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THE ENVIRONMENTAL IMPACT OF REMOTE WORKING. INSIGHTS FROM A SURVEY CONDUCTED AT BANCA D'ITALIA

by Dario Alessandro de Pinto*, Donato Milella*, Daniele Macali*, Riccardo Basile**, Carmen Lavinia**, Giovanni Murano**, Marco Rao**, Roberta Roberto**, Andrea Tortora** and Alessandro Zini**

Abstract

Banca d'Italia has signed a cooperation agreement with the National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA) to quantify the changes in greenhouse gas (GHG) emissions and energy consumption associated with the adoption of flexible working arrangements. As part of this collaboration, a questionnaire was drawn up and administered to the Bank's employees in 2023 to assess the environmental impacts of the hybrid work model, which was introduced in 2022 and integrates remote work and on-site work. An analysis of the 4,255 responses collected at both the head office buildings in Rome and Frascati and at 38 branches across Italy has made it possible to estimate, based on empirical evidence, the environmental impact of employee commuting and the additional household energy consumption associated with remote working, an aspect still relatively underexplored in the literature. Taking into account the number of days worked remotely, the average per capita emissions for staff commuting to work amount to 4.1 kilograms of carbon dioxide equivalent ($kgCO_{2e}$) for each working day in the office (compared with 4.8 kilograms in 2020, before the hybrid work model was introduced). The emissions associated with additional household energy consumption for heating, cooling, IT equipment and lighting amount to 1.1 $kgCO_{2e}$ per day of remote working. The study also provides an estimate of the average GHG emissions related to the additional household energy consumption linked to a day of remote working, broken down by climate zone. This estimate is potentially usable by other companies and institutions to calculate the indirect GHG emissions (Scope 3) linked to employee commuting.

JEL Classification: D13, H83, J22, M54, O33, R11, R41.

Keywords: remote working, teleworking, greenhouse gas (GHG) emissions commuting, hybrid work model, energy consumption, Scope 3, GHG Protocol.

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* Banca d'Italia.

** National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA).

1. Introduction

Before the COVID-19 pandemic, remote working was used marginally in Banca d'Italia: in 2019, net of teleworkers, the actual share of remote working days was around 4 per cent of the total number of days worked during the year. During the pandemic, remote working accelerated sharply: in 2020, staff worked remotely on average for almost 60 per cent of the working days, with 90 per cent peaks during the lockdown (for more details, see Martiello and Parigi 2022).

In May 2020, a reflection began, which led to the publication of a final report on the Bank's strategic vision and on the new hybrid work model, which integrates on-site and remote working (for more details, see *The Bank of Italy's organization of work in the new normal*, 2021). The model, which entered into force on 1 April 2022, provides that, as a general rule, work can be performed remotely for a maximum of 100 days per year, with a monthly limit of 10 days ('standard arrangement' or '10/100'); in relation to the 'teleworkability' of processes or operational conditions, the cap can be reduced to 5/50 or increased to 12/120. Finally, in some organizational units, people can work remotely only on an occasional basis.

From an environmental point of view, remote working leads to a change in the greenhouse gas (GHG) emissions associated with: (a) the reduction of commuting; (b) the increase in household consumption; (c) the reduction of office building energy consumption, especially if the configuration of the systems makes it possible to adjust consumption in relation to the actual presence of people in the offices or if the policies adopted (e.g. desk sharing) make it possible to decommission certain areas of a building – or even an entire building – and thus avoid the energy consumption for the heating and cooling of those areas.

In this study, the environmental impacts of the new work model are estimated by assessing the effects of the reduction of commuting and the additional energy consumption in the areas used for remote working.[1] The reduction in corporate buildings' energy consumption was considered negligible in light of: the empirical evidence on the effect of staff's presence on the energy consumption of buildings that was observed during the pandemic; the current building system layout of the Bank's premises, which makes it possible, only in limited cases, to adjust consumption based on the actual presence of staff; and the limited use of desk-sharing in the Bank's buildings when the information was collected.

In order to obtain the detailed data needed to estimate as accurately as possible the emissions associated with the new organization of work, a questionnaire was drawn up and administered to all employees. Participation in the questionnaire was voluntary.

The results were used to calculate the Bank's indirect GHG emissions (Scope 3) connected to employee commuting.[2]

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[1] 'Extra consumption' refers to the difference due to the need to cool or heat remote working environments compared with baseline scenario in which a portion of energy is consumed to heat and cool those environments regardless of the presence of remote workers. This difference depends on numerous factors, including the type of systems in the homes, the energy efficiency of the remote working locations, the climate zones in which the buildings are located, the presence of other people in the remote working environment, and, more generally, employees' household consumption habits.

[2] The Greenhouse Gas (GHG) Protocol classifies companies' greenhouse gas emissions as: Scope 1 (direct emissions related primarily to the use of fossil fuels for heating and transport and fugitive emissions of climate-changing gases); Scope 2 (indirect emissions due to energy purchase); Scope 3 (other indirect emissions related to the upstream and downstream value chain). The Corporate Value Chain (Scope 3) Standard of the GHG Protocol provides that emissions associated with remote working may optionally be included in companies' greenhouse gas inventories; the revision of this Standard, which is still in progress, suggests that the inclusion of these emissions will be made mandatory.

2. The literature on the subject

The increasing adoption of remote working has stimulated numerous studies to analyse its impacts on mobility practices and environmental emissions. The overall assessment of the environmental impacts of remote working encounters methodological difficulties related, on the one hand, to the lack of high-resolution data – especially relating to individual behaviour and to the type and energy efficiency class of the buildings used for remote working – and, on the other hand, to the variability of the parameters involved; this reinforces the need for further, more detailed, comparable and robust studies based on empirical evidence.

The main effect induced by remote working is the reduction of the frequency of commuting, especially during peak hours, known as the work-travel effect: this brings both benefits, such as the decrease in road congestion, and uncertain effects, mainly due to greater freedom in relocation choices, fostered by the reduced need to live near the workplace. Some studies also show potential rebound effects (i.e., an increase in personal travel, which can partially decrease the environmental benefits of reducing commuting) as well as the tendency of people to relocate to suburban or less densely populated areas (often by purchasing larger homes in areas that are farther away from the workplace, a choice which can sometimes lead to an increase in household energy consumption).

Although the direction of the causal link remains undetermined in the literature, the analyses conducted by Ory et al. (2006) and Asmussen et al. (2024), which were carried out in California and Texas, respectively, indicate that it is more likely that distance influences the choice to work remotely than the other way around.

