Arbeiten nach Corona

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Kurzzusammenfassung

Die „Corona-Krise“ hat im Jahr 2020 unser gesellschaftliches Leben von einem Tag auf den anderen komplett verändert. Gleichzeitig eröffnet der Bruch mit alten Routinen neue Möglichkeiten, die über die Pandemie hinaus Bestand haben könnten. Besonders deutlich wird dies in der Arbeitswelt: Der sprunghafte Anstieg von Menschen, die plötzlich von zuhause aus arbeiten, hat der digitalen Durchdringung unserer Gesellschaft einen Schub versetzt. Arbeitsroutinen werden durch die erworbenen Erfahrungen in der Pandemie neu bewertet: Müssen wir fünf Tage die Woche von unserer Wohnstätte zu einem teilweise weit entfernten Schreibtisch bewegen? Oder lassen sich viele Tätigkeiten nicht ebenso gut am heimischen Schreibtisch erledigen?

Bereits jetzt zeichnet sich eine starke Dynamik ab. Deutsche und internationale Unternehmen werden ihre Mitarbeitenden auch künftig im Homeoffice arbeiten lassen. Die für manche überraschende Effektivität der Arbeitsprozesse während der ersten Monate der Pandemie haben die weltweit Akzeptanz gegenüber dem Homeoffice gestärkt. Zukünftig ist daher mit einer stärkeren Rolle des Homeoffice in der modernen Arbeitswelt zu rechnen.

Mit Blick auf eine Zeit nach Corona muss sich insbesondere vor dem Hintergrund der virulenten Klimakrise die Frage gestellt werden, was wir als Gesellschaft aus den COVID-19-Erfahrungen lernen können. Die weltweiten CO_2-Emissionen sind auf dem Höhepunkt der „Corona-Krise“ deutlich zurückgegangen, auch weil flexible Arbeitsstrukturen mit mehr Homeoffice weniger Pendelverkehr bedeuten. Das Homeoffice ist eine Möglichkeit, stau- und abgasgeplagte Städte dauerhaft zu entlasten und Emissionen im Verkehrsbereich zu senken. Die vorliegende Studie will die Frage beantworten: Wie viele CO_2-Emissionen lassen sich durch Homeoffice einsparen?

Wieviel CO_2 kann Telearbeit in Deutschland sparen?

Die Corona-Pandemie erlaubt eine realistische Einschätzung darüber, wie viele Arbeitnehmende grundsätzlich – und damit auch nach der Pandemie – von zu Hause arbeiten können. Verschiedene Studien beziffern den zeitweisen Telearbeit-Anteil während COVID-19 in Deutschland zwischen 25% (*Möhring et al. 2020*) und 37% (Eurofound 2020a, 2020b). Bereits vor Corona deuteten Umfragen darauf hin, dass ein Anteil von 40% sowohl für Arbeitnehmende als auch Arbeitgebende möglich wäre (*Brenke 2016, Arnold et al. 2015*).

In dieser Studie gehen wir davon aus, dass der zukünftige Anteil der Telearbeit in Deutschland sich dem Anteil der Arbeitnehmenden im Homeoffice während der Corona-Pandemie nähert. Dabei ist es unwahrscheinlich, dass ein großer Teil der Arbeitnehmenden nach COVID-19 weiter in Vollzeit von zuhause arbeiten wird. Wir nehmen daher an, dass die Menschen in Zukunft ein bis zwei Homeoffice-Tage pro Woche einlegen können. Um die mögliche Spannbreite der Emissionseinsparungen abzubilden, gehen wir in dieser Studie von zwei Szenarien aus:

1) Ein **konservatives Szenario** mit einem Telearbeit-Anteil von 25%
2) Ein **fortschrittliches Szenario** mit einem Telearbeit-Anteil von 40%

Um das Potential an Emissionsreduktion durch Telearbeit abzuschätzen, beziehen wir uns in dieser Studie auf die Gesamtemissionen des Pendelverkehrs in Deutschland, die auf Basis des Datensatzes „Mobilität in Deutschland“ 2017 des Bundesministeriums für Verkehr und digitale Infrastruktur ermittelt wurden. Hierfür wurden die zurückgelegten Personenkilometer auf dem Weg zur und von der Arbeit mit den verkehrsträgerspezifischen Emissionsfaktoren multipliziert.

In unserem **konservativen Szenario** könnte ein zusätzlicher Homeoffice-Tag in Deutschland **1,6 Millionen Tonnen CO_{2e}** pro Jahr einsparen und die Verkehrsleistung des Pendelverkehrs um 10,9 Milliarden Personenkilometer reduzieren. Neue Arbeitsroutinen könnten die Emissionen des Pendelverkehrs somit pro Jahr um 5% senken. Falls Arbeitnehmende zukünftig zwei Tage pro Woche von zuhause arbeiten, könnten **20,9 Milliarden** Personenkilometer im Pendelverkehr und somit **3,2 Millionen Tonnen CO_{2e}** eingespart werden. Das entspricht einer Einsparung von 11% der Emissionen aller Pendelwege und 2% der Gesamtemissionen des Personenverkehrs. In unserem **fortschrittlichen Szenario** liegen die jährlichen Emissionseinsparungen durch einen zusätzlichen Homeoffice-Tag sogar bei **18,4 Milliarden Personenkilometer** bzw. **2,8 Millionen Tonnen CO_{2e}** und bei zwei Tagen bei **35,9 Milliarden Personenkilometer** und **5,4 Millionen Tonnen CO_{2e}**. Dies entspricht 18% der Emissionen aus dem Pendelverkehr und 4% der Gesamtemissionen des Personenverkehrs in Deutschland.

	Konservatives Szenario (25% Telearbeit-Anteil)		Fortschrittliches Szenario (40% Telearbeit-Anteil)	
Extra Homeoffice-Tage pro Woche	**Ein Tag**	**Zwei Tage**	**Ein Tag**	**Zwei Tage**
Eingesparte Personenkilometer pro Jahr (in Mrd.)	**10,9**	**20,9**	**18,4**	**35,9**
Eingesparte Emissionen pro Jahr (in Mio. t CO2e)	**1,6**	**3,2**	**2,8**	**5,4**

Eine Frage der Balance

Um die Ziele des Pariser Klimaschutzabkommens zu erreichen, sind auch kleine Schritte nötig. Telearbeit auszuweiten, ist dabei eine Möglichkeit, die weltweiten Emissionen aus dem Personenverkehr zu begrenzen. Als Teil einer nachhaltigen Mobilitätswende kann Telearbeit jedoch nur ein Teil der Lösung sein, denn Telearbeit kommt überwiegend für gut ausgebildete und entsprechend gut verdienende Arbeitnehmende in Frage. Gerade für Arbeitswege, die zukünftig nicht durch Telearbeit ersetzt werden können, müssen erschwingliche und umweltfreundliche Alternativen geschaffen werden. Dazu gehören ein leistungsfähiges öffentliches Verkehrssystem sowie ein sicheres und dichtes Netz aus Fuß- und Radwegen. Ziel muss es dabei immer sein, die ökologischen Chancen mit den sozialen Anforderungen in Einklang zubringen. Mithilfe eines **gut gestalteten regulativen Rahmens, fairen Arbeitsbedingungen**, kombiniert mit Maßnahmen wie der **Förderung erneuerbarer Energien**, kann Homeoffice ein wichtiger Teil der Mobilitätswende sein.

Greenpeace fordert:

- **Ein Recht auf Home Office: Arbeitende, deren Tätigkeiten sich auch von zuhause erledigen lassen, sollten daran von ihren Arbeitgebern rechtlich nicht gehindert werden können.**
- **Gutes Netz für alle: Durch einen raschen Ausbau von Glasfaseranschlüssen und der Einführung eines flächendeckenden 5G-Netzes sollen für alle Haushalte, auch in ländlichen Regionen, die Voraussetzungen für Telearbeit geschaffen werden.**
- **Steuervorteile für Home Office und Abschaffung der Pendlerpauschale: Wer im Home Office arbeitet sollte die dadurch entstehenden Kosten einfach und unkompliziert steuerlich absetzen können. Parallel sollte die Pendlerpauschale, die einen Anreiz setzt für weite Arbeitswege, abgeschafft werden. Die so gewonnen Steuereinnahmen sollten in den Ausbau des öffentlichen Nahverkehrs fließen, um auch Menschen zugute zu kommen, die nicht aus dem Home Office arbeiten können.**

Content

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1 The 'COVID-19 effect'

Over the course of the COVID-19 pandemic, numerous measures were implemented to contain the spread of the virus. The result was a worldwide shutdown. In addition to the short and long-term economic and social consequences of the 'Corona Crisis', environmental impacts can also be observed when viewed through the lenses of climate protection and the achievement of the Paris Agreement.

The lockdown measures had a drastic impact on global greenhouse gas emissions. In particular carbon dioxide (CO_2) declined by 17% at the beginning of April 2020, with the transport sector totalling nearly half of the observed decline of global CO_2 emissions (Le Quéré et al. 2020). Alongside reduced freight travel, the 'paused' everyday mobility also contributes to a COVID-19 effect on transport emissions. Work commutes and daily trips for retail and recreation have fallen worldwide. In Germany alone, an average of 43% fewer work trips and a 55% decline in retail and recreational travel occurred between early March and mid-April 2020, compared to the baseline period from February 3rd to February 6th 2020 (Google Mobility Report 2020).

With daily travel around the globe largely paused, the shared experience led to a discourse about work habits, routines and mobility behaviour, regarding the emission savings potential and other travel-related effects — such as noise or air pollution. Measures that aim to keep the long-term impacts of declining emissions from the shift in commuting seem to be a low-threshold measure for politics, as well as the majority of the population. Yet the climate impacts from COVID-19 will not be permanent without behavioural changes or political measures taken to address the structure of emission-intensive sectors, such as passenger transport. Over the course of economic recovery, the transport sector has the potential to return to pre-COVID-19 levels, reversing the emission-saving effects (DIW Berlin 2020; Haxhimusa et al. 2020; Hein et al. 2020).

