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The Telework Transition

Implications for Emissions Reporting, the Environment, and the Contemporary Workplace

Table of Contents

Introduction 1

At the start of COVID-19, regional lockdowns were mandated around the world to reduce the number of cases and avoid the worst health effects of the virus. Los Angeles County, in particular, issued a stay-at-home order on March 19, 2020, requiring all non-essential businesses to shut down and banned gatherings larger than 10 people. For the most part, L.A. County remained in the most restrictive purple risk tier until February 2021.[1] The abrupt closure of many offices and workplaces brought a new age of teleworking, or working from home, for millions of white-collar Americans. This may lead to a significant shift in the way a large portion of the workforce operates in the future, as many companies anticipate a hybrid workplace post-pandemic. Most workers whose job duties can mainly be done from home say that before the pandemic they rarely or never teleworked – only one in five worked from home all or most of the time.[2] As of December 2020, 71% of those workers were doing their job from home all or most of the time. And according to a new Pew Research Center survey, more than half of respondents said if they were given the choice, they prefer to keep working from home even after the pandemic.[3]

As vehicle miles travelled and air pollution significantly decreased in the weeks following the COVID-19 stay-at-home orders,[4] many people began to see teleworking as a feasible strategy to reduce greenhouse gas (GHG) emissions in the long-term. News outlets and politicians alike began framing teleworking as an unexpected benefit for the environment. On the surface, the argument to mitigate climate change with teleworking appears logical: “More telecommuting means fewer vehicles on the road which should lead to decreased GHG emissions.”[5] There is some research that shows it is a practical way to reduce emissions, air pollution and energy consumption in buildings. However, before enacting teleworking policies for environmental reasons, a comprehensive depiction of teleworking impacts is suggested.

At this stage of the pandemic – with a likely future of increased teleworking and hybrid workplaces ahead of us – it is important that we investigate the real, complex nature of the impacts of teleworking on greenhouse gas emissions and provide guidance to companies and firms looking to be proactive and navigate this new, uncharted territory.

The purpose of this paper is to discover and synthesize common perspectives, trends, and challenges as corporations reflect on the previous year and make decisions about how to move forward with their sustainability goals while incorporating this ‘new normal’ of increased teleworking. We did this through collecting information from various studies, reports, and direct company interviews. Using the information we gathered, we developed a simple model to help individual firms assess the materiality of their teleworking emissions. This report is an initial exploration, and more research is needed as more data becomes available.

Our analysis is organized into six sections. After the Introduction, in Section II, we briefly explain how emissions reporting is traditionally conducted. This includes exploring reasons why companies have not reported teleworking emissions in the past. In Section III, we delve into the insights, trends and reporting adaptations gained from various company interviews on teleworking. In Section IV, we explore the energy impacts of teleworking. In Section V, we discuss the concept of ‘materiality’ when calculating teleworking emissions and introduce the Materiality Model we created which aims to provide an estimate and sense of significance for a firm’s teleworking emissions in relation to its overall emissions. This is meant to give firms a clearer idea of next steps, if any, to reduce emissions. Lastly, we discuss further reduction potential and research opportunities in Section VI.

2

Background on Emissions Reporting

In this section, we provide key definitions and background information to contextualize the topics we will discuss in this paper. We also provide a brief review on the relationship between greenhouse gas emissions reporting and the uncertainty regarding the reporting of Scope 3 emissions and teleworking calculations.

Greenhouse gases make the planet warmer by trapping heat in the atmosphere. These include carbon dioxide, methane, nitrous oxide, and hydrofluorocarbons. According to The Carbon Trust, “a carbon footprint measures the total greenhouse gas emissions caused directly and indirectly by a person, organization, event or product.”[6] Corporations may choose to report their carbon footprints for a variety of reasons, including to attract customers and investors and to adhere to regulatory reporting requirements. Each year, more companies around the world disclose their greenhouse gas emissions through CDP (formerly the Carbon Disclosure Project). According to CDP, “the business world shows growing environmental awareness despite the unprecedented challenges faced in 2020.”[7]

Emissions disclosure is encouraged as it provides market participants a strategic lens on carbon risks and opportunities.[8] In 2019, over 8,400 companies released emissions data through CDP, representing about half of global market capitalization.[9] Among those reporting to CDP, 85% utilize the Greenhouse Gas Protocol (GHGP) standards to calculate emissions. The GHGP divides emissions into three “scopes”. Scope 1 includes direct emissions such as fuel combustion, company vehicles and facilities, and fugitive emissions. Scope 2 are indirect emissions encompassing purchased electricity, heat, and steam. Scope 3 emissions are indirect emissions that a company can influence but cannot control directly, such as purchased goods and services, business travel, employee commuting, and investments.[10] Scope 3 emissions are often the most challenging to quantify and tend to be underreported.

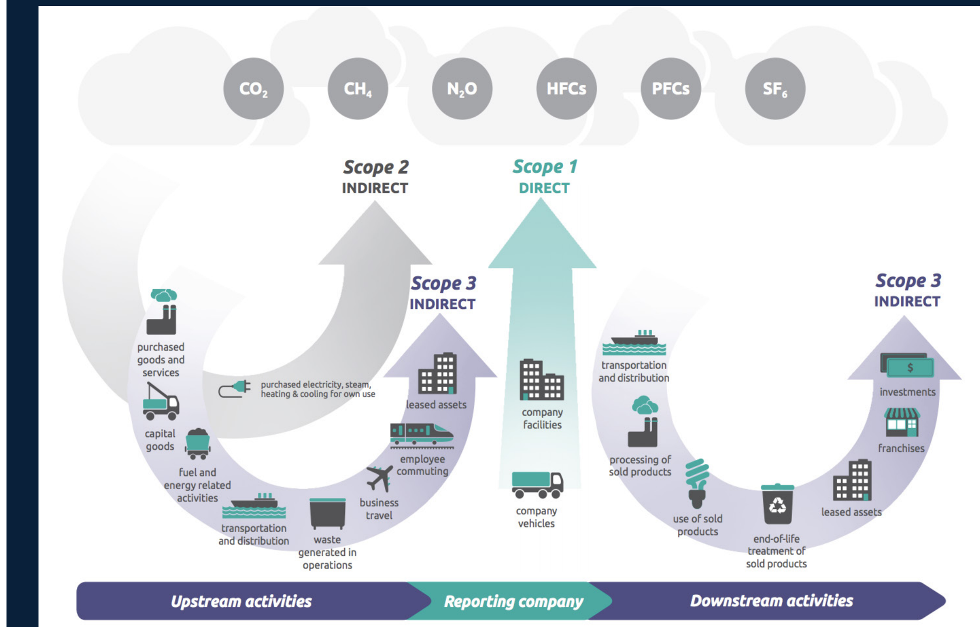

Figure 1[11]: Overview of the Greenhouse Gas Protocol scopes and emissions across the value chain