Systematic literature reviews were conducted by Halefom et al. (2024), Rios Villacorta et al. (2025), Sepanta and O'Brien (2023) and Hook et al. (2020). The main evidence is that, overall, the use of remote working reduces transport-related consumption, while the effects of the increase or decrease in energy consumption related to the use of work environments are less investigated or uncertain. Only a few papers analyse both issues jointly, attempting to assess the net balance, but this remains challenging and highly dependent on the context. Among these papers, two studies indicate that remote working could increase overall energy consumption, four conclude that the effect is uncertain, and five studies support the hypothesis of a reduction in consumption. Only three studies, conducted on cases in South Korea and the USA, include an estimate of rebound effects, reaching conclusions that are not homogeneous.[3]

Crow and Millot (2020), in a comparative analysis of several cases globally, focus on balancing the reduction in emissions related to commuting and the increase related to household consumption. The results show that, on average, the energy savings resulting from the elimination of systematic shifts are about four times larger than the increase in residential consumption, with significant regional differences related to travel habits, the fuels and energy sources used in homes, and differences in the composition of the national energy mixes.

[3]According to Larson and Zhao (2017), remote working leads to an overall increase in consumption, linked to a double rebound effect (transport and residential consumption). In a simplified urban model, the authors estimate that, with one day of remote working per week for 20 per cent of workers, travel consumption decreases by 23.0 per cent and household consumption increases by 5.3 per cent, with a slight net increase of 0.4 per cent. This outcome reflects lower transportation costs, greater urban sprawl, and larger homes, and varies depending on the energy mix and socioeconomic context. Kitou and Horvath (2003), however, do not reach unequivocal conclusions: remote working can reduce consumption and emissions, but the effect varies across different pollutants and depends on climate, building system technologies, and space use patterns. Their simulations show that on cold days, savings in transportation can be almost offset by increased household consumption, while on hot days a net reduction is observed. According to Kim et al. (2015), based on a survey of 1 per cent of residents in the Seoul Metropolitan Area, increased remote working would significantly reduce transportation emissions, moderately increase household consumption, and encourage some non-work related travel. Despite the rebound, the net reduction in mobility consumption would remain around -38 per cent. Furthermore, greater schedule flexibility would help distribute traffic patterns more evenly during rush hour, with an overall positive effect on emissions.

Recent research has analysed the energy performance of residential and office buildings to better understand the dynamics associated with increasing energy consumption associated with heating and cooling. Nerouziasas et al. (2024) assessed ten hybrid and remote working scenarios in Norway using data from sensors, direct measurements and simulations; the results show significant reductions in energy consumption in the scenarios with more remote working. The scenario with one day per week at the office is the one with the sharpest energy intensity reduction (Energy Use Intensity, EUI), down by 46 per cent compared with the baseline case. The implementation of flexible hours and remote working in the different scenarios leads to a reduction in the demand for electricity for heating purposes of up to 23 per cent.

A study by Wu et al. (2024), based on US national datasets, estimated an increase of 1.51 kilograms of carbon dioxide equivalent (kgCO_2e) per person per day due to higher household consumption, offset by 4.23 kgCO_2e reductions from reduced commuting and 1.34 kgCO_2e from reduced use of office buildings, with a net budget of 4.06 kgCO_2e per person per day.

A further quantification of the emissions associated with remote working is available in the Emission Factors Database maintained by UK Government's Department for Energy Security and Net Zero: the estimate is 0.334 kgCO_2e for every hour of working from home. This value, which considers a standard 7.5-hour working day, corresponds to total GHG emissions of around 2.5 kgCO_2e per day of remote working. The figure is based on an analysis conducted by Skillett and Ventress (2020) and covering the United Kingdom, which considers additional energy consumption attributable solely to heating and use of IT and lighting equipment and is representative of the UK energy and real estate environment.

In Italy, a study conducted by Roberto et al. (2023), which focused on workers in the public administrations of Bologna, Rome, Trento and Turin, investigated the socio-demographic and behavioural characteristics of remote workers and assessed the environmental benefits associated with remote working: it showed that the elimination of systematic commuting to reach the workplace, made possible by the adoption of remote working, can contribute significantly to the reduction of GHG emissions. Specifically, the authors estimated an average saving of around 6 kgCO_2e per day for workers who, without the option of working remotely, would reach the office by car. Cattani et al. (2024) conducted a dynamic analysis of consumption in a residential building in Genoa, simultaneously considering the main factors influencing the energy balance of remote working; the results point to an average increase of 15 per cent in residential consumption when working exclusively from home. An additional assessment at Italian level is provided by the Politecnico di Milano's Smart Working Observatory (2022); according to this study, the systematic adoption of remote working would reduce average annual emissions by around 450 kgCO_2e per person, resulting from a combination of lower emissions linked to commuting (-350 kgCO_2e), the reduction of the use of company space (-400 kgCO_2e) and the increase in household emissions due to higher energy consumption (+300 kgCO_2e). Moreover, assuming a hybrid model with two days of remote working per week, the study estimates an average reduction in individual commuting costs of around €1,000 per year, which is partially offset by an estimated increase in household energy costs of around €400 per person.

An analysis of the propensity to work remotely has recently been carried out in Banca d'Italia. A study by Mariani et al. (2023) highlights that employees who have longer travel times to work, have small children or benefit from Law 104/1992 are more likely to work remotely, while those who live alone are less likely; as age increases, there is a lower inclination to work remotely; furthermore, with the exception of some specific categories, there is no evidence of gender-based differences. The work also suggests that the boss's remote working choices can influence the behaviour of collaborators.

3. The questionnaire for assessing the environmental impact of hybrid work

The research project carried out by Banca d'Italia in collaboration with ENEA was based on a questionnaire, administered in 2023, for assessing the environmental impact of hybrid work and collecting information useful for drawing up the Commuting Plans (*Piano degli spostamenti casa-lavoro,* PSCL) for employees working at the head office buildings in Rome and at the Centro Donato Menichella (CDM) in Frascati (including the two branches located in Rome and at the CDM, respectively), and in the six largest branches, for which it is a legal requirement to draw up a PSCL.[4] The final version of the questionnaire was administered following two pilot surveys conducted in April 2023. The distribution of the final version started on Thursday 8 June 2023 and ended on 10 July 2023; overall, 4,255 responses were collected, of which 3,089 complete and 1,166 partial.[5] Some 46 per cent of respondents answered in full, with no gender differences; the figure was 48 per cent for the staff working in the Bank's 36 branch network throughout Italy and 45 per cent for Bank employees in the Rome area.[6] In terms of career stream, the figure was 51 per cent for the managerial area and 40 per cent for the operational area (Table 1).

An assessment of the adherence of the sample to the population showed significant differences for two key variables, on which a post-stratification was carried out: a) the workplace, broken down between the Rome area and the branch network (fig. 1); b) the remote work arrangement category (teleworking, occasional remote working, reduced remote working, a standard range, extension to the standard range; Figure 2). The results presented below take account of the recalibration based on the combination of these two variables.

3.1 Remote working habits emerging from the questionnaire

The share of employees who work remotely mainly from their home is 80 per cent; 17 per cent work elsewhere (Figure 3a). One third of those working mainly in their primary residence said that they never worked remotely from a different home, not even occasionally (Figure 3b); for those who work remotely from other homes occasionally (e.g. a second home), this is more distant from the workplace than the primary one (78 per cent of the cases).