To achieve the Paris Agreement target of halving CO_2 emissions by mid-century, the observed changes caused by COVID-19 could be the basis of new mobility behaviour and contribute to decline emissions from passenger transport. Triggered by the 'Corona Crisis', new routines could accelerate trends towards more flexible working patterns and increased telework, as both employees and employers re-evaluate the forms of new work and adapt to the new normal.

The aim of our study

The aim of this research is to analyse whether telework can reduce the emissions of passenger transport by replacing work-related travel such as daily commuting.[1] Thus, the question is as follows: Does telework contribute to a decline in emissions in the transport sector, especially from passenger transport in the long term, therefore helping to achieve the climate targets of the Paris Agreement? In the context of the shift in daily routines, such as commuting patterns due to the coronavirus pandemic, we aim to estimate how post-COVID-19 work routines and working from home, can contribute to decreasing emissions of passenger transport by reducing work-related trips. The main question is: To what degree can emissions be saved if the employees who could work from home at the peak of the pandemic in mid-

[1] Telework not only has the potential to reduce CO_2 emissions but also other climate impacting emissions such as nitrogen oxides (NO_x), especially nitrogen dioxide (NO_2), particulate matter (PM2.5 and 10) and other greenhouse gases, mainly from the transport sector. Thus, teleworking is also discussed in the context of air quality and noise pollution, especially in cities. Though, the present study focuses on the emission saving potentials on CO_2 emissions, respectively CO_2 equivalent (CO_2e), when discussing emissions.

April 2020 continue to do so? We use Germany as the example and consider the savings potential of one or two additional working days from home in a post-COVID-19 period.

First, we give a short overview discussing the average European work-from-home model, which the savings potentials are discussed in the literature review on home-based telework, and then narrow focus to home-based telework in Germany. Based on the pre-COVID-19 share of commuters and employees who could occasionally work from home, we estimate the degree to which emissions could be saved in the future if more employees could work from home instead of commuting daily. We assume that the share of employees who work from home at the peak of the coronavirus pandemic in mid-April 2020, indicate the potential for implementation in Germany and in other European countries. Finally, we discuss the transferability of the results to Europe and the possible broader implementation of home-based telework.

2 State of telework before COVID-19

Teleworking is not a new phenomenon. With the worldwide adoption of technical innovations such as the widespread use of smartphones, laptops and mobile Internet, teleworking complements regular work forms (Welz and Wolf 2010; Bieser and Hilty 2018). With the broader implementation of teleworking, various methods have evolved and increasingly established themselves in organisations worldwide (see Definition Box). Not all forms of telework are the same and many terms are used synonymously for each other. However, all forms of telework have the common denominator of breaking up traditional work routines. Business meetings can be conducted remotely without the need for long business trips by private car, public transport or airplane. Home-based telework could also be pursued, so that employees could work from home if they need to take care of children or relatives — or just to integrate their work schedule better into their daily routines.

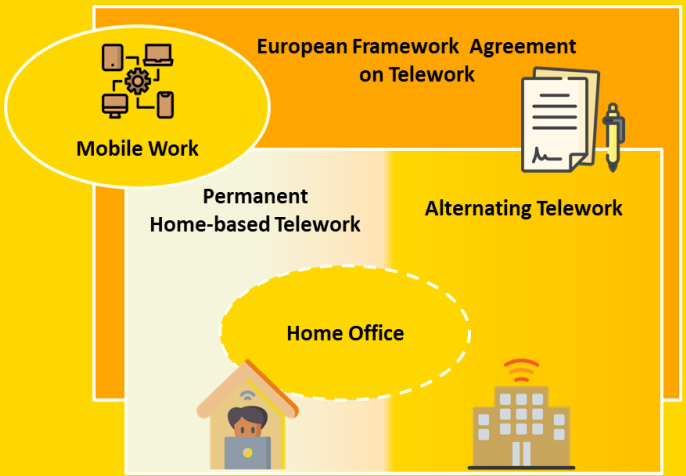
But teleworking didn't reach the early optimistic forecasts. For example, in the 1980s, some projections estimated that 40% of US employees will be teleworking by 2000 (Qvortrup 1998). Today teleworking is still below the early estimates in the US as well in Europe. Yet it has been gaining in popularity in the past years, as it promises employees savings in time, a higher self-determination and an enhanced work-life balance (Kurland and Cooper 2002; Hill et al. 2003; Gajendran and Harrison 2007). Since these factors lead to greater job satisfaction, which in turn results in higher productivity (Mokhtarian et al. 1995; Banister et al. 2007), more and more organisations have begun to accept it as a fixed working condition (Bitkom 2013; Brenke 2016). Also, surveys of employees in Europe show the increased requirement of occasionally working from home (Goers and Tichler 2012; Arnold et al. 2015; Coppola et al. 2018). The momentum that teleworking has reached during the coronavirus pandemic could further intensify the wish of many to integrate telework in their work life.

Definition Box: Telework, mobile work and home office

Teleworking: Any work based on information and communication technology, at a fixed workstation with a display screen, which is examined by the employer and the use and duration of which are laid down in a contract or agreement.[2]

Mobile work: Work supported by information and communication technology, independent of location, which is not covered by a contract or an agreement (Erle 2017).

Home office: Home office is a flexible form of work in which employees carry out all or part of their work from their private environment.



How common is home-based telework in Europe?

The coronavirus pandemic put this issue on the public agenda because many people were forced to work from home. However, prior to the coronavirus pandemic, telework was practised in Europe but with broad variations between the countries (see Figure 1). In Europe, nearly 5% of the employees aged between 15 and 64 usually work from home, i.e., they regularly work from home and only occasionally go to the job site. This means that, for 5% of the European workforce, it is commonplace to work from home instead of commuting to an official office. This is especially true in the Netherlands (14%) and Finland (13%), where working from home is more common. Romania and Bulgaria are at the bottom of the list, with figures ranking below 1% (Eurostat 2020a).

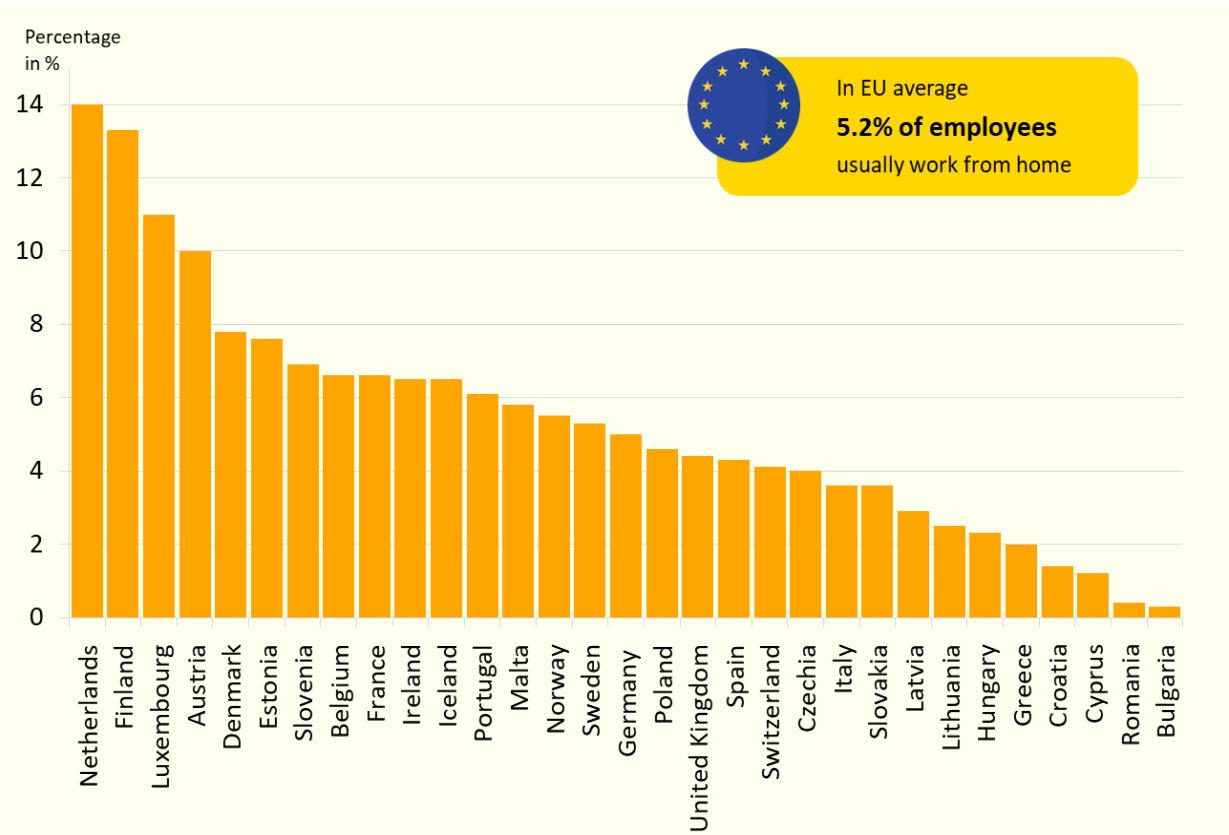
This variation might occur due to the different institutional and labour policy conditions within respective European countries (Welz and Wolf 2010; Eurofound 2020a). In particular, the institutional settings such as a Working Hours Act, the work culture of trust towards the employees and entrepreneurial, organisational, and technical requirements. Studies indicate that a high level of coordination and open communication can contribute to making work from home more attractive for employees and employers (Hammermann and Stettes 2017; Stowasser 2019a).

Additionally, the share of professions determines the level of implementation of home-based telework in each respective country. In many occupations, working from home is difficult or not possible, particularly in location-dependent professions such as retail or manufacturing. Studies indicate that teleworking is most likely seen in IT, communication or education sectors (Adams-Prassl et al. 2020; Eurofound 2020a; Möhring et al. 2020). However, in professions such as education, or within the financial sector where a high implementation is possible, it might depend on the individual's position. Surveys found that

[2] Although there is no legislative act issued on EU level on telework, telework is regulated by the European Framework Agreement on telework, which was signed by the European social partners on and creates a contractual obligation for the signatory parties. The framework agreement regulates employment conditions, health and safety, data protection, privacy, and equipment amongst other things. It has been the first European agreement of this kind and is, therefore unique (EUR-Lex 2005). While it has been enacted differently in the European Union's member states, the definition has been used for national agreements in nine European countries (Belgium, Finland, France, Germany, Greece, Italy, Norway, Spain and the United Kingdom (Eurofound 2010).

especially in high-level and top-level management positions that working from home is more common (Arnold et al. 2015; Piele and Piele 2017). Overall, the very specific country-related conditions determine the level of acceptance, as well as the barriers to home-based telework and define the level of implementation EU-wide.

