newTRENDs

Focus study report on sharing economy in the tertiary sector

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Executive Summary

The sharing economy is a new trend that promotes sustainability and resource efficiency by better using idle assets. However, its actual effects on sustainability are debated. To investigate its impact on energy outcomes, we conduct a quantitative model-based study focusing on the tertiary (i.e. service) sector.

The sharing economy encompasses a wide range of heterogeneous concepts. In this respect, this report focuses specifically on the impact of new working patterns in the tertiary sector, in particular shared offices, co-working spaces and teleworking, on energy consumption. It is worth noting that this study does not consider the impact of these changing working patterns in other sectors, such as in the residential sector through home offices, or in the transport sector through changing mobility patterns.

Changes in the diffusion of such labour patterns have a twofold effect on energy consumption. Firstly, the usage of information and communication technologies (ICT) and the resulting energy demand will likely increase due to emerging forms of digital communication and collaboration tools such as data sharing and online meetings. Secondly, the shift of work from conventional offices to remote teleworking presumably decreases the floor area need in the tertiary sector. This effect might be offset by a potentially increase, in the long run, in the floor area demand for co-working spaces and in private homes. While effects in the residential sector are not subject of this study, we analyse the impact on the tertiary sector in-depth. (For a cross-sectoral analysis see newTRENDs WP3, "Transition Pathways for New Societal Trends and Methodological Improvement in Modeling such Trends"). Moreover, the interconnection between new labour patterns and the mobility sector, such as a reduction in commuting rides due to remote work, is a key topic discussed in the scientific journal paper on modeling the sharing economy and new trends in transport and the tertiary sector (Deliverable 7.3).[1]

The modelling and assumptions in this focus study are based on an extensive literature review of the new trends in the sharing economy. We then expand the FORECAST modelling framework to incorporate the effects of these trends, notably on the specific floor area, the share of employees and the ICT demand.

The results of our analysis incorporate a sensitivity analysis and scenario-based analysis of the aggregated effects of ICT and teleworking. Specifically, the study examines the increased ICT demand in the tertiary sector and the impact of teleworking on the same sector.

The ICT demand is modelled through the proxy of the installed electric power of the ICT infrastructure. The different scenarios of the sensitivity analysis calculate the energy consumption for an increase of the installed power by factors between 2.5 and 10 compared to the installed power of 2020. The increase of installed power does not equal a proportional increase of the usage of ICT services as the energy consumption is decoupled from the computed power due to technology developments. The analysis shows that, in 2050, the ICT-related

1 At the time of writing, this paper was in preparation.

energy consumption in the EU27 could reach on average a level of 35% of the other electric demands in the tertiary sector in the extreme scenario. Two ICT scenarios (increase by factor 5 and factor 10 until 2050 compared to 2020) are selected for further analysis of teleworking.

The main results show that the effects of teleworking are in general positive when the boundaries are set to the tertiary sector, as the energy savings of heating, cooling and lighting applications are higher than the additional ICT demand (Table 1). With a high share of teleworking, the total final energy consumption of the EU27 average in the tertiary sector is 6% to 12 % lower compared to a low share in the scenario with moderate development of ICT usage. In the scenarios with high ICT usage, the absolute values of energy savings from teleworking are identical, but the total energy consumption is higher due to the increased ICT activity. In these high-ICT scenarios, the final energy savings in 2050 is slightly lower, it amounts to around 6% to 11% (compared to 2021).

While our study provides valuable insights into the impacts of the shared economy in the tertiary sectors and its teleworking and shared office aspects, there is a need for further research to fully understand the economy-wide net effects. Specifically, it is important to estimate the effects on residential floor area and final energy demand resulting from the shift of labour from offices to the residential sector as well as the impacts on mobility patterns.

Table 1 Key Numbers about the Impact of Teleworking and Rising ICT Demand in the Tertiary Sector for EU27 According to the Results of this Study

Effects of teleworking on energy demand of …	**Absolute Changes (all scenarios)**	**Relative Changes (high share of teleworking; moderate ICT scenario)**	**Relative Changes (high share of teleworking; high ICT scenario))**
ICT applications	+5 to 12 TWh	+3% to +8%	+2% to +4%
Space heating (all energy carriers)	-41 to -72 TWh	-9% to -16%	-9% to -16%
Thereof electricity	-9 to -16 TWh	-9% to -16%	-9% to -16%
Other electric appliances	-33 to -71 TWh	-6% to -14%	-6% to -14%
Total	-69 to -131 TWh	-6% to -12%	-6% to -11%
Thereof electricity	-37 to -74 TWh	-5% to -10%	-4% to -8%

Effects in other sectors (residential, mobility) or economy-wide net effects are not evaluated.

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List of Abbreviations

CWS	Co-Working Spaces
GHG	Greenhouse gases
GHGE	Greenhouse gas emissions
ICT	Information and communication technologies (ICTs)
NACE	Statistical Classification of Economic Activities in the European Community.
SE	Sharing economy
RQ	Research question
WFH	Working from home
WP	Work Package

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1. Introduction

The 21st century has brought new societal trends (Brugger et al., 2021) . Among them is the sharing economy (SE). SE business models are conceived as a potential solution to reduce natural resource use and waste production (Botsman & Rogers, 2010). It promises a better use of under-utilised assets, and thereby promotes sustainability and resource efficiency (Cheng et al., 2020; Dabbous & Tarhini, 2021; Frenken & Schor, 2017).

However, the actual impact of the SE on sustainability is strongly debated, with some arguing it is a new form of capitalism (Martin, 2016). Although tackling the climate change problem is a priority (IPCC, 2007), it is unclear how much the SE can contribute to this matter. Therefore, we conduct a quantitative investigation to determine the potential effect of the SE on final energy demand in the tertiary sector. It is important to note that the impacts in other sectors, such as in the residential or mobility sectors, are not scope of this study, and therefore, we do not report any economy-wide net effects.

SE business models have emerged in various tertiary (i.e., service) sub-sectors, including retail, tourism, housing, real estate, and transportation, and have received increasing research attention (Agarwal & Steinmetz, 2019). This report specifically focuses on quantifying the effects of *changing labour patterns*, particularly on the floor area and final energy demand in shared office spaces. Within the SE, these patterns may contribute to a better use of underutilised resources.

Our explorative research is relevant due to the lack of quantitative studies on the SE, and related aspects such as teleworking and co-working spaces (Agarwal & Steinmetz, 2019; Laurenti et al., 2019). Although teleworking has been explored in more depth, gaps still exist for co-working and the overarching SE concept. It remains unclear how changing labour patterns, including the shift of the working place from the tertiary to the residential sectors, impact the long-term energy demand. Thus, our main research question (RQ) is: *What is the effect of changing labour patterns, such as remote work, on energy demand in the tertiary sector*?

The main results (see Section 5) illustrate that teleworking leads to a decrease of about 2–3% final energy demand in the tertiary sector (depending on the ICT load). Building on this insight, future model-based studies will be able to conduct cross-sectoral analyses, notably incorporating the residential and mobility sectors. Such work will be essential to derive the net effects of the sharing economy.

The remainder of this report is structured as follows: This section explains the scope, focus, relevance and RQ. Section 2 reviews existing definitions of the three focal topics, namely sharing economy, teleworking and shared office/co-working spaces, and provides an overview of the current relevance, statistics and findings. At the end of this section, we summarise the findings of the literature review related to the focal topics and the according research gaps are identified. Section 3 describes the (tertiary-focused) FORECAST model, which was used to answer the research question. Section 4 defines the different scenarios that are the basis of our simulation, e.g. the assumed future share of employees that are working in other locations than the conventional office. Section 5 analyses the results of the simulation and compares the different scenarios. Finally, Section 6 summarises and discusses the results of this paper and names its constraints.

As part of the newTRENDs project, this report (D7.2) contributes to the broad topic of mobility in WP7. Mobility not only encompasses transportation, as analysed in D7.1, but also mobility in a broader sense such as the flexibility to choose the workplace location – in that sense being mobile. However, effects in the transportation sector, for instance due to changes commuting patterns, are not estimated and quantified.

2. Literature Review

This Section reviews the existing literature and data that is relevant for modelling the sharing economy and answering the overarching research question. Our review is based on a semi-systematic review method (Snyder, 2019) and includes scientific journal papers, grey literature such as research reports and whitepapers, as well as aggregated databases and survey results.

The findings of our review provide an overview of current trends, the state of knowledge about the impact of sharing economy, teleworking and co-working spaces. It lays the foundation for the scenario assumptions and quantitative evaluation in the remainder of the report.

2.1 Sharing Economy – General Concept and Effects

Sharing is not a new trend per-se; humanity has been sharing for centuries. However, with the digitalisation of our lives and the emergence of new information and communication technologies (ICT) tools, its significance has changed fundamentally. The emergence of popular sharing platforms, for instance Airbnb, now enables the sharing of goods and services with strangers (Frenken & Schor, 2017). With the rise of co-working services like WeWork, the global Covid-19 pandemic and the growing popularity of teleworking, the concept of sharing has become increasingly prevalent in the workplace, as well (see also next sections).

Frenken & Schor identify recurring themes in the SE-literature, such as efficient use of under-utilised resources, inefficiently used stocks and the common believe in social, environmental and economic benefits. This applies to the sharing of food (Meshulam et al., 2022), appartments (Cheng et al., 2020), cars (Hoerler et al., 2021) and to our focal topic, office spaces (Berbegal-Mirabent, 2021).

However, measuring these benefits may be more complex than it appears at first glance. While there are substitution effects due to sharing, overall demand might nevertheless increase, for instance towards larger open-plan offices (Savills Research, 2022). Also rebound effects can induce additional consumption due to additional income from renting in peer-to-peer business models (Cheng et al., 2020; Frenken & Schor, 2017). Thus, to assess the impact of SE, different levels must be considered, including the energy consumption of sharing platforms, e.g. due to websites and blockchain technology (Fiorentino & Bartolucci, 2021), effects from the substitutions and better utilisation (floor area or materials) and long-term structural changes and rebound effects (Pouri & Hilty, 2018).

Overall, the sharing economy literature has potential for expansion. While teleworking has been explored deeply, there is limited research on workplace mobility and co-working spaces (Laurenti et al., 2019). Additionally, most literature is qualitative and conceptual, but systematic reviews suggest a need for quantitative and empirical analyses to examine sustainability aspects

(Agarwal & Steinmetz, 2019; Laurenti et al., 2019). Our research addresses these needs by modelling the effects of shared offices and telework on energy demand.

2.2 Shared Office and Co-Working Spaces

Most of the literature on shared offices and co-working spaces (CWS), see Table 2 for definitions, is from management and social sciences, covering topics such as entrepreneurial performance (Bouncken & Reuschl, 2018), preferences and motivations (Weijs-Perrée et al., 2019) and general topics and trends (Berbegal-Mirabent, 2021). Conversely, the impact of shared offices on the environment and energy demand is less researched.

Table 2 Definitions of Shared Offices

Concept	Definition	Source
Shared office or on-demand workplaces	Any sharing of office space without emphasis on community.	Own definition
Co-working spaces (CWS)	A business model in which office space and resources are rented. A sense of community and collaboration is promoted.	Yu et al., 2019

The increasing proliferation of shared offices and co-working spaces could impact energy demand due to spatial changes, lifestyle changes, ICT-related energy demand or general changes in electricity demand (e.g. for lighting). The spatial dimension includes effects on the office floor areas, density and utilisation rates in all office types (home office, shared office and conv. offices, see Section 4).

First, co-working spaces may contribute to better utilisation of available urban space, which is a core aspect of the sharing economy (Huang et al., 2020). Co-working spaces are often located in urban areas and can help to reduce underutilisation of urban space. Space is also used more efficient in comparison to remote working, as the infrastructure is used by more than one person. Overall, this could lead to a more efficient use of space and energy.

However, in the sense of a rebound effect, the shift of the workforce from homes to shared offices may have the potential to increase energy demand in the long term. From the perspective of the self-employed workforce, co-working spaces offer an opportunity to escape the isolation of working from home or coffee shops (Fuzi et al., 2014). This may lead to additional demand for co-working spaces and shared offices, thus increasing the heated floor areas in the tertiary sector over time. Conversely, shared office space is likely to be associated with a higher space utilisation rate and thus a reduction in energy demand. The quantification of these effects is currently missing and needs further investigation.

Due to Covid-19 and potential pandemics in the future, the need for more spacious office spaces could lead to a redistribution of workers to co-working spaces (Berbegal-Mirabent, 2021). It is unclear whether this will increase demand for additional shared office spaces or rather lead to better use of overall floor space. Future studies should investigate this further. In this report, we assume the floor area changes as introduced in section 4.2.

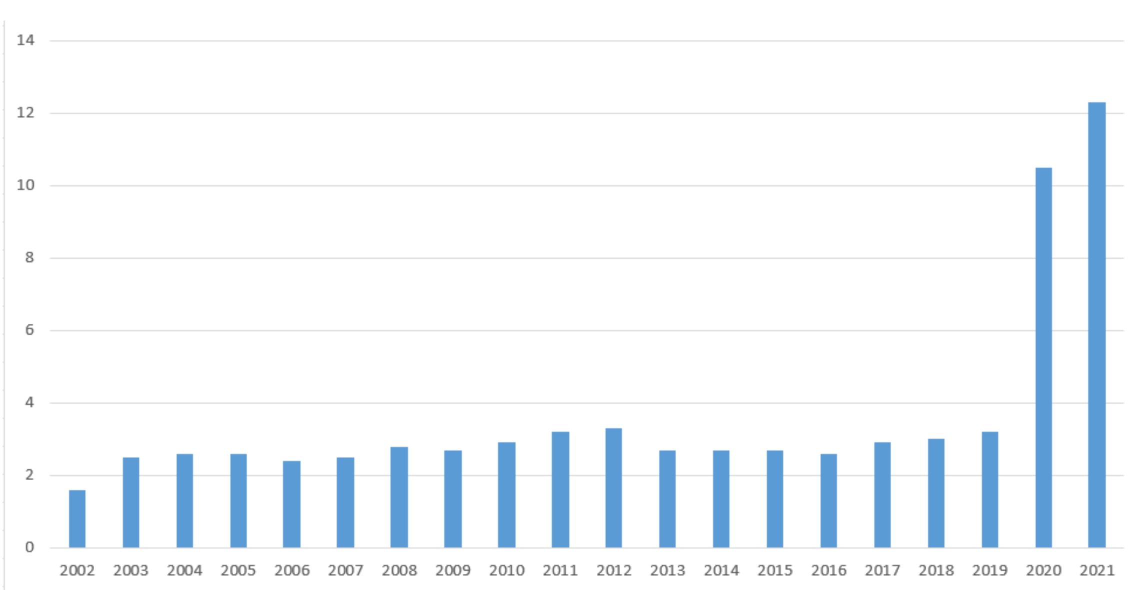
Furthermore, co-working spaces could foster general lifestyle changes towards a mindset of sharing, collaboration and sustainability (Petch, 2015; Yu et al., 2019). These lifestyle changes may have complex effects which are not further quantified in this report.

One fundamental aspect of shared offices is the use of teleworking, explored in the next section. The ICT-related energy demand effects consider that ICT-use in shared office spaces may increase, particularly if teleworking methods are used (see also scenario definition in Section 4).

2.3 Teleworking

Teleworking, or working from home (WFH), is not a new concept either - it dates to the 1980s. Despite the prediction that half of the UK workforce will be working remotely by 2050 (e.g., Baruch 2001), limited technology development has hindered widespread adoption in the past. However, with the rapid development of information and communication technologies (ICTs), teleworking has become more common in Europe, with teleworking and the sharing economy developing in parallel. The COVID-19 lockdowns in 2020-2022 brought about an unprecedented surge in teleworking, with adoption rates reaching levels never seen before in most sectors (See Figure 1).

Figure 1 Working from Home as a Share of Total Employment (%)



Source: own figure based on Eurostat (2023)

These developments have been accompanied by an increase in scientific and grey literature providing an increasing number of concepts, terms and definitions. To structure this breadth of information, we first review the different definitions in Section 2.3.1

Secondly, as sub questions to the overarching RQ, what the effect of sharing economy on energy demand is, we pose five specific questions:

1. What is the impact of teleworking on energy consumption?
2. In which sub-sectors is teleworking feasible?
3. For what percentage of employees is teleworking possible?
4. How does teleworking affect the floor area demand?
5. What is the relationship between the share of employees working from home and the floor area occupation in the long-term?

Answering these questions via literature review forms the basis for modelling the teleworking part of the sharing economy (see Section 4) and identifying research gaps. One relevant gap is the lack of quantitative evaluations in the sharing economy (see also Section 2.1).

2.3.1 Historic Context, Terms, Concepts and Definitions.

In the scientific literature, different concepts of teleworking have been developed to reflect the impact of new information and communications technologies (ICT). The definitions introduced in this section outline the main concepts and demonstrate how they have evolved over recent decades, characterised by rapid and significant changes in technology and work organisation practices.

Early concepts of ‘telework’ and ‘telecommuting’ date back to the 1980s and early 1990s (Messenger & Gschwind, 2016; Nilles, 1975; Toffler, 1980). At that time, telework was understood as home-based work carried out by employees. Considering the abilities of the first ICT generations (early personal computers and fixed-line telephones), the flexibility and mobility to choose the place of work was very limited. Therefore, these early concepts referred to remote but stationary work.

The significant and rapid development of ICT led to the diffusion of cheaper, smaller and increasingly interconnected devices such as smartphones and tablets. At the same time, the emergence of the internet changed and diversified the way in which ICT-enabled work was performed and organised.

Today, *telework/teleworking* is the most prevalent term used in empirical research, in European regulation and in national legislation to refer to diverse, ICT-enabled work forms and arrangements outside employers’ premises. Table 3 provides an overview of the different concepts found in literature, ranging from the well-established concept of telework to the more recent concepts of ICT-based virtual work, mobile virtual work and hybrid work.