8400 companies released emissions data through CDP in 2019

Scope 3 emissions are often the most challenging to quantify and tend to be underreported

Many corporations – especially healthcare, financial services, and information technology – do not fully track carbon sources that are most material to their business activities, according to the Corporate Carbon Disclosure in North America.[12] However, recent trends due to stakeholder concerns and enhanced data gathering capabilities in disclosure reflect that Scope 3 categories such as purchased goods and services, employee commuting, and waste generated have grown in importance. Conversely, other Scope 3 emissions sources have decreased in importance, such as processing of sold products, downstream leased assets, and franchises.[13]

Within the GHGP, emissions associated with working from home fall into Scope 3 emissions as an optional component of the Employee Commuting category.[14] The GHGP does not provide a methodology for including teleworking emissions due to difficulties in sourcing data to base emissions calculations on, as well as a previous assumption that it would not be as material as other elements.[15] For these reasons, most companies have not endeavored to include teleworking emissions in their reporting. However, a need exists for an improvement in corporate emissions reporting and data collection.

Next, we dive into specific firms' approaches to addressing teleworking emissions.

3 Teleworking Trends and Reporting Adaptations

In the spring of 2020, the COVID-19 pandemic spread its reach to much of the United States, bringing with it limited direct interactions among people as well as closures and remote-work transitions for many businesses. While these impacts have set back a variety of industries and their plans for the future, the pandemic has also demonstrated the resiliency of firms in overcoming and thriving in the face of adversity. In an effort to better understand the perspectives and experiences of firms who increased their teleworking populations during the pandemic, we interviewed three firms - X, Y, and Z- about this topic. Firm X is a United States-based management consulting firm, while Firm Y and Z are both United States-based technology firms. We have chosen to not disclose the identities of the firms, to encourage a more transparent insight into their true experiences with teleworking and emissions reporting. These firms were chosen based on their unique position as companies who, previous to the pandemic, already had a portion of their population working remotely. Based on our previous research on teleworking, we formulated our interviews to explore topics including materiality, data sourcing, calculations, and potential Scope 1 and 2 emissions impacts due to reduced real estate and office occupancy.[16] In the remainder of this section, we will explore our interviews with Firms X, Y, and Z within the context of the pandemic's impacts on businesses and trends that these companies expect to see, or have already observed, in this field.

The following overarching themes emerged from the interviews:

1. The importance of considering materiality in emissions calculations and reporting
2. A lack of teleworking emissions reporting due to inconsistent data
3. Cultural impacts within firms resulting from a dramatic increase in teleworking
4. The effect of increased teleworking on real estate management and portfolios

One of the largest unifying topics among all of the firms interviewed was the importance of materiality in reporting and calculating emissions. Firm X noted that the pandemic's transition to remote work has generated a significant source of emissions that will likely go unaccounted for, due to their misunderstood size in relation to other value chain emissions. They also added that true materiality depends on factors including the sector of work, the number of remote workers, and the timeframe of the remote work, differentiating between a long-term remote work program versus one that will only remain until the pandemic subsides. For example, sectors accounting for manufacturing, distribution, and product life cycles in their emissions, like engineering and technology firms, will certainly yield higher emissions due to production than sectors with intangible products, like consulting firms. Therefore, those firms with already-large Scope 1, 2, or 3 emissions may not find significance in calculating and reporting Scope 3 teleworking emissions.

In the case of Dell Inc., who is not included among our interviewed firms, their 2020 CDP Climate Change report clarified that scope 3 categories composing under 1% of their overall scope 3 emissions were not significant enough to be captured within their report.[17] Firm Z echoed this narrative, stating that they previously chose to exclude teleworking emissions from within their Scope 3 reporting due to its lack of materiality in their overall emissions. However, with their transition to increased telework, they hope to calculate and report these emissions after the pandemic is over and teleworking trends have plateaued to more uniform and reliable values. Firm Z avoided reporting teleworking emissions for 2020 due to the drastic and immediate changes in employee teleworking data, which they felt would be a poor representation of their employee population and possibly yield inaccurate conclusions in their analysis of these emissions' impacts.

A lack of materiality was the rationale also expressed by Firm Y for choosing not to calculate and report teleworking emissions. The firm transitioned from around 30% working remotely before the pandemic to around 99% working remotely during the pandemic. Firm Y has years of experience analyzing and attempting to quantify teleworking emissions long before 2020. Despite their established presence in the realm of partial telework, they still believe that even with the majority of their employee population teleworking, the value of these emissions relative to their total emissions is negligible. Instead, they found it to be more effective to address the largest sources of emissions and adjust their sustainability and carbon reduction goals accordingly, rather than engaging in the tedious work of attempting to calculate emissions from teleworking. In other words, Firm Y addresses their environmental impact in the most time- and cost-effective way for their particular firm. They also greatly value promoting solutions to reduce teleworking emissions. They feel that the resources put into calculating and reporting teleworking emissions would be better suited for encouraging employees to take on sustainable lifestyle practices and promoting related initiatives.

Adapted reporting practices were not the only effects of increased telework. Firms X, Y, and Z all discussed real estate and cultural impacts faced during the past year. For Firm X, there was a change in the culture of remote work, as preconceived misconceptions of telework were proved wrong over the course of the year. Despite worries around the impacts of remote work on employee productivity, management found that employee efficiency and management are nearly the same as those found in a traditional office setting. Firm X also found that for some, remote work increased productivity by allowing for more flexibilities throughout the workday.