Figure 1: Percentage of employees who work from home in Europe 2018



Note: Own figure based on Eurostat 2020a

Existing findings on the CO_2 saving potential of telework

Concerning work routines and culture, as well as regulations, telework is implemented EU-wide in various ways, and even more so if the global context is taken into account. On a whole, telework promises great potential for organisations, employees, and society. By reducing the kilometres travelled to a job site, telework also illustrates a high potential to be a positive factor in climate protection, as it can reduce emissions from passenger transport. The discussion about the saving potential of telework evolved together with the broader implementation (Kitamura et al. 1991; Mokhtarian et al. 1995; Henderson and Mokhtarian 1996).

The range of emission savings thereby depends on energy and travel-related rebound effects (see Box 1). The efficiency of the rebound effect is determined by commuting and work conditions, as well as the fossil fuel mix of the vehicle of choice and the energy consumption on the residential side and the job site, which are varied by region and the time of year. In the US in particular, where the average one-way commute by car is furthest with around 18 kilometres (km) and 45% more fuel is consumed than the average in Europe (15 km) for a trip of the same length, and where seasonally air-conditioning is more

relevant (IEA 2020), previous studies discussed more frequently energy and travel-related rebound effects concerning telework.

BOX 1: Rebound Effects

Our literature review indicates two kinds of rebound effects: 1) energy and 2) travel-related.

1) For the assessment of the energy-related rebounds, the amount of energy used at home needs to be related to the electricity and fuel mix, the energy usage in the regular office for the respective employee: the same accounts for technical devices, cooling, heating, light, and data traffic. The impact of teleworking in terms of data traffic became clear at the peak of COVID-19: on average 10% more data traffic and 120% more video conferencing traffic were registered in April 2020, by the internet exchange point situated in Frankfurt Germany (DE-CIX 2020). Even before COVID-19, the data traffic generated by video streaming on platforms such as Netflix and Amazon Prime, and also video and teleconference services like Skype Business or Zoom, accounted for more than half of the data volume of the internet worldwide (Sandvine 2018). Even if the level decreases after COVID-19, telework increases data traffic, which in return requires energy. The IT-organisation Cisco (2020) suggests global streaming could accrue to 200 billion kilowatt-hours of electricity per year. This must be kept in mind when discussing the emission saving potentials of telework.

2) Besides energy-related rebounds, possible travel effects are also discussed in the literature. Teleworking leads to additional trips because the trips that would have been combined with the daily commuting still have to be travelled. For example: trips for daily needs like shopping, dropping or picking up children from school. Additionally, teleworkers tend to undertake more leisure time trips, freed from having to commute every day (Pendyala et al. 1991; Mokhtarian 1998; Nelson et al. 2007; Zhu and Mason 2014). On the contrary, several studies — particularly from Europe — indicate a positive spillover effect in travel behaviour of the household members (Banister and Marshall 1999; Lim et al. 2003; Glogger et al. 2008). Hamer et al. (1991) described this effect as “increased hominess”. The regular homeworking of at least one family member led to 'contracted action spaces', which means choosing non-work destinations that were closer to home, as well as other employed household members, are prompted to work from home more often.

But even within a US context, the specific measurement of the efficiency of the various rebound effects is difficult and exact figures are difficult to determine. Valid figures therefore cannot be found in the literature. Regional and seasonal specifics make it additionally difficult to transfer efficiency of identified rebounds to other regions of the world, as a recent study by the International Energy Agency (IEA) (2020) elucidate. Using China as an example, even though the average one-way commute by car (8 km) is smaller compared to the US and Europe, the net decline in energy demand for a single household by working from home on day per week only returns in a small decrease in CO_2 emissions. The decline of the net CO_2 emission amounts to 1.5 kilogrammes (kg) CO_2 accumulated in the winter months, compared to Europe (3.1 kg) and the US (4.9 kg). One reason could be the relatively high emissions intensity of the power sector as well as the widespread use of coal on the residential side in China (IEA 2020).

Despite the rebound effects, studies on telework available suggest a positive emission savings potential (The Climate Groupe and GeSi 2008; Pahlman et al. 2009; IEA 2020). Considering mobility behaviour, spatial structures, as well as fossil fuel mix and energy consumption, teleworking has the potential to cut back emissions from commuting, thus of overall passenger transport, as the analysis by the IEA (2020) recently indicated. One day working from home could save 1% of global oil consumption for road passenger transport per year, therefore an annual drop by 24 million tonnes CO_2 equivalent (CO_2e) of the global CO_2 emissions assuming that 20% of global work could accomplish from home (IEA 2020).

Especially in terms of the annual global carbon footprint, the identified saving amount seems rather small. One reason could be the assumed share of work, which could be accomplished from home. Another is, as mentioned before, the region-specific — economical, socially or culturally — conditions,

which are very heterogeneous, especially in a global context. Concerning commutes, mobility behaviour is a determining factor. While some countries, such as the US or Europe, tend to travel more long distances to work, usually by car and alone, taking public transport or sharing vehicles to commute to work is more common in other parts of the world (IEA 2020). The choice employees make in taking a car, bus, cycling or walking to work has different repercussions on emissions. The emission-reducing effect is strongest when a large share of employees regularly uses private internal combustion engine cars for commuting. Here having the ability to work from home, thereby replacing most of the work-combined trips and thus addresses daily needs by public transport or bicycle.

Studies have shown that the positive effects of telework on emissions can contribute to pursuing international as well as national climate goals. For Germany, studies indicate a saving range of about 0.9 million tonnes (Stowasser et al. 2019b) and 1.6 million tonnes CO_2 per year (Zondler 2018) if 10% of work was accomplished from home.[3] The savings potential of telework is also evident at the per capita level. The results of the various studies suggest that telework can reduce the carbon footprint per employee on the one hand, on the other hand, the studies point out the range of savings in the various European countries. The Carbon Trust (2014) estimates that for the UK, working from home two days a week could save 390 kilogrammes CO_2e per average employee. A previous survey by Gloggler et al. (2008) suggests that employees of the greater Munich area showed a decrease of about 22 kilogrammes CO_2 per week, from the 36 participating commuters.

Our literature review shows that telework could be one piece of the solution for a decline in the overall emissions in passenger transport. During peak-hours in urban areas, teleworking could additionally minimise the number of daily commuting trips by lowering the passenger transport mileage and induced effects, such as noise and high air pollution levels.

3 The emission saving potential of telework in Germany

The potential emission savings depend not only on energy-related, spatial or socio-economic conditions but on the underlying definitions and crucially on the specific conditions of telework. Depending on whether employees work overtime hours from home, or split workdays with an employee working at home throughout the morning and then commuting to the office or nearest co-working space, affects the savings potential. All these cases are considered telework, although they have a different influence on the number of work-related kilometres travelled, when compared to those who work from home and accrue no or few kilometres.

To estimate the emission savings potential of replacing the daily commute; 1) we introduce 'home office' as a synonymous term for home-based telework further on and 2) we assume that the home office means spending the regular daily working hours at home. Splitting daily hours between the home office and the usual workplace, as well as working from home after hours, is not considered as home-based telework in our assessment. Based on the 'Mobility in Germany 2017' (MiD) data set (BMVI 2020) (see Method Box 1), we first describe who has the opportunity to work from home in Germany. In contrast to the European statistic (see Figure 1), we focus on employees aged between 18 and 65, who

[3] The estimates by Stowasser et al. (2019b) on behalf of the parliamentary group of the Free Democratic Party (FDP) based on 44.8 million employees, a modal split about 68% of the private car in commuting, and an average commuting distance of 17 km, in Germany. Zondler (2018) based his estimates also on 17 km average distance travelled, and assumes about 18 million employees who commute 200 working days per year.

occasionally work from home. Thus, in our calculations the total employment refers to employees who work at least 11 hours a week; in other words, marginally employed, part-time, and full-time employees. Secondary employment, as well as education, vocational training, and internships, are not considered. After the state of home office in Germany, we give a snapshot of the home office during COVID-19. On the basis of COVID-19 telework shares, we estimate possible emission savings for the post-COVID-19 period.

Method Box 1: Mobility in Germany 2017

Mobility in Germany (MiD) is a representative cross-sectional survey, which provides extensive information on the current state of daily travel and mobility behaviour in Germany. 316,000 people from over 156,000 households were surveyed in the MiD 2017, of which around 38% provided information on their personal mobility characteristics, including information on home office. Population figures were retrospectively corrected based on the micro-census. In addition, extrapolation and weighting factors were considered in data processing. As a result, the MiD makes it possible to identify who works from home and to what extent (number of days). The MiD 2017 additionally collects household, personal and travel-specific data, which is also used as the basis for our estimates. The data not only allows us to estimate the passenger transport mileage of total employment, but also the share of home-based teleworkers in Germany. Additionally, we could determine the socio-demographic characteristics of commuters and home-based teleworkers (Eggs et al. 2018; Nobis et al. 2018a).

Who works occasionally from home in Germany?

Our analysis of the MiD 2017 data set shows that in Germany, 13% of the total employees occasionally worked from home before COVID-19, one or some days per month or week. Thus, our calculation based on the MiD 2017 is in line with the projections of Brenke (2016) at 12%.[4] To put it another way, nine out of ten professionals in Germany never worked at home. Of those employees, who are occasionally teleworking, most work part-time from home, either one (30%) or two (18%) days per week. Around 25% of all teleworkers work full-time from home, which means that three-quarters of home-based teleworkers have the potential to increase their teleworking days by at least one day.