Response analysis shows a positive but very weak linear correlation between kilometres travelled to work and the number of days worked remotely on average (including both remote workers and teleworkers).

The possibility of working remotely on a stable basis has had an impact on individuals' willingness to change their primary residence:[7] some 12 per cent of respondents said they considered doing so and 2 per cent did actually change it, in connection to the option of working remotely on a reasonably stable basis (Figure 4a). The reasons appear to be diverse (Figure 4b),

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[4] Article 229, paragraph 4, of Legislative Decree 34/2020, converted, with amendments, by Law 77/2020, requires businesses and public administrations with individual local units with more than 100 employees that are located in a regional capital, a metropolitan city, a provincial capital, or a municipality with a population of more than 50,000 inhabitants, to adopt a Commuting Plan (PSCL) for their employees aimed at reducing the use of individual private transport. They must also appoint a Mobility Manager to provide ongoing professional support for the decision-making, planning, scheduling, management, and promotion of optimal sustainable mobility solutions.

[5] For approximately 600 of the latter, at least one section was filled in, while the remaining ones do not contain usable information.

[6] Two Banca d'Italia branches, Roma Sede and Roma CDM, are located in the Rome area; the other 36 branches are distributed across different climate zones: 4 in zone B, 7 in zone C, 7 in zone D, and 18 in zone E.

[7] One of the findings emerging from the literature is that there is a one-to-one correlation between the frequency of remote working and the duration of the home-work commute. On the one hand, the possibility of working remotely on a permanent basis – as in a hybrid work model – increases the tendency of people to relocate to peripheral or less densely populated areas, and, on the other hand, higher commuting time affects individual behaviours, increasing the use of remote working. For a quantification of the effects of commuting time on remote working propensity, see Mariani et al. (2023).

but generally attributable to a better quality of life. The results as a whole do not show a rebound effect linked to an increase in personal travel.

The distribution of days that can be worked at the office and remotely (excluding teleworking, which is broadly constant) is influenced by seasonal factors: remote working is more frequent during the summer and the main holiday periods. The percentage of on-site work changes accordingly (Figure 5).

In terms of intra-week variability, there is a general preference for on-site working in the middle days of the week, though the differences observed compared with Monday and Friday are limited overall (Friday is the preferred day for remote working). However, there is a significant difference between the Bank's head office and the branch network in relation to the different degree of remote working that may be used (Figure 6).

4. Calculating emissions from commuting to work and back

4.1 National data on people's mobility and seasonality in travel to the city of Rome

The *Report on the mobility of Italians* and the *2025 Report on mobility in Rome* make it possible to compare the external context and the results presented in this paper.

The *Report on the mobility of Italians*, published by the Istituto Superiore di Formazione e Ricerca per i Trasporti (ISFORT), gives an overview of the demand for mobility of the Italian resident population in the 14-85 age group. The 21st edition of the Report, published in November 2024, confirmed the structural imbalances in the transport modes used by citizens: in terms of overall travel, pedestrian mobility is 2.6 per cent, bicycle and micro-mobility 1.2 per cent motorbikes 4.0 per cent, cars 75.1 per cent and public transport 17.1 per cent. The daily travel time was 53 minutes per person in the mobile population in 2023, 43 minutes per person in the total population.[8] The average distance per capita travelled each day was 25.6 km in the mobile population, 20.9 km in the total population.

The *2025 Report on mobility in Rome* gives an overview of the travel patterns of people living in Rome; data on the distribution of the predominantly used means of transport confirm that private motor vehicles (car and motorcycle) make up 61 per cent of travel preferences, and more than 70 per cent if only the active population (aged between 30 and 65) is considered. The Report also contains a special section on traffic levels, both for overall travel and for travel on metro lines and regional commuter trains. A comparison between the city of Rome and the metropolitan area shows that, for overall travel, the hourly profiles show a peak during the 8–9 am and 6–7 pm time windows, with a range of 1-2 hours due to the fact that, in the morning, residents of the metropolitan area start their commute before people living in Rome while in the afternoon they take longer to travel the way back. The data regarding the use of metros and regional commuter trains, which are recorded automatically, make it possible to appreciate the existence of an intra-week pattern: Wednesdays and Thursdays are the busiest days, whereas Mondays are the least busy.

4.2 Results

Prior to the 2023 survey, Banca d'Italia had conducted other sample surveys to investigate employees' commuting habits. The latest questionnaire, distributed in December 2020 during the pandemic and also drawn up in collaboration with ENEA, had made it possible to estimate

[8] The mobile population is defined as those who made at least one trip on an average weekday, excluding walking trips lasting less than 5 minutes; the total population is defined as people aged between 14 and 80.

commuting patterns to and from work before and during the pandemic; its results had highlighted an increase in GHG emissions (from 4.8 to 6.1 $kgCO_2e$ per day of office work), due to an increased use of private means of transport during the pandemic (Figure 7).

The 2023 sample survey showed that transport modes have by and large returned to those observed in the pre-pandemic period. An analysis of the data collected has made it possible to estimate the daily average per capita emissions of employees' commutes to work at 4.1 $kgCO_2e$: the decrease compared with the emissions calculated in 2020 and referring to the pre-pandemic period (2019), which were equal to 4.8 $kgCO_2e$, is mainly due to increased use of public transport and less polluting private cars. Indeed, 56 per cent of the cars currently used by employees comply with the Euro 6 emission standards (compared with just under 40 per cent in 2019, Figure 8).

The average commute for Banca d'Italia staff was 22.2 km. More specifically, it was19.4 kilometres for the Rome area (18.2 km for the staff working in the Rome buildings and 22.9 km for those working at the CDM) and 30.5 kilometres for the branch network. Average travel time was 42 minutes: 41 minutes for people working in premises in the Rome area (42 minutes for the Rome headquarters and 38 for the CDM) and 46 minutes for people working in the branches (Figure 9). Both the distance travelled and the travel time increased slightly compared with the previous survey, when the distance travelled was 21 kilometres (18 kilometres for the Rome area and 28 for the branches) and the travel time was 38 minutes. For teleworkers alone, the average distance travelled to the office in the one-way commute is 78.4 kilometres, with an average travel time of around 87 minutes, in line with relevant literature. The travel time to reach the office and the use of remote working are correlated.

The increase in distances travelled and in travel times may have been affected by different factors. For the Bank's branches, some organizational reforms have led to the closure or redesign of some offices in provincial capitals and have increased work–home distances for a marginal share of employees. For the Rome area, the growth in the mobility rate and in the motorization rate of residents as well as the growth in tourist flows, recorded in the *2025 Report on mobility in Rome*, have increased the frequency of congestion events. The possibility of working remotely on a permanent basis, in and of itself, could have led, in a small number of cases, to the moving of some places of residence further away from the workplace.

