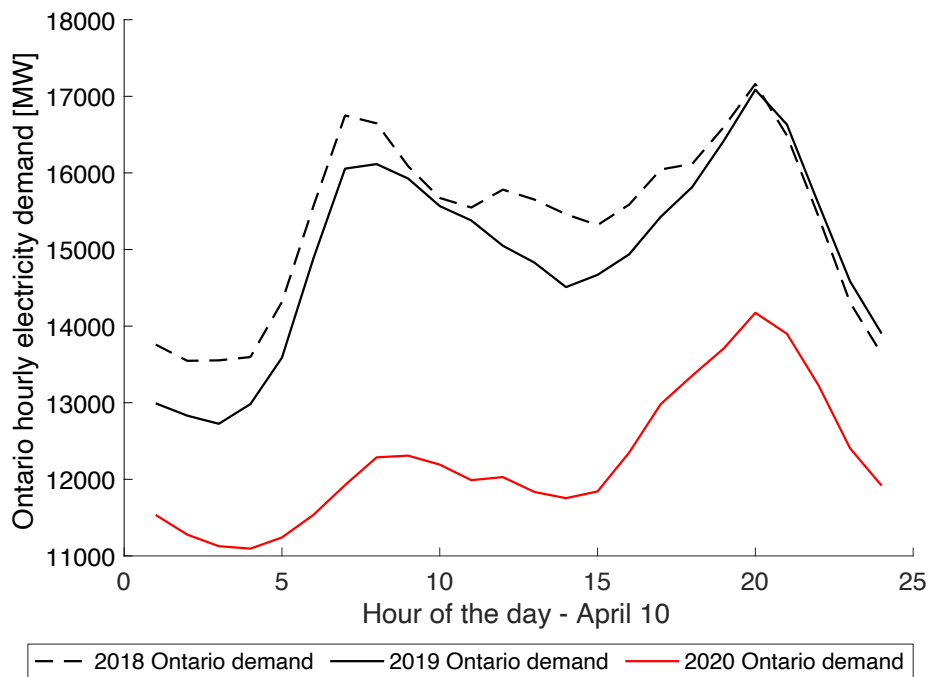


Fig. 1: Ontario electricity demand profile on a typical day in April (April 10) during COVID-19 restrictions (2020) and during 2018 and 2019. April 10 was a weekday during each of these years and had very similar outdoor air temperatures. [Data from (IESO 2020c; Government of Canada 2020c)].

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 overall and during peak times were 4 percent and 14 percent higher in Ontario, Canada (IESO 2020a; 2020d).

2.3 Influencing people to reduce residential electricity usage through TOU pricing

Occupant behavior can significantly impact 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 grid-wide electricity demand is lower and to avoid carbon-intensive energy sources (Newsham and Bowker 2010; Forsberg 2009; Maya Papineau 2019). TOU pricing can reduce peak electricity consumption by approximately 5 percent (Newsham and Bowker 2010; Ontario Energy Board 2004). For TOU to be effective at reducing peak residential energy consumption, it is imperative to understand energy-related attitudes, behaviours, and activities of building occupants (Beaman 2020).

2.4 Regional impact of 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. While Ontario electricity providers charged TOU electricity pricing for residential customers, they temporarily implemented a flat-rate from March 24 to October 31, 2020 (Ontario Energy Board 2020).

Ontario has warm, humid summers that cause peak electricity loads in the afternoon due to air-conditioning usage (IESO 2020e). Accordingly, electricity demand in the summer is highly dependent on outdoor air temperature (Sahay, Sahu, and Singh 2016) (see Fig. 2).¹