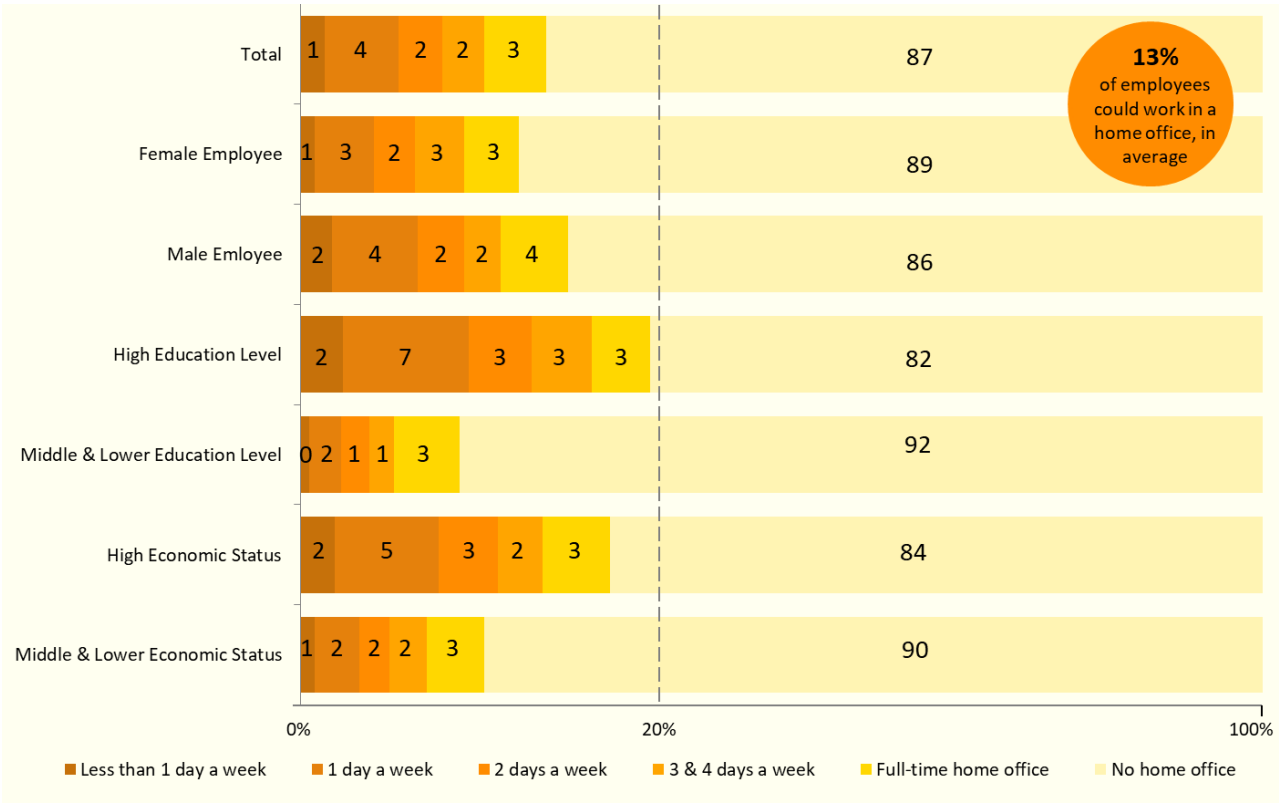
Our analysis of the MiD 2017 shows that teleworkers share common characteristics (see Figure 2). The home office model is more common in young households and families.[5] In terms of gender: the share of female employees with children is 10% higher among teleworkers compared to all female employees. However, in total numbers, there also are 20% more male than female employees working from home. Around 50% of the teleworkers have a degree from a university or a university of applied sciences, which makes up an over-proportional high share of well-educated employees. In line with these results,

[4] Brenke's (2016) projections are based on the Socio-Economic Panel, which collects information about home office since 2014. Earlier estimates by Brenke (2014) are based on micro census data and assume 8% of employees working occasionally at home.

[5] The size of household members differs according to the number of adults and children living in the household. No distinction is made between single- and multi-person households. Four categories exist: 1) young households, in which all persons are aged between 18-34, 2) family households, in which at least one person is younger than 18 years, 3) adult households, in which all persons are over 18 years and at least one person is aged between 35 and 64, and 4) households with persons over 65 (Nobis et al. 2018b).

teleworkers generally have a high or very high economic status that is 12% above that of the average employee.[6]

Figure 2: Teleworkers in Germany



Note: Own calculations based on MiD 2017 data set (BMVI 2020)

This profile has been found in other European studies, with teleworking being more common among the highly-educated and upper-level employees with administrative, managerial, professional and skilled-trade occupations (Banister et al. 2007). In the EU, teleworkers often work in real estate, finances, education, and, in general, in occupations like senior management (Pahlman et al. 2009).

There are differences between urban and rural areas. The home office is slightly more common in metropolitan areas compared to the regional distribution of total employment in Germany. Regarding the distance travelled and the connection to public transport, a substantial emission savings potential through telework in rural areas can be assumed. One reason for a slow implementation could be an inadequate broadband in some German regions (BMVI 2019). Additionally, the job profile, individual preferences, and the specific culture of the organization may be reasons for a higher implementation in urban areas. It is also possible that employees combine their trips with trips of other household members, such as going to and from school each day, so that they wouldn't benefit from the possibility to work from home.

[6] The economic status of a household is derived from the household net income and the weighted household size, according to the principle of equalized income. Thus, certain household sizes are not disproportionately allocated to income groups. The weighted household size is determined by the number and the age of the household members. The economic status is described in five categories, from very low to very high (Nobis et al. 2018b).

Is there more home office due to COVID-19? — An empirical snapshot

Public discourse suggests that a majority of employees worked from home during COVID-19 but the empirical Corona Study by the University of Mannheim (Möhring et al. 2020) points out a different development in Germany at the peak of COVID-19:

- More than half of the workforce worked on-site.
- The number of teleworkers nearly doubled, reaching around 25% in April 2020.[7]
- There are no evident differences between childless employees and those with children in the amount of telework.
- Slightly more male employees worked from home more often, while female employees are more affected from reduced work hours', time out and unemployment.

In line with our findings, Möhring et al. (2020) mark that mainly employees with high educational levels and an above average income worked from home before and during COVID-19. Results of an online survey from Civey (2020), a market research organisation, suggested in particular that workers from public and financial services or insurance companies changed to telework during the 'Corona Crisis'.

Although the socio-demographic structure of employees who work at home has not changed much due to COVID-19, many employees who had not previously worked in a home office were also able to gain initial experience, as the latest survey from Eurofound (2020b) indicates. In Germany, 37% of the responded employees started to work from home — daily or just a few days a month — as a result of the outbreak of the coronavirus pandemic.[8] In contrast to Möhring et al. (2020), the Eurofound survey covers a much larger share of teleworkers, resulting in the definition used. As we stated before, the percentage of teleworkers strongly depends on the definition of the home office. Considering the question of who started to work from home as a result of COVID-19, the latest Eurofound survey underlies a broad understanding of the home office (Eurofound 2020c): working from a home office daily, up to employees working from home just a few days a month. Whereas Möhring et al. (2020) primarily analyses is on how many employees fully relocated their job site to a home office — regardless of whether they have previously gained home office experience, the Eurofound study (2020a) also covers those employees who rarely and occasionally were able to work from home during COVID-19.

The European results therefore complete the 'picture' of the likely share of teleworkers post-COVID-19 and consolidate earlier estimates about the possible implementation of telework in Germany. But even before COVID-19, surveys of employees showed that 40% of employees who have not worked from home could imagine occasionally working from home (Arnold et al. 2015), which could be confirmed by the recent work experience. Surveys on perceptions of telework during

[7] In the Corona Study by Möhring et al. (2020) from April 2020, the observation period is of 20 March until 15 April 2020. A 4-week comparison shows an average home office share of 25% (26.1% in the first week, 26.5 in the second week, 25.0% in the third week, and 22.5% in the fourth week).

[8] The participants of the Eurofound survey (2020a, 2020c) were recruited using online snowball sampling methods and social medial advertisements. As a result, one can expect to overweight the number of people who regularly appear in social media. It can be assumed that this includes particularly employees who are already "digitized" and accept working from home. The total number of interviews after cleaning – respondents aged under 18 and non-EU-members – was 61,788 respondents, with alone in Germany 3951.

COVID-19 indicates that many employees could imagine continuing to work from home regularly, especially after a certain normality has returned to their work-life (Eisenmann et al. 2020; Rubin et al. 2020). They enjoy not having to commute anymore, the ability to combine work with other activities and increased schedule flexibility.

Overall, the ad hoc implementation has shown that most organisations already have the technical capabilities and infrastructure in place. Furthermore, a lot of sectors do have the possibility to occasionally offer the opportunity of home office to their employees. Moreover, there is still room for improvement in the group of employees who work from home pre-COVID-19: 75% of the occasional teleworkers could theoretically add an extra home office day per week. The following question arises: How much greenhouse gas emissions (in CO_2e) could be saved by changing working routines and by an expansion of weekly home working days due to COVID-19?

What savings potential has the home office post-COVID-19?

In our study, we assume that passenger transport-related emissions can be saved if more employees occasionally work from home post-COVID-19, and that those who already do so have the opportunity to increase their home office days. The research has shown that teleworking, specifically the opportunity to work from home, has the potential to reduce the emissions from passenger transport. It is assumed that less commuting, especially by private car, means less travel-related emissions. As we have mentioned before, spatial and socio-economic structures additionally influence the savings potential and the current implementation level of the home office, as well as the commuting behavior of each employee who occasionally works from home.

In order to estimate the potential emission savings of a possible increase in the percentage of the home office commuting patterns from the period before COVID-19 are crucial, in particular the annual kilometres travelled to work and the choice of transport mode. Together with the work patterns, such as the number of employees already working from home occasionally or full-time, we determine our baseline (see Method Box 2). On this basis, we estimate the potential emission savings from post-COVID-19 working routines, measured in CO_2 equivalent (CO_2e).