Similar to Firm X, Firm Z also recognized these characteristics of a traditional workplace carrying over to the remote setting. Employees had more time in their workdays and personal life without the need to make long commutes to and from their offices. Firm Y's opinion on cultural changes within remote work mirrored the other two firms, yet also acknowledged that the success of remote work came with initial difficulties of adapting to a new work environment. Many firms never previously managed employees through technology. Looking forward, they see remote work remaining a popular option for employees, but predict that many will yearn for a hybrid approach to maintain a sense of community, engagement, and overall satisfaction. With the increase in telework, they also look forward to more potential recruitment

opportunities, as individuals who were previously unwilling or unable to relocate can now work from their desired location.

In examining the impacts of increased telework on firms' real estate portfolios, all the firms interviewed recognized the decrease in their portfolios due to decreased occupancy. For Firms Y and Z, which are involved in manufacturing and engineering, they noted the necessity to keep some office building spaces open, which are required for these sectors. However, Firm Z expects that buildings with sporadic occupancies will adopt a combination of monitoring devices and occupancy-based technologies to deal with the dynamic nature of hybrid work.

Firm X's portfolio expects similar alterations to their offices, and some of their office buildings have already improved over the past year with the integration of new sustainability practices and high-level technologies that connect energy use with occupancy. They will likely continue downsizing as partial remote work becomes the normal practice for employees, creating central offices and spaces for particular teams to meet and interact in when they are on premise.

Overall, firm interviews reflect the positive future of remote work, even in industries that differ in their environmental impacts. While the materiality of teleworking emissions may vary from firm to firm, the greatest player in decreasing emissions lies in promoting sustainable lifestyles among employees, making the best use of home office space and energy, and using technology that empowers remote workers when possible in place of business travel and commuting. Looking towards a post-pandemic future where hybrid and remote work have become more normalized, in-person work may lose its pre-pandemic dominance to these alternative work styles. In the next section, we examine specific energy impacts associated with teleworking, including those relating to transportation, central office spaces, and homes.

Context is Key

Firm X provided insightful advice for companies interested in attempting to calculate and report their Scope 3 emissions. They invested substantial time and resources into the Scope 3 space and find it interesting since the field is so new. Yet, at the same time, they emphasized the importance of contextualizing work like this within understanding a company's value chain emissions. In other words, they stressed that companies should study work-from-home as part of the entire value chain, rather than zeroing in on only teleworking. They noted that when determining whether or not to quantify teleworking emissions – or how much time and resources to devote to the practice – other important Scope 3 categories should not be discounted solely because of a new cultural relevance of teleworking.

Changing Mindsets for Sustainability

A key takeaway from multiple interviews was that rather than studying intricate calculations of teleworking or avoided emissions, some companies may find it more impactful to promote overall sustainable mindsets and behaviors among employees. Therefore, it may be useful to conduct further research examining the most – and least – effective sustainability programs, information campaigns and behavioral nudges already implemented by firms or businesses. Doing so may provide tangible guidance for companies seeking to reduce their carbon footprints. This guidance could be categorized and filtered by industry, size of firm, company culture, location, and employee capabilities – among other characteristics – for more useful and applicable recommendations.

4

Energy Impacts of Teleworking

Through our extensive research and company interviews, we found that the problem of accounting for teleworking emissions is not only highly complex, but it also remains uncertain whether it is more beneficial for the environment than traditional work. The majority of studies indicate reductions in energy and GHG emissions from teleworking, however, this finding is not universal.[18] Rebound effects – such as non-work related travel, home energy use, and office energy use – can diminish, to varying extents, the potential energy savings and environmental benefits of teleworking. Additionally, lifestyle changes are not linear and can elicit unexpected results.

Literature reviews conducted in the summer of 2020 revealed that the energy-related environmental benefits of teleworking may be "vastly overestimated due to the tendency for telecommuting studies to have a limited scope in terms of study length and variables evaluated."[19] Most of these studies fail to take into account the full span of possible impacts and instead focus only on work-related travel. According to the report, "A Systematic Review of the Energy and Climate Impacts of Teleworking," when studies consider more domains, an environmental benefit is less likely to be uncovered.[20] The report extrapolated that energy savings associated with teleworking are modest and may even have a negative or negligible impact.

Next, we examine energy usage associated with transportation, central office spaces, and homes, as well as the reduction potential, rebound effects, and research methods for each. Figure 2[21] summarizes the advantages and disadvantages of the primary and secondary effects of teleworking on energy use. Primary effects refer to immediate and direct impacts on energy use, whereas secondary effects are unanticipated and/or indirect.

Teleworking Effects on Energy Use	Advantages	Disadvantages
Primary Effects	Reduced commuting time and distance Reduced traffic due to less congestion during peak hours Reduced office space and associated operating costs/ energy	Increased energy use at home for lighting, office equipment and HVAC (heating ventilation, air conditioning) Increased use of HVAC if it is centrally controlled and used during telework days Increased reliance on Internet Communications Technology (ICT) for work-related communications and associated energy use/ infrastructure More space required for a home office, which may lead to purchasing a larger home with higher energy use
Secondary Effects	Outward movement of teleworkers to suburbs, allowing non-teleworkers to live closer to work on average Reduced traffic congestion resulting from fewer commuters Improved energy efficiency behaviors at home because teleworkers pay for their own energy use	Increased transportation energy because teleworkers opt to live further from the workplace and some amenities Increased non-commuting trips for errands since they cannot integrate them into commutes Increased non-commuting trips because household members have access to cars on the days when the worker works from home Larger homes and cars are more affordable due to reduced commutes

Figure 2: The primary and secondary effects of teleworking and their associated advantages and disadvantages.

Transportation

The potential for teleworking to positively impact transportation patterns and associated emissions is a key motivator for the environmental impacts of teleworking. More people teleworking decreases overall traffic congestion and reduces energy use and vehicle emissions. In regions with a large amount of walking, cycling, and public transportation, the benefit of teleworking is less than in spread-out cities where commuters mainly rely on personal cars and with significant congestion.[22] A prominent short-term rebound effect of transportation is the increased frequency and/or distance of non-work trips. For example, many commuters incorporate errands into their commute, which means increased personal travel for non-commuters.[23] In a 2016 report, Dell Inc. found consistent data stating that teleworkers drive more in their personal vehicles than traditional workers.[24] Limitations of current research methods on transportation include varying sample sizes as well as errors and bias as a result of self-reporting surveys.