Table 3 Terms, concepts and definitions of teleworking used throughout the scientific and grey literature

Concept	Definition	Source
Remote work	Remote work refers to any work which is carried out outside the employer’s premises regardless of the technology used.	Eurofound, 2022

Concept	Definition	Source
Part-time telecommuting	This work arrangement mixes remote-working days with office-based days and was first put in practice in the early 1970s in the USA.	Messenger & Gschwind, 2016; Nilles, 1975
Telework	Telework is any form of organizing and/or performing work using information technology, in the context of an employment contract/relationship, in which work, which could also be performed at the employer's premises, is carried out away from those premises on a regular basis.	ETUC, 2002; Eurofound, 2022
Telework and ICT-based mobile work (TICTM)	TICTM refers to the use of ICT for the purpose of working outside the employer's premises. It comprises all forms of telework but tries to distinguish between working from home or a fixed place (telework) and ICT-based mobile work. The latter term is used in Germany to distinguish home-based telework from a more mobile form of work.	Eurofound, 2022
Smart work or agile work	Smart work refers to a flexible working system that allows workers to work in a convenient and efficient manner free from time and place constraints (anytime, anywhere) using ICT on a network. A similar term, 'agile work', is used in the context of Italy.	Lee, 2016
Flexible working arrangements	Flexible working arrangements are alternative work options that allow work to be accomplished outside the traditional temporal and/or spatial boundaries of a standard workday.	Allen et al., 2015
Virtual work	Virtual work is labour, whether paid or unpaid, that is carried out using a combination of digital and telecommunications technologies. It may produce content for digital media.	Webster & Randle, 2016; Meil & Kirov, 2017
Mobile virtual work	Virtual work that is physically mobile is referred to as mobile virtual work.	Vartiainen, 2006
Hybrid work	This is a work arrangement in which work can be performed partly from the employer's premises and partly from home or other locations.	The term was popularised in the aftermath of the COVID-19 pandemic.

2.3.2 Impact on Energy Demand and Emissions

2.3.2.1 Pre-Covid-19: Review of teleworking impacts

The effect of teleworking on energy demand has been assessed in various studies, with results ranging from positive to negative effects on energy demand and greenhouse gas emissions (Hook et al., 2020; O'Brien & Yazdani Aliabadi, 2020). Reasons for such heterogeneous findings are the generally complex task of assessing its impact, the interactions of the tertiary, residential and transport sectors, and the influence of the regional and temporal scope. Overall, the most relevant and comprehensive studies suggest that the economy-wide energy saving potential of teleworking might only be modest (Hook et al., 2020).

Furthermore, the impact of teleworking on energy consumption and the environment depends on the perspective (Table 4). Previous research shows that impacts occur directly or indirectly, either affecting energy use through embodied energy, disposal of energy, substitution or rebound effects (Hook et al., 2020; Pohl et al., 2019).

Hook et al. (2020) have also identified other high-order effects of teleworking on energy use. These include increases in weakly commuting times due to non-work travel and increased availability of cars, but also a reduction in office energy use including the energy applications of cooling, heating and other uses.

Table 4 Different Perspectives and Mechanisms which Impact Energy Consumption in Teleworking. Impact Mechanisms Indicate the Type and Direction of the Effect (+/-)

Perspective	Impact Mechanism and direction	Relevance for teleworking
Technology perspective	Embodied energy (+)	Energy used to manufacture and operate the ICT infrastructure, including storage and video streaming demands.
	Disposal energy (+)	Energy used to dispose of the ICT equipment for teleworking
User perspective	Substitution (+ or −)	Energy saved by avoiding commuting to the office.
	Direct rebound (+)	Energy consumed in longer commuting trips, owing to the availability of teleworking, encouraging people to take jobs that are further away from home.
	Indirect rebound (+ or −)	Energy used for heating (or cooling) the home during days in which the commuter is working from home.
System perspective	Economy-wide rebound (+ or −)	Energy used and saved in multiple markets owing to economy-wide adjustments in prices and quantities (e.g. investments previously made in the car industry are now redirected towards ICTs).
	Transformational change (+ or −)	Energy used and saved because of far-reaching changes in the spatial structure of societies, including where people live and work.

Source: Hook et al., 2020, Pohl et al., 2019.

2.3.2.2 Covid-19: Telework Prevails

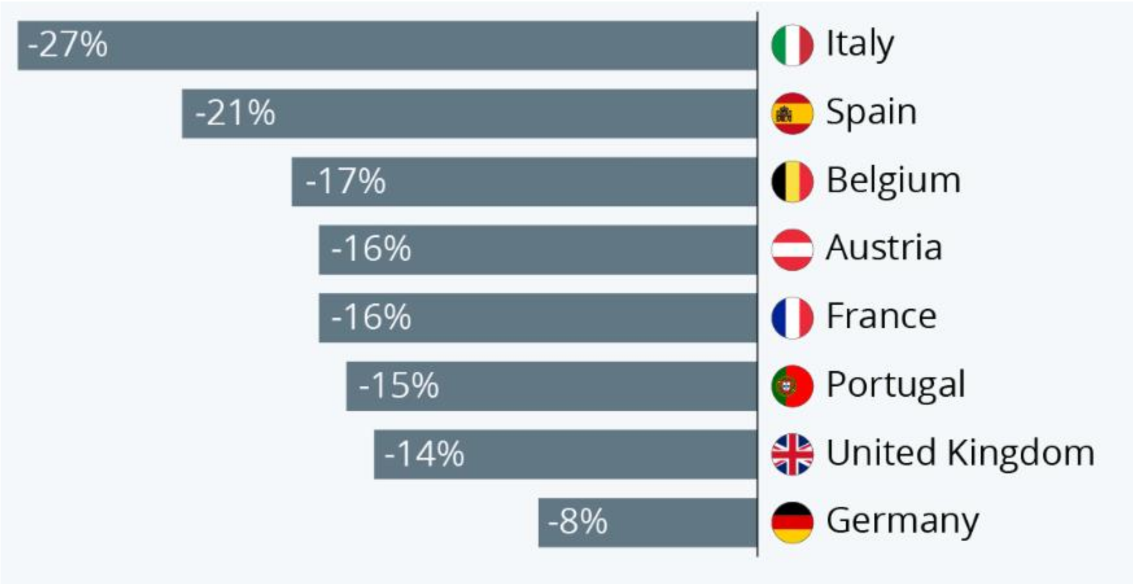
With the global Covid-19 lockdowns, teleworking has gained attention globally and in research. Telework was introduced in almost all professions because many companies had to let their employees work from home. For research, these disruptive events brought about new opportunities to explore the impact of teleworking on energy consumption. Some studies find a decrease in energy consumptions and greenhouse gas emissions (GHGE) in the tertiary sector (Bover et al., 2020; Gaspar et al., 2022; MacWilliams & Zachmann, 2022; Santiago et al., 2021). Factors for this impact were a decrease in the energy consumption in companies and factories (Bover et al., 2020), confirming past research about the contributions of offices to such savings (Hook et al., 2020).

The Covid-19 lockdowns led to a significant decrease in energy consumption in several European countries (Figure 2). For instance, in Spain, the electricity consumption declined between 13.5% (Santiago et al., 2021)[2] to 21% (MacWilliams & Zachmann, 2022). According to preliminary data analyses of EU data, there may have been a decrease of more than 10% of energy consumption during the lockdowns (Figure 3). While these are exceptional figures caused by a pandemic, they might hint towards energy saving potentials from teleworking in the sharing economy, too.

The teleworking potential might be harnessed in various sectors, for instance in the education (Gaspar et al., 2022) and other sub-sectors (see next section). Still, the real potential of teleworking in the sharing economy in the tertiary sector is not yet fully understood and, therefore, we perform a model simulation in this report.

2 In the review time period, electricity consumption was 25,441 GWh lower than the total consumption in the same periods in the previous five years.

Figure 2 Change in Electricity Demand between 2019 and April 2020

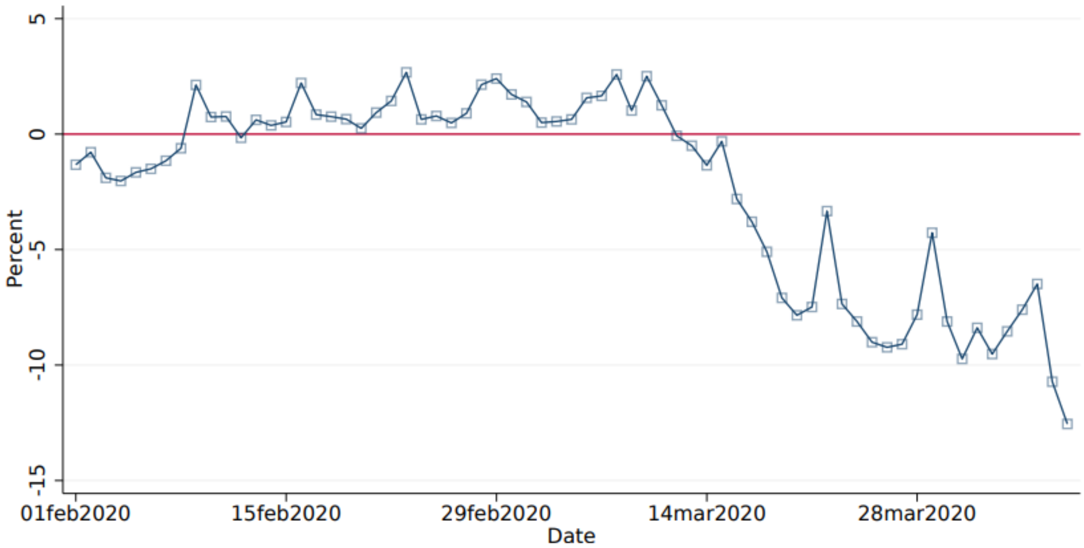


Source: MacWilliams & Zachmann (2022)

It should be noted that the above figures are net values. While the energy demand of the service and industrial sectors, and possible the transport sector (O'Keefe et al., 2016), decreased during Covid-19 lockdowns, household energy demand partly offsets or even surpasses these savings (Shi et al., 2023).

For the case of Spain, Bover et al. (2020) show that the total electricity demand during the first lockdown in 2020 declined in net by 18%. This reflects a reduction of about 29% in the tertiary sector (e.g. from business closures) and an increase of 9.6% in the residential sectors. However, during the second lockdown, the decline in electricity demand was smaller. This is partly due to the less stringent lockdown measures.

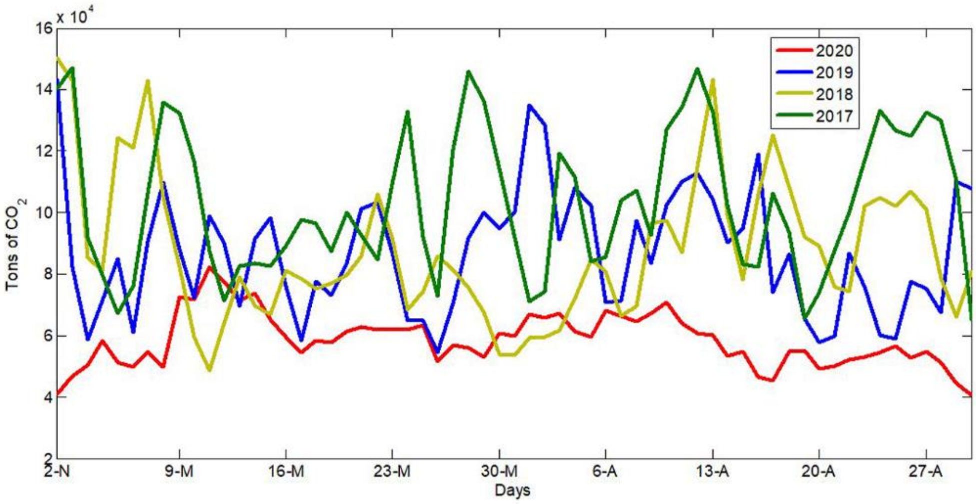
Figure 3 Changes in EU Electricity Consumption



Source: Cicala (2020a)

Energy demand changes due to the lockdowns in 2020 also manifested in GHG emission saving. For the case of Spain, Santiago et al. (2021) found a significant decline of emissions (Figure 4). For example, in the two months of March and April, around 32.6% or 1.7 million tonnes of CO_2 were emitted less than in 2019. The reductions compared to 2018 and 2017 were around 33% and 43%, respectively.

Figure 4 Tons of CO_2 Emitted by the Electricity Generation System in Spain (Peninsula) During March and April from 2017-2019



Source: Santiago et al. (2021)

2.3.3 Employees Working from Home

Telework has inspired research in disciplines ranging from transportation and urban planning to energy, law, sociology and organisational studies. In our examination of this literature, we seek answers to the three questions:

- For which share of employees is WFH possible (Section 2.3.3.1)?
- In which sub-sectors is teleworking feasible (Section 2.3.3.2)?
- What is the effect on overall productivity (Section 2.3.4)?

In particular, knowledge about the share of workers working from home is relevant for the scenario definition in Section 4.

2.3.3.1 Share of Teleworking in the Workforce During the Pandemic

Due to the Covid-19 lockdown in 2020, teleworking prevailed in the EU, with nearly half of all employees working from home (Eurostat, 2023). This change was particularly pronounced in the Netherlands, Finland, Luxembourg and Austria. Similarly, teleworking was adopted outside the EU, for example, approximately half of the workforce in the US was working from home in the summer of 2020 (Brynjolfsson et al., 2020).[3]

According to Eurostat, this increase of the labour force working from home occurred both in countries with (e.g., The Netherlands, Belgium, Finland, Ireland and Luxemburg) and without previous teleworking experience (e.g., Bulgaria and Romania). The largest increase in the share of teleworking in 2020 compared to 2019 was found in Norway (+49 percentage points of the labour force), Italy (+40%), Ireland (+37%) and Lithuania (+35%). The smallest increase in teleworking occurred in Denmark (+5%) and Sweden (+6%). Across the EU-27, the average increase in the proportion of teleworking was 28%. Overall, the share of female employees working from home has been slightly higher than of male ones (see Appendix A1.1.3).

2.3.3.2 Distribution Across Sub-Sectors and Countries

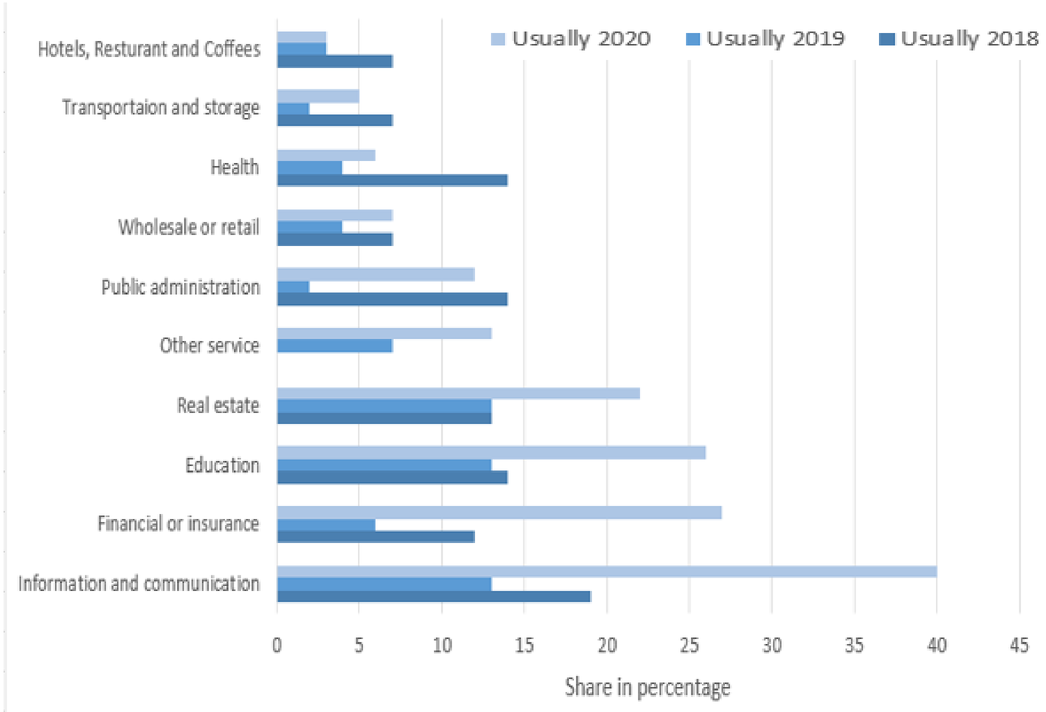
The prevalence of remote work differs significantly between sub-sectors (Bartik et al., 2020a). and is an important factor to consider for our analysis Our review of literature and public data, suggest that in particular the ICT, administration, education, business service and financial sectors have a high potential to adopt teleworking in the future.

Covid-19 had a significant impact on the share of employees working from home and importantly, highlights the abilities of different sub-sectors to rely on teleworking. Before the lockdowns, teleworking was mainly performed in sectors in which employees relied on computers (e.g. ICT or public administration), the data from 2020 (post lock-down) shows that WFH is also possible on a larger scale in other sectors, that previously relied less on the use of computers (Figure 5). The figure also shows that in sub-sectors relying largely on ICT, the share of

3 Based on an economy-wide, representative sample of 25, 000 respondents in the US

employees has increased disproportionately. An opposite effect can be observed in the health care section, for the obvious need of healthcare personnel.

Figure 5 Share of Employees Working from Home Regularly, i.e. on Most Days of the Week. Data Including the Lockdowns in 2020, Comparing the Years 2018, 2019 and 2020 for Different Sub-Sectors

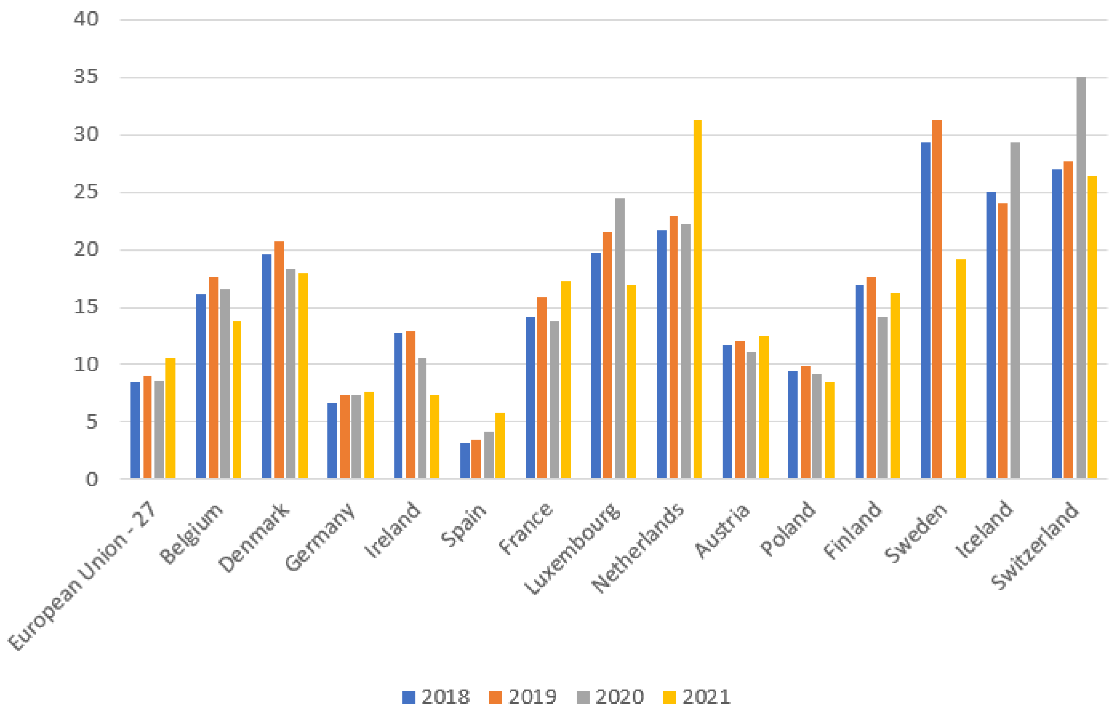


Source: own figure based on Eurostat (2023)

Figure 5 highlights the dynamics for employees who worked form home regularly ("usually"). These dynamics are less pronounced for employees who only sometimes or never worked from home (see Appendix).