Method Box 2: Methodological approach

To estimate the potential emission savings, we determine the number of employees who commute daily to work. Based on the commuters identified, we estimate the volume of passenger travel — the total number of passenger kilometres travelled by commuters based on MiD 2017 (BMVI 2020). As with total employment, commuters refers to employees aged between 18 and 65 who are in marginal, part-time and full-time employment (excluding secondary employment, education and vocational training and internships). In a second step, the emissions of the passenger kilometres they travel are determined. The *total emissions from commuting* depend on the distance travelled but also on the mode of transport used, e.g. private car, public transport or bicycle. We have therefore allocated the calculated passenger-kilometres *Pkm* covered by each commuter *i* to the respective mode of transport *m* and its specific emission factor *e* for each mode of transport *m*.

$$\sum Pkm_{m,i} \times e_m = total\ emission\ of\ commuting$$

The specific emission factor for each mode of transport indicates how many emissions (measured in CO_2e) were emitted per passenger kilometres driven. For our calculation, we have used the specific emission factor for each mode of transport based on the TREMOD (Transport Emission Model) of the German Federal Environment Agency (UBA 2019) (see Table 1). In doing so, we consider the different occupancy rates in passenger transport.

We weighted the TREMOD factor with an occupancy rate of 1.2 persons per car. To determine an average emission factor for public transport, we weighted the TREMOD factor by the passenger kilometres travelled by the different modes of public transport in 2018 (VDV 2019). The fleet composition, age and weight of private cars which were used or within the public transport fleet, as well as preliminary chains were neglected in our study.

Table 1: Overview of the emission factor were used

Mode of transport	Emission factors in CO_2 equivalents (in g CO_2e / Pkm)	References and assumptions
Pedestrian	0	Assumption
Bicycle*	0	Assumption
Private car**	183.75	TREMOD 6.03, weighted by occupancy rate per private car in commuter travel after UBA 2019
Public transport***	64	TREMOD 6.03, weighted according to passenger-kilometres in public transport after VDV 2019
Public transport*** from 50 km	32	TREMOD 6.03, weighted according to passenger-kilometres in public transport after VDV 2019
Airplane	230	TREMOD 6.03

* Pedelecs and e-bikes were not considered ** Single driver and passenger *** Public bus, railway, tram, city and underground

Based on the *total emissions of commuting* and the average working week, we calculate the *emission saving potential* through an additional day working from home. Therefore, we assume an average German working week is 3.97 days long (Deutschland in Zahlen 2020). The potential savings can be described as the ratio of the additional days spend in the home office d_{HO} and the average working days per week d_w multiplied by the share of employees who occasionally work from home HO_{total} minus the share of employees who cannot add an extra day working from home HO_{not}, e.g. employees regularly working from home 5 days a week.

$$\left(\frac{d_{HO}}{d_w} \times (HO_{total} - HO_{not})\right) \times total\ emissions\ of\ commuting = emission\ saving\ potential$$

In Germany, 199 billion passenger kilometres were travelled by commuters in 2017. Thus, commuting accounts for 17% of total passenger transport mileage. As with in the overall passenger transport, the private car dominates with 70% of the commuting mileage (see Box 2). The scope of this “private car dominance” in terms of climate policy becomes clear, especially when considering the emissions emitted by commuting.

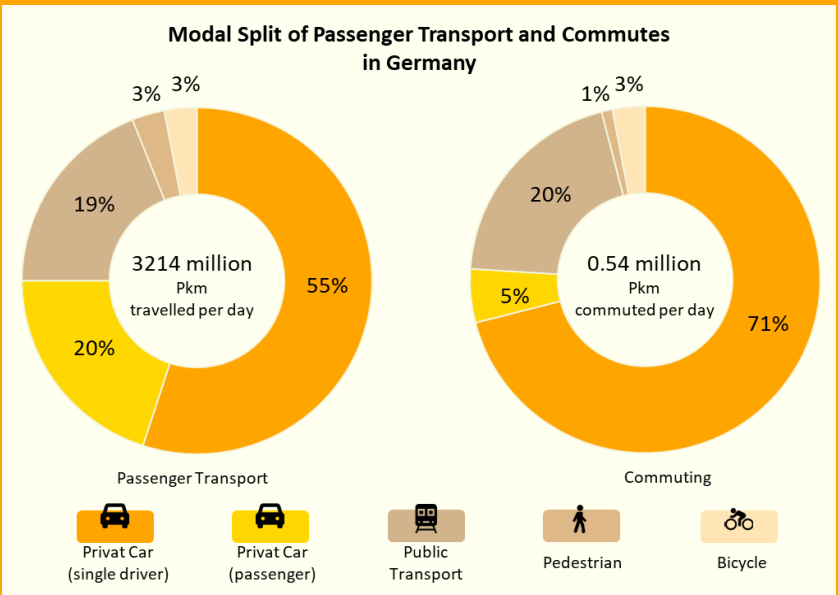
Taking into account the specific emission factors (see Method Box 2), commuting emits 30 million tonnes CO_2e per year, thus, 21% of the emissions of the total passenger transport in 2017. Thereby, commuting by private cars accounts for nearly 92% of the annual commuting emissions. Admittedly, emissions also depend on the occupancy rate of the vehicle, i.e. how many people in a private car travel together to work. With a high occupancy rate the carbon footprint is better, so general carpooling and fully occupied private cars would be beneficial. But in Germany the trend is towards driving alone in a vehicle with an occupancy rate is 1.2 persons per car in commutes, compared to 1.5 persons in everyday travel (Nobis et al. 2018a; UBA 2019). Thus, the share of commuters who were riding a car as passenger is rather low with nearly 6%.

BOX 2: Commuting in Germany

In Germany, commuting accounts for around 16% of trips and 21% of the total passenger transport mileage, including trips for secondary employment as well as education, vocational training and internships. The share of commuting is around 28% higher within the total private car mileage. Together with work-related trips, commuting accounts for 38% of passenger transport mileage. Thus, on working days, about two-thirds of mileage goes back to work-related mobility (Nobis et al. 2018a).

The average distance of trips directly from home to work is 16 kilometres (km). There are spatial differences in the distance travelled. Commuting is less long in metropolitan areas: on average 12 km compared to 19 km in rural areas. In terms of economic and educational status, there are further differences in the average distance travelled to work. Persons from high-income households not only travelled 6 km longer to their workplace than employees of lower economic status but also the share of long-distance commuters is three times higher (Nobis et al. 2018a).

Dense streets and crowded urban areas show the prevalence of private cars. In Germany, around 64% use their private car for commuting, particularly long-distance commuters (Nobis et al. 2018a). Cycling and walking accounts for a small share of the modal split during the rush-hour, but cycling has experienced an increase in recent years (Jurczok 2019). This development is increasingly becoming evident during COVID-19, when the bicycle became the "safe" and healthy alternative to the private car.



Note: Own figure based on Nobis et al.2018a and the MiD 2017 data set (BMVI 2020)

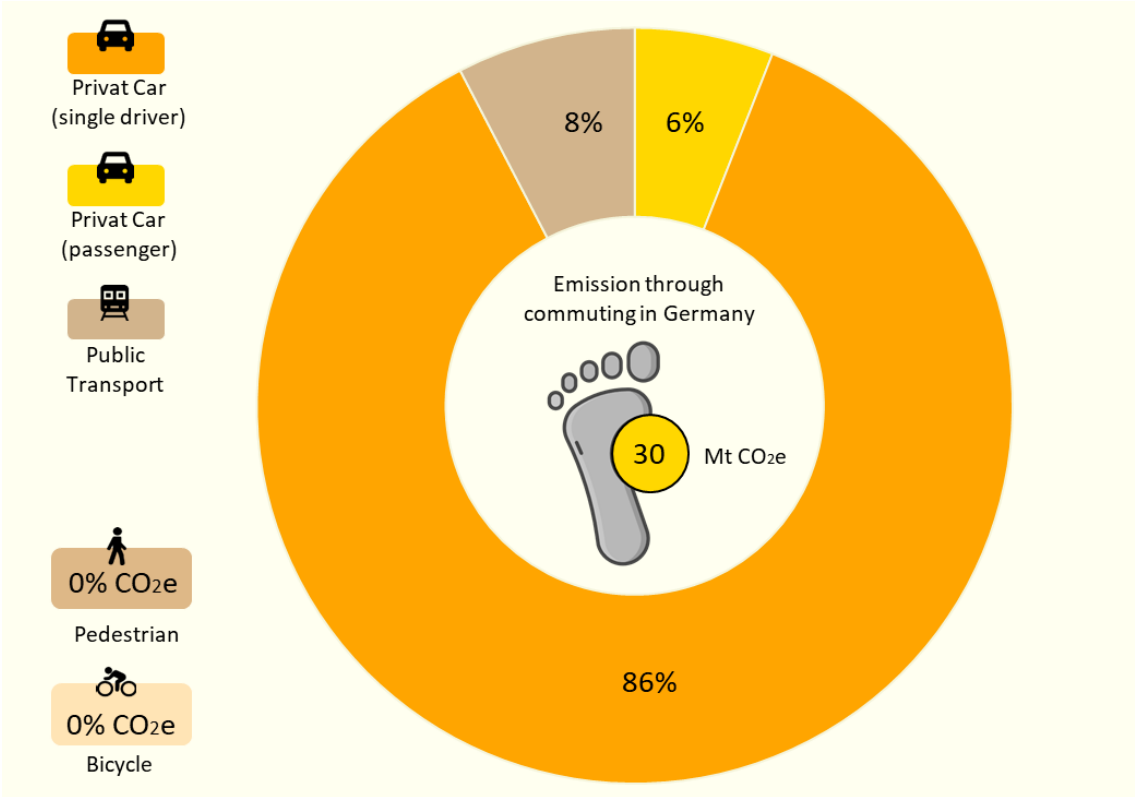
Taking into account the specific emission factors (see Method Box 2), commuting emits 30 million tonnes CO_2e per year, thus, 21% of the emissions of the total passenger transport in 2017.[9] Thereby, commuting by private cars accounts for nearly 92% of the annual commuting emissions. Admittedly, emissions also depend on the occupancy rate of the vehicle, i.e. how many people in a private car travel together to work. With a high occupancy rate the carbon footprint is better, so general carpooling and fully occupied private cars would be beneficial. But in Germany the trend is towards driving alone in a vehicle with an occupancy rate is 1.2 persons per car in commutes, compared to 1.5 persons in everyday travel (Nobis et al. 2018a; UBA 2019). Thus, the share of commuters who were riding a car as passenger is rather low with nearly 6%.