Central office spaces

A shared office space approach can maximize the environmental benefits of teleworking, whereby employees are not assigned specific workstations, and occupant capacity is achieved. Optimal benefits occur when an office implements energy-saving HVAC and other technologies. However, unanticipated rebound effects limit the energy-saving potential. For example, if a company increases teleworking while each employee still has a dedicated workspace, there will be minimal energy savings. Buildings are not typically designed to easily adapt to variable occupancy, and many continue to run on centralized heating and cooling systems, thus reducing the potential for saving energy.[25] In addition, many teleworkers have a computer at home and at work, and 40-50% leave them on all the time.[26] Research on office space energy use requires many assumptions regarding office operations, occupant behavior and occupancy patterns, resulting in significant limitations in our understanding of the real environmental impacts of teleworking.

Homes

The potential for energy savings at home via teleworking is unlikely, as office equipment is merely transferred from the office to the home. Short-term rebound effects of home energy use focus on usage behavior of office equipment, lighting, and HVAC. In North American homes, HVAC tends to be centralized which does not allow temperature in individual rooms to be easily adjusted.[27] Therefore, a teleworker needing only a small area of the home may ultimately condition the entire house at comfortable and energy-intensive conditions. However, the presence of multiple teleworkers or family members in one home reduces this energy waste.[28] Long-term effects include change of home location, size of home and home office, and other large purchasing decisions.[29] Research on home energy involves a reliance on simple assumptions and calculations for equipment. This approach misses phantom loads – devices that consume electricity when turned off but are still plugged into an outlet. Additionally, methods of estimating the impact on home HVAC energy are similarly simple and typically disregard the role of behavior and climate.[30]

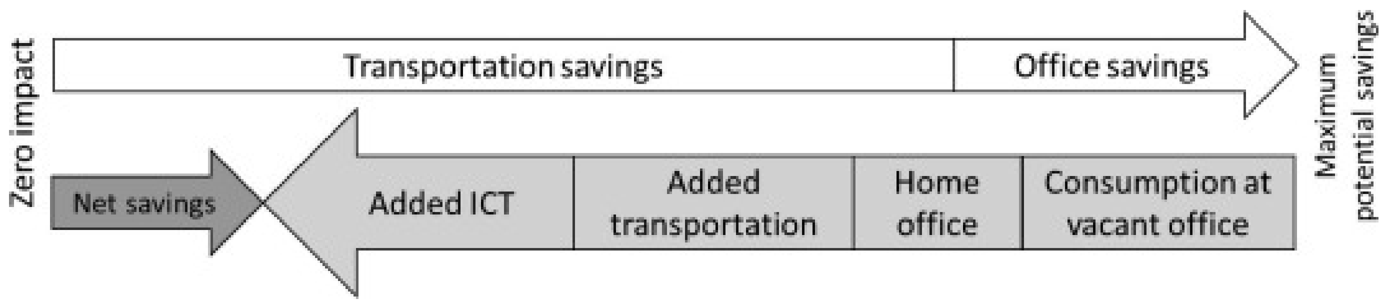

Figure 3[31] This illustration of primary potential for net energy savings from telecommuting and rebound effects shows a conceptual balance between zero impact of teleworking and the maximum theoretical potential. This reveals the possibility of a negative net impact.

Dell Inc. found that "the benefits persist and remain material even when rebound effects such as home electricity use and non-business-related personal trips during the day are taken into account."[32] While the majority of studies like Dell's indicate that teleworking decreases energy use, rebound effects tend to significantly offset and sometimes exceed energy savings. A wide variety of research methods have been used but have not yet been combined for comprehensive analysis.[33] Current studies and their findings largely depend on contextual details, as well as research methods with significant limitations. Consequently, the findings vary greatly and are not easily comparable. In Section VI, we propose specific and improved research methods.

Examining energy impacts and rebound effects provides a deeper understanding of the complex task of assessing the environmental impacts of teleworking. With this information, we can explore further how companies can attempt to tackle the challenge of evaluating their teleworking emissions and footprint.

Materiality and Methodology Background

5

In this section, we briefly introduce the meaning of materiality and its relevance to our Materiality Model, which is discussed more in Appendix E. Estimating Scope 3 teleworking emissions is not a one-size-fits-all process, and can be subject to great variability depending on calculation inputs. Formulating a reliable calculation methodology relies on the availability of data sources, the consideration of relevant energy sources, and rationalized assumptions.

Within the Greenhouse Gas Protocol's "A Corporate Accounting and Reporting Standard," one accounting and reporting principle is "completeness" and the expectation of a clear rationale behind exclusions of emissions in calculation and reporting processes.[34] Although teleworking emissions are optional to report and calculate, we created a model to enhance firms' fulfillment of this "completeness" principle. Our Materiality Model approximates carbon emissions for teleworkers centered in Los Angeles based on inputs and data available to most firms. By giving a value and materiality to teleworking emissions, the model provokes an improved understanding of teleworking emissions and provides an avenue for them to be considered in reporting.

Exploration of materiality within the model occurs within the context of their total Scope 1, Scope 2, and Scope 3 emissions. By comparing overall or individual Scope emissions to teleworking emissions, there is a chance for quantitative insight into the impactfulness of pursuing potential reduction strategies, and whether reduced teleworking emissions could be an asset to these strategies.

In the development of our Materiality Model and in firms' own calculations of teleworking emissions, there are three vital factors to take into account: energy sources, emissions factors, and data sources. Energy sources include all of the potential items in the house that use electricity or natural gas during an individual's working hours. Emissions factors yield various results depending on the energy type used to power the items and the location of the home or energy supplier. Data sources support the exploration of energy sources and emissions factors by providing energy consumption values or estimates of different electronics and appliances. Additionally, data sources inform emissions factors. Within data sources, firms must also provide information like the number of employees and their frequency of telework to account for possible employee commuting or business travel emissions in Scope 3. These three factors and the model's background can be explored further in Appendices A-E.