Furthermore, the share of employees working from home differs considerably between different countries. According to Eurostat, up to 11% of the employees are working from home as average in Europe. Countries with the highest percentage included Switzerland, Iceland, Sweden, Luxembourg and the Netherlands (Figure 6). The peak share of WFH was either during 2020 or 2021, presumably due to different political situations.

Figure 6 Share of Employees Working from Home in EU and Some Other Countries (Usually)



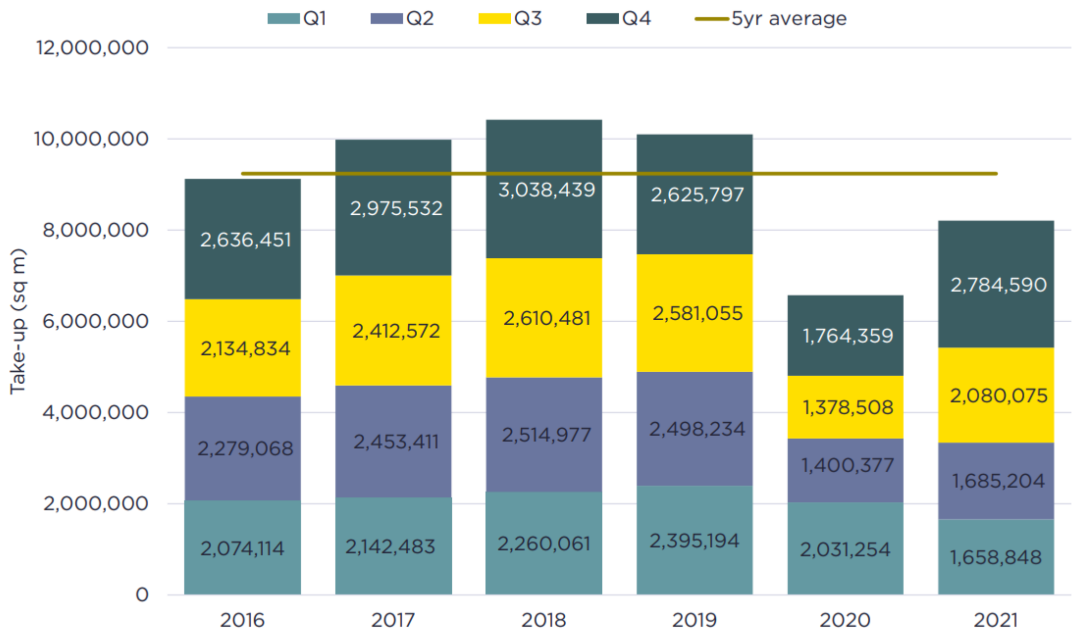
Source: own figure based on Eurostat (2023) and Milasi et al. (2020)

2.3.4 Future Potentials and Effects on the Floor Area Demand

According to Savills Research (2022), teleworking has impacted European office demand. They show a clear change in office demand in Europe over the past 5 years, which is attributed to the mandatory lockdowns and the associated increase in teleworking (see Figure 7). However, whether these effects persist in the long term, remains to be seen as the circumstances were an exception. First, there has been a noticeable increase in demand for office space after the pandemic due to a backlog of companies wanting to rent office space. Second, while some companies have increased workplace flexibility, they may not reduce floor space demand if they compensate by doubling their open-plan working areas.

Office work has changed considerably due to advances of ICT and the ability to work from home. Hence, teleworking might be a model of the future (Bartik et al., 2020b). Stott (2020) envisions that by 2030, remote work in urban areas will strongly increase, potentially affecting 27% of the labourforce. This may lead to a shift to smaller offices, and thus a decrease in office floor area need. This shift has significant implications, as even partial shifts to remote work can decimate the need for large offices (Stott, 2020). Additionally, it is questionable whether small businesses will need distinct offices at all, or whether co-working spaces are a potential model for them.

Figure 7 Floor Area Take-Up in Europe (m²)

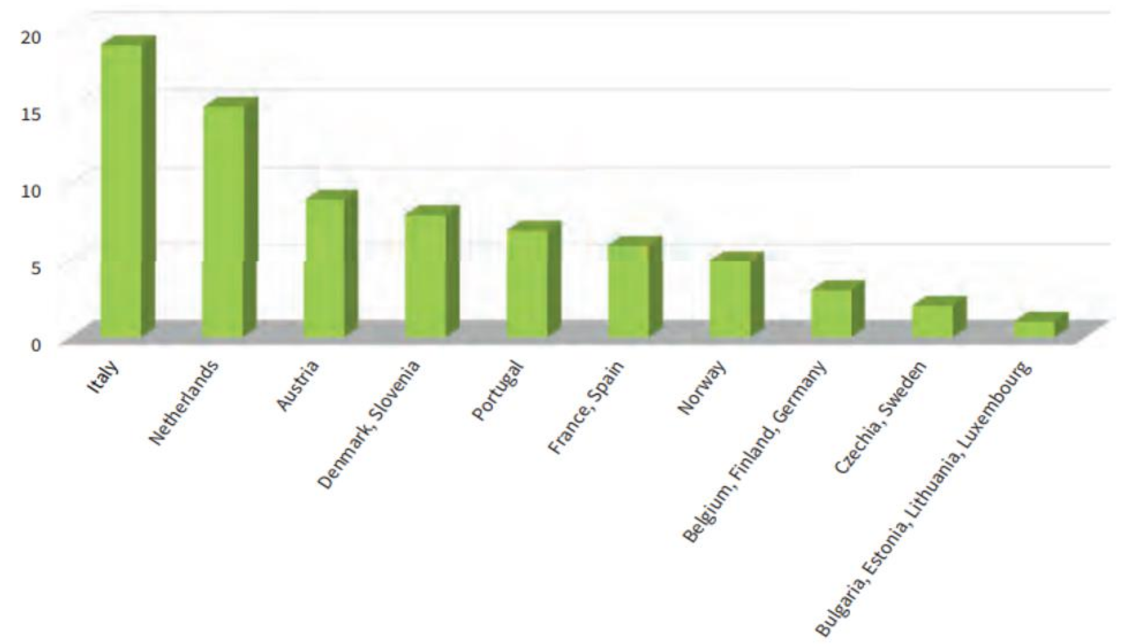


Source: Savills Research (2022)

2.3.5 Policies in EU Member States

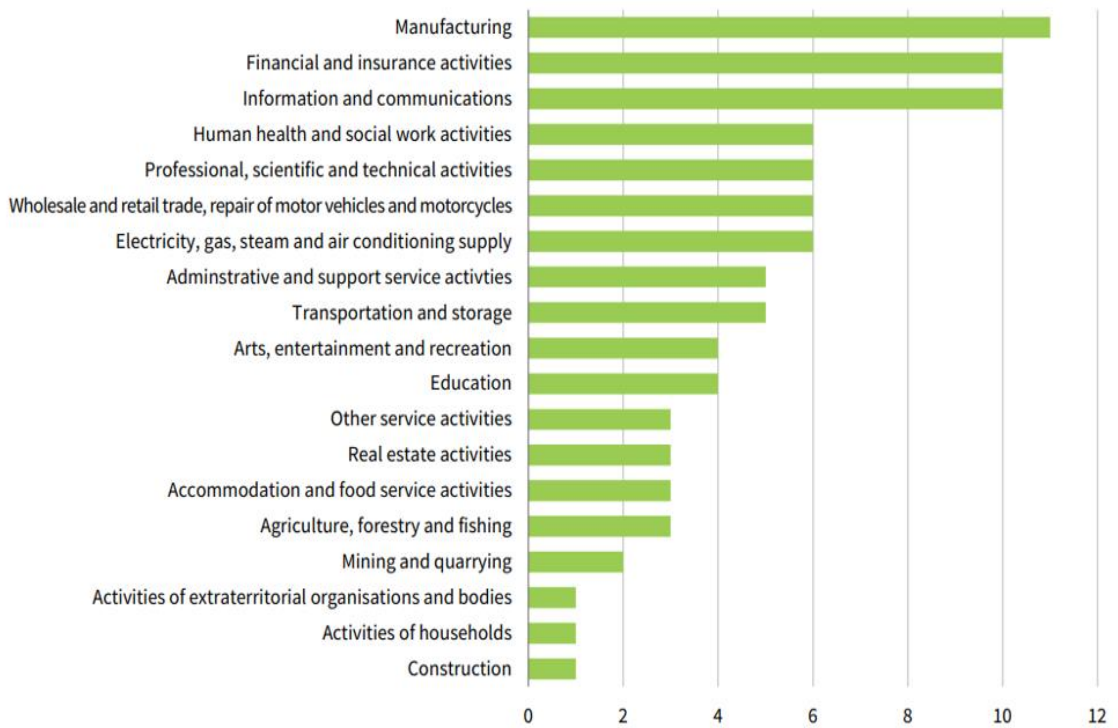
In Austria and the Netherlands, telework is regulated by very broad legislation, leaving key aspects to be regulated by sectoral-level agreements. In Italy, Portugal, Slovenia and Spain, telework saw a pandemic-induced increase in collective agreements at sectoral and company levels that complemented the statutory legislation regarding telework. An overview of polices per country and sector is provided in Figure 8 and Figure 9. This illustrates that most regulatory policies were adopted in Italy, the Netherlands and Austria as well as in the manufacturing, financial and ICT sub-sectors. (A detailed table of policies by country and difference NACE sub-sectors is presented in the Appendix in Table 9.)

Figure 8 Number of Countries that have an Agreement for Teleworking in Each Sector



Source: Lodovici et al., (2021)

Figure 9 NACE Sectors covered by Sectoral Agreements with Telework Provisions



Source: Lodovici et al., (2021)

3. Model Features Overview

In the FORECAST Simulation Framework (Fleiter et al., 2010), labour only reflects the conventional pattern: work takes place in the service sector (or industry, but that is not topic of this WP) and private activities in the residential sector. With new trends towards more flexible life and labour patterns, the model is adjusted in order to take teleworking and shared offices into account.

The energy demand in the FORECAST model is calculated by two different modules. Firstly, the heating demand is based on the parameters of the building envelope and the heating system. Its value depends on the energy reference floor area. The floor area itself is dependent on the number of employees working in that sub-sector and the specific floor area (floor area per employee). Secondly, the electricity demand of electric appliances depends on the installed power and its utilisation rate (effective full load hours). The technical equipment and its usage are differentiated by sub-sector and either depend on the floor area or directly on the number of employees.

The FORECAST model differentiates the following sub-sectors, of which several show a high potential for the adoption of teleworking and shared offices (see Section 2):

- Wholesale and retail trade
- Hotels, cafes, restaurants
- Traffic and data transmission
- Finance
- Health
- Education
- Public offices
- Other services

With the enhancement of the model[4], three different types of work locations have been defined:

- On site, conventional office
- Co-working spaces
- Home-office

The energy demand in offices is dominated by the heat demand for space heating and for domestic hot water as well as the electric demand for appliances including ICT applications. Some demands depend on the floor area, e.g. heating, ventilation and lighting, whereas others depend on the number of employees, e.g. ICT workload.

Table 5 shows the qualitative differences of energy demand depending on the location of work. Shifting from conventional offices to co-working spaces does not have a big impact on energy demand related to the floor area. As it is

4 The details of changes to the concept and code can be found in the newTRENDS report of WP3.

assumed that the size of the floor area in the co-working spaces is similar to the on-site offices and that heating, cooling and technical equipment is comparable, the energy demand in both locations is in the same range. However, the ICT workload is higher in co-working spaces, as data transfer and online meetings are more significant. The same higher ICT-related demand applies for employees working from home. Regarding the energy demand for heating and electric appliances, home workers take profit from synergies regarding space heating and cooling.

Table 5 Qualitative Differences of Energy Demand Depending on the Working Location

Energy demand	Driver	On site office	Co-working space	Work from home
E.g. heating, cooling, ventilation, lighting	Demand depends on floor area	Reference case	Similar to conventional offices	Smaller than in conventional offices, allocated in residential sector
ICT infrastructure, work load	Demand depends on number of employees	Reference case	Higher than in conventional offices	Higher than in conventional offices

In order to calculate the energy demand of different ways of lifestyle regarding the labour patterns, the above-described model is used. In the following Section 4, the assumptions and inputs of the defined scenarios are presented.

4. Scenario Definition

4.1 Overview

In total, six scenarios are analysed, encompassing three different levels of teleworking and two different levels of ICT demand (Table 6). In 2050, the share of employees working from home reaches 25% (Scenario Teleworking 1), 38% (Teleworking 2) and 61% (Teleworking 3), respectively. The share of employees working in co-working spaces is 5%, 8% and 12% for the three scenarios in 2050.

The higher usage of ICT infrastructure is expressed by an ICT infrastructure index that is based on the values of 2020. Cooling measures are modelled explicitly, whereas internal efficiency measures like virtualisation are included in the ICT infrastructure index. For that reason, the ICT infrastructure index rises slower than the expected increase of workload. Compared to 2020, the two ICT scenarios assume a moderate (index=5; ICT1) and high (index=10; ICT2) increase of the ICT infrastructure until 2050.

In the ICT1 scenarios it is assumed that each full time equivalent of a teleworker increases the ICT demand by 30% compared with a colleague in the office. This factor includes ICT demand for data sharing and online meetings of the teleworkers and their on-site colleagues. In the ICT2 scenarios, the additional relative impact of telework is smaller (15%) due to the higher offset of the general ICT demand.

The following sub-sections cover the assumptions in detail.

Table 6 Overview of Scenario Definitions

Scenarios	ICT1 - Moderate	ICT2 - High
Teleworking 1 - Low	**TW1_ICT1** Assumption for 2050: • working from home: 25% • from co-working space: 5% • ICT infrastructure index: 5 • add. ICT demand of teleworker: 30%	**TW1_ICT2** Assumption for 2050: • working from home: 25% • from co-working space: 5% • ICT infrastructure index: 10 • add. ICT demand of teleworker: 15%
Teleworking 2 - Moderate	**TW2_ICT1** Assumption for 2050: • working from home: 38% • from co-working space: 8% • ICT infrastructure index: 5 • add. ICT demand of teleworker: 30%	**TW2_ICT2** Assumption for 2050: • working from home: 38% • from co-working space: 8% • ICT infrastructure index: 10 • add. ICT demand of teleworker: 15%

Scenarios	ICT1 - Moderate	ICT2 - High
Teleworking 3 - High	**TW3_ICT1** Assumption for 2050: • working from home: 61% • from co-working space: 12% • ICT infrastructure index: 5 • add. ICT demand of teleworker: 30%	**TW3_ICT2** Assumption for 2050: • working from home: 61% • from co-working space: 12% • ICT infrastructure index: 10 • add. ICT demand of teleworker: 15%

4.2 Specific Floor Area in the Tertiary Sector

One important parameter for the energy consumption in the tertiary sector is the floor area per employee. Based on this parameter, the electricity demand for lighting or for heating is calculated in the FORECAST simulation.

Figure 10 shows the specific floor area (i.e. the heated floor area) for Germany and different sub-sectors of the service sector. According to these model assumptions, the floor area per employee varies significantly across the different sub-sectors. The specific floor area does not only take the office space into account, but all areas that are assigned to the corresponding sub-sector, e.g. exhibition and storage space in the trading sub-sector or classrooms in the education sub-sector. The lowest floor area per employee is found in the finance and health sub-sectors and the highest area in the fields of trading and education. Across all sub-sectors, we assume a slight increase until 2050 due to the general trend towards larger office areas in the tertiary sector.

There is a relationship between the share of employees working remotely and the floor area in the office, the co-working spaces, and the office spaces in private homes. To represent this relationship, we propose the following set of assumptions:

- Workers choose co-working spaces that have, on average, the same area as their conventional offices.
- The office space in conventional offices is reduced when the share of employees working remotely (either from home or in co-working spaces) passes a certain threshold.

These assumptions are illustrated in Figure 11, which gives a theoretical example. The specific floor area stays constant until it reaches a threshold of the share of employees working remotely. From that value onwards, it decreases proportionally until it reaches a lower limit that cannot be undercut. This lower limit is explained by meeting rooms and other infrastructure that would still be available onsite, even if all employees work remotely.