Commuting by private car is responsible for a large percentage of the emissions (see Figure 3). The slight increase in transport distance over the recent years and the overall small changes in emissions of passenger transport suggest that the previous measures had no significant effect on travel behaviour. The home office could be a low-threshold measure, especially for those who often travel by private car

[9] Based on the MiD 2017 data set (BMVI 2020) and the transport mode specific emission factor of the German UBA (see Method Box 2), we estimate the total emissions of passenger transport to nearly 145 million tonnes CO_2e per year. By using the emission factors of the TREMOD, not only the direct emissions, including evaporative emissions, were taken into account but also the emissions that occur in the upstream process chain of the final energy consumption of the specific transport mode.

and long distances, which relates mostly to people with a higher education level and a higher economic status. This option is particularly appealing since these people have the opportunity to work from home more often.

Figure 3: Emissions through commuting in Germany by transport mode



Note: Own calculations based on MiD 2017 data set (BMVI 2020)

How many emissions could an additional day in the home office save?

To estimate the savings potential of one and two extra days of telework, we assume on the basis of the statistics of employment in Germany (Deutschland in Zahlen 2020) that an average working week is nearly 4 days long (see Method Box 2). We expect furthermore that the 13% of employees who worked occasionally from home before COVID-19 will continue to do so. Considering that 3% of employees were already working from home at least five days a week and 4% of previous teleworkers stay four days in a home office, 10% of teleworkers could integrate an additional day, respectively, 9% could add two extra days at home into their work routine. Triggered by new work routines due to COVID-19, we assume a prospective increase of this previous share of teleworkers, so that, in addition to the 13% of pre-COVID-19 teleworkers, more employees will be able to work one or two days a week from home in the future.

Various COVID-19 statistics have shown that a broader implementation of the home office is possible, as we described before. To give a realistic range of possible savings potential, we assume two post-COVID-19 scenarios for the future development of the home office in Germany: 1) **a conservative scenario** with a percentage of 25% and 2) an **advanced scenario** with a higher share of 40% of employees working from home post-COVID-19. We consider that the lowest possible share of employees who could work from home post-COVID-19 is 25%, equivalent to the assumption of the Corona Study by

Möhring et al. (2020) for Germany in mid-April of 2020 and the highest plausible share could be 40%. Although the assumed telework share exceeds the estimates of the Eurofound study (2020b), in which 37% of employees started working from home as a result of COVID-19, thus we can take into account previous estimates of employees such as employers, as well as surveys assessing telework during COVID-19. Judging from the COVID-19 surveys we consider assumptions higher than 40% to be unrealistic at this time. In sectors such as gastronomy, culture or health workers are unlikely to work from home regularly.

Table 2: Savings potential for one and two additional days a week in a home office for Germany

	Conservative Scenario		Advanced Scenario	
Extra teleworking days per week	+1	+2	+1	+2
Saving potential: Passenger kilometres (in billion Pkm)	**10.9**	**20.9**	**18.4**	**35.9**
Saving potential: Emissions (in million tonnes CO_2e)	**1.6**	**3.2**	**2.8**	**5.4**

1) Based on the Corona Study by Möhring et al. (2020), we assume a conservative scenario with a total share of 25% of employees who could work from home. Given the full-time teleworkers before COVID-19, we assume that 22% of occasional teleworkers have the potential to add an extra day per week. In this **conservative scenario**, one additional day at home could save **1.6 million tonnes of CO_2e** per year, by reducing passenger kilometres travelled by **10.9 billion passenger kilometres**. The new work routines our society established during the coronavirus pandemic could contribute to a cut of annual emissions of commuting by 5%. If the employees were able to work two additional days per week from home the saved amount would almost double to **20.9 billion passenger kilometres** and **3.2 million tonnes CO_2e** per year — which corresponds to 11% of the emissions from commuting and 2% of the total passenger transport emissions.

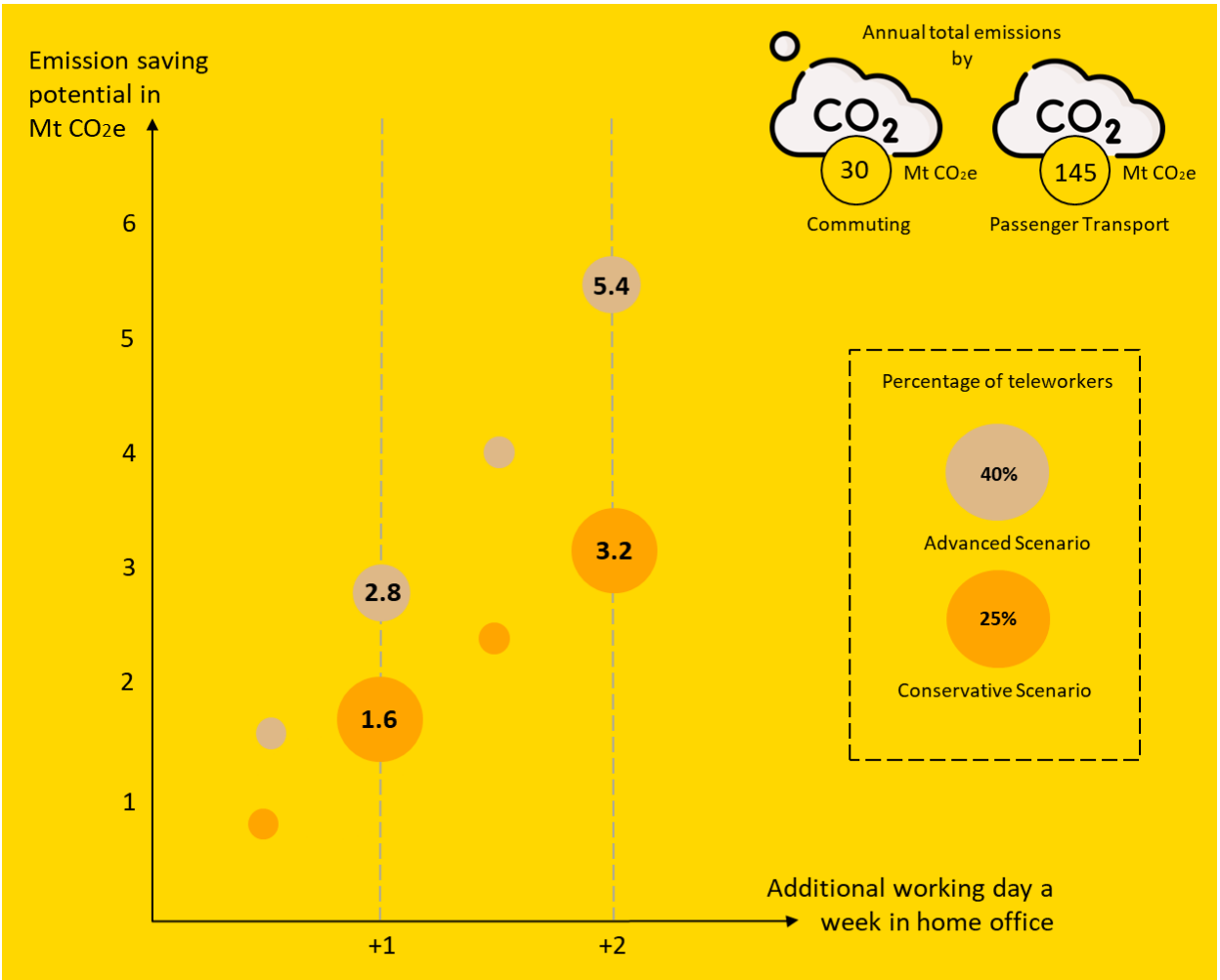
2) Based on the studies by Brenke (2016) and Arnold et al. (2015), which have shown that the home office is theoretically possible in 40% of the workplaces, along with the same percentage of employees being open to occasionally working from home, we assume in an **advanced scenario** a home office share of 40% in Germany. Taking into account those who already worked full-time in the home office, the savings potential of one day per working week is **18.4 billion passenger kilometres**, respectively**, 2.8 million tonnes CO_2e** per year, around 9% of the annual emission of commuting in Germany. For two days, the saving amounts to **35.9 billion passenger kilometres** and **5.4 million tonnes CO_2e** per year, thus a drop by 18% of the emissions of commuting and 4% of the total passenger transport emissions.

The post-COVID-19 scenarios show that with a generally higher share of home-based teleworkers in the total workforce, as well as with more home office days per working week, the savings potential increases rapidly (see Figure 4). Overall, the results for Germany show that working from home can help to reduce emissions from passenger transport. For an extra day at the home office, we estimate an emission savings range between 1.6 and 2.8 million tonnes of CO_2e depending on the assumed post-COVID-19 scenarios. This could reduce emissions from commuting, which is heavily dominated by the private car in Germany, by 2% to 9%.

Even more emission savings could be achieved if long distances to work are considered, especially those made by a car with a low load factor. When commuting between the periphery and the city centre, a

broader implementation of the home office could, in the long term, help to reduce the total number of kilometres travelled and thus travel-related emissions. At the same time, less commuting could have an impact on noise and air pollution on the main traffic routes and on the flow of traffic at peak times, so that employees who do have to travel could benefit from the time saved.

Figure 4: Emission savings potential for one and two additional days a week in a home office for Germany



Note: Own calculations based on MiD 2017 data set (BMVI 2020)

Critical reflection on the results of our study

For a more comprehensive evaluation of our results, any rebound effects that may occur must be quantified. However, based on the literature analysis, we assume that the potential for rebound effects will be low, due to the spatial structures, mobility behaviour, and working and living conditions in Germany. Therefore, we have initially neglected energy and travel-related rebounds (see Box 1) and assume a higher emission saving potential.

Especially in larger cities, where a home office is more common, we expect less travel-related rebounds. The infrastructure of daily life such as shopping facilities, schools, and health centres should be more accessible on foot, by bicycle, or by public transport. In rural areas, however, there could be travel-related effects, as the distances for daily needs are usually longer, so that additional trips by private car of the household could become necessary. To what extent these rebound effects outweigh or

compensate each other would have to be further investigated for the overall assessment of the emission saving potential of the home office.