Materiality Model Factors

Energy Sources

Emissions Factors

Data Sources

While the model intends to illuminate the materiality of teleworking emissions, due to the simplicity of the data inputs, its main goal is to assist organizations in estimating Scope 3 emissions. It is in no way an exact measure of teleworking emissions, and should not be used for reporting purposes, but rather as a look into possible emissions values.

For required emissions calculations and reporting — like Scope 1 and Scope 2 categories — the Greenhouse Gas Protocol recommends against the use of materiality thresholds in an effort to reduce bias, since the testing of emissions against such thresholds is often based on estimated emissions, and not real values.[35] Despite this recommendation, we believe firms could benefit in using a materiality threshold approach for the optional teleworking category. Since teleworking emissions are optional to report, firms understandably would not prioritize investing time in calculating a number that may ultimately be of insignificant value. Using a materiality threshold against an estimated teleworking emissions value, which our model does, allows firms to establish a sense of significance for this emissions value before undertaking further investigation.

After inputting the requested data of total Los Angeles teleworkers into the model, firms can input their Scope 1, Scope 2, and Scope 3 emissions values for comparison to their potential teleworking emissions.

The Greenhouse Gas Protocol's "A Corporate Accounting and Reporting Standard" defines a material error as one greater than "5% of the total inventory for the part of the organization being verified."[36] Alternatively, some firms use a threshold of 1% of their total Scope 3 emissions to determine materiality.[37] To align with these varying definitions of materiality, we recommend firms to choose a threshold percentage between 1% to 5% when considering the materiality of teleworking emissions within the Scope in focus. Therefore, teleworking emissions would be considered material if they are greater than the chosen threshold percentage of the total Scope 3 emissions.

Our model encompasses the no survey, base case approach due to its intent to serve a variety of firms. Focusing on publicly-available data and averages is the best approach in creating a model that serves the end goal of approximating a value while catering to numerous professional fields. In addition to requiring firms to input the number of teleworkers, the model offers inputs for total commuting and business travel mileage of teleworkers so that these values can be compared to overall teleworking emissions from the home office. This addition intends to inform how commuting and business travel emissions compare to teleworking emissions, which are based mostly on heating, cooling, and electronic devices.

6 Reduction Potentials and Future Research

Considering the COVID-19 pandemic, and the shift toward a knowledge-based economy, teleworking is anticipated to become more crucial than ever. As alluded to in Section IV, more long-term and comprehensive studies are needed for various contexts to deliver better evidence on the impact of teleworking on company emissions. Moreover, the long-term effects of teleworking, such as changes to home or vehicle purchases, are also undocumented. Sustained research is needed to gain a complete understanding of environmental impacts so firms/society can take the necessary steps to mitigate them.

The energy and greenhouse gas emission impacts of teleworking have yet to be studied using a mixed methods approach, which would provide the most accurate and comprehensive findings. This should include a combination of surveys/interviews/diaries, modelling/simulation, secondary data analysis, and field studies.[38] Current literature does not yet utilize data beyond traditional census-like surveys to study telework.[39] For example, “Google can provide location and trip data, smart meters can provide high-resolution electricity and water data for homes and offices, and Ecobee provides thermostat-related behavior and performance.”[40] These advanced forms of data collection could improve companies’ understanding of their teleworking footprints, and consequently, their overall carbon footprints.

In addition to the environmental footprints of electricity use, a potential reduction strategy and an area for further research in this new world of increased teleworking are the carbon, water and land footprints of data storage, transmissions and use. The article, “The Overlooked Environmental Footprint of Increasing Internet Use,” discusses how increased teleworking prompts a “blind transition to an unregulated and environmentally unaudited digital world,”[41] a path that has been accelerated by the global COVID-19 crisis. According to the article’s authors and the majority of the current teleworking literature, the newly developed digital lifestyle is advantageous in terms of its reduction of travel-related carbon dioxide emissions. Yet, it may be worth also accounting for the hidden environmental impacts of internet use[42] as technology improves, calculation tools advance, and further research is conducted.

Conclusion

7

Compared to other categories of emissions for a company, associated carbon dioxide emissions of teleworking are especially difficult to calculate. Companies will face challenges in reducing teleworking-related emissions because they have less direct control over teleworking environments. However, we hope this report provides context on the emerging topic and that our Materiality Model can support firms as they address their respective impacts on the global climate crisis while simultaneously adapting to a new workplace normal of increased teleworking.

Appendix A: Considerations for Teleworking Energy Sources

In this section, we explain the possible household sources of teleworking emissions. Establishing these sources is valuable in calculating teleworking emissions and in our own [Materiality Model](). Common energy sources considered in studies include office equipment, lighting, heating, cooling,[43] furniture, house space,[44] IT applications and services, and data centers.[45] Additional sources considered when calculating *avoided* emissions from teleworking include employee commuting,[46] business travel,[47] and office space.[48] While avoided emissions is certainly a valuable number to understand the environmental benefits of teleworking, we will not explore these calculations as they are not considered in our model where direct teleworking emissions are the main focus.

Typical office equipment considered include any work-specific devices that rely on energy, including a “laptop or PC, monitor, phone and printer”[49] and a “modem, speakers, camera,” fax machine, and copier.[50] An in-depth exploration of emissions from such equipment requires data on the amount and type of this equipment used for homework, how much time is spent on this equipment for work (and the energy mode of the equipment during this time), and even factors such as “number of users, life span, purchased specifically for telework purposes or not, life-cycle energy consumption, induced equipment use.”[51]

With regards to lighting, the energy required for this component is often difficult to differentiate from typical household lighting if other residents are present during the workday, but it can be separated by considering the amount of lighting required to provide necessary visibility in a workspace of a specific area. In calculations related to lighting, it is important to clarify the light bulb type used in the household, as this can greatly affect the energy consumption. For example, despite providing similar lighting, compact fluorescent lamps (CFLs) bulbs require much less energy than traditional incandescent bulbs, which release 90% of their energy consumption as heat.[52] Where lighting source information is unavailable, assumptions may be made regarding light bulbs used, as long as they are stated in the methodology.