Employees were asked to indicate the usual time of entry when working on site: the average for the Rome area is 08:31, while the average for the branches is 8:06, in line with the need to guarantee services to local users. Both distributions are slightly platykurtic, with the distribution of the observations concentrating mainly between 7:00 and 9:30 for the Rome area and between 7:00 and 9:00 for the branches, also a reflection of the narrower hourly range in which the working day can begin in the branch network. The asymmetry of the distributions, especially that of the Rome area, makes it possible to appreciate a tendency to postpone one's daily commute slightly, contributing to a more homogeneous distribution of traffic in the early hours of the morning (Figure 10).

Other financial institutions also quantify emissions related to employee commuting, with results that also depend on the different geographical organization.[9]

[9] The Intesa Sanpaolo Group, as part of its environmental reporting (see the *2024 Climate Report*), indicated that the emissions generated by the commuting of its employees in Italy amounted to 33,441 tCO_2e in 2024, corresponding to around 0.484 tCO_2e per employee per year. In its sustainability reporting (see the *Annual Financial Report for the financial year 2024*), Banca Popolare di Sondrio provided evidence of issues related to employee commuting, estimated based on a survey conducted on employees in its parent company: the emissions, which take account of remote working days, amounted to 3,714 tCO_2e, corresponding on average to 5.3 $kgCO_2e$ per employee per day and 1.177 tCO_2e per employee in one year. Banco BPM Group also publishes information on commuting emissions: the data published in the latest sustainability report indicated a value for Italy of 11,974 tCO_2e, corresponding to around 0.616 tCO_2e per employee in one year (see *Sustainability Report for 2024*).

4.3 Details

The analysis of the responses provided via the questionnaire shows that the most widely used means of transport are trains and private cars (which account for 39 and 38 per cent of kilometres travelled, respectively). The choice of which means of transport to use is especially affected by the time saved and the autonomy afforded by the various solutions and, for the Rome area, by the inadequacy of public transport. For this reason, too, employees working in the Rome area tend to use their private vehicle more than those who work in the branches (Figure 11a).

Most of the cars used by Bank employees when travelling to and from work run on diesel or petrol (70 per cent); 10 per cent run on LPG or methane. The share of conventional hybrid cars is around 14 per cent, while the number of plug-in hybrid cars is 3 per cent. Purely electric vehicles account for 3 per cent (Figure 11b). Around 56 per cent of cars comply with the Euro 6 standards, 23 per cent with Euro 5, and 17 per cent with Euro 4. Analysing the emissions of private cars and motorcycles used by employees made it possible to estimate the average annual emissions per capita (referring only to those who commute using their private vehicles) of various pollutants (Table 2).

Some 13 per cent of employees always walk to the office (9 per cent in the Rome area and 23 per cent in the branches), while just under 4 per cent only use ‘soft mobility’ solutions such as bicycles, e-bikes or electric scooters.

The study investigated the propensity to change travel-to-work habits in favour of more sustainable choices, asking respondents whether they would be willing to use sustainable means of transport in a systematic/predominant manner. Some 19 per cent of respondents said they were unwilling to change their habits. Among those who declared themselves willing to change them, 35 per cent said they would use public transport, almost 30 per cent would use corporate shuttles and 22 per cent forms of ‘soft’ and electric mobility.[10] With reference to the use of local public transport, the main reasons for not using it are that it is difficult to navigate and the unreliability of the service, which translates into a lack of functionality (Figure 12).

4.4 Methodological aspects

For the calculation of GHG emissions and other pollutants related to the use of private motor vehicles and motorbikes used by employees, the COPERT software tables were used[11], the development of which is coordinated by the European Environment Agency. For the calculation of these emissions, the type of vehicle, the type of fuel, the engine size and the emission standard were taken into account;[12] moreover, the features of the means of transport used by each respondent were associated with the corresponding emission factors in the COPERT tables. The data collected were partly transformed to match them with the labels in the COPERT tables.

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[10] The failure to use soft/electric forms of mobility depends on: perceived road safety (41 per cent), excessive distance (30 per cent), weather conditions (7 per cent), lack of coverage of sharing services (6 per cent), costs of sharing services (6 per cent), other (9 per cent).

[11] The database of average emission factors for road transport in Italy maintained by ISPRA (Institute for Environmental Protection and Research) was used, considering the following pollutants: CO, VOC, NMVOC, NOx, Benzene, PM2.5, PM10, PM_exhaust, Me, IPA, BaP, N_2O, CH_4.

[12] The variables considered were: a) Fuel type: Petrol, Petrol plug-in hybrid, Traditional petrol hybrid, Diesel, Diesel plug-in hybrid, Traditional diesel hybrid, Electric, LPG, Methane, Other. b) Engine size of car with internal combustion engine: Large (over 2000 cc), Medium-large (1400-1999 cc), Medium-small (800-1399 cc), Mini (up to 799 cc), Other. c) Engine size of motorcycle with internal combustion engine: 2-stroke moped < 50 cc, 2-stroke motorcycle > 50 cc, 4-stroke motorcycle < 250 cc, 4-stroke motorcycle 250 cc - 750 cc, 4-stroke motorcycle > 750 cc. d) Emission standard: Pre-Euro, Euro 6/a/b/c, Euro 6/d-temp , From Euro 1 to Euro 5, Do not know/Do not wish to answer.

The GHG emissions for public transport (train, urban bus, extra-urban bus, metro, tram, ferry, electric bicycle, electric scooter) were calculated by using the emission factors provided by the UK Government's Department for Energy Security and Net Zero (DESNZ).[13] To calculate the daily average emissions, the emission factors were multiplied by the kilometres travelled by each respondent using the various means of transport; these emissions were then weighted by the number of days actually worked on-site by each respondent.

The results were aggregated considering the two variables (workplace and remote working arrangement category) on which post-stratification was performed; emission factors specific to each of the 12 statistical sub-groups, characterized by the combination of these two variables, were thus obtained. Recalibration according to the population composition made it possible to calculate the daily average per capita emissions for employee commuting.

5. Estimating additional household energy consumption linked to remote working

5.1 Results

The work conducted with ENEA has made it possible to estimate the daily emissions for a day's remote working at 1.1 $kgCO_2e$: this is about one quarter of the equivalent environmental impact of a day's commuting to the office. These emissions are due to additional household energy consumption[14] for heating (63 per cent), cooling (29 per cent), and the use of IT equipment and lighting (8 per cent) respectively.

Only the 2,335 responses (out of 4,255) that declared an additional energy consumption for heating and/or cooling were used to calculate the additional energy consumption for remote working. More specifically, 1,646 respondents reported extra heating consumption and 1,732 extra cooling consumption. Some 3 per cent of respondents who declared an additional energy consumption work in climate zone B, 4 per cent in climate zone C, 82 per cent in climate zone D and 11 per cent in climate zone E. Very few work in climate zone F and none in climate zone A.[15]

Some 72 per cent of respondents reported sharing their homes with others (e.g. family members) when working remotely (Figure 13a), but never or almost never (70 per cent) sharing the room in which they work (Figure 13b).