Regarding the energy-related rebounds, we assume that the energy consumption in the home office does not deviate significantly from that in the regular office, based on the literature analysis. We assume small energy-related rebounds for Germany, since even with a broader implementation not all employees of a company will be in the home office at the same time. Even in professions where a broader implementation is theoretically possible, such as in the knowledge sector, there are areas that require at least an agreed on-site presence, e.g. receptionists, assistants or secretaries. For this reason, offices will continue to be needed in the future and workspaces will continue to be supplied with energy.

In addition, information and communication technology (ICT) is increasingly used in the traditional office, as is digital working. We therefore expect less significant energy-related returns in data traffic volume. The increase in traffic data volume observed during COVID-19 due to streaming and video communication is not only caused by an increased share of home offices. This is especially true since empirical studies indicate that the majority of employees continued to go to work during the pandemic. The increase in data traffic and the growing demand for virtual meetings must be seen in tandem with the lockdown at the peak of the pandemic. With regard to Internet emissions, it would also be important to investigate the potential of "green digital work".

The question of rebounds could be also important in the area of business trips. Especially, the use of ICT can reduce long distance trips, and thus, work-related emissions. To which extent the usage of ICT could lower work-related emissions, requires a further assessment of the overall emission saving potential of telework (see Box 3). This is particularly true since in the business travel sector, longer distances are usually covered by air (Eurostat 2020c) and thus a significantly higher greenhouse effect is expected for business travel due to the radiative forcing of aviation emissions (UBA 2012).[10]

BOX 3: Savings potentials of business trips

In addition to the replacement of daily commuting through telework, there is potential for business trips, such as regular internal meetings, project presentations and consultations, to be replaced by virtual meetings and ICT. The recent experiences from the coronavirus pandemic have shown that this is possible when necessary. Due to COVID-19, more than 90% of the global business travel was cancelled or suspended (GBTA 2020). For Germany, the Wuppertal Institute and EY (2020) suggest that 30% of all business trips could be replaced by virtual meetings, an even higher share is expected worldwide (39%). Given the urgency of the climate crisis, the question must be asked which personal encounters are justified and which can be realized just as well in the future with ICT.

More precise estimates of the emission savings potential would be necessary and could support the discourse about the environmental benefits of telework. However, for a complete analysis, the data basis turns out to be difficult for several reasons: First, in the official EU statistics business trips are considered as touristic trips. Thus, business trips, which were undertaken without overnight stays were excluded in the EU statistics. To provide complete information on the impact, one-day trips with a professional purpose must also be considered. To give an example: in the EU, statistics show 126 million trips by EU residents with one or more overnight stays for professional reasons (Eurostat 2020c). In contrast, the German Business Travel Association (VDR) counts 189.6 million business trips alone for German companies in 2018 (VDR 2019). In addition, statistics on business travel usually come from the companies themselves or are collected by travel planning management providers or transport companies, such as airlines and are often only used for internal statistics.

[10] Due to the radiative forcing, which is twice as high in aviation as the radiative forcing of CO_2 alone, emissions from aviation have a higher impact on the climate. The radiative forcing describes the variations in the atmosphere as a result of a disturbance (for example, the emission of greenhouse gas). The ratio of radiative forcing of all effects of aviation to the radiative forcing of air travel-related CO_2 indicates the Radiative Forcing Index (RFI) (UBA 2012).

Secondly, in order to estimate the savings potential for a representative number of business travellers, we need to know what distance was travelled by which mode of transport and under what conditions. In the case of air travel, for example, the decisive factor is whether a direct flight was booked and which travel class was chosen. However, the model of the aircraft also has an influence on emissions due to its weight and specific kerosene consumption. Similarly, cross-border business travel by rail makes it difficult to accurately estimate the emission savings. Each individual business trip would require precise connections, so that the respective specific emission factors could be assigned to each route, since each country has a different electricity mix that influences the emissions of the rail trip. In addition, emissions from business travel are also generated by the journey to the hotel or onward journey, e.g. if the business traveller hires a car after a long-haul flight. Furthermore, the emissions per overnight stay must also be converted to the footprint of a business traveller.

An assessment of the emission reduction potential of business travel requires a comprehensive business travel data set or at least representative surveys of companies about the specific travel behaviour of their employees at EU or national level. Only on the basis of such business travel data could the total emission saving potential in terms of distance travelled be determined and recommendations be formulated.

The results for Germany in a European context

The estimated emission savings potential for Germany cannot be transferred one-to-one to other European countries; the national circumstances are too different in terms of spatial distance, the transport mode, and also the pre-COVID-19 adoption of home office. However, for all European countries it can be assumed that if telework is possible at least one day a week, commuting trips can be saved and thus work-related emission.

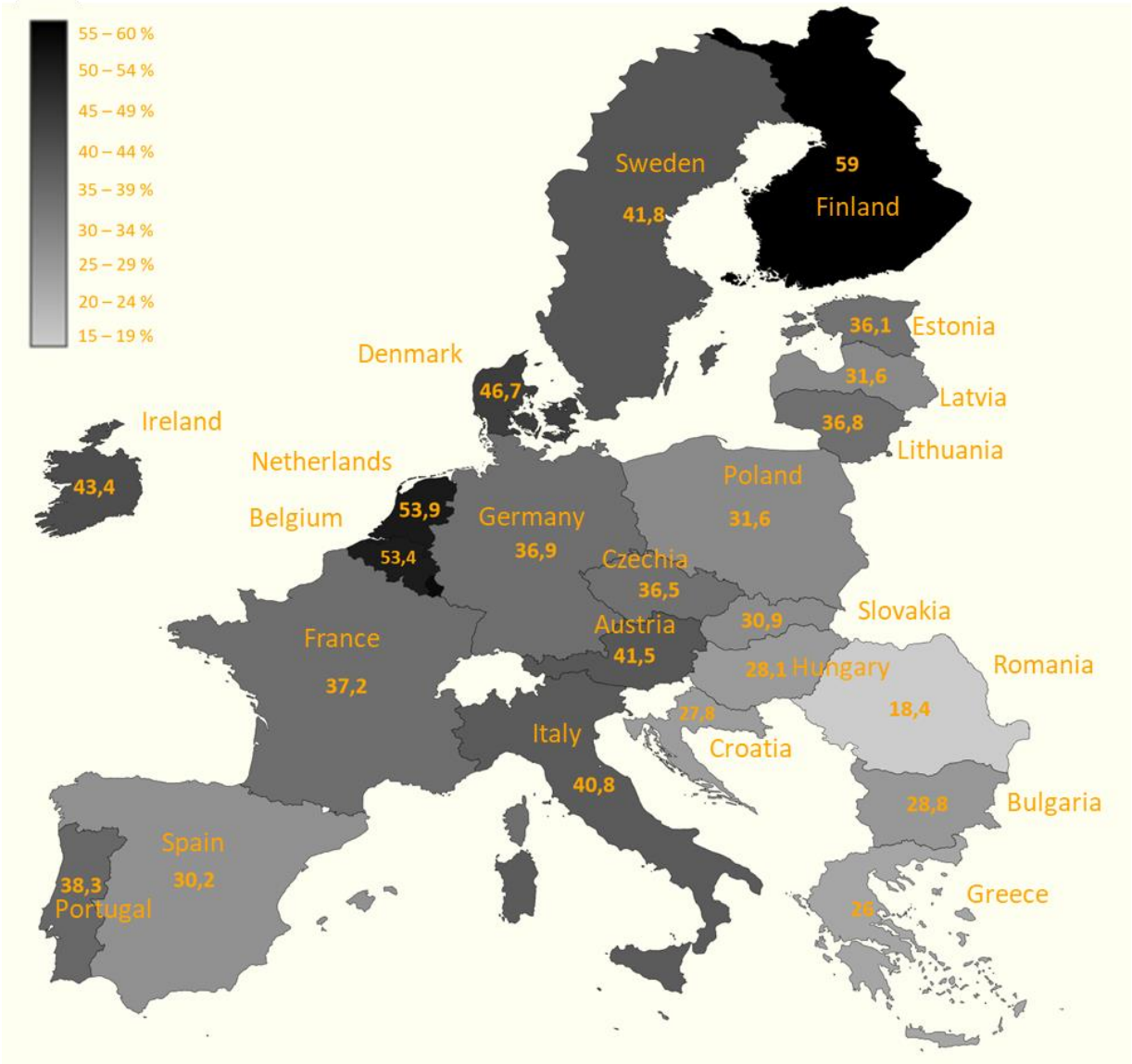
Under this assumption, the possible emission savings can also be discussed for other European countries. As in Germany, COVID-19 has led to an increase of home working employees EU-wide, at least temporarily. The recent Eurofound survey (2020a) therefore shows not only a growth in telework in Germany., Over a third (39%) of all European employees started to work from home following the coronavirus pandemic at least 'several times a month'.[11] The range of incidence between countries is wide, with 59% in Finland at the top of the table and 18% in Romania at the bottom (Eurofound 2020b) (see Figure 5).

As described before, the Eurofound study (2020b) refers to a broad understanding of telework and covers employees who rarely and occasionally were able to work from home during COVID-19, and therefore shows high potential for future development of telework in Europe. Despite a high share of teleworkers before COVID-19, European countries such as the Netherlands, Finland, and Austria also show a notable increase, but above all, the recent Eurofound study demonstrate the saving potential of a home office in countries that were previously below the EU average (see Figure1). Especially in countries like Portugal, or Poland, where the average distance per person a day is comparable with Germany (17 km respectively 18 km), and over 40% of the daily distance travelled for professional purposes (Eurostat 2020b, 2020c), the gained home office experience due to COVID-19 could mean a high potential for emission savings in the future.

[11] The exact data can be retrieved on the following website: https://www.eurofound.europa.eu/data/covid-19/working-teleworking (as of 20th July 2020).

If we consider the proportion of the Eurofound survey (2020b, 2020a) as the current potential for the home office, we could conclude that at least **one third of the European Union's workforce** could telework for at least one or two days a week. The amount of the emission savings potential depends on how many employees commute daily to their workplace, how many kilometres are travelled, and whether they use a bicycle, walk or travel together. Since the private car is the predominant mode of transport in most European countries (Eurostat 2020b, 2020c), particularly in domestic travel, and available EU statistics suggest that the largest daily distance travelled is due to work; there will be similar saving effects in other European countries. Especially because the European home office average is stated at 39% during COVID-19, which is almost identical to our advanced scenario, so in the EU average similar savings are conceivable. But to estimate the exact amount an EU-wide data set is required, further on.