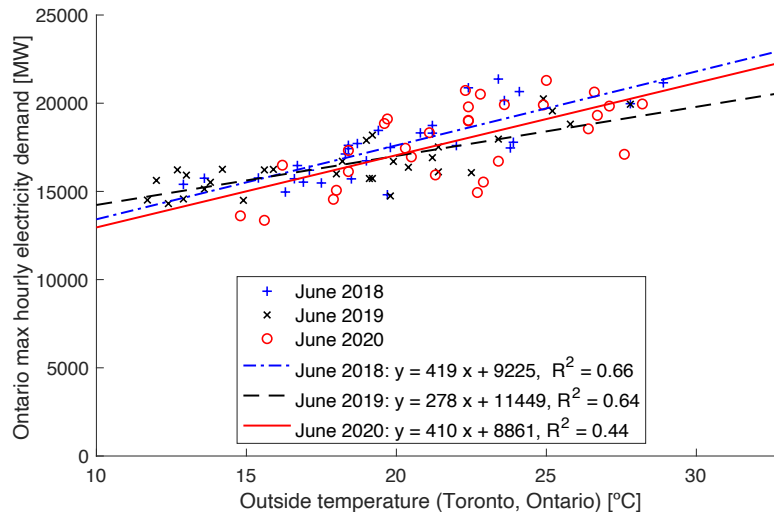


Fig. 2: Maximum hourly electricity demand per day for Ontario and outdoor air temperature during the peak load for June 2018, 2019, and 2020. Temperature is shown for Toronto because this city and the surrounding cities have similar weather and contain approximately two-thirds of Ontario’s population (IESO 2020b; Government of Ontario 2019). The lines were fit with linear least-squares regression. [Data from (IESO 2020c; Government of Canada 2020c)].

Fig. 2 indicates that even with the reduction in peak demand expected from the economic slowdown during COVID-19 (Cicala 2020), there was no substantial change in peak electricity demand compared to the previous two years. The high peak electricity consumption despite the economic slowdown may be a rebound effect of the suspension of TOU, 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. Fig. 3 shows that the highest annual peak electricity demand for 2020, which occurred on July 9, is higher than the preceding six years, which is a change from the downward trend over the past decade.

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 (NRCan 2019).

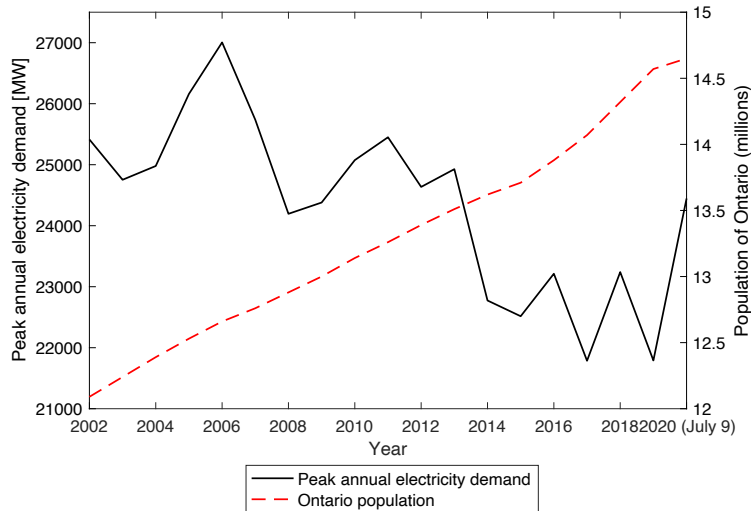


Fig. 3: Ontario peak annual electricity demand and population, 2002-2020 (as of mid-December 2020). [Data from (IESO 2020c; Duffin 2020)]

3. 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 had the opportunity to win one of five randomly drawn \$100 gift cards. Participants had to be older than 18, primarily working from home as a result of COVID-19 restrictions, and perform full-time knowledge-based work (e.g., engineering, design, administration, creative, education, business/accountant, manager, project manager, marketing, etc.) to be included in the survey results.

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 time-of-use pricing; and attitudes surrounding teleworking. All response data are self-reported due to the inherent nature of using a survey-based approach. The questions used to elicit the responses are presented alongside the results throughout the results and discussion section.

The first round of responses was collected between May 4 and June 1, 2020. Eligible response data from 297 participants were analyzed, three quarters of which 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 the categories.

As it became evident that COVID-19-induced telework would continue well into the cooling season, a short survey about air-conditioning use was sent to Ontario-based participants in July 2020. This narrow focus was used due to 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 in Subsection 4.3.3.

4. Results & 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 will be discussed throughout to inform policies and provide recommendations for future research.

4.1 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 (86.5 percent), while the others worked in a co-working space (6.1 percent), at home (4.4 percent), or a rotation between different offices (1.7 percent). Though a few participants said they primarily worked from home before COVID-19, 98.7 percent of all participants work more days at home during COVID-19 than before. The vast majority (89.9 percent) of participants live with at least one other adult, and 39.1 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).

4.2 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 occupancy was virtually zero (St. John 2020). The survey explored how teleworkers affected office energy consumption right before COVID-19 restrictions began. Throughout Section 4.2, only the responses of participants who primarily worked in a central office (i.e. not a co-working space or rotation between offices, etc.) before COVID-19 (n=257, or 87 percent of participants) are presented.