The most recurring type of home (Figure 14) is an apartment located in climate zone D, in a small building (47 per cent), built in the period 1961-1975 (around 30 per cent), with double-glazed windows (74 per cent) and wooden window frames (47 per cent), equipped with an independent heating system (67 per cent), composed of a gas boiler (50 per cent) along with radiators (97 per cent), and air-to-air heat pump cooling system (73 per cent of respondents[16]).

The average operating time of both the heating and the cooling system was 4 hours a day. Some 39 per cent of respondents with additional household energy consumption reported that in recent years they had replaced window frames and doors; 7 per cent said their building was

[13] The UK Government's Department for Energy Security and Net Zero (DESNZ) emission factors database was used.

[14] Additional domestic energy consumption is defined as occurring only when the fact that an employee is working remotely results in a change in energy consumption (and the related emissions) in a given work environment that would not have occurred if the employee had worked on-site. For example, additional heating consumption does not occur in a home with a centralized heating system where the radiators are not turned off on days when the employee works on-site.

[15] Italy is divided into six climate zones, from A (warmest) to F (coldest), based on the average daily outdoor temperature. As a first approximation, employees were assumed to work remotely in the same climate zone as their workplace.

[16] Some 23 per cent reported using a fixed air conditioner for cooling only, while 3 per cent reported using a portable air conditioner.

refurbished with an external thermal insulation system; 7 per cent with ceiling insulation and 3 per cent with floor insulation.

The average number of days spent working remotely was 8 days a month.

ENEA developed a calculation tool which was then applied to the results obtained through the survey.[17]

The average emission factors per climate zone are given below: they are applicable to any remote working day, regardless of the month of the year, and refer, respectively, to the contribution of heating (Table A) and cooling (Table B). The Appendix (Tables 4 and 5) gives details of the emission factors relating specifically to the days worked remotely during the periods in which the heating and cooling systems are used.

Table A

Average daily emission factors linked to additional household energy consumption for heating (1)
(kgCO₂e per day of remote working)

Climate zone (Decree of the President of the Republic 412/1993)	GHG emissions linked to heating in case of additional household energy consumption	Multiplicative correction factors linked to energy efficiency interventions			Multiplicative (optional) correction factors for the occupancy of the areas used for remote working	
		Replacement of existing window frames	External thermal insulation system	Both measures (window replacement and external thermal insulation)	Sharing areas with another person (always, almost always, often)	Sharing areas with another person (for about half of the time)
A and B	0.788	0.89	0.31	0.20	0.5	0.75
C	1.035	0.87	0.37	0.25	0.5	0.75
D	1.196	0.87	0.40	0.28	0.5	0.75
E	1.963	0.86	0.43	0.31	0.5	0.75
F	2.346	0.86	0.44	0.31	0.5	0.75

(1) Data are averaged over the year.

Table B

Average daily emission factors linked to additional household energy consumption for cooling (1)
(kgCO₂e per day of remote working)

Climate zone (Decree of the President of the Republic 412/1993)	GHG emissions linked to cooling in case of additional household energy consumption	Multiplicative (optional) correction factors for the occupancy of the areas used for remote working	
		Sharing areas with another person (always, almost always, often)	Sharing areas with another person (for about half of the time)
A and B	0.428	0.5	0.75
C	0.301	0.5	0.75
D (2)	0.355	0.5	0.75
E	0.293	0.5	0,75
F	0.182	0.5	0,75

(1) The data are averaged over the year; the effects of energy efficiency measures on the cooling factor were considered negligible for the model. – (2) The trend of the emission factors does not necessarily decrease when going from climate zone A to climate zone F due to specific local climate conditions in terms of temperature and solar radiation.

By considering the distribution of the Bank's employees across the climate zones, taking into account the cases in which additional household energy consumption occurs and applying the model corrections for the efficiency actions reported by the respondents (accounting for 36 per

[17] To use this tool, the data were cleaned, considering only valid responses in terms of technical/scientific reliability. Specifically, for energy consumption data, a refined sample of 1,195 respondents with additional household energy consumption for heating and a refined sample of 1,316 respondents with additional household energy consumption for cooling was used.

cent of the sample),[18] two separate average emission factors were derived that were applicable to each day worked remotely by all employees, equal to 0.688 $kgCO_2e$ for heating and 0.327 $kgCO_2e$ for cooling, respectively.

These factors were then added to a factor of 0.084 $kgCO_2e$ per day of remote working,[19] linked to the use of a computer and of lighting. The total factor thus obtained was 1.1 $kgCO_2e$ per day of remote working. This represents the average GHG emission of a Banca d'Italia employee connected with a day of remote working; this figure was then multiplied by the total number of days worked remotely in one year by Banca d'Italia employees to obtain an annual estimate of the corresponding indirect GHG emissions (Scope 3).[20]

5.2 Methodological aspects

To calculate the emissions, reference was made to the dynamic energy balance model described in the reference ISO standard,[21] which makes it possible to calculate the energy needed to maintain a given indoor comfort temperature in a given climate zone. In a simplified form, the thermal balance depends on several factors such as:

- heat exchanges due to transmission, including thermal bridges;
- outdoor air exchanges due to ventilation and infiltrations;
- internal thermal inputs (people, equipment, lighting);
- solar thermal inputs through opaque and glazed surfaces;
- any energy supplied or subtracted by installations;
- variation of accumulated energy in the internal thermal mass.

The energy calculation also incorporates the losses detected for the components of the building sub-systems (emission, adjustment, distribution and generation components), associated with heating and cooling.

The additional energy consumption for heating and cooling was calculated through a tool, developed specifically by ENEA, which applies the energy balance to the most recurrent dwelling type based on responses to the questionnaire, identified as the 'archetype': it represents a typical dwelling, in terms of climate zone, building characteristics, and type and operating hours of the heating and cooling systems. The Typical Meteorological Years (TMY)[22] developed by the Comitato Termotecnico Italiano (Italian Thermotechnic Committee, CTI) were used in the energy simulations.

The archetype was determined by using the data both directly acquired and indirectly estimated from the responses to the questionnaires and makes it possible, when varying the input parameters, to calculate separately the additional energy consumption linked to remote working (*lavoro agile,* LAG) due to heating and cooling, and to estimate the associated GHG emissions.

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[18] For conservative purposes, it was decided not to apply the multiplication factor for the degree of occupancy of the rooms.

[19] Specifically, such factor was obtained by adding the energy consumption of a Lenovo ThinkPad T490 PC (the model currently most used by employees) for 8 hours of operation and the average energy consumption of compact fluorescent light bulbs capable of illuminating a work environment for 4 hours; the related emissions were obtained by applying the emission factors of the national energy mix.

[20] Banca d'Italia's GHG emissions, calculated according to the GHG Protocol methodology, are published annually in the Activity and Sustainability Report available on the Bank's website.

[21] For more information and the formula of the dynamic energy balance model, see ISO 52016-1, par. 6.5.7.2 'Energy balance on zone level'.