Figure 5: Percentage of employees who start working from home during COVID-19



Note: Own figure based on Eurofound 2020b

The right conditions as a boost for the home office

If we assume that emission saving potentials goes with a broader implementation of telework, the prerequisites for telework in respective countries with a high home office percentage — prior to and because of COVID-19 — could indicate how telework can be promoted in the future and thus reduce work-related emissions.

1) Profession: A broader implementation is more likely in countries with more people working in 'home office friendlier' occupations. For example, a survey from Luxembourg (Statec 2020) states that 69% of active residents switched to telework during COVID-19, compared to 20% in 2019. The relatively high percentage of people working in finances and administration in Luxembourg could therefore explain the high teleworking share (Statec 2020). Therefore, we could assume the implementation potential being essentially high for those countries with a high share of people working in the knowledge, IT or finance sector. If teleworking were to be promoted, many Western European countries would be able to reach levels similar to the European forerunners Finland, Netherlands and Luxembourg. Even though the potential of many Eastern-European countries might be smaller due to different economic and labour market conditions, the growth they experienced during the coronavirus pandemic was remarkable, e.g. Romania and Bulgaria climbing up from less than 1% before COVID-19 to around 19% and almost 30% during COVID-19 respectively (Eurostat 2020a; Eurofound 2020b).

2) Institutional setting: Although the profession is a strong indicator for the potential teleworking workforce, other factors are likewise decisive, like the institutional setting (Eurofound 2020b). The institutional setting can be an incentive to foster telework. While there is not yet a right to telework, some countries implemented regulations that accelerated the upsurge of telework during COVID-19 in Europe. In Finland, the leading teleworking country, it is a right to adjust the working hours (Yle 2020). Flexible work has been embedded in the work culture for more than two decades, due to the Working Hours Act adopted in 1996. It gives most employees the right to adjust the typical daily working hours of their workplace, by starting or ending up to three hours earlier or later (Savage 2019). To boost the telework share in Germany, a right to telework could be proposed by the German Minister of Labour Hubertus Heil (Der Spiegel 2020). However, some countries, e.g. Romania or Hungary, have teleworking regulations but are still among the lowest ranking with regard to the percentage of teleworkers. The composition of the labour market is certainly crucial in these cases and shows that regulation alone is not enough. However, as Finland has shown, the institutional setting is an important step, since it leads to a higher acceptance within the population fostering a working culture that is built on trust.

3) Level of Digitalisation: While there is an important connection between the distributions of working sectors within the countries, the level of digitisation of countries plays a role as well. The Digital Economy and Society Index (DESI) is a composite index published annually by the European Commission since 2014 and measures the progress made by EU Member States towards a digital economy and society (European Commission 2020). Important indicators are broadband coverage, internet user skills and advanced skills, business digitisation and e-commerce. The DESI score shows a clear link between the digitisation of a country and the share of teleworkers. According to the DESI score Finland, Sweden, Denmark and the Netherlands have the most advanced digital economies in the EU. Bulgaria, Greece, Romania and Italy have the lowest scores on the index (European Commission 2020) — simultaneously, these countries are also below the EU home office average (5%), pre-COVID-19 (see Figure1).

4) Incentives and culture: Another factor that can incentivize telework is tax advantages for employees working from home. For example, under French law, and some regions in Malta and Austria, employees are allowed to be compensated for costs arising from telework (Eurofound 2020b). On the contrary, in

Germany the traveling allowance compensates people financially who travel long distances — independent from their travel mode. For many employees, commuter travel expenses are the largest tax-deductible position that can be claimed more easily. At the same, it is much more difficult, or in some constellations impossible, to get tax deductions on home office-related expenses. Furthermore, incentives and institutional conditions help to integrate flexible work forms, such as the home office, into a country's work culture. The work culture is another important reason for acceptance for higher home office percentages. For example, in Finland where telework has been accepted quickly by most employees is a deeply rooted culture of trust. A recent Eurobarometer survey showed that Finns' trust in their fellow citizens is higher than elsewhere in Europe (Yle 2018).

Indeed the prerequisites described do not say anything about the level of the specific emission saving potential in the several European countries. Nevertheless, on the basis of the best practice cases in Europe, conditions for a broader and well-thought-out implementation for Germany, as well as other European countries, can be gained. With the appropriate institutional framework, such as working hours acts, financial incentive structures through tax exemptions especially with regard to more environmentally friendly commuting behavior, as well as the technical requirements, the observed developments during COVID-19 regarding the percentage of the home office could be become the new baseline, so that there is a higher potential to save work-related emissions.

4 Conclusion

In general, teleworking reduces the emissions from daily commuting, if daily kilometres travelled could be reduced by a higher share of employees who work from home, as well as an increase in working days from home. Our study shows that the home office could reduce commuter travel, and thus contributes to reducing emissions from passenger transport. However, it also becomes clear that increased opportunity to work at a home office could only be one component in a combination of measures toward limiting CO_2 emissions while reaching the European climate goals.

However, to reach the Paris Agreement targets, we have to consider even small steps for a sustainable transition of the transport sector. Also given that emissions from the transport sector, especially from passenger transport, have remained relatively constant over the last years, home-based telework could be an agent of change. Expanding the approach of working from home is one way to contribute to environmental benefits, which could be implemented with low transaction costs. Without greater personal effort or the need for political control mechanisms, the home office could be a fast and low-threshold way to cut the annual emissions in the EU.

Besides the environmental benefits of reducing work-related trips, companies and employees could also gain from telework in general, which could contribute to a broader implementation. Under the right conditions, telework could increase the workers' productivity through increased autonomy, with employees developing a stronger bond to their company and showing higher job satisfaction. In addition, telework can be associated with better general health of employees. The opportunity to occasionally work at the home office could be a competitive advantage on the job market, when well-trained employees will become increasingly in demand in the future. Given that the digitization of countries becomes more essential economically, telework is an important indicator for resilient future jobs and a resilient economy, as the coronavirus pandemic has demonstrated.

The shared experience of working from home due to COVID-19 also emphasizes that in particular families with young children face difficulties finding structures, which enable a good family-to-work-relationship. Despite this fact, working from home is more common for younger households and families who enjoy an enhanced work-life balance and the opportunity to integrate their working hours to their personally preferred daily routines. In addition to incentives for companies and employees to accept telework, the right conditions and limitations are also needed. Without an institutional condition, working from home could lead to a level of constant availability, which impairs well-being and performance. Therefore an agreement with the employer is necessary, and a legal framework that protects the employees is a helpful instrument for setting clear boundaries and expectations. Furthermore, legal and institutional conditions for home-based telework, as well as financial incentives, are essential for a broader implementation in the future.

The 'Corona Crisis' has also shown that not everyone can or will be able to work from home. Our study indicates also a risk that, in the long run, only wealthy and high-level educated employees have the opportunity to occasionally work from home, while the working class still needs to commute daily by public transport. From an environmental perspective however, high income groups show a higher emission saving potential because they would rather commute by private cars and frequently travel longer distances. From a social perspective though, a broader implementation of telework, post-COVID-19, could enhance social inequality. Telework will not be feasible for all income and professional groups in the future; therefore, from a social perspective teleworking can only be one part of the solution. For work related trips especially, which cannot be replaced in the future, affordable and environmentally friendly transport alternatives must be created For example, a strong public transport and the development of safe pavements, or fast cycling infrastructure.

Spatial issues must also be considered as a result of telework. A high share of telework can change the appearance of cities in the future because fewer people commute daily, which means that less space is needed for car travel in the long run. These results can have a positive effect on air quality and noise. Therefore, telework has the opportunity to give dense cities more room to breathe, and choosing where to live will not depend so much on the place of work anymore. In the long term, this could make rural areas — which have previously experienced a strong decline in population, among others reasons due to a lack of work opportunities — more attractive. Business districts in cities on the other hand, could become smaller and life can return to the business districts themselves, especially the opportunity to work in a co-working space nearby. This "increased hominess" of teleworkers could lead to shorter trips and more bicycling.

Society can enjoy many benefits if teleworking becomes a well-thought-out part of our work routine, with a positive effect on the climate. However, the discourse on telework shows that not only positive effects could be accompanied by this change. For example, the described spatial effects could lead to longer distances, i.e. in general fewer but longer distances need be travelled, even though daily commuting trips become less through a higher home office percentage. In addition an increase in home office and a spatial development as described before could affect local public transport services. In the long term, the public transport service could become less profitable for transport companies. A decrease in commuters coupled with a decrease in spatial density, could decrease profitability to a point where services could be restricted, and the overall social cost of mobility could rise.

Finally, it is a question of balancing the emission saving potentials and risks. With well thought out, institutional and work conditions, in combination with other transport policy measures and special planning, along with green energy and digital working solutions, teleworking and especially the increased opportunity to use a home office can be one part of a sustainable development strategy and can contribute to the reduction of emissions.

One thing is clear: we need to cut back emissions because the 'Corona Crisis' is only one of the many crises of our time. Our study has shown that telework has the potential to save emissions. Despite the far-reaching and hardly foreseeable social consequences and individual tragedies of the COVID-19 pandemic, lessons can be learned regarding sustainable behavior. The challenge lies in keeping the momentum going.

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Abbreviations

CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
COVID-19	Coronavirus disease 2019
DESI	Digital Economy and Society Index
EU	European Union
EY	Ernst & Young Europe LLP
FDP	Free Democratic Party
Gt	Gigatonne
ICT	Information and telecommunication technology
IEA	International Energy Agency
IT	Information technology
kg	Kilogramme
km	Kilometres
MiD	Mobility in Germany
Mt	Million tonnes
NO_2	Nitrous oxide
NO_x	Nitrogen oxide
PM	Fine particulate matter
Pkm	Passenger Kilometres
RFI	Radiative Forcing Index
TREMOD	Transport Emission Model
t	Tonne
UBA	German Federal Environment Agency
UK	United Kingdom
US	United States
VDR	German Business Travel Association
VDV	Association of German Transport Companies

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