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 (see Table 1).

Table 1: Actions participants took to save energy before leaving the office for the last time before COVID-19 restrictions

Action	Percentage of participants who took this action [%]
Turn off light	59.1
Turn off computer	46.3
Turn off the printer or other auxiliary equipment	14.0
Close windows	13.6
Open or close blinds	13.2
Unplug equipment	12.8
Turn down thermostat	12.8
(None of the above)	22.6
(I do not remember)	3.5

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). The other energy-saving actions had lower participation, possibly because teleworkers did not habitually take these actions, or 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 since 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 completed in the central office.

4.3 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.

4.3.1 Energy impact of specific activities & systems

Participants were asked how their energy usage from certain activities or systems were affected by COVID-19 restrictions compared to one year ago (see Fig. 5).

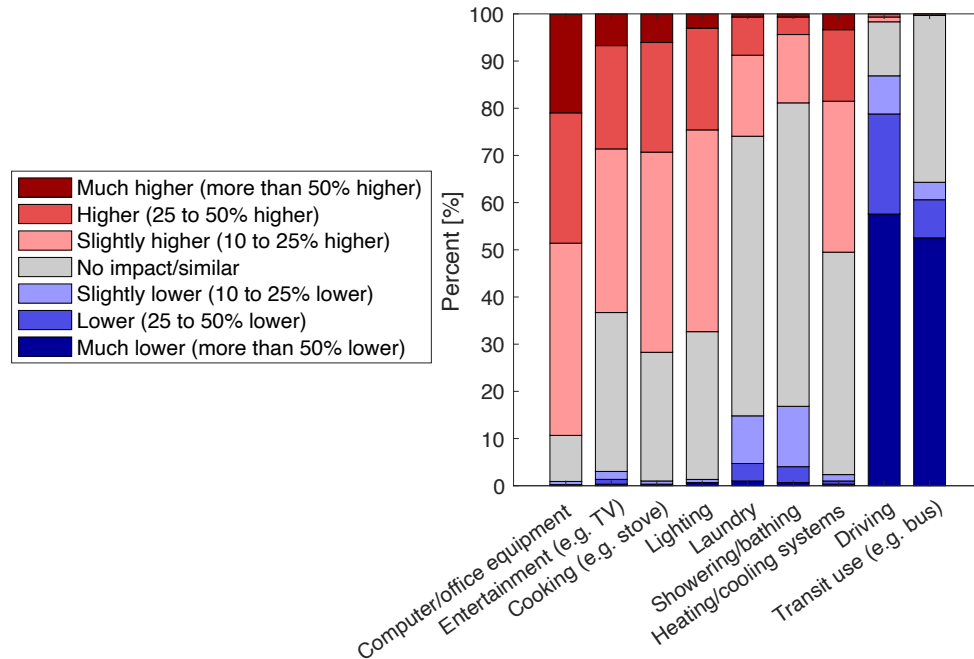


Fig. 5: Self-reported energy impact of certain activities during COVID-19 restrictions (May 2020) compared to May 2019

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, because they had more time from not commuting or because entertainment outside the home was inaccessible due to 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 an increase of 3.6 percent compared to non-teleworkers (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 if teleworking definitively saves transportation energy. Their estimates vary because of different proportions of teleworkers, transportation modes, and methodologies. The decrease in transportation energy typically comes from reduced commuting due to teleworking (Hook et al. 2020). Teleworkers may have increased transportation energy compared to non-teleworkers because they tend to commute farther for 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 demand for living in lower density communities increases commuting distances for both work and leisure (Mokhtarian 2009).

One area with particularly little research is home thermostat use (Papineau et al. 2020; Newsham and Donnelly 2013). There is uncertainty about schedules, setpoints, and whether teleworkers control their home as a single zone or focus on improving comfort in 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, 46.8 percent of participants made no changes, and 37.7 percent raised the setpoint during the day, likely resulting in increased heating usage. Most participants were from Canada (n=278)², which was predominantly still in the heating season when most of the participants completed the survey. When asked about their heating bill, over 90 percent of participants indicated 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 HVAC could reduce their household energy consumption by lowering the setpoint during the heating season, raising the setpoint during the cooling season, and directing heating and cooling to occupied spaces only.

4.3.2 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 (O'Brien and Yazdani Aliabadi 2020; Nakanishi 2015). This is in part due to the fact that previous studies span several decades, during which office equipment evolved significantly. Fig. 4 shows the equipment that participants reported having in their home working environment during COVID-19 lockdown measures.