[22] Typical climatic years are calculated according to the procedure described in the UNI EN ISO 15927-4 standard and consist of 12 characteristic months selected from an archive of meteorological data collected over a period of time preferably greater than 10 years. They represent, over the long term, the average values of the most important climatic parameters (air temperature, relative humidity, global horizontal solar irradiance, and wind speed) for 110 reference locations throughout the country. For more information, see the 'National Typical Climatic Years (TRY) for Thermotechnical Applications' page available on the Italian Thermotechnical Committee website.

In the scenario under consideration, the baseline energy consumption is assumed to ensure thermal comfort for potential occupants (to prevent excessive thermo-humidity gradients, or based on established consumption habits), when the Banca d'Italia employee is not working remotely from that dwelling. Accordingly, the spread assigned to the LAG variable is calculated as:

$$\Delta E(LAG) = E(tot) - E(base)$$

where $E\ (base)$ incorporates the typical working day set-up, with no remote working. In practical terms, this methodological choice is equivalent to assuming that the LAG variable induces an increase in the duration and intensity of heating and cooling limited to the actual hours of remote working.

Further methodological details and the technical assumptions of the model are given in the Appendix.

6. Conclusion

This paper assesses the environmental impact of adopting a hybrid work model. In particular, it estimates GHG emissions linked to the additional energy that people working remotely use in their homes or, in general, in the places where they work remotely.

The results show that, for a Banca d'Italia employee, the average daily emissions generated by commuting to work are equal to 4.1 $kgCO_2e$.

The average emissions related to additional household energy consumption due to remote working amount to 1.1 $kgCO_2e$ per day of remote working, regardless of the month of the year. This factor is composed of:

- 0.688 $kgCO_2e$ for the additional use of energy due to household heating;
- 0.327 $kgCO_2e$ for the additional use of energy due to household cooling;
- 0.084 $kgCO_2e$ for the use of a computer and of lighting.

This emission factor is about one quarter of that related to commuting to work.

The results presented are in line with the relevant literature and highlight the positive net environmental impact resulting from the implementation of a working model that integrates remote working, thereby reducing commuting. At aggregate level, in 2024, Banca d'Italia recorded a 31.5 per cent reduction in total GHG emissions associated with staff commuting and remote working, compared with 2019.

When interpreting the results, it should be taken into account that they depend above all on Banca d'Italia's geographical organization across Italy, on the remote working policies implemented, and on the consumption and travel habits of its employees.

At the same time, the methodological approach and the results of this paper - while based on empirical evidence from a single sample survey carried out in 2023 - potentially provide other firms or institutions with a tool to calculate their indirect GHG emissions (Scope 3) due to remote working. This calculation may be made by:

- directly using the average emission factor of 1.1 $kgCO_2e$ calculated for Banca d'Italia (to be multiplied by the total number of days worked remotely by their employees over the year); *or*

- using the daily average emissions presented in Tables A and B, or in Tables 4 and 5 in the Appendix, together with specific data to be obtained by administering an internal questionnaire.[23]

[23] The data to be collected are the number of days worked remotely by employees in a year, broken down by climate zone of the location where the remote work is performed and the related energy efficiency interventions implemented. When using Tables A and B, where the factors are averaged over the year, these factors must be multiplied by the number of days worked remotely in a year by each employee in their climate zone. When using Tables 4 and 5, where the factors refer exclusively to the actual periods in which heating and cooling systems are turned on, these factors must be multiplied by the number of days worked remotely by each employee in their respective climate zone, divided into the respective heating and cooling seasons. The resulting greenhouse gas emissions for heating and cooling are then to be added to those relating to the energy consumption for the use of a computer and of workplace lighting.

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Appendix

Table 1

Questionnaire response rates
(numbers and per cent)

	Total	Head office	Branch network
	Total Banca d'Italia population as at June 2023		
Total	6,731	4,755	1,976
Men	4,183	3,018	1,165
Women	2,548	1,737	811
Managerial area	3,526	2,782	744
Operational area and other areas	3,205	1,972	1,233
	Complete responses		
Total	3,089	2,149	940
Men	1,910	1,359	551
Women	1,179	790	389
Managerial area	1,802	1,370	432
Operational area and other areas	1,287	779	508
	Response rates for complete questionnaires		
Total	46%	45%	48%
Men	46%	45%	47%
Women	46%	45%	48%
Managerial area	51%	49%	58%
Operational area and other areas	40%	40%	41%

Figure 1

Place of employment of respondents, comparison with the population
(relative frequencies)

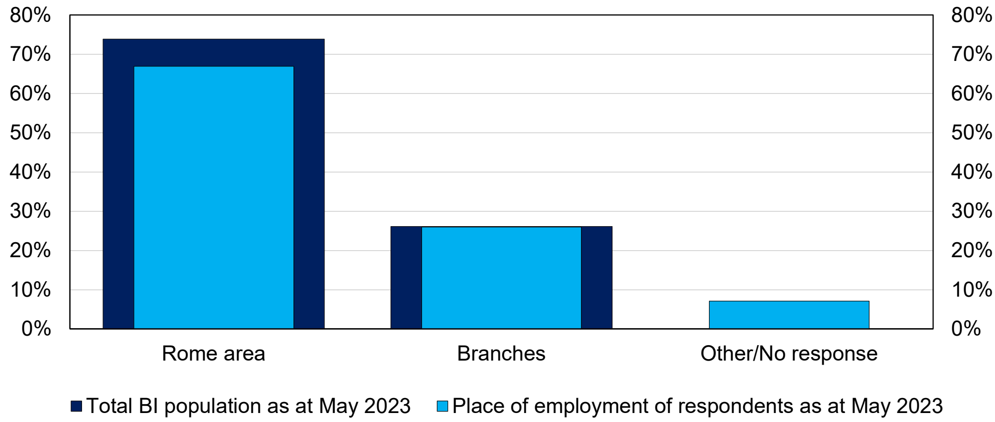


Figure 2

How work is carried out, comparison with the population

(relative frequencies)

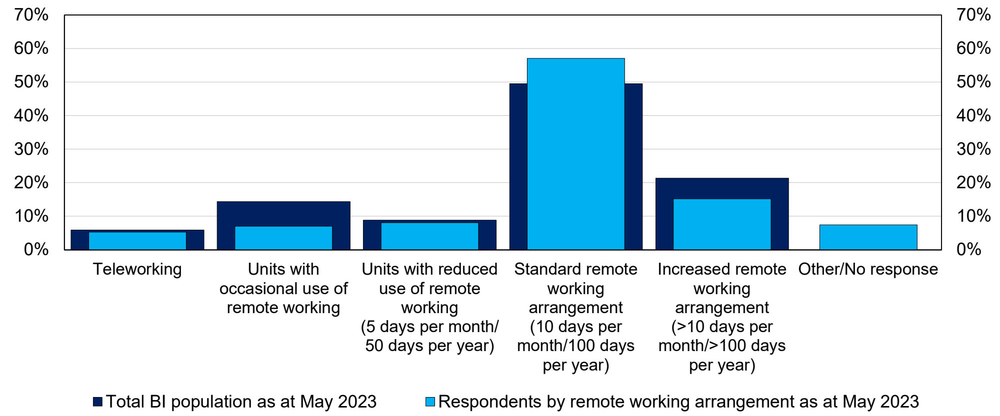


Figure 3

Remote working

(per cent)