In the calculation of heating and cooling energy, an important factor to first consider is the source of energy, which is most often provided by natural gas or electricity.[53] This ensures that the emissions factors multiplied by the energy used produce accurate emissions values. Another variable within heating and cooling to consider is the type of system used and whether it is centrally- or locally- controlled, as these differences can provide varying energy values for each type. Centrally-controlled systems can sometimes demand twice the energy of locally-controlled systems.[54]

If teleworking emissions are found to be material, firms may choose to undergo a deeper exploration of teleworking emissions sources in addition to the considerations above. This approach is recommended for firms that intend to report their calculated teleworking emissions in Scope 3’s employee commuting category. Further teleworking considerations may include furniture and house space[55] and rebound effects, which are increased emissions resulting from decreased energy costs or lowered energy consumption. Emissions may also be explored of IT applications and services necessary for office equipment, and of rebound effects like increased demand of data centers from teleworking equipment in the home setting.[56]

Appendix B: Emissions Factors

In this section, we define emissions factors and their impact on teleworking emissions values. While the consideration of devices and elements using energy has a vital impact on teleworking emissions, the sources of the energy powering these components is just as important — if not more — in yielding an accurate value. Energy sources across the globe take on many forms and variations, most notably in their impacts on the environment.

When calculating carbon emissions from a given device, like a laptop, the energy source and its level of sustainability can greatly alter the final emissions value. For example, an individual using a laptop for one hour in Florida produces higher emissions than if they had used the same laptop for the same amount of time in California or Illinois. This is due to the energy sources in California and Illinois producing less carbon dioxide emissions for every unit of electricity generated than the energy sources in Florida. The connection between carbon emissions and electricity generated can be visualized in Figure 4.

Regional and sourcing variabilities in energy are accounted for in emissions calculations by emissions factors. Also called carbon intensities, these ratios draw emissions values from energy data.[57] Emissions factors are determined by the supplier of the energy through the "market-based methodology" or by regional averages through the "location-based methodology".[58] When calculating emissions from energy sources in the home, for example, it is important to ensure that the regional or supplier-based emissions factors align with the location and supplier of the home. This will guarantee that the true energy mix received by the home is accurately accounted for in the final emissions value.

While emissions factors are simple to understand once a singular region is established, firms may face more difficulties in calculations when employee distribution is spread over multiple regions. The role of carbon intensities in finding emissions can be further explored by diving into the calculations necessary in quantifying such emissions.

State	Carbon Intensity (lb of CO2 per kWh of electricity produced)
California	0.446[59]
Illinois	0.752[60]
Florida	0.886[61]

Figure 4: Carbon Intensity Values in California, Illinois, and Florida. Carbon intensities vary based on energy suppliers and mixes from one region to another. The differences in carbon intensity values between California, Illinois, and Florida are based on the sources of supplier's energy production in these states. This figure is made from data provided by the U.S. Energy Information Administration.

Appendix C: Determining Energy Usage

In this section, we explain the different avenues to calculate energy usage from telework. Based on the teleworking components considered, and the emissions factors by region and supplier, one approach to calculating teleworking emissions is finding the sum of the components' emissions based on their associated energy usage values, time used, and emissions factors.

An alternative approach that can provide more direct calculations with fewer variables is a comparison between a household's baseline and incremental energy intensities to find the difference in these values that occurs from teleworking.[62] In understanding energy intensities, it is important to note their difference from emissions intensities. While emissions intensities inform the emissions resulting from energy produced, baseline and incremental energy intensities are terms referring to the amount of energy consumed, often in a specific timeframe. This methodology is most useful when there is a recent baseline to compare the incremental energy intensity to. For example, a teleworker would compare their current household energy usage in February of 2021 to February of 2020, when they had not yet begun teleworking. Ideally, the only changes in household occupants from the baseline to the incremental energy intensity would be of the singular teleworker. If more than one individual changed their time spent at home since the baseline measurement, the increase in energy usage due to teleworking will be more difficult to track and analyze.[63]

Another essential component to calculating teleworking emissions is establishing a timeframe for telework and energy usage. In their calculations, EcoAct's "Homeworking Emissions" methodology assumes a 5-day, 40 hour work week not including paid leave, allowing the establishment of a timeframe on which to base calculations.[64] They also consider regional data in calculating heating and cooling energy, which creates an improved estimation of how many months per year and hours per day heating and cooling components are utilized.[65]

Appendix D: Data Sourcing

In this section, we aim to break down the approaches of data collection necessary to understanding teleworking emissions. The most essential aspect to successfully calculating or estimating any teleworking emissions is data sourcing. Data sourcing is the process of collecting and aggregating data relevant to components considered in the methodology and is representative of the overall employee population. However, for firms that manage large and widespread employee populations, that lack the resources and technology to collect data, or that question the materiality of teleworking emissions, sourcing data can become a barrier to calculating teleworking emissions.

Figure 5 provides data resources and informs firms on different avenues for sourcing data based on the variables they have considered in their methodologies. Nearly all of the data sources recommended in the table, except those recommending a survey, align with a "base case" methodology which yields data from averages, extrapolations, and approximations.[66] Firms seeking higher accuracy in their final emissions value may opt for an "enhanced case" approach relying on actual data values collected through surveys and direct studies of the employee population in question.[67]

Similar to the opportunity for increased accuracy through the advancement from a base to enhanced case, firms looking to improve their data may prefer to follow one of Anthesis' approaches of an "enhanced survey" in place of a "basic survey" or "no survey" at all, which mirrors the base case approach.[68] The easiest — yet least accurate — approach is omitting the survey and instead using available company data on the quantity and regions of remote workers. Additional data used in this option is finding "recommended baseline regional energy intensities" through the U.S. Energy Information Administration's "energy consumption data" and "population data".[69] This data is then coupled with "incremental to baseline energy intensity" ratios calculated in a study by Anthesis to yield the increase in energy intensity due to telework.[70]

The second potential approach is the "basic survey" which still relies on the factors considered in the first approach but involves alterations to "certain assumptions regarding energy use" based on survey responses.[71]

The third approach of the "enhanced survey" aims to collect specific data values from the employee population, allowing for an understanding of regional energy usage and types.[72]

Given these options, we recommend that firms at a minimum follow the base case approach of excluding any survey, since this would give an approximate value of teleworking emissions. Alternatively, firms undertaking this approach may utilize our model which would offer a similar approach, yet a simplified one since most of the data sourcing has already been executed. For those with the resources to do so, the "basic survey" would be the next best approach followed by the "enhanced survey." However, it may be the best use of resources and time to first determine the likely materiality of teleworking emissions before taking these approaches.