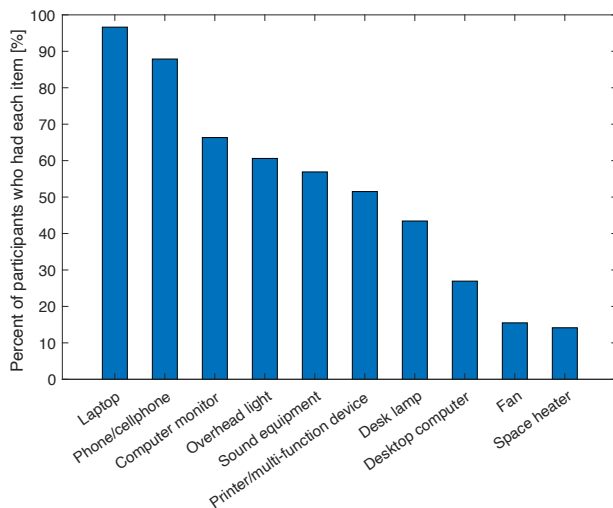


Fig. 4: Equipment respondents have in their home working environment. Sound equipment includes headphones, external microphones, and headphones. Printers or multi-function devices includes fax machines or scanners.

² Others were: Brazil (1), Denmark (1), France (1), India (2), Iran (1), Italy (2), Lebanon (1), UK (1), USA (9)

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

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 (Webber et al. 2006; Gunay et al. 2016). Participants also commonly have peripheral computer monitors. Participants who indicated that they had a computer monitor (other than integrated laptop monitors) were asked how many they have: 49.8 percent have one monitor, 33.0 percent have two monitors, and 17.3 percent have three or more monitors.

Participants were asked if 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. Over half (52.9 percent) had to start using more electric devices or appliances that they already owned, such as computer monitors, computers, lights, headphones, and tablets. Nearly a third (32.3 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 to be generalizable to teleworking during post-COVID-19 times since the equipment is necessary for teleworking. Regardless, the energy impact of ICT for teleworking is not negligible and should be explored in more detail since 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).

4.3.3 Second survey: use and adoption of air-conditioning due to teleworking

The second survey that asked about air-conditioning (AC) use was completed by 66 of the 224 Ontario participants. Respondents were asked if 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 to last 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 last summer. These results help explain the trend shown in Fig. 2 of continued high summer peak electricity demand during COVID-19. Home AC is relatively inefficient at maintaining a comfortable workspace compared to AC in office buildings, due to 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 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(s).

Respondents were asked what their current daytime thermostat setpoint was. The most common thermostat setpoint range was 22°C to 24°C (44 percent of respondents). This is a relatively low setpoint for the cooling season considering that the National Building Code assumes a cooling

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

setpoint of 25°C when occupants are present (Abdeen et al. 2020). Respondents also commonly had thermostat setpoint 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. While this could be viewed negatively as participants not considering saving energy a priority, it is reassuring that participants are comfortable at home: buildings are designed for people and should protect the health and comfort of occupants (O’Brien et al. 2020).

Respondents were asked if they or a member of their households purchased an air-conditioning unit this summer as a result of working from home. Of the respondents who had air-conditioning, 5 percent installed a window air-conditioning unit this summer as a result of working from home. This is equivalent to the number of Canadian households that installed air-conditioners over the entire period from 2013 to 2017 (Government of Canada 2020b). Because of the high upfront cost of air-conditioners, it is likely that these households will continue to use them even if they do not telework after the pandemic. This trend has long-lasting implications for peak electricity demand. According to the International Energy Agency, the energy impact from air-conditioning could triple worldwide in the next thirty years (IEA 2018).

4.3.4 Energy usage patterns from household chores

Participants were also asked how often they cooked, baked, and did laundry between 9 a.m. and 5 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 above. If participants did laundry, 57.9 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 from reduced commuting to do these tasks (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 Section 4.5 for a more detailed discussion on TOU).

4.3.5 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: 88.6 percent pay for their electricity bill, and 74.1 percent pay for their heating. The remaining participants have utility bills included in rent, 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; Levinson and Niemann 2004; Jessoe, Papineau, and Rapson 2020).