Figure 10 Specific Floor Area **per Employee working on-site**(i.e. Heated Areas) of the Tertiary Sector for Germany in the Years 2025 and 2050

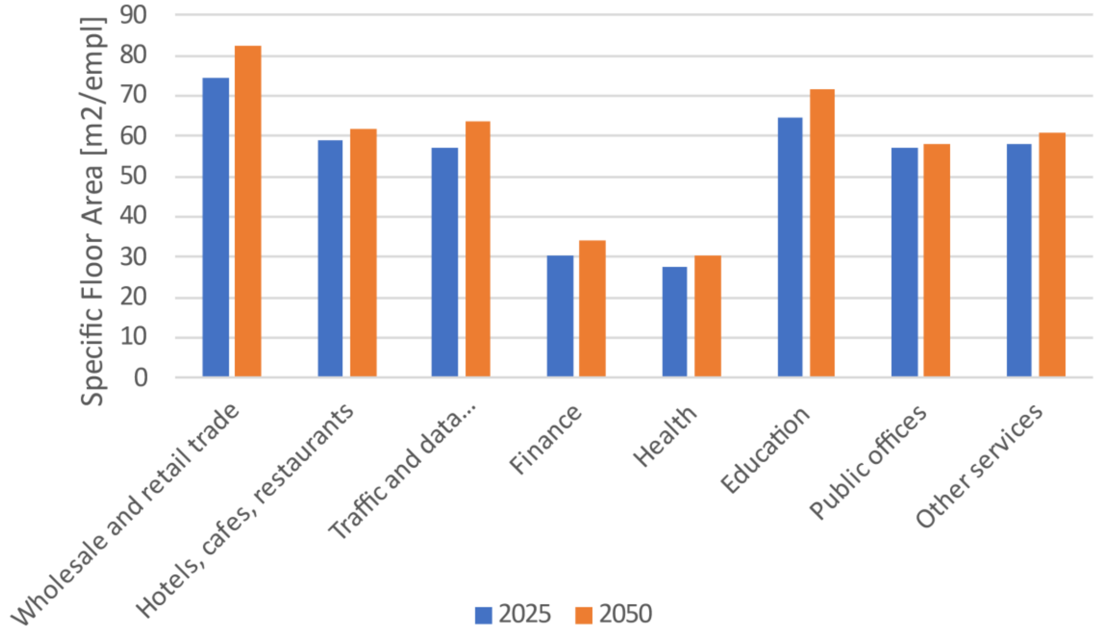
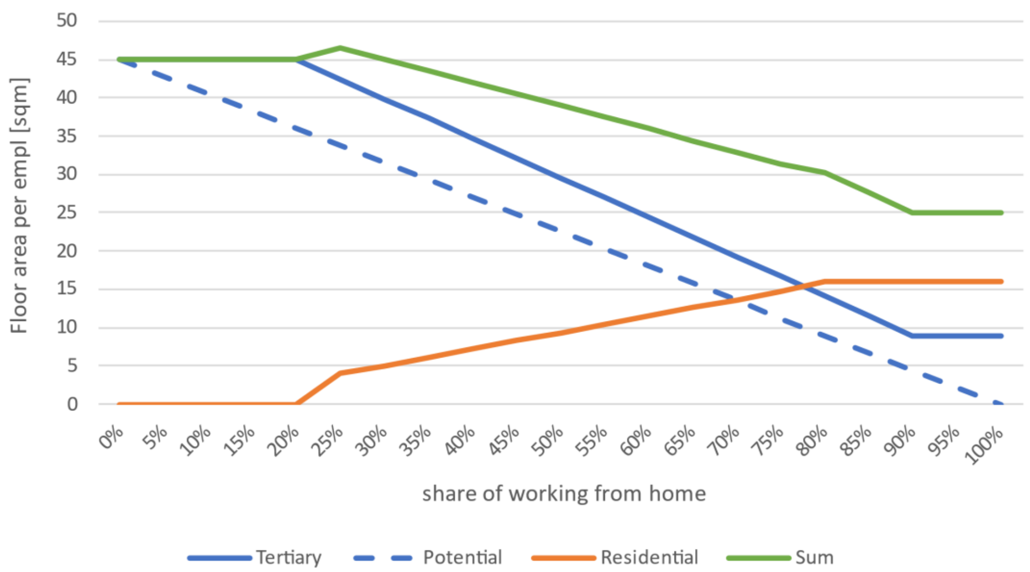


Figure 11 Assumed Relation Between Share of Employees Working from Home and Specific Floor Area (i.e. Heated Areas) per Employee



Source: assumptions by TEP

As the total floor area in the sub-sectors also contains storage, exhibition and sales areas, the share of office space needs to be determined. Only this share could potentially be moved to home office. The assumed factors are listed in Table 7.

Table 7 Assumed Share of Office Space (vs Total Floor Area) in Tertiary Sub-Sectors

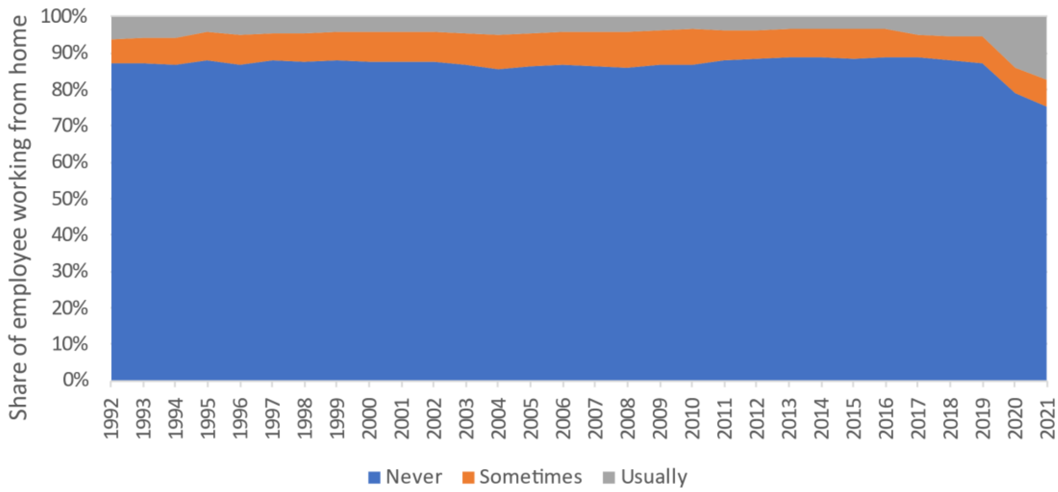
Sub-sector	Share of office space
Wholesale and retail trade	5%
Hotels, cafes, restaurants	5%
Traffic and data transmission (including ICT companies)	85%
Finance	85%
Health	5%
Education	20%
Public offices	90%
Other services	70%

Source: assumptions by TEP

4.3 Employees Working from Different Locations

Eurostat provides a data set on the share of employees working from home, differentiated by country and frequency. Figure 12 shows the data set of Germany. The situation before Covid-19 was quite stable, dominated by a share of employees larger than 85% who never worked from home. Covid-19 changed the picture in the years 2020 and 2021: the number of employees that usually work from home tripled in 2021 compared to 2019.

Figure 12 Share of Employees Working from Home in Germany



Source: own figure based on Eurostat (2023), table LFSA_EHOMP

The basis of analysing the impact of teleworking on the energy consumption in the tertiary sector is the trajectory of the work-from-home share over the whole simulation horizon until 2050. It is generated on the basis of the presented statistical data and scenario assumptions.

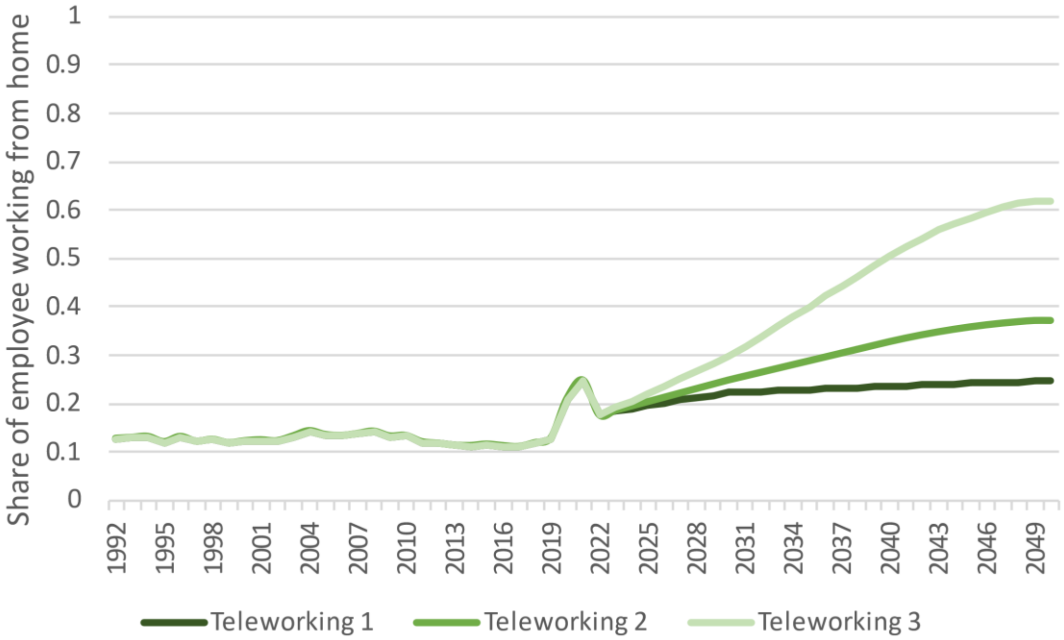
We have defined a multiplicative factor to describe the relative development assumptions of the teleworking share (relative to 2021) in three teleworking scenarios (see Table 8). While all scenarios consider a decrease in work-from-home activities after the Covid-19 lockdown peaks, we expect that the share of teleworking will remain higher than pre-Covid-19 levels, due to increased familiarity among employees and businesses with the form of work (see Figure 13). After 2024, we differentiate the three different trajectories.

Table 8 Scenario Assumptions for Development and Testing of the New Teleworking Module

Scenario	Factor 2030*	Factor 2050*	Description
Teleworking 1 (TW1)	0.9	1.0	This scenario assumes a low share of teleworking: from 2024 onwards, the share of teleworking increases moderately and reaches a value of 90% in 2030, compared to 2021. From then, the development is slowed down due to saturation effects and reaches the level of 2021 again in 2050.
Teleworking 2 (TW2)	1.0	1.5	In this scenario, the share of work from home rises linearly until 2030, reaching again the level of the Covid-19 year 2021. In the following 20 years up to 2050, the share increases to a level of 1.5 compared to 2021.
Teleworking 3 (TW3)	1.2	2.5	Teleworking 3 scenario is defined analogously to Teleworking 2, but its share in 2030 is 1.2 compared to 2021 and in 2050, the factor 2.5.

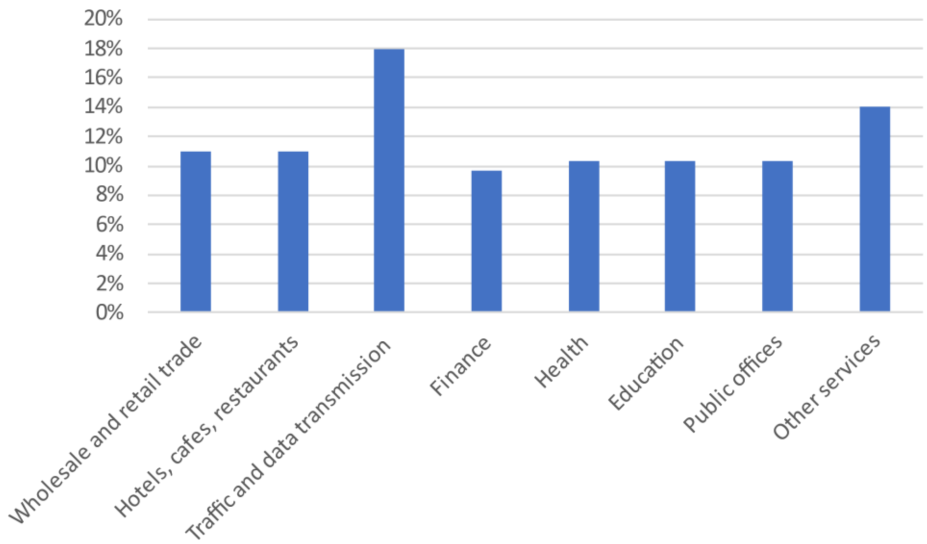
* As compared to 2021

Figure 13 Assumed Trajectory of Share of Office Employees Working from Home by Teleworking Scenarios



In order to model the impact of teleworking on the different sub-sectors separately, differentiated input data is needed. Figure 14 shows a sample of this data, namely the share of employees usually working from home in 2018 in Germany by sub-sector. Employees of the ICT field working in the traffic and data transmission sub-sectors show the highest value.

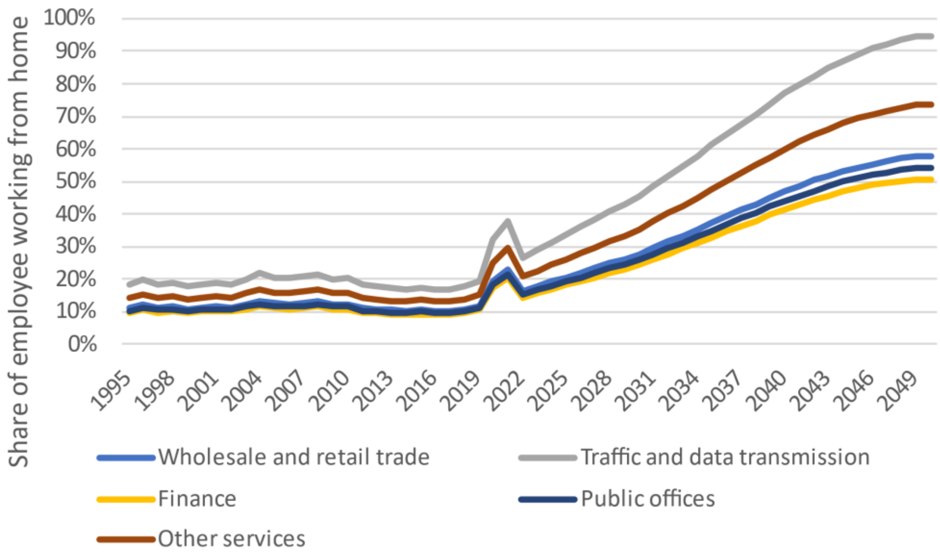
Figure 14 Share of Employees Working Usually from Home in Germany, 2018



Source: own figure based on Eurostat (2023), table ISOC_IW_HEM

This data about the work from home patterns per sub-sector is available for all European countries and is used in this study to split the above generated country-specific trajectory into its sub-sectors. The result of selected sub-sectors is shown in Figure 15 (scenario TW3) based on the example of Germany.

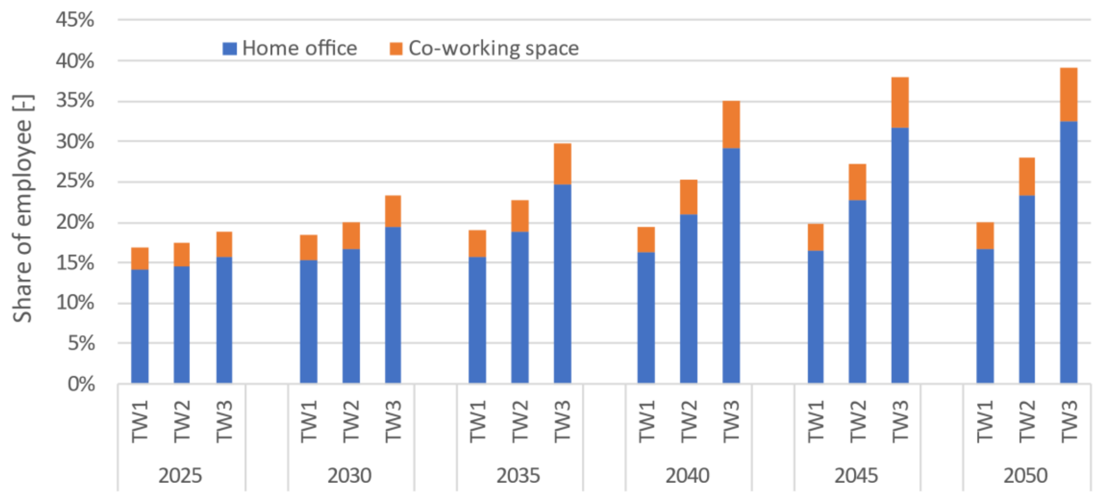
Figure 15 Share of Office Employees Working Usually from Home in Germany Derived from Historical Data and Assumptions of Future Developments in Scenario TW3.



Source: own figure based on Eurostat (2023), table ISOC_IW_HEM

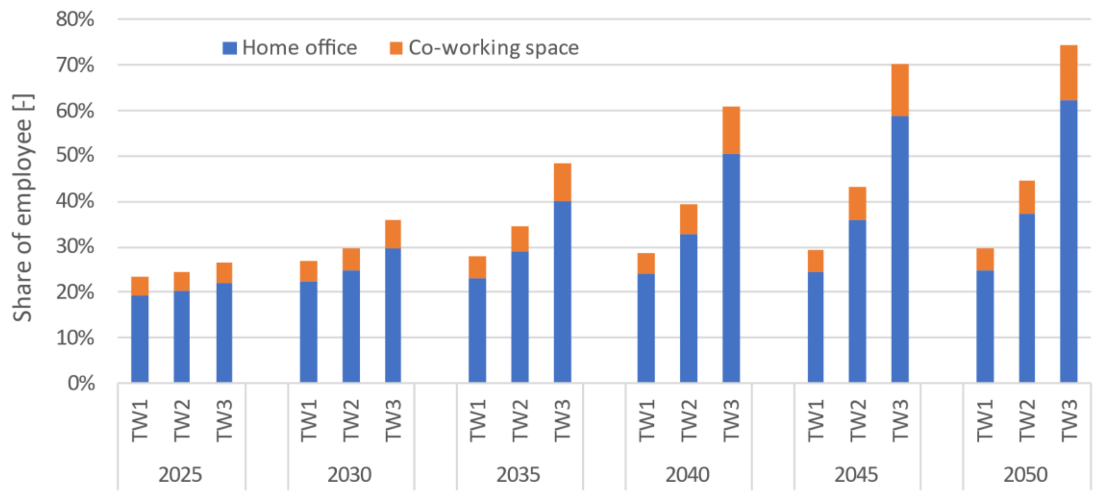
Across all employees, including office and other workers, the share that can work remotely is lower. Figure 16 illustrated the assumed and projected development of the three teleworking scenarios for EU27. The assumptions distinguish between employees working from home and from co-working spaces and cover all sub-sectors of the tertiary sector. We assume that the majority of the teleworkers use home offices and only 16% use co-working spaces.

Figure 16 Share of all Workers Working Remotely, EU27, all Sub-Sectors



A closer look at a selected country and sub-sector shows the country- and sub-sector-specific values. In the example of Germany and an ICT dominated sub-sector (traffic and data transmission), the share starts from a higher starting point and reaches a higher value in 2050. The differences of the three teleworking scenarios are more prominent in this sub-sector than on the average of the whole tertiary sector.