Data Source	Relevant Variables
U.S. Energy Information Administration (EIA) State Electricity Profiles	- Emissions Factors
U.S. Environmental Protection Agency (EPA) eGrid emissions[73]	- Emissions Factors
U.S. Energy Information Administration (EIA) Residential Energy Consumption Survey[74]	- Baseline and Incremental Energy Intensities - Office Equipment (i.e. Desktop or Laptop) - Heating - Cooling - Lighting - Appliances
U.K. Department for Environment Food & Rural Affairs (DEFRA) Emission Factors Toolkit[75]	- Emissions Factors
Manufacturer Documentation[76]	- Furniture
National Household Travel Survey (NHTS)[77]	- Employee Commuting

Employee Survey	- Employee Commuting
	- Business Travel
	- Usage of
	  - Office Equipment
	    - i.e. Network, Computer, Mobile Phone
	  - Lighting
	  - Heating
	  - Cooling
	- Household Occupants
	- Frequency of Telework
	- Region of Teleworker's Residence

Figure 5: Potential Data Sources for Informing Teleworking Variables. In addition to calculating teleworking emissions from employee surveys, firms may use publicly-available data sources to guide and estimate their emissions.

Appendix E: Model Calculations

Employee Commuting Estimation:
At what distance from the office does teleworking save energy relative to commuting?

- Average gallons used = Total miles commuted / 24.9 mpg
  - Total miles commuted: provided by firm
  - 24.9 mpg is the efficiency of an average commuter's vehicle[78]
- CO_2 emissions (lb) = Average gallons used / 10.42 lbCO_2/g
  - 19.42 lbCO_2/g is an average estimate of a commuter's vehicle's emissions per gallon[79]

Business Travel Estimation:
At what distance does a teleworker flying outweigh the avoided emissions from not commuting?

- Average emissions per passenger kilometer = 90 g CO_2 / km [80]
  - 1 g is approximately 0.00220462 pounds

Teleworking Estimate:
What are the emissions generated by a teleworker?

- Emissions Factor (lb/kWh) = 0.787
  - 2020 estimates of LADWP's lb CO_2/MWh at mid-demand are 787 lb CO2/MWh[81]
  - 787 lb CO@/MWh = 0.787 lb CO_2/kWh

Table 1: Estimated energy consumption of U.S. residential small network equipment					
Product Type	**Average Power (W)**	**Average Unit Energy Consumption (kWh)**	**Units (millions)**	**National Energy Use (TWh)**	**Power Plants**
Modems	5.7	50	40	2.0	0.7
Gateways	7.9	69	42	2.9	1.0
Routers	5.7	50	53	2.6	0.9
Switches	1.9	17	1	less than 0.1	0.0
Access Points	2.6	23	2	less than 0.1	0.0
ONTs	16.2	142	6	0.8	0.3
Total			**144**	**8.3**	**2.9**

Figure 6: "Estimated energy consumption of U.S. residential small network equipment."[82] This table estimates the kWh used by various network equipment, and provides the Materiality Model's estimate of router and modem energy consumption. This figure is sourced directly from the Natural Resources Defense Council.

Network (router and modem)
- Energy Consumption (kWh) = 0.0114z
  - 5.7 W + 5.7 W = 11.4 W = 0.0114 kWh
- Assumptions
  - Timeframe
    - Assumed that a router and modem are in use for the entirety of the workday

Computer (laptop or desktop)
- Energy Consumption (kWh) = 0.096223
  - Power Consumption by Usage
    - In use: laptop uses 60 W, while desktop uses 145W[83]
    - In idle: laptop uses 25 W, while desktop uses 100 W[84]
  - Device Distribution Ratio
    - Laptop to Computer US ratio: 63.62% have at least one laptop, 41.7% have at least one desktop computer[85]
      - (44.6+21.2+9.4) : (41.5+6.5+1.3) = 75.2 : 49.3
      - Total households: 118.2
      - Laptop: 75.2 / 118.2 = 63.62%
      - Desktop: 49.3 / 118.2 = 41.7%
  - Assumptions
    - Timeframe
      - Assumed that in a workday of 8.5 hours, 8 hours are spent working on a computer source and the other 0.5 hours are spent on a break, meaning the device would be idle during this time.
  - Energy Consumption by Usage Calculation
    - In use:
      - Time on: 0.94118* (0.06kWh*0.6362 + 0.145kWh*0.417)
        - 8 h / 8.5 h = 0.94118
    - In Idle:
      - Time off: 0.05882 * (0.025kWh*0.6362 + 0.1kWh*0.417)
        - 0.5 h / 8.5 h = 0.05882
    - Total (distribution of time in use and idle) = 0.096223 kWh

Mobile Phone
- Energy Consumption (kWh) = 0.01
  - Assumptions
    - Timeframe
      - Assumed teleworkers use an iPhone periodically during their workday which requires charging twice a day for an hour, for a total of 2 hours charging.
  - Power Consumption
    - Versions previous to the iPhone use a 5W power adapter[86]
  - Energy Consumption
    - 0.005kW * 2 h = 0.01 kWh

Lighting

- Energy Consumption (kWh) = 0.8
  - Assumptions
    - Timeframe
      - Assumed that the workspace lighting is on at all times during the teleworker's workday
    - Area
      - Assumed 300 SF is the maximum necessary area to be used (and require lighting) for a homeworker[87]
    - Device
      - Assumed that the teleworker has CFL bulbs for their workspace lighting needs
  - Energy Consumption by Area
    - 20 lumens are necessary for sufficient lighting per SF[88]
      - 300 SF * 20 lumens = 6000 lumens
    - A typical CFL bulb yields 60 lumens per watt[89]
      - 6000 lumens * (1 W/ 60 lumens) * (1kW / 1000W) = 0.1 kW*8 = 0.8 kWh