(a) Mainly location of remote working **(b) Frequency of remote working in a dwelling other than the primary residence**

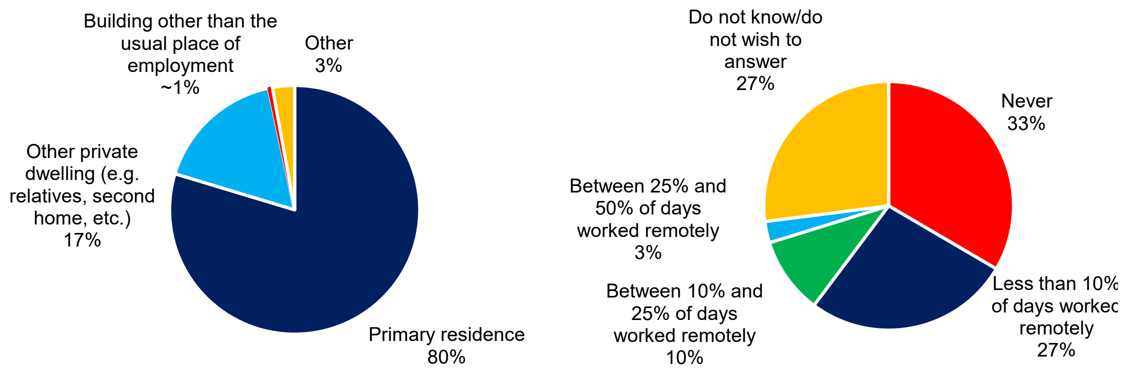


Figure 4

Propensity to change primary residence induced by the possibility of working remotely

(per cent)

(a) Propensity to change primary residence given the possibility of remote working **(b) Main reasons for the propensity to change primary residence**

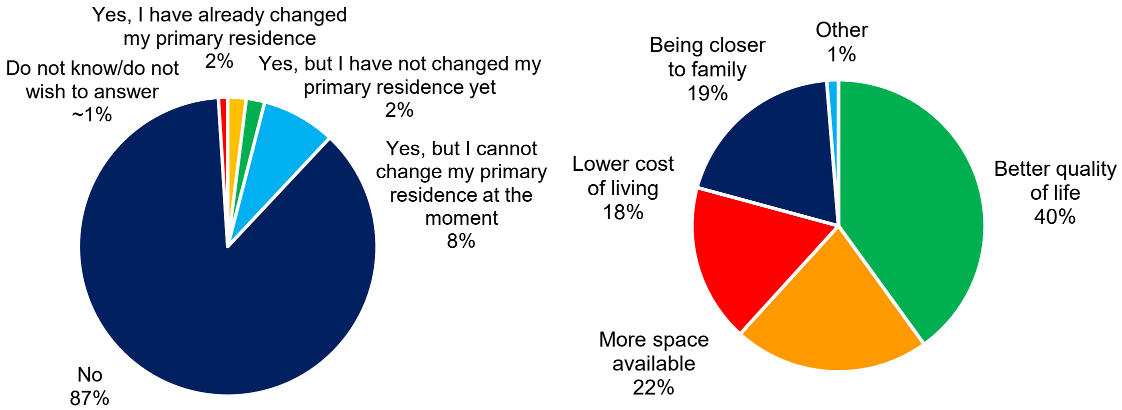


Figure 5

Monthly breakdown of days worked between January 2023 and June 2025

(per cent)

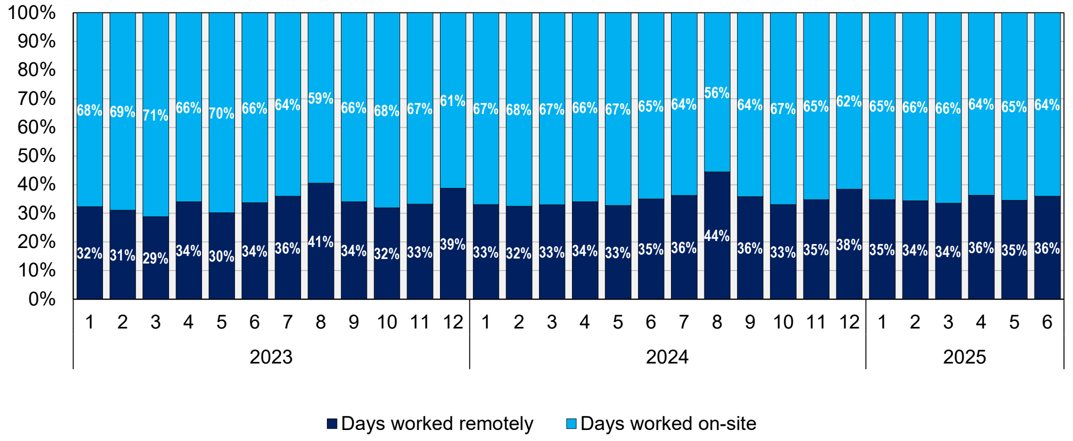


Figure 6

Days worked on-site and remotely on average for the different days of the week, excluding teleworking

(per cent)

(a) Head office **(b) Branches**

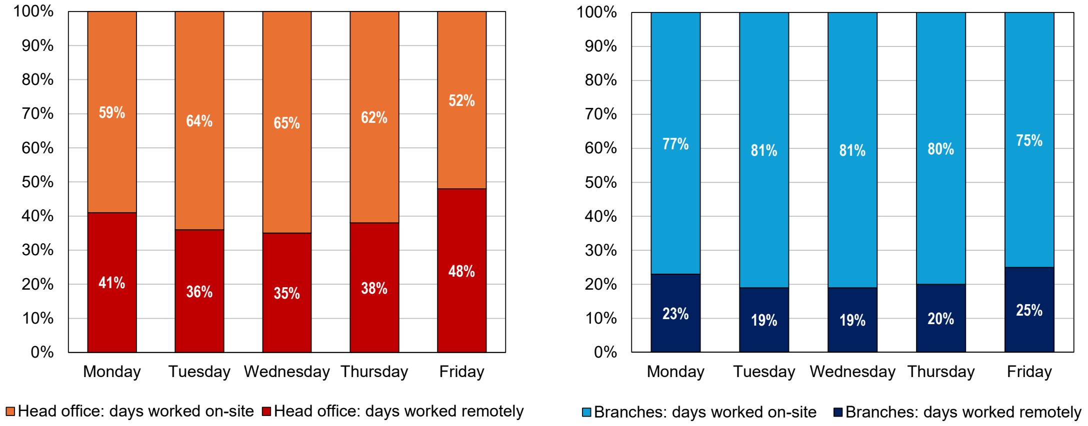


Figure 7

Kilometres travelled by different means of transport when commuting to work

(per cent)