Figure 17 Share of all Workers Working Remotely, Germany, Sub-Sector Traffic and Data Transmission



4.4 ICT Demand

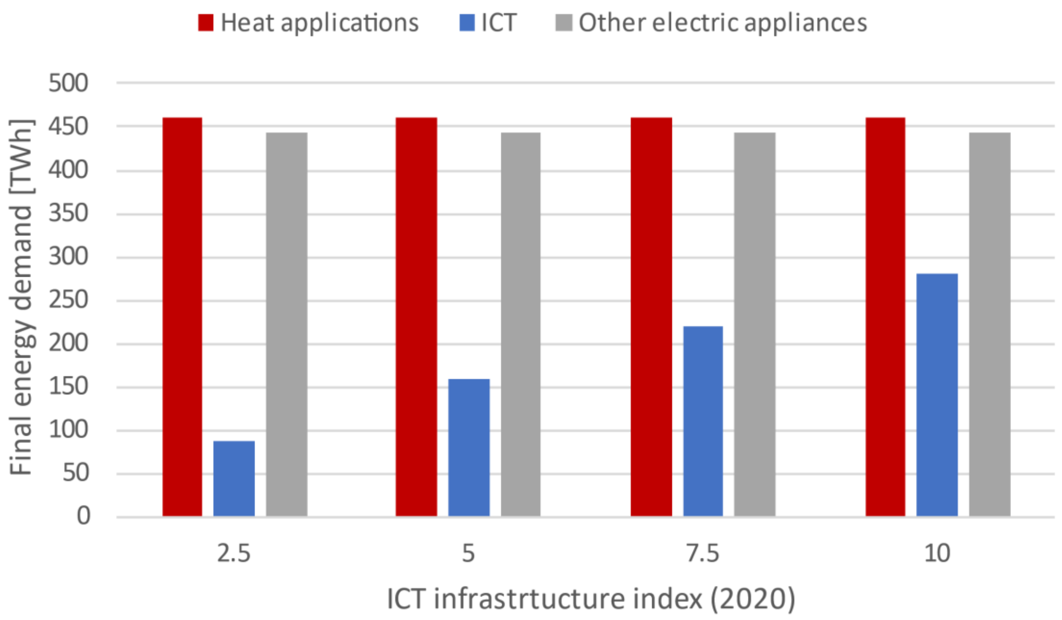
The workload demand of ICT is not an easily tangible term; here, we define it as the installed power of servers. Moreover, the increase of energy demand is decoupled from the ICT demand, as technology improvements in the fields of hardware and software could compensate the rising demand partially. For the future, it is not clear how long the technical development can keep pace with the rising demand.

In FORECAST, the ICT demand is modelled as the installed power of servers. For easier handling, an ICT infrastructure index is introduced, being defined as the increase of the installed IT power compared to the year 2020. IT power includes, among others, the electric power of IT devices such as servers, storage infrastructure, network and communication devices. The power of building technologies to cool server rooms and data centers is considered explicitly. A sensitivity analysis of four different ICT demand scenarios is conducted to analyse the impact on the total energy demand in the tertiary sector.

Figure 18 shows the relationship between the ICT infrastructure index and the energy demand on the tertiary sector in EU27 in the year 2050. The heat applications (space heating, domestic hot water and process heat) and the other, non-ICT appliances are shown for comparison. They are not affected by the shown variation of ICT infrastructure development.

An index of 2.5 means that in 2050 the installed power of servers is 2.5 times higher than in 2020. In this scenario, the ICT energy demand would only be 17% compared to the other electric appliances. An index of 10 means that the energy consumption of ICT in 2050 would reach a level of 55% of the electricity demand of all other non-ICT demands. The rise is not linear, as energy saving options of the peripheral infrastructure reduce the energy demand at the same time. In this report, the focus is set on two ICT scenarios, ICT1 with the index of 5 and ICT2 with the index of 10.

Figure 18 Impact of the ICT Development (Expressed by the ICT Infrastructure Index) on the Total Final Energy Demand in the Tertiary Sector in EU27 for the Year 2050



5. Results and Discussion

In Section 5.1, we provide aggregated results for the tertiary sector. Due to the extensive range of sub-sectors, applications, countries and years, we have chosen to additionally focus on specific examples to illustrate particular and interesting effects. These examples, outlined in Section 5.2, differ regarding sub-sectors, applications and countries. Results are structured according to the scenario definition in Section 4.

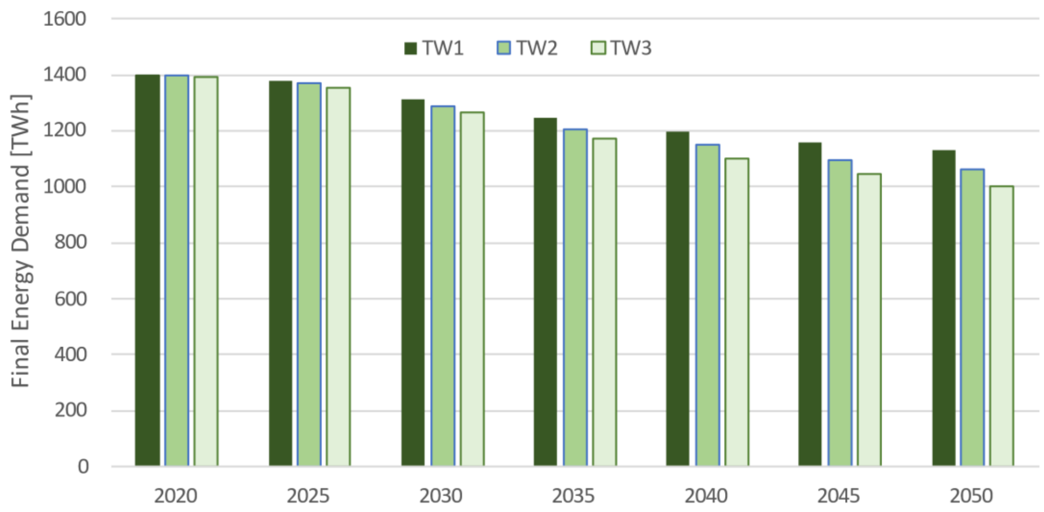
5.1 Results Aggregated Across the European Union

In this section, we provide the final energy demand results for the aggregated demand across all sub-sectors of the European Union, either as combined or distinct effects regarding applications (Sections 5.1.1–5.1.2).

5.1.1 Combined Effects

To investigate the yearly impact of teleworking and shared offices across all sub-sectors, countries and applications, we first focus on the three scenarios with moderate ICT demand (ICT1 with an ICT infrastructure index of 5). In these scenarios, TW1/TW2/TW3, the share of teleworking in 2050 is assumed to be 25%/38%/61%, respectively. Overall, the differences between teleworking scenarios are minor in early years (i.e., 2020/2025) but increase until 2050 (Figure 19).

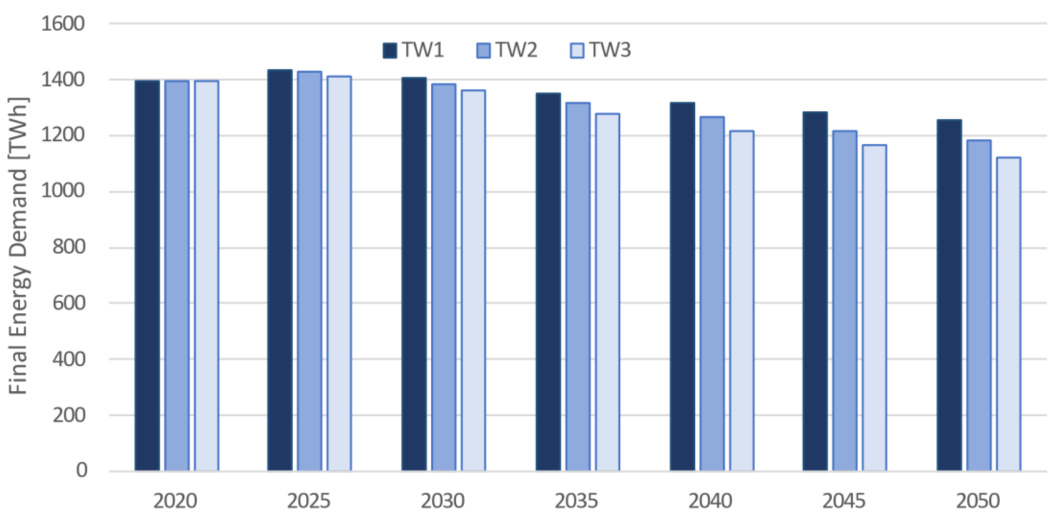
Figure 19 Total Final Energy Demand in the Tertiary Sector for the **Moderate ICT (ICT1) and three Teleworking** Scenarios (EU27, all Sub-Sectors, all Applications)



Total energy demand decreases in all three teleworking scenarios. This is mostly driven by only moderate ICT demand development in combination with more efficient building envelopes and building technologies (such as lighting, ventilation, pumps, etc.), which reduce the heat demand in the respective buildings of the tertiary sector. Teleworking contributes to additional heat demand savings in the long run by reducing the need for office space.[5] Comparing the three teleworking scenarios in 2050, TW2 and TW3 can save 6.1% resp. 11.6% against TW1.

In the ICT 2 scenarios, the resulting energy demand savings are lower than in the previous moderate ICT scenarios because of a higher ICT infrastructure index of 10 (i.e., twice the installed power of servers compared to ICT1; see Figure 19 vs Figure 20). Until 2025, ICT demand contributes to slightly rising energy demand, compensating any building efficiency measures. In the long term, final energy demand decreases, albeit to a lesser extent than in the moderate ICT scenarios. Comparing the three teleworking scenarios in 2050, TW2 and TW3 can save 5.5% resp. 10.5% against TW1.The effects of TW appear smaller in this case, but in absolute terms it is almost identical. Only its relative impact is smaller due to the higher total energy demand.

Figure 20 Total Final Energy Demand in the Tertiary Sector for the High ICT (ICT2) and three Teleworking Scenarios (EU27, All Sub-Sectors, All Applications)



5.1.2 Distinct Effects in Different Applications

Focusing on different energy applications, which contribute to the aggregate results (Section 5.1.1.), illustrates that the final energy demand reduction from

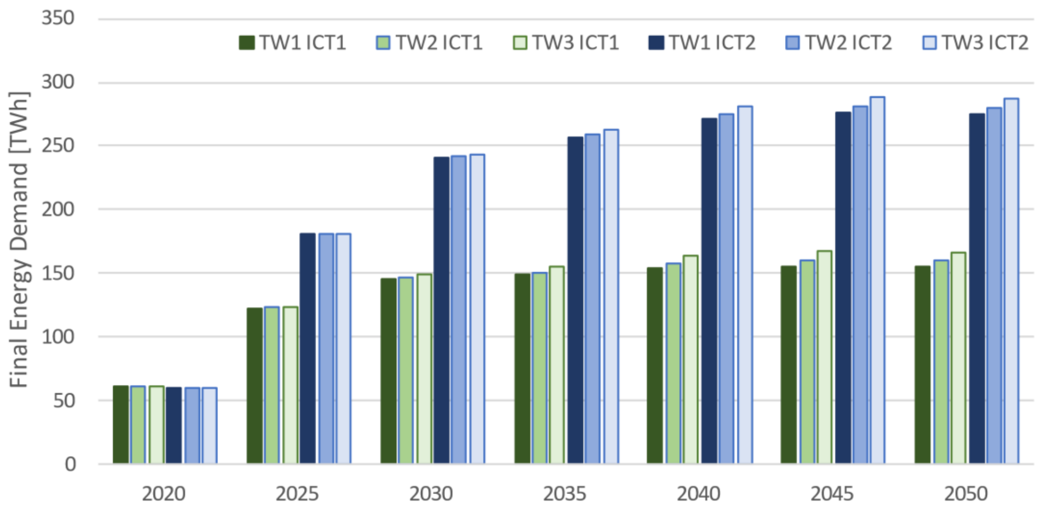
5 Results only apply to the tertiary sector. In this work package, we do not account for a potential increase in residential energy demand. In a follow up development, the residential module of FORECAST should hence be adjusted Furthermore, in an upcoming scientific paper (WP7.3), the residential sectors will be considered.

heat and non-ICT electric applications are compensated for by an increase of ICT demand.

Firstly, for ICT applications (Figure 21), the additional energy demand caused by teleworking is much smaller than the effect of doubling the ICT infrastructure index. While in the high ICT scenarios, the final energy demand until 2050 nearly doubles (compare difference blue to green bars), the effect of telework is orders of magnitude smaller (compare differences between the shades). For instance, in 2050, higher teleworking (TW3 ICT1) only adds about 12 TWh, while higher ICT demand (TW1 ICT2) adds about 120 TWh compared to the demand of TW1 ICT1.

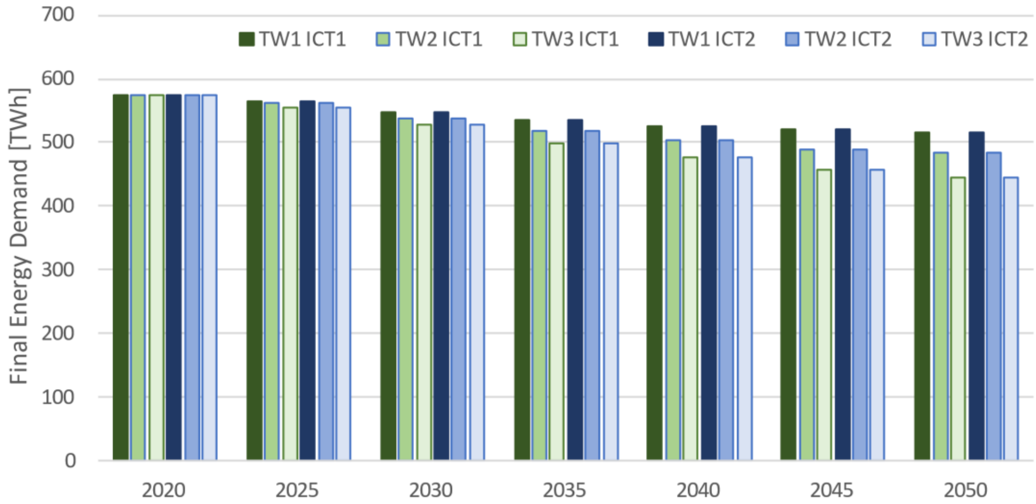
A generally higher ICT demand caused by video calls and cloud computing covers already many applications that are needed in conventional, home and shared offices. Therefore, a higher development of ICT application affects all employees, and the additional ICT demand of teleworkers does not rise disproportionally. Hence, the contributions of teleworking are small and homogenous across both ICT scenarios.

Figure 21 Demand for ICT Applications, EU27, all Sub-Sectors in the Tertiary Sector. Green bars denote ICT1, blue ICT2. Shaded bars represent teleworking.



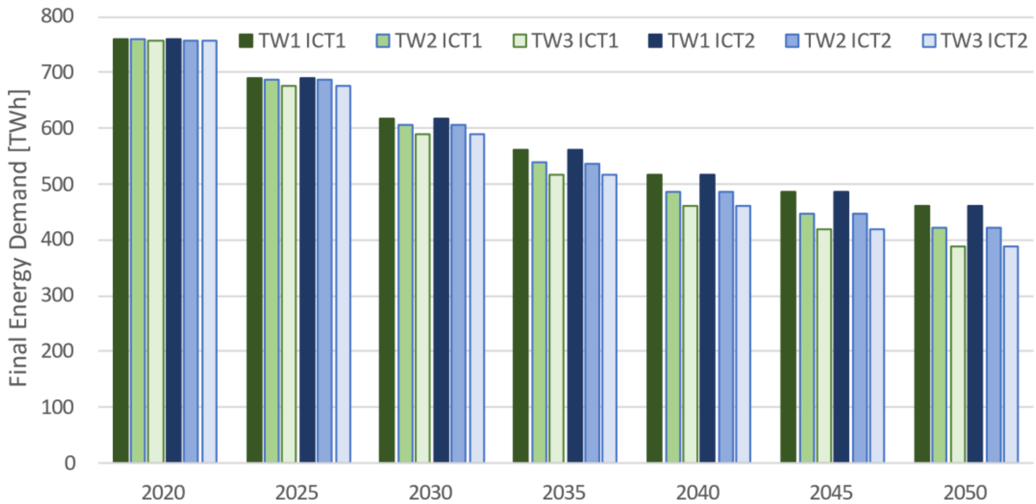
Secondly, the electric demand for non-ICT applications related to the on-site office space decreases with higher shares of teleworking (Figure 22). Comparing the demand of the three teleworking scenarios in 2050 shows that demand is reduced by 6% and 14% (resp. by 33 and 71 TWh) for both ICT scenarios.

Figure 22 Demand for Electric Appliances without ICT and Heat Applications, EU27, all Sub-Sectors in the Tertiary Sector



Thirdly, teleworking reduces the energy demand for space heating and domestic hot water in the on-site offices (Figure 23).[6] This reduction increases the effect of the building efficiency measures and is caused by the higher share of employees working from home. In 2050, this reduction amounts to 9% and 16% (resp. by 41 and 72 TWh) for both ICT scenarios.

Figure 23 Demand for Space Heating and Domestic Hot Water, EU27, all Sub-Sectors in the Tertiary Sector



6 The demand for process heat is not included in the chart, as this part is independent of the office work.

5.2 Selected Results

5.2.1 Final Energy Demand in the Sub-Sectors

The impact of teleworking on the different sub-sectors of the tertiary sector varies significantly. The reasons are that the share of employees who telework is different across the sectors and that energy demand for these sub-sectors varies, depending on the total floor area, the share of office floor and the importance of lighting e.g., in shops and supermarkets. This finding is in line with the insight from the literature review (see Section 2.3.3.2).

Figure 24 describes the final energy demand of the eight sub-sectors in the year 2050. For easier comparison, two of the six scenarios are selected: "low" denotes the scenario with a low share of teleworking and low ICT demand (i.e. TW1 ICT1) whereas "high" stands for the scenario with highest teleworking and ICT activity (i.e. TW3 ICT2). The figure denotes the shares of space heating and domestic hot water (Heating), ICT-related demand (ICT), and other electrical appliances and building technologies (Other el. appliances) on total energy demand. Process heat is not included, as it is not affected by teleworking activity.