When asked how they expected their electricity bills to change as a result of working from home during COVID-19, some participants (21.2 percent) answered that their electricity bill is 25 to 50 percent higher because of teleworking. Just over half (51.9 percent) believed their electricity

usage was 10 to 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 if they think teleworking during COVID-19 saved them energy overall, when taking into account home, office building, and transportation energy use, as shown in Fig. 6. The most common response was that that teleworking probably saved them overall energy costs, but answers were mixed, with a quarter of respondents believing telework did not save them energy.

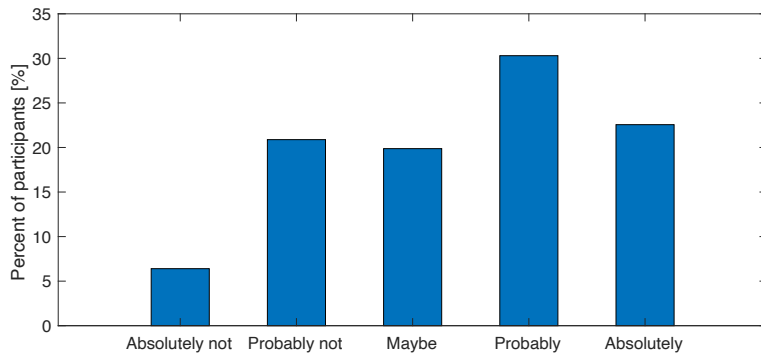


Fig. 6: Distribution of answers to, “Do you think telework overall saves you energy during COVID-19, taking into account home, office building, and transportation energy use?”

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

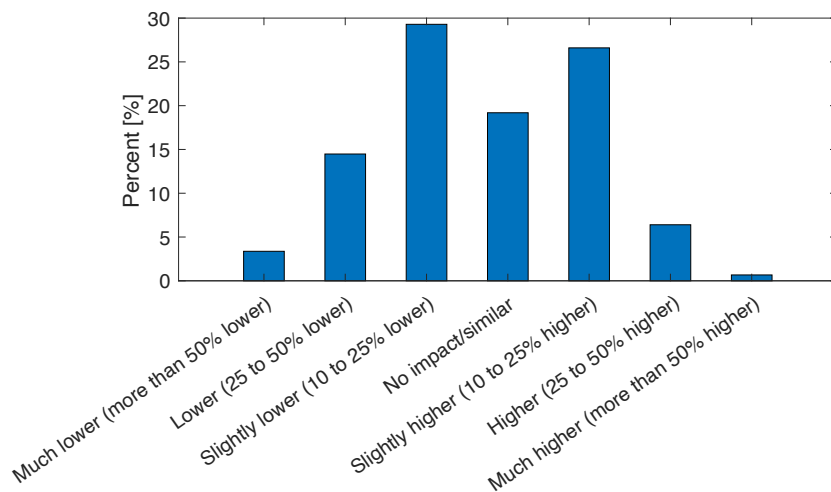


Fig. 7: Answers to, “Considering all household energy bills and transportation costs, how do you expect your total monthly costs to change, as a result of COVID-19 restrictions?”

There are many explanations for the wide variation in responses observed in both Fig. 6 and Fig. 7, especially since participants were asked about the combined energy usage or costs from the home, office, and transportation. As previously noted, most participants expected higher electricity bills, but their other energy bills may not have changed or 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 (O'Brien and Yazdani Aliabadi 2020; Giandomenico, Papineau, and Rivers 2020; Gillingham, Keyes, and Palmer 2018).

4.4 Attitudes towards teleworking going forward

Attitudes towards teleworking are important for gauging of how COVID-19 may influence the future of teleworking and for informing related policies. Based on their current teleworking experience, two thirds of all participants expressed a preference to work from home more often than before, once the pandemic is over. This is similar to a previous survey that found 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).⁵

4.5 Awareness and effect on behaviour of time-of-use (TOU) pricing suspension

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

Since there were 224 participants 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 time-of-use pricing where you pay different rates at different times of day?". Fig. 8 presents the answers 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, Papineau, and Rapson 2020).

⁵ We also conducted statistical tests to evaluate whether attitudes to teleworking going forward differ among households with and without children and found no statistical differences (p-value=0.6). This analysis is available from the authors by request.