Heating

- Energy Consumption (kWh) = 5.320784353
  - Assumptions
    - Location
      - Assumed that the teleworker resides in Los Angeles, and that heating and cooling usage align with typical users in a hot-dry/mixed-dry climate[90] akin to that in Los Angeles
    - Timeframe
      - Assumed alignment with "...the widely recognised northern hemisphere heating season of October to March (6 months / 182 days).[91]
        - 182 d * 10 hr heating = (1,820 hr/y) / (8760 hr/y) = 20.78% of total hours worked in year use Heating
    - Power
      - Natural Gas Furnace
        - Assumed that the furnace powers aligns with that of a medium efficiency system, using around 125,000 BTU/hr[92], which is the equivalent of around 36.62 kWh (considering that around 3,413 BTU = 1 kWh).
      - Electric Heating System
        - Assumed that the heating system using electricity is a central warm-air furnace using around 20 kWh.[93]
      - Propane Furnace
        - Assumed that a propane furnace uses around 100,000 BTU/hr[94], which is the equivalent of around 29.30 kWh (considering that around 3,413 BTU = 1 kWh).
  - Usage Distribution Ratio
    - Around 10.6 out of 12.7 (83.46%) households in climate regions like that in Los Angeles "Use space heating equipment" that falls under "natural gas", "electricity", or "propane"[95]
      - For "Main heating fuel and equipment", around
        - 6.7 out of 10.6 (63.20%) households use "natural gas"
        - 3.7 out of 10.6 (34.91%) households use "electricity"
        - 0.2 out of 10.6 (1.89%) households use "propane"
          - 1 BTU = 0.293071 Wh
          - 1 BTU =*0.293071 / 1000) kWh
          - 100,000 BTU furnace uses 100,000*(0.293071 / 1000) = 29.3071 kWh
  - Energy Consumption
    - 0.2078 * 0.8346 * ((0.6320 * 36.62kWh) + (0.3491 * 20kWh) + (0.0189 * 29.3071kWh)) = 5.320784353 kWh

Cooling

- Energy Consumption (kWh) = 0.3501052622
  - Assumptions
    - Location
      - Assumed that the teleworker resides in Los Angeles, and that heating and cooling usage align with typical users in a hot-dry/mixed-dry climate[96] akin to that in Los Angeles
    - Timeframe
      - Assumed that "In the US, the cooling season is typically accepted as the summer months, from June to September"[97] (4 months / 122 days)
        - 122 d * 10 hr cooling = (1,220 hr/y) / (8760 hr/y) = 13.93% of total hours worked in year use Cooling
    - Power
      - Central Unit
        - Assumed that this type of cooling uses 3.5 kWh[98]
      - Window/Wall Unit
        - Assumed that this type of cooling uses 1.4kW/hr[99]
  - Usage Distribution Ratio
    - Around 9.9 out of 12.7 (77.95%) households in climate regions like that in Los Angeles "Use air-conditioning equipment"[100] (excluding those who use more than one individual unit, since it is assumed only one would be needed to cool an office space)
      - 8.6 out of 9.9 (86.87%) use a central cooling unit
      - 1.3 out of 9.9 (13.13%) have 1 individual cooling unit assumed to be a window/wall unit
  - Energy Consumption
    - 0.7795 * 0.1393 * ((0.8687 * 3.5kWh) + (0.1313 * 1.4kWh)) = 0.3501052622 kWh

Appendix F: Model Preview

	A	B	C	D	E	F	G	H	I	J	K
1	**Employee Commuting Estimate:**	Total Miles Commuted		Average Gallons Used	Total CO2 Emissions (lb)			**Key:**	Firm Inputs		
2		0		0	0				CO2 Emission Estimation		
3									Materiality Estimation		
4		Total Kilometers Flown		CO2 Emissions (g)	Total CO2 Emissions (lb)						
5	**Business Travel Estimate:**	0		0	0						
6											
7	**Teleworking Estimate:**	Total Hours of Telework		Energy Source	Energy Consumption (kWh)	Emissions Factor (lb/kWh)	CO2 Emissions (lb/hr)	Sum of CO2 Emissions (lb/hr)	Total CO2 emissions (lb)	Total CO2 emissions (tons)	Total CO2 emissions (metric tons)
8		0		Network	0.0114	0.787	0.0089718	5.185159428	0	0	0
9				Computer	0.096223		0.075727501				
10				Mobile Phone	0.01		0.00787				
11				Lighting	0.8		0.6296				
12				Heating	5.320784353		4.187457286				
13				Cooling	0.3501052622		0.2755328414				
14											
15	**Materiality:**	Chosen Materiality Threshold (recommended 0.01-0.05)	Total Scope 1 Emissions (metric tons CO2)	Materiality in terms of Scope 1	Total Scope 2 Emissions (metric tons CO2)	Materiality in terms of Scope 2	Total Scope 3 Emissions (metric tons CO2)	Materiality in terms of Scope 3	Total Scope Emissions (metric tons CO2)	Materiality in terms of Scopes Totals	
16		0	0	#DIV/0!	0	#DIV/0!	0	#DIV/0!	0	#DIV/0!	

Figure 7: Materiality Model Preview. The Materiality Model allows firms to input their unique data in yellow cells, yielding associated emissions values in green cells and associated materiality values in blue cells. See Appendix E for calculations supporting the estimates in this model.

Endnotes

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Page 4: Raybay via Unsplash

Page 5: Marc Olivier Jodoin via Unsplash

Page 8: Jeff Sheldon via Unsplash

Page 10: Olena Sergienko via Unsplash

Page 12: Tina Witherspoon via Unsplash

Page 14: Nonsap Visuals via Unsplash

Page 17: Raybay via Unsplash; Smartworks Coworking via Unsplash; Scott Webb via Unsplash

Page 19: Sebastian Bednarek via Unsplash

Page 20: Carl Nenzen Loven via Unsplash

Page 23: Annie Spratt via Unsplash

Page 24: Jess Bailey via Unsplash

Page 26: Vadim Kaipov via Unsplash

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