Comparing the sub-sectors shows the different magnitudes of energy demand for heating, which, on average, is defined by the floor area of the sub-sector. The non-ICT electric demand (Other el. appliances) is dominated by lighting, which is especially significant in the trading and gastronomy sub-sectors.

In all sub-sectors, the ICT demand almost doubles (factor 1.91). This is due to combination of different factors, namely a doubled ICT infrastructure index, ICT efficiency measures and the contribution of teleworking. The highest increase occurs in the traffic and data transmission sub-sector with a factor of 1.97 and the lowest in education sub-sector with a factor of 1.73. The average of all sub-sectors is 1.85.

Figure 24 Final Energy Demand in **EU27** in 2050 for the Scenario with low Teleworking and low ICT Development against the Scenario with high Teleworking and high ICT Development in the Tertiary Sector

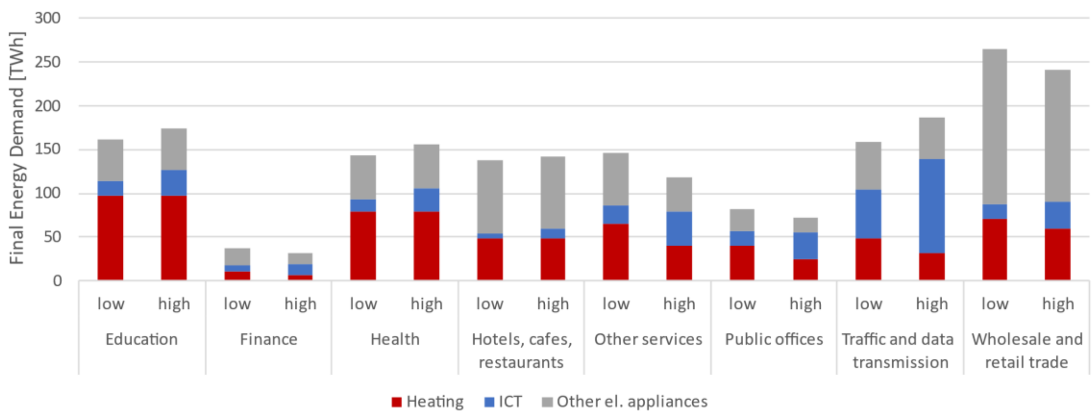
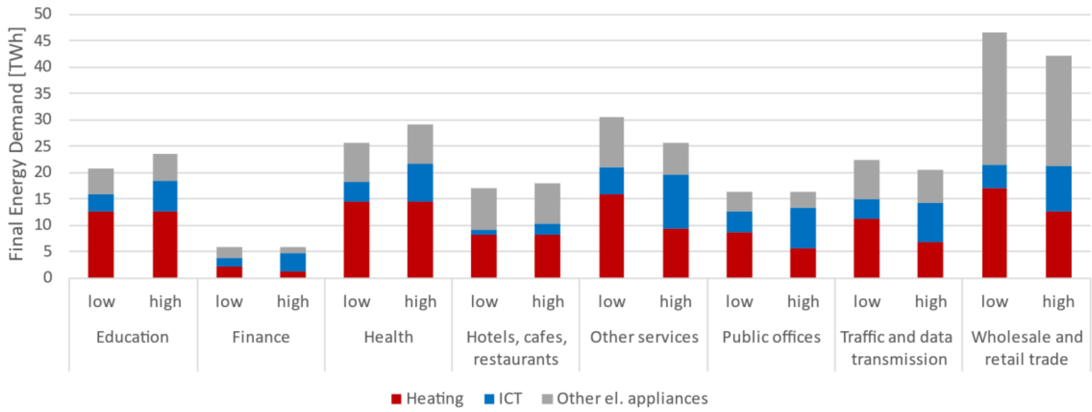


Figure 25 highlights the final energy demand of the eight sub-sectors for Germany. The difference of the ICT demand between the two selected scenarios in 2050, on average, almost doubles by a factor of 1.91 and thus is marginally higher than in EU27. The specific factors vary slightly, in education the increase is lowest with 1.84 and highest in traffic and data transmission with a factor of 1.95. The small difference can be explained by the different efficiency measures and different development in these sub-sectors (i.e., number of employees) in Germany compared to the EU27 average.

Figure 25 Final Energy Demand in **Germany** in 2050 for the Scenario with low Teleworking and low ICT Development against the Scenario with high Teleworking and high ICT Development in the Tertiary Sector



5.2.2 Floor Area Development in the Sub-Sectors

Figure 26 shows the development of the absolute floor area across the different sub-sectors in the context of little teleworking activity (TW1). In several subsectors, our simulations suggest a considerable decline of the floor area demand, for instance in trading. In the long run, an increasing share of employees working from home will lead to a decrease in office floor space in these subsectors.[7] However, in subsectors with limited WFH possibilities, such as Health and Education, the floor area strongly increases.

With higher teleworking activities (TW2 and TW3), the reduction of floor area demand continues in subsectors that allow for a higher share of teleworking, such as traffic and data transmission, public offices and other services (Figure 27 and Figure 28). In contrast, the sub-sectors Health and Education remain unaffected.

These heterogenous trends across the sub-sectors are driven by differences in the underlying drivers, namely the number of employees, specific floor area per employee and share of teleworkers able to WFH. Furthermore, demographic and macro-economic developments in the EU-27 increase the floor area need in the tertiary sector, thus partly compensating any teleworking-effects.

7 The increase of the floor area in private homes is not in the scope of this study but will be analysed in the cross-sectoral simulation of newTRENDs' WP 3.

Figure 26 Floor Area per Tertiary Sub-Sector in EU27 for low Teleworking Scenario (TW1)

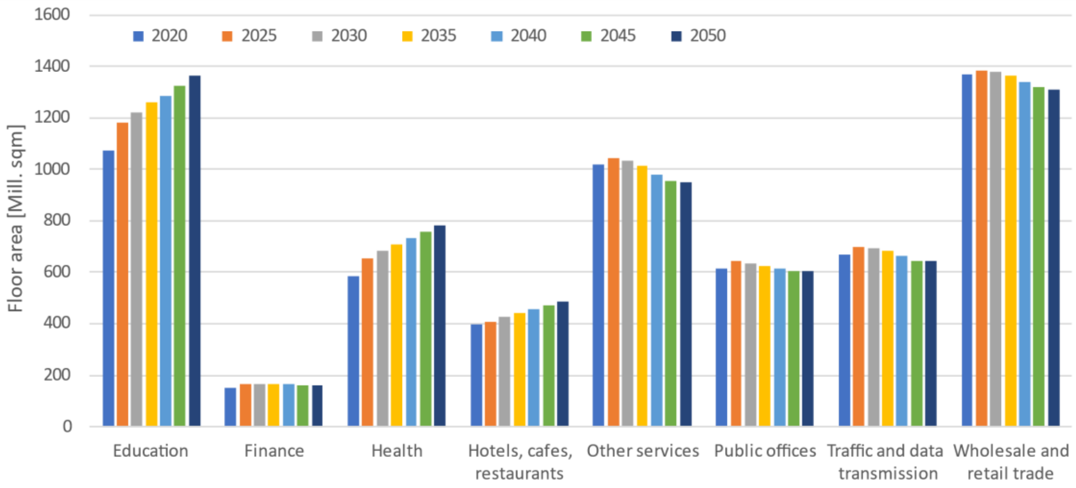


Figure 27 Floor Area per Tertiary Sub-Sector in EU27 for Moderate Teleworking Scenario (TW2)

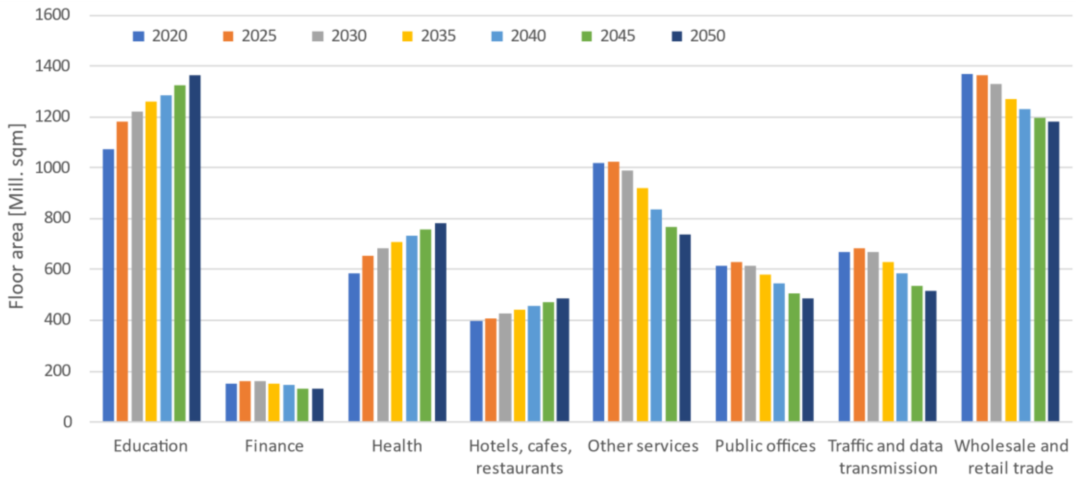
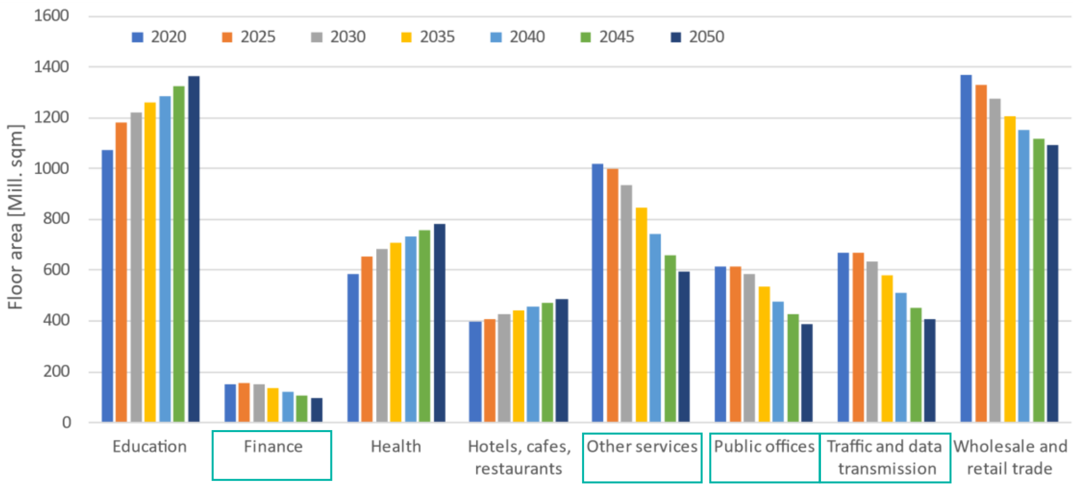


Figure 28 Floor Area per Tertiary Sub-Sector in EU27 for high Teleworking scenario (TW3). Labels in Boxes Denote Sub-Sectors with Decreasing Areas



5.2.3 Impact on Different Energy Applications in Different Countries

This section sheds light on the impact of the different teleworking and ICT scenarios on the different energy services in the tertiary sector. Figure 29 shows the final energy demand of the EU27 in the year 2025 by energy application. Most prominent is the energy demand for space heating. The impact of teleworking is very small, as this labour pattern is not very prominent in 2025. A comparison of these numbers with the situation in 2050 (Figure 30) reveals the growing impact of teleworking.

Furthermore, the insulation of the building envelopes will be improved and, in general, the heat demand is significantly lower in 2050 compared to 2025, whilst other applications such as room air conditioning, ventilation and building services, ICT and other electric appliances increase their demand and diffusion (potentially offsetting efficiency improvements). Except for ICT applications, teleworking activity reduces the demand in all other applications. As seen in Section 5.2.1, which focused on the sub-sectors, the demand between the scenario TW1 ICT1 and TW3 ICT2 almost doubles in 2050.

Figure 29 Final Energy Demand in **EU27**, all Tertiary Sub-Sectors by Energy Application in Year 2025

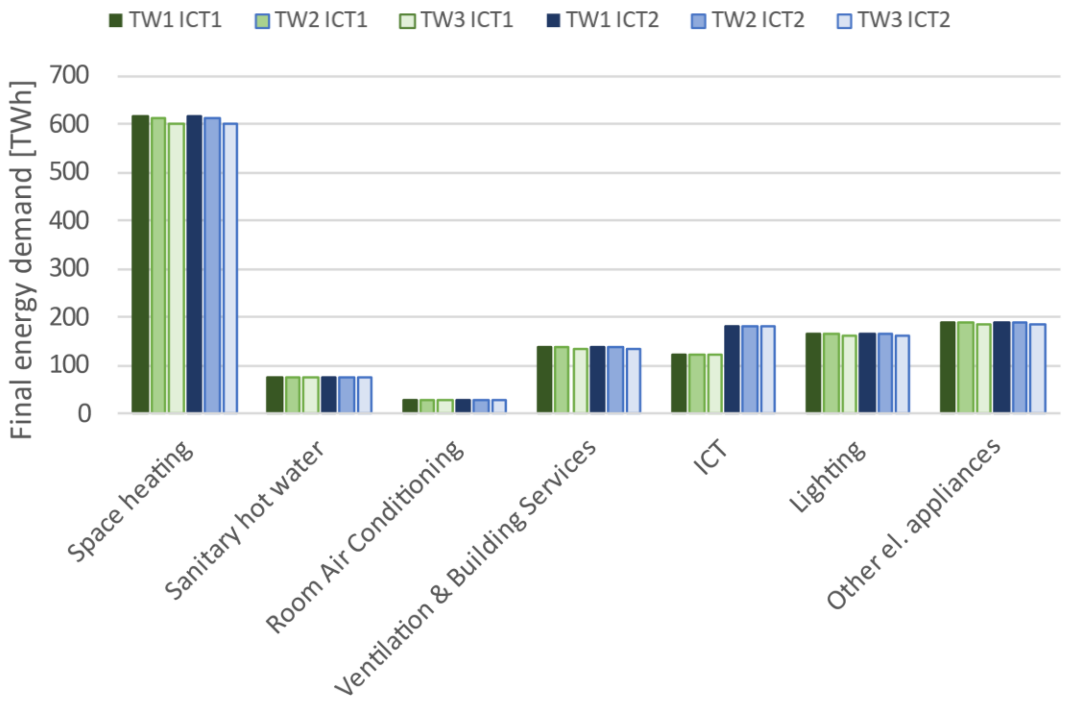


Figure 30 Final Energy Demand in EU27, all Tertiary Sub-Sectors by Energy Application in Year 2050

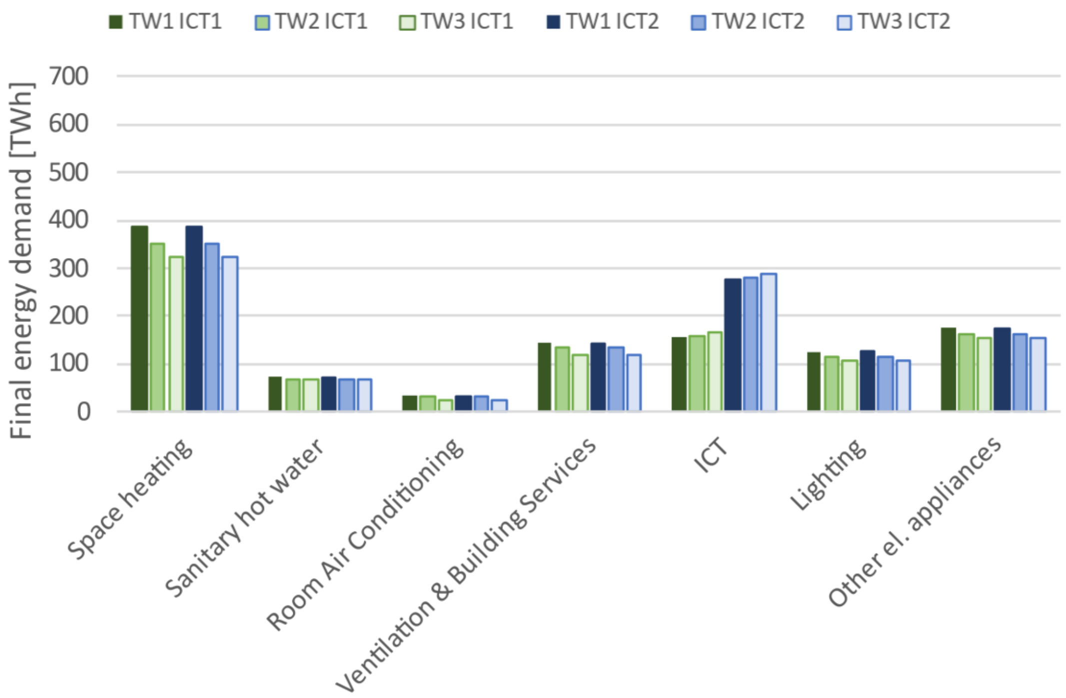


Figure 31 and Figure 32 focus on Germany. Compared to the situation of the EU27 aggregate, the dominance of space heating is more pronounced due to the climatic conditions. For the same reason, air conditioning and ventilation and building services play a minor role. On the other hand, the reduction of heat demand is more prominent than in the EU27. Analogue to the EU27 situation, teleworking generally reduces the demand for energy of all energy applications except for ICT.