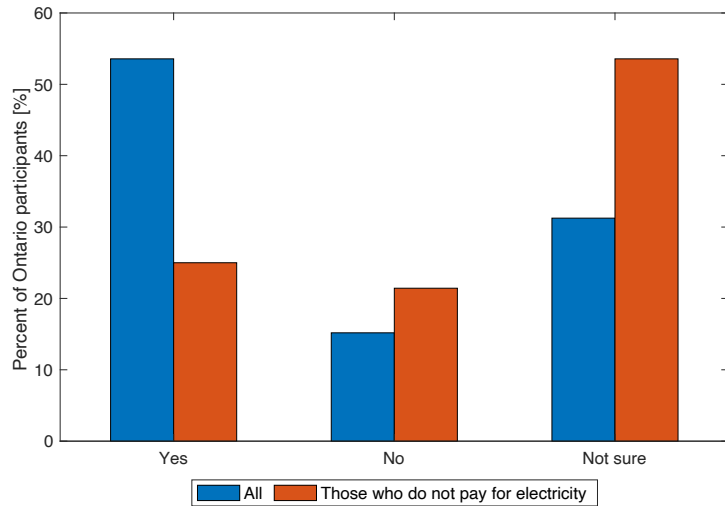


Fig. 8: Percentages of all Ontario participants (n=224) and Ontario participants who do not pay for their electricity bill (n=28) who answered “yes”, “no”, or “not sure” when asked if their electricity provider started charging a flat or constant rate during COVID-19, rather than time-of-use pricing.

Just over 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 due to its inclusion in rent or condo fees were less certain about electricity pricing.

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

Those who answered “yes” to 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. Fig. 9 shows the answers for these Ontario participants.

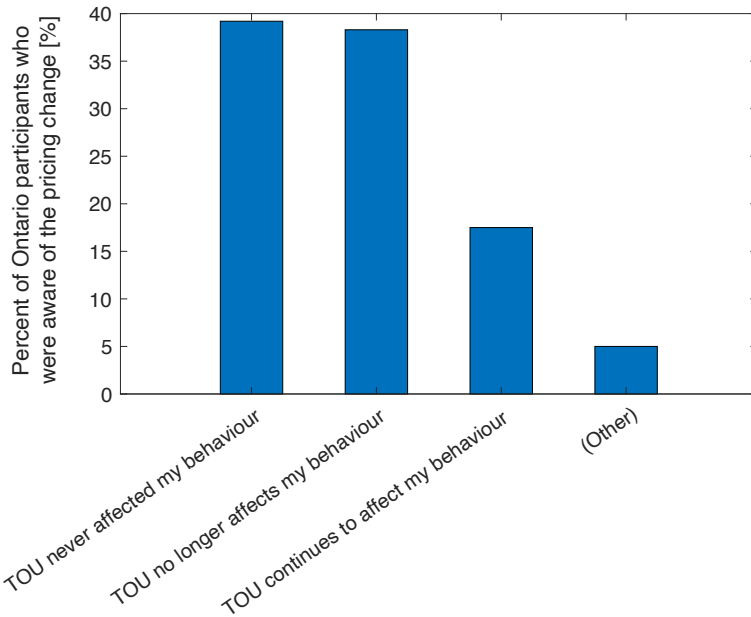


Fig. 9: Responses among Ontario participants to a question asking whether the TOU pricing suspension affected their behaviour, for respondents who were aware of the pricing change.

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", and 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 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 prior research, these findings indicate 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, since education can help consumers shift electricity use away from peak hours (Faruqui, Sergici, and Sharif 2010; Delmas, Fischlein, and Asensio 2013).

4.6 Study limitations

The survey method and results have some limitations. While the survey was open to eligible participants globally, responses are from only ten countries, with 93.6 percent from Canada⁶. For this reason, the findings of this paper may not apply to all regions, though key factors (e.g., proportion of workforce teleworking during COVID-19, COVID-19 restrictions, reductions in overall electricity consumption) are similar across many countries (IEA 2020c).

⁶ Provincial breakdown: Alberta (9), British Columbia (18), Manitoba (1), Newfoundland and Labrador (2), Northwest Territories (4), Nova Scotia (3), Ontario (224), Quebec (16), Saskatchewan (1)

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 setpoint, amount of lighting, etc.), which in turn affects energy consumption. However, we mitigated the influence of seasonal effects by framing most survey questions as changes due to teleworking during COVID-19 or changes compared to the previous year.

While the large shift towards teleworking due to 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. Additionally, some participants had to undertake extra responsibilities, such as childcare and educating their children since daycares 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.

5. Conclusions and future work

This paper evaluates how 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 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 may make it difficult and costly for electricity system operators to match supply and demand. Accordingly, new policies and technologies are 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 policymakers 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).

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 policymakers' 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. Lastly, 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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