Figure 31 Final Energy Demand in **Germany**, all Tertiary Sub-Sectors by Energy Application in Year 2025

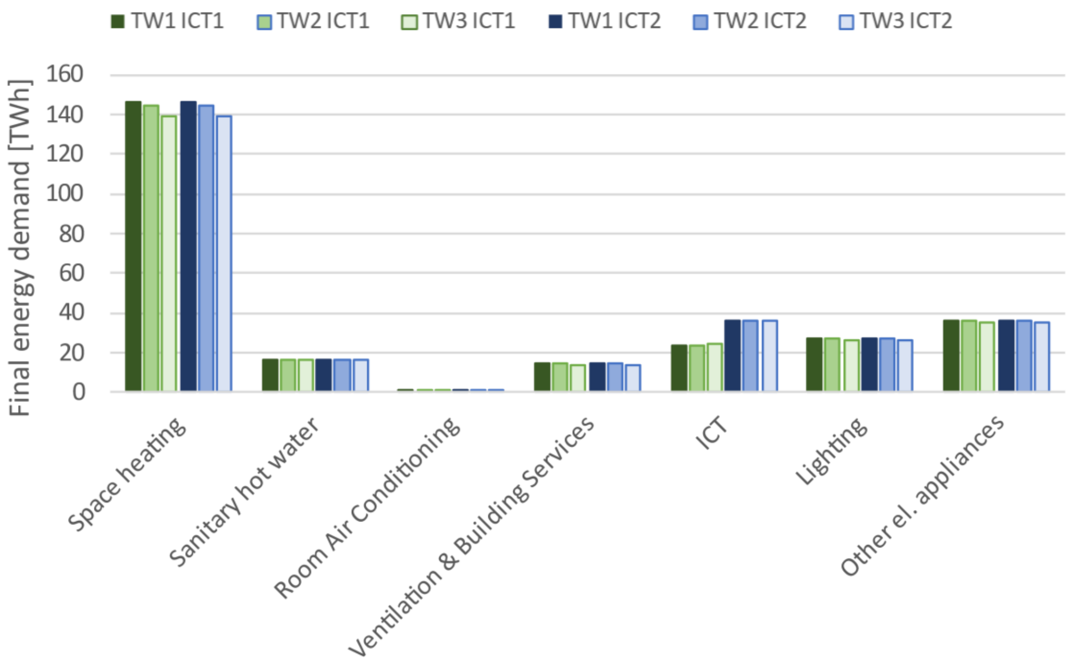
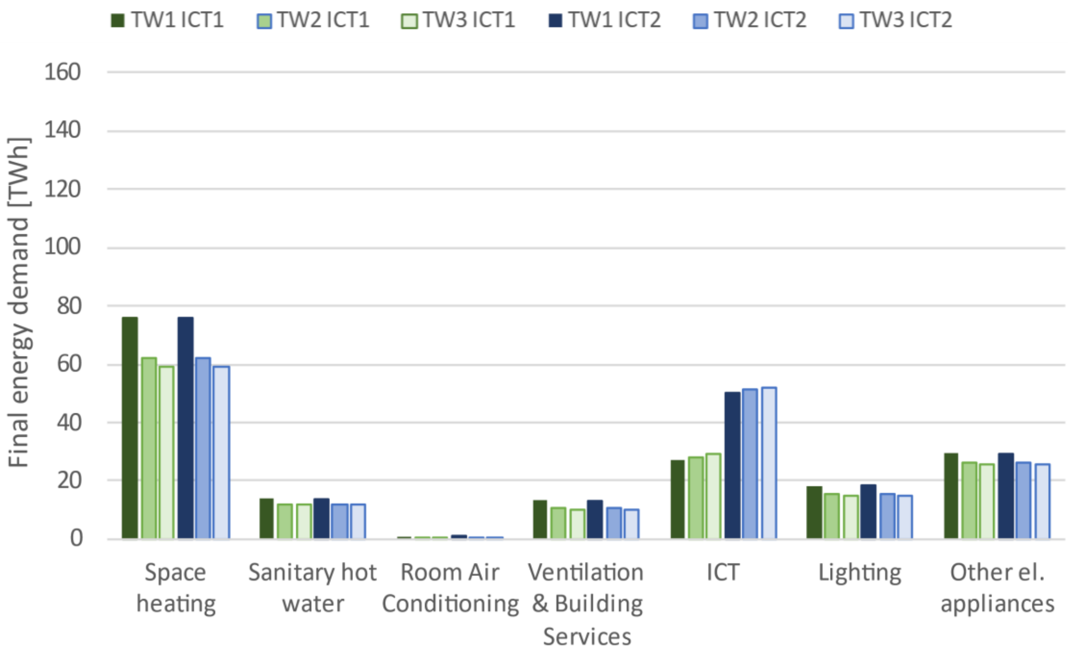


Figure 32 Final Energy Demand in **Germany**, all Tertiary Sub-Sectors by Energy Application in Year 2050



Greece is selected as a third case study, due to its different climatic conditions and diffusion rates of ICT applications. Figure 33 and Figure 34 show the lower importance of heat applications, but a higher share of air conditioning and ventilation services. In 2050, the difference of ICT demand in the lowest (TW1 ICT1) and highest scenario (TW3 ICT2) almost doubles, but due to the ICT development, energy demand rises at a slower pace than in Germany or the EU27 aggregate. This effect can be seen when comparing the ICT demand of a specific scenario in 2025 and 2050.

Figure 33 Final Energy Demand in Greece, all Tertiary Sub-Sectors by Energy Application in Year 2025

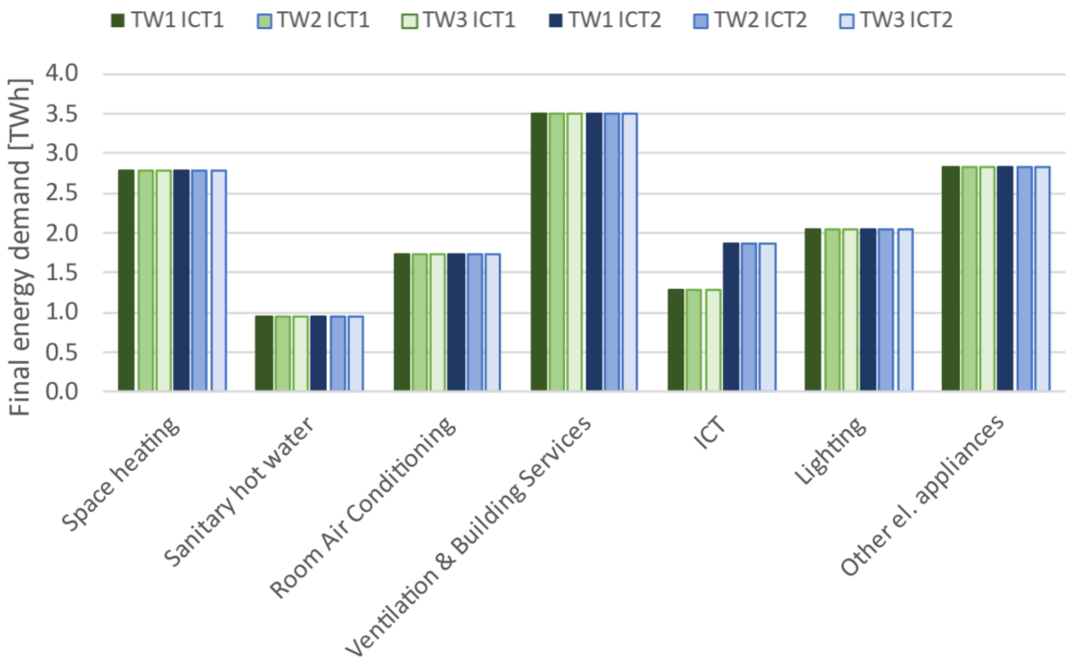
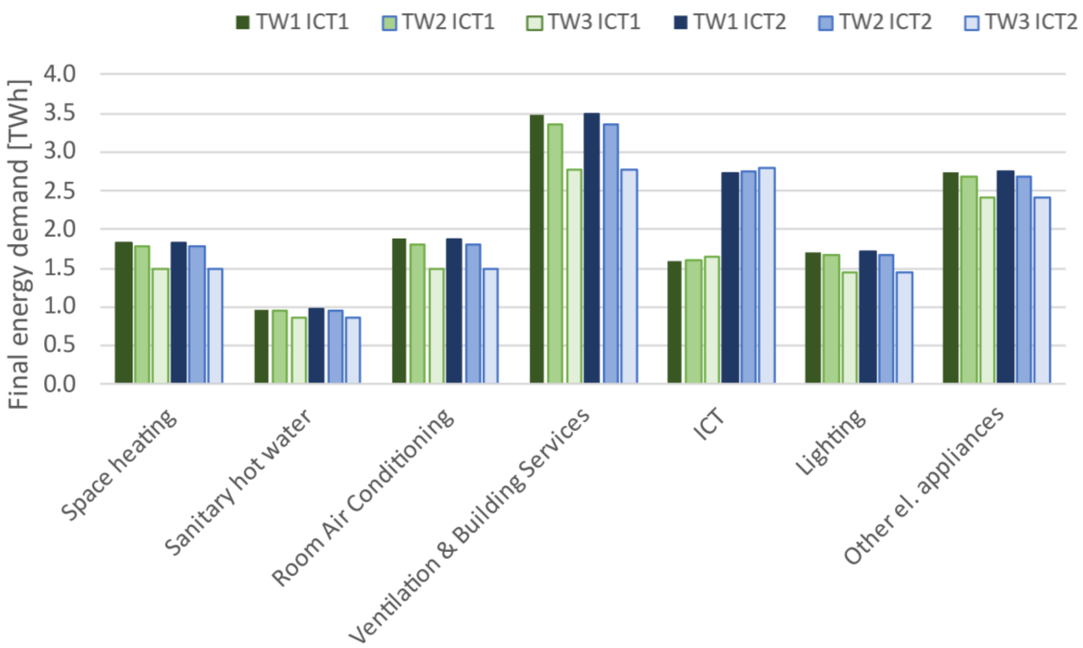


Figure 34 Final Energy Demand in Greece, all Tertiary Sub-sectors by Energy Application in Year 2050



5.3 Limitations

While our study provides a detailed analysis of the effects of the shared economy, teleworking and shared offices in the tertiary sector, some caveats exist, which provide opportunities for future research.

Most importantly, the scope of this study lies on the tertiary sector. Therefore, our results do not reflect the additional demand in the residential sector or the savings in the transportation sector. Specifically, there is a need to estimate the effects on floor area and final energy demand resulting from the shift of labour to the residential sector, as well as the impacts on commuting patterns.

We recommend that future model-based studies build upon our results and educated assumptions on the relationship between working from home and the floor area developments (Section 4.2). A first step in this direction is the cross-sectoral analysis in WP3 of the newTRENDs project, which expands the scope by the transportation sector.[8]

Furthermore, an estimation of greenhouse gas emissions resulting from the shared economy is still missing but will be essential in the context of climate change mitigation.

Overall, our research focuses on important aspects of the shared economy, namely teleworking and shared offices. Future research should explore other aspects of the shared economy, such as the differences between owning, renting and sharing in e-commerce and transportation, or the impacts on tourism and catering services.

8 General trends illustrated in WP3 may differ due to different modelling assumptions.

6. Conclusions

The purpose of this study is to address the gap in quantitative research on the impact of the sharing economy on final energy demand. To achieve this aim, we have enhanced the existing FORECAST simulation framework as part of the newTRENDs project. Due to the nature of FORECAST, we place an explicit focus on the sharing economy in service sector buildings, namely the new trends of changing working patterns and their facets of teleworking such as co-working spaces and home offices.

The impact of teleworking on the energy demand in the tertiary sector and its office spaces is threefold. Firstly, teleworking likely decreases the floor area on site, which, in the long run, will result in a reduced heat demand of office spaces. The additional heat demand in private homes and changes in the commuting behaviours are not scope of this study. To derive the net effect of teleworking, future studies should expand the scope to the residential and transport sectors.

Secondly, the electric consumption of ICT applications contributes to a rising energy demand due to teleworking activity. This demand increase is relatively higher in a scenario of generally low ICT demand. In a scenario of high ICT demand, the additional teleworking plays a minor role. In the latter case, it is assumed that both the on-site employees and the teleworkers use data centre-based applications regardless of their location. Finally, we considered the energy demand of other electric appliances and building technologies such as lighting and ventilation. In the tertiary sectors, this demand will be reduced if employees work in their private homes.

The main results illustrate the simulated energy demand in the tertiary sector of EU27. Although the entire period between 2019 and 2050 was simulated, the focus is set on the year 2050, as it is assumed that the share of teleworking and of ICT demand development is steadily rising. 2050 is taken as a blueprint for modern lifestyle regarding these modern working patterns.

We here analyse six scenarios, which are a combination of three variations of different extents of teleworking and two variations of increasing ICT demand. Defining the future trajectory of the electric demand of ICT applications is challenging, due to lacking data and the volatile and uncertain development. Nevertheless, the results show that the absolute energy savings caused by teleworking are not impacted by the general ICT demand, but the relative impact of the additional teleworking ICT demand shrinks with higher general ICT demand.

The energy balance of teleworking is positive, in the sense of reducing energy demand. On the one hand, the ICT demand is increased by 5 to 12 TWh in EU27, on the other hand, the demand for space heating and other electric appliances in the tertiary sector declines by 74 to 143 TWh in the corresponding energy services. In total, the analysed teleworking scenarios can reduce the total final energy demand in EU27 by 69 to 131 TWh. Relative to the total energy demand in the tertiary (service) sector, that corresponds to -6% to -12 % in a moderate ICT scenario or to -6% to -11% in a high ICT scenario.

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A.1 Appendix

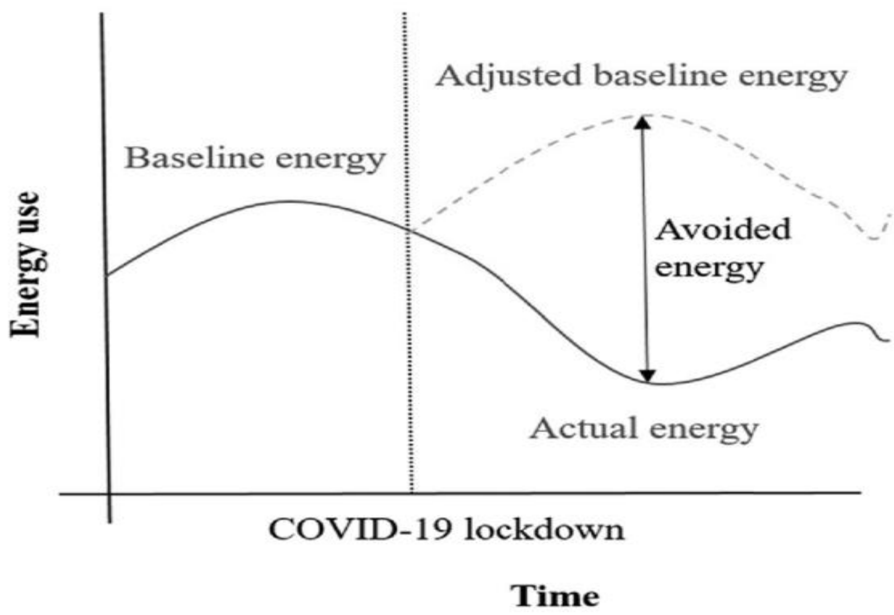
A.1.1 Teleworking

A.1.1.1 Energy Consumption

Is the comparison of energy consumption before (pre-COVID periods) and after (post-COVID periods) the lockdown where it fulfils the following equation:

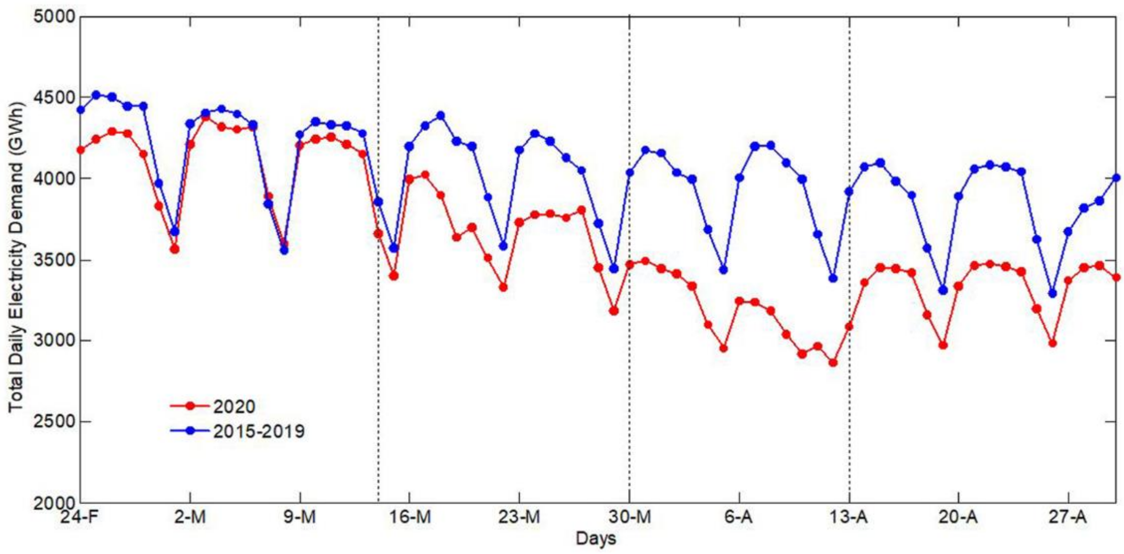
$$E_{avoided} = E_{adjasted\ baseline} - E_{actual} \mp NRA$$

Figure 35 Estimation of Avoided Energy Consumption due to COVID-19



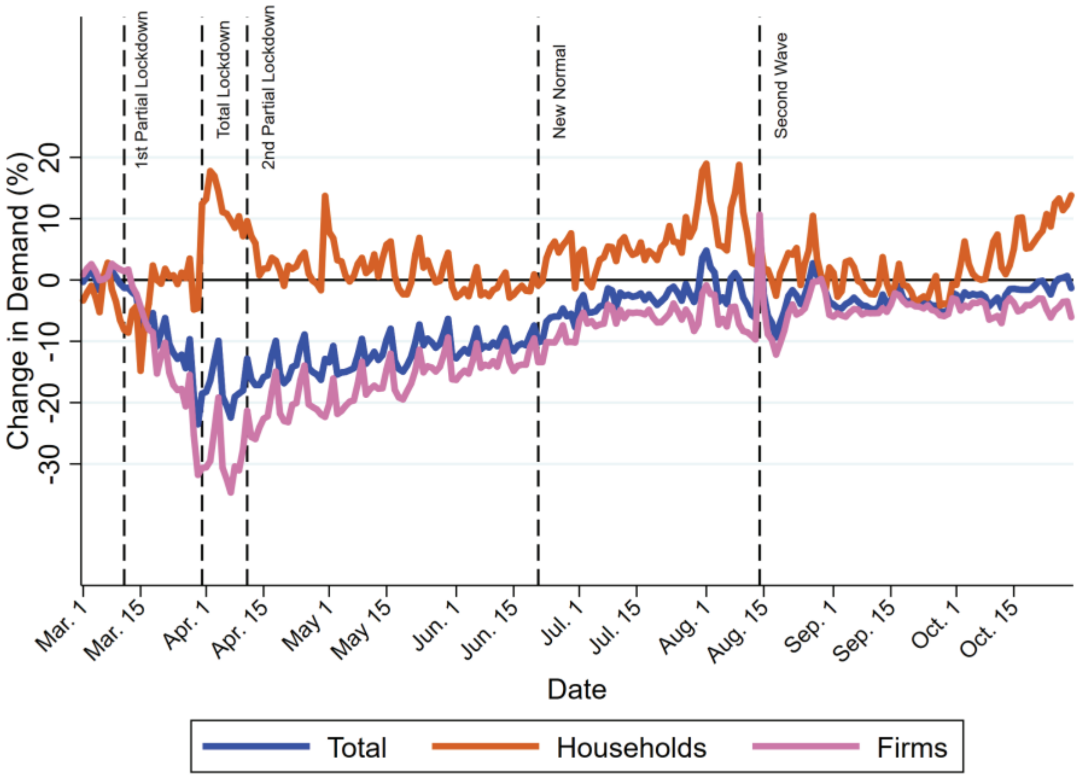
Source: adapted from the Efficiency Valuation Organization

Figure 36 Total Daily Electricity Demand (GWh) in 2020 and the Average Value of 2015-2019



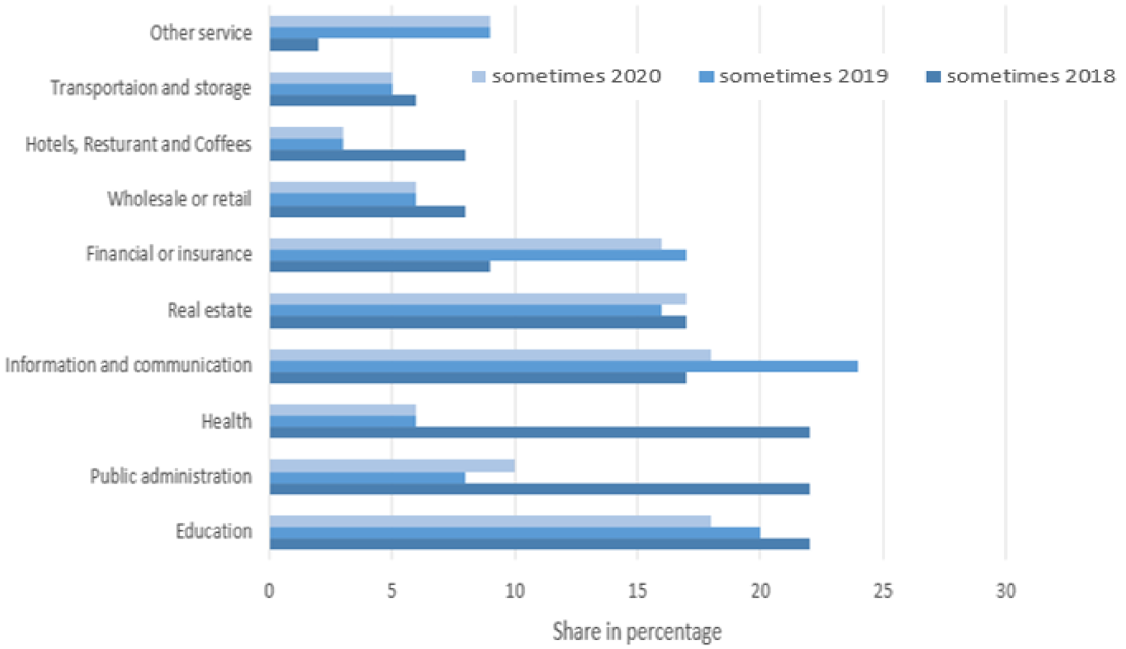
Source: Santiago et al. (2021)

Figure 37 Electricity Demand of Firms, Household and the Total During the Lockdown



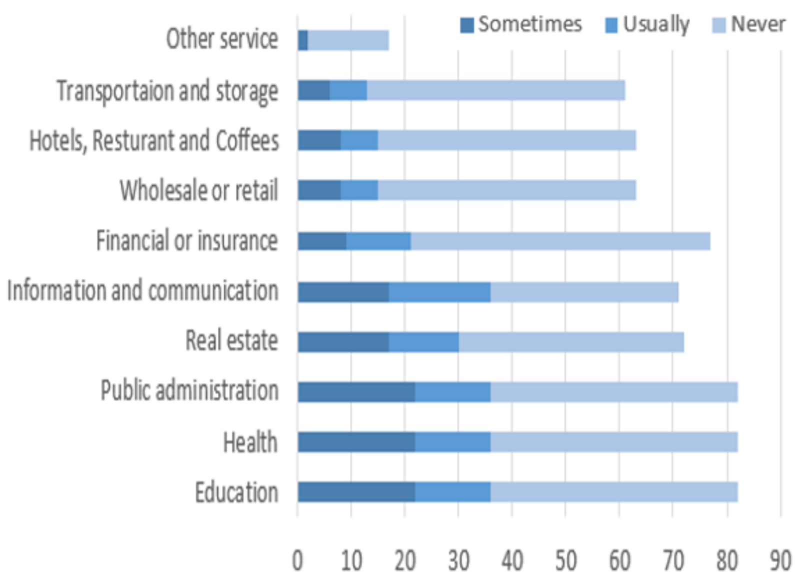
A.1.1.2 Working from Home, Differentation Across Days per Week

Figure 38 Pre-Lockdown Share of Employees Working from Home 1-2 Days per Week. Data for Different Sub-Sectors Before the Lockdowns in 2020, Comparing the Years 2018, 2019 and 2020



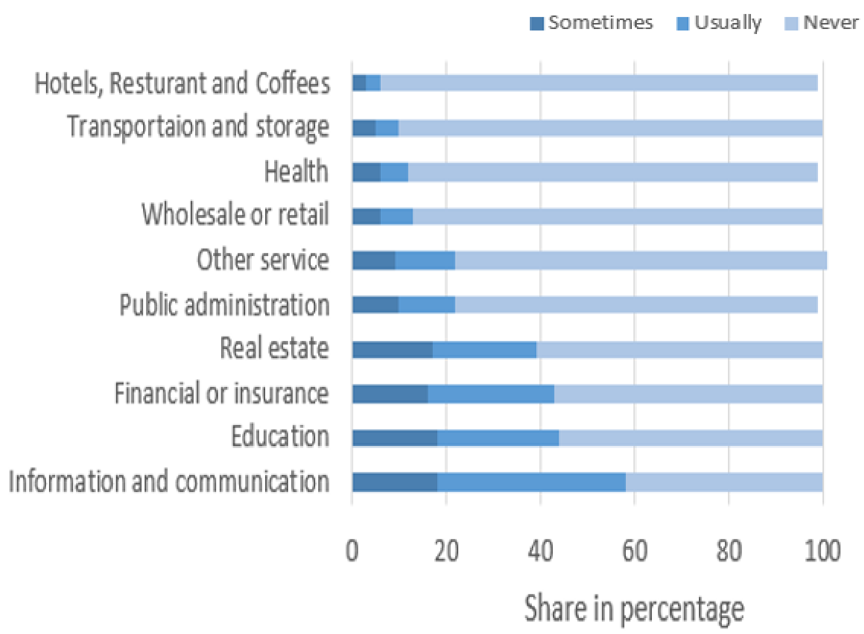
Source: own figure based on Eurostat, 2023

Figure 39 Share of Employees Working from Home in 2018



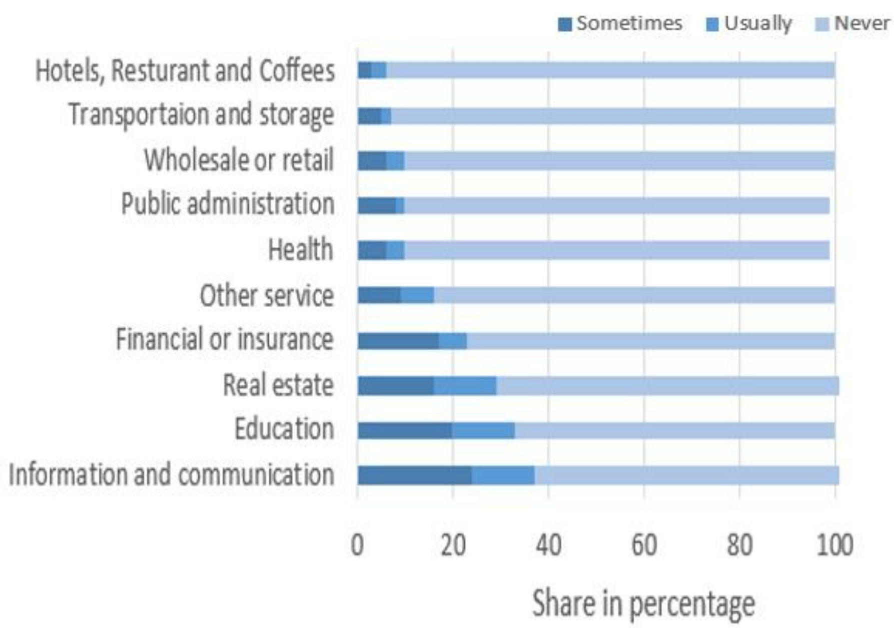
Source: Eurostat

Figure 40 Share of Employees Working from Home in 2019



Source: Eurostat

Figure 41 Share of Employees Working from Home in 2020

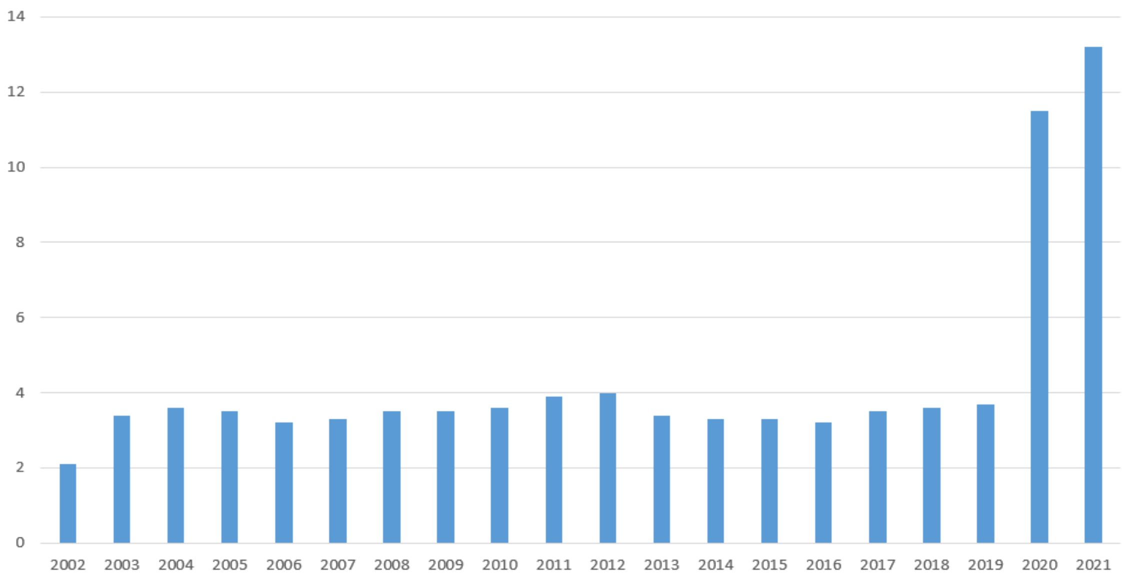


Source: Eurostat

A.1.1.3 Working from Home – Gender Perspective

Most studies based on statistics from Eurostat have shown that the highest percentage of employees working from home where female, and this percentage has increased with time. See Figure 42, the percentage of females working from home was 4% as average and it increased to 11.5% in 2020, and to more than 13% in 2021.

Figure 42 Share of Female Employees Working Usually from Home in EU-27

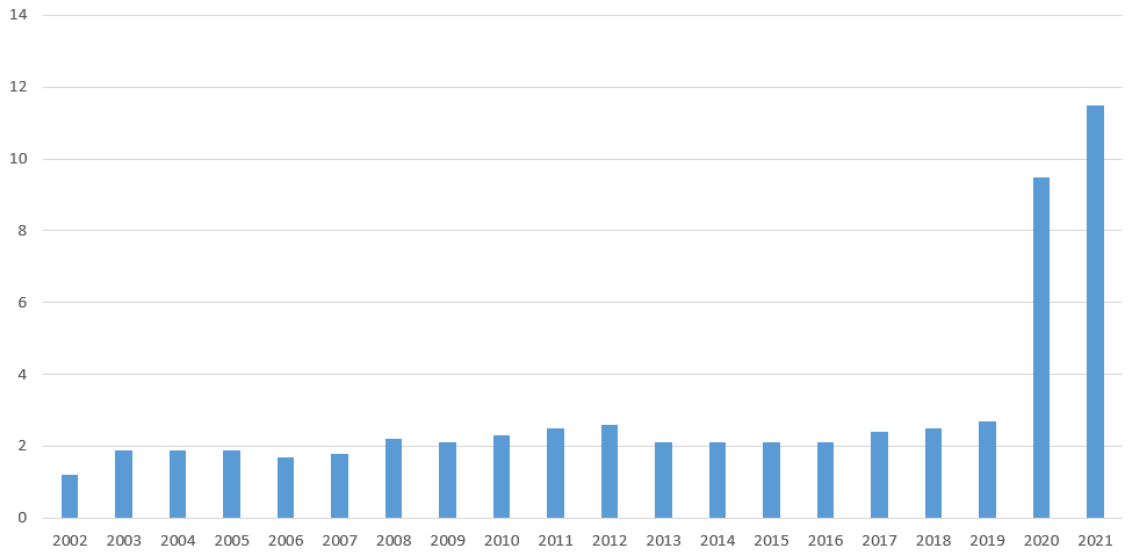


Source: Eurostat table LFSA

Also, the percentage of the men working from home increased, even though not to the same extent as for females but close to it. According to Eurostat data, we see in Figure 43 that the percentage of male employees working from home was around 2.5% on average until 2019, when it increased to 9.5% in 2020 and to 11.5% in 2021.

As described above, teleworking became a common work status after covid-19, but it can be increased more alignment with the development of the technology as well as the work mentality.

Figure 43 Males Working from Home Usually in EU-27, (%) Eurostat LFSA



A.1.1.4 Policy

Table 9 Countries which Adopted Telework Policies or Collective Agreements in Different NACE Sub-Sectors (the Statistical Classification of Economic Activities in the European Community)

NACE sub-sector	Countries
Wholesale and retail trade	Belgium, France, Italy, Netherlands, Norway, Spain
Transport and storage	Austria, Denmark, Italy, Netherland, Slovenia
Accommodation and food service activities	Italy, Netherland, Portugal
Information and communications	Austria, Denmark, Finland, France, Italy, Netherlands, Norway, Slovenia, Spain
Financial and insurance activities	Austria, Denmark, France, Italy, Netherlands, Slovenia, Spain, Germany, Luxembourg, Portugal
Real estate activities	Italy, Netherland, Slovenia
Administrative and support service activities	Denmark, Norway, Italy, Netherland, Spain
Public administration, civil protection and defence, and compulsory social security	Czechia, Estonia, Italy, Netherlands, Sweden
Education	Bulgaria, Italy, Netherlands, Slovenia
Human health and social work activities	Italy, Lithuania, Netherlands, Portugal, Slovenia, Spain
Other service activities	Italy, Netherlands, Norway

NACE sub-sector	Countries
Manufacturing	Austria, Belgium, Czechia, Denmark, Finland, France, Germany, Italy, Netherlands, Portugal, Spain
Electricity, gas, steam, and air conditioning supply	Austria, Denmark, Germany, Italy, Netherlands, Portugal

Source: Contributions from the Network of Eurofound Correspondents and Lodovici et al., (2021)

A.1.1.5 Other Effects of Teleworking

In addition to the focal topic of the literature review in Section 2.2, Table 10 provides an additional overview of potential effects of teleworking on various outcomes, identified for different countries. These studies cover different aspects concerning teleworking such as mental-health, gender equality, education level, share regarding sectors and sub-sectors, reducing the commute and productivity and other aspects.

Table 10 Literature Review of Teleworking Tackling Various Fields

Source	Country	Result
Röder & Nagel, 2014	Germany	Potential reduction in energy demand through teleworking. Teleworking by 10% of the sample (unspecified frequency) within this model reduces commuter mileage and transport energy consumption by 10% but increases energy consumed at home by about the same amount. By contrast, office energy consumption is barely affected.
van Lier et al., 2014	Belgium	Commuting distance displaced by teleworking. Difficult to say. All that is reported is that working from home reduces teleworkers' commute by 45 km per day on teleworking days and that working in a satellite centre reduces the commute for these workers by 38 km, from 60 km to 22 km per day.
O'Keefe et al., 2016	Ireland	The reduction in emissions through travel-savings via teleworking. Based on patterns in the sample data (which showed that 44% of the population in the Greater Dublin Area teleworks once a month and which showed how certain segments travel to work), teleworking by between 20% and 50% of the population once a week would contribute to emission reductions of between 31 000 tonnes and 78 000 tonnes of CO_2 per year.
Næss et al., 2015	Sweden	Teleworkers travelled further than non-teleworkers on both teleworking and non-teleworking days. While non-teleworkers travelled an average of 46 km per day, teleworkers travelled 54 km on teleworking days and 64 km on non-teleworking days.

Source	Country	Result
Giovanis, 2018	Switzerland	Teleworking (by 8.43% of the population) is associated with a reduction in traffic volume on average by 1.9% and equivalent reductions in various pollutants
Gubins et al., 2019	Netherlands	Commuting distance reduced by ICT-enabled homebased working. The existence of ICT has increased commuting distance by 13% for each worker between 1996 and 2010
Adams-Prassl et al., 2021	UK	A survey shows evidence on variation within and across occupations and industries. Where it shows that the average percentage that can perform home office is 39%. Also, the range of tasks that can be done from home varies significantly across occupations, ranging from 14% for 'Food Preparation and Serving' to 68% for 'Computer'. Similarly, across industries the range varies between 18% for 'Accommodation and Food Service Activities' to 70% for 'Information and Communication'.
Morawski, 2022	Europa	The impact of teleworking in Europe on the offices rent, vacancy and the limitation for working from home.
Melo & de Abreu e Silva, 2017	UK	The impact of teleworking on commuting of individual.
Landers, 2019	UK	Teleworking environment implementation. Preparation of physical tele environment access and technology tools. Preparation of telework processes, ways of working and management rules.

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