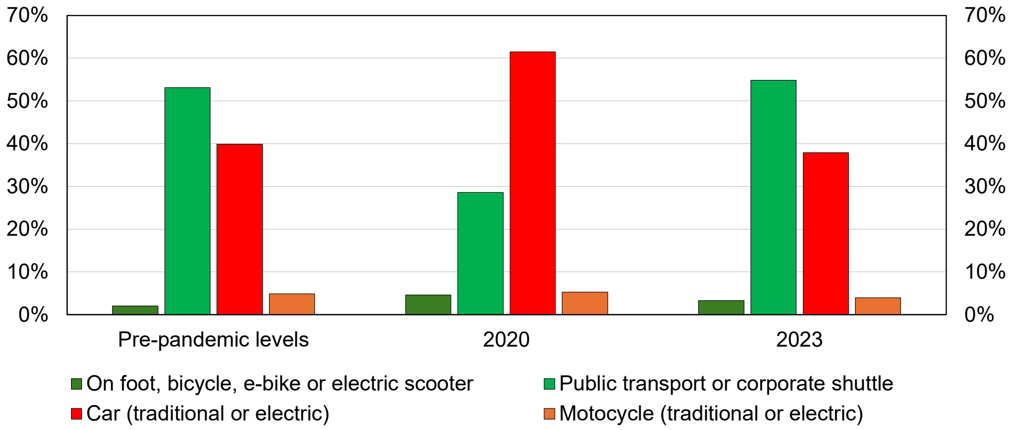


Figure 8

Emission standards for private motor vehicles used for travel – years 2019 and 2023

(per cent)

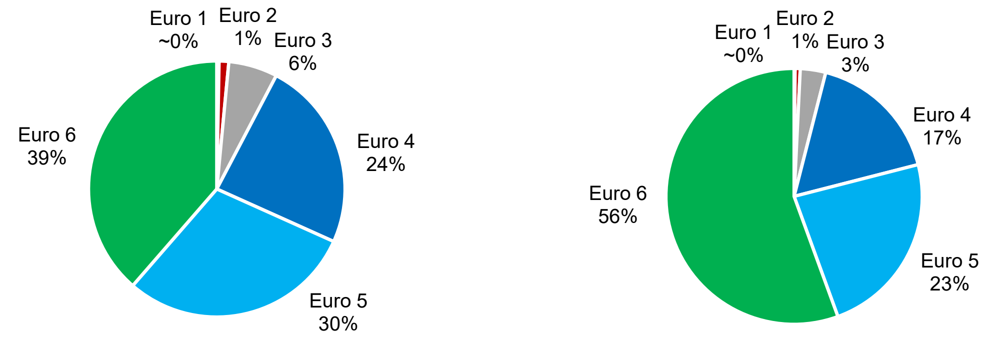


Figure 9

Respondents' home-to-work journey

(relative frequencies)

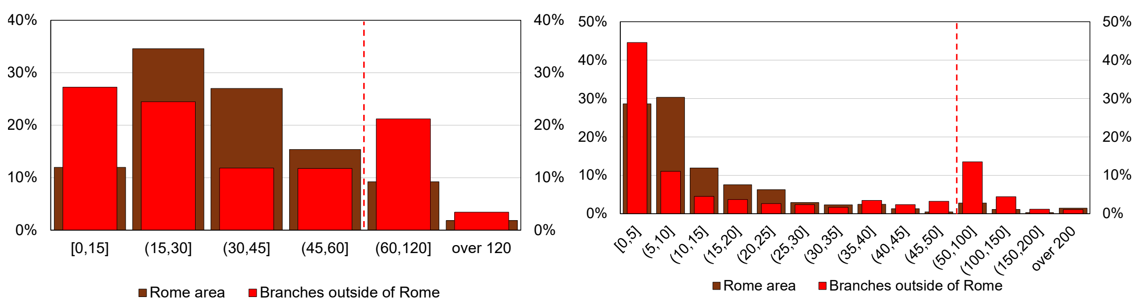


Figure 10

Arrival time when working in person

(relative frequencies)

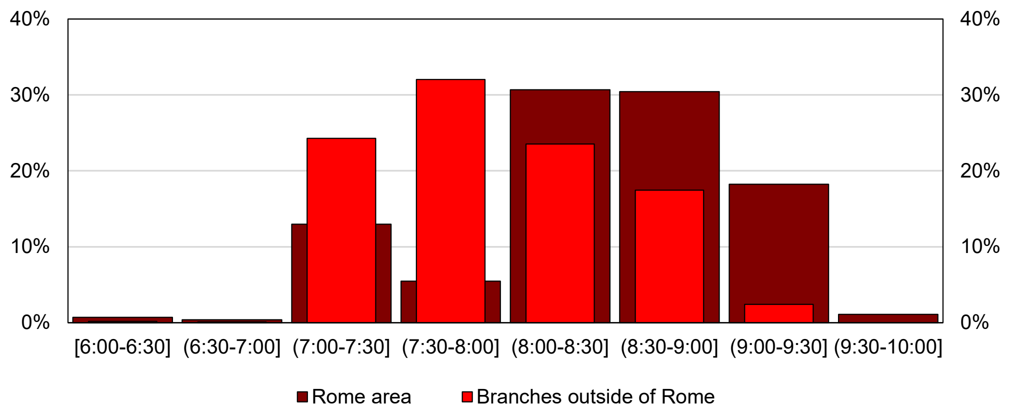


Figure 11

Means of transport used for commuting

(percentages)

(a) Kilometres travelled by different means of transport: comparison between the Rome area and the branches — **(b) Type of car used by employees who commute by car**

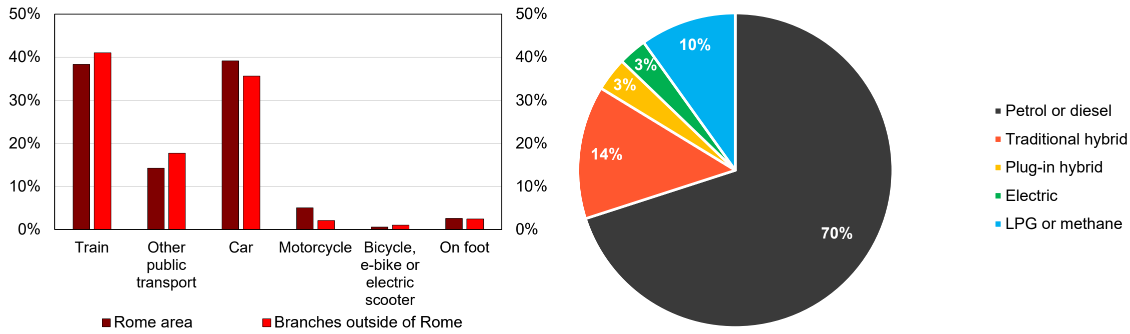


Figure 12

Alternatives to using privately owned vehicles (car and motorcycle)

(per cent)

(a) Willingness to use sustainable mobility means systematically / predominantly in place of private vehicles — **(b) Main barriers to switching to local public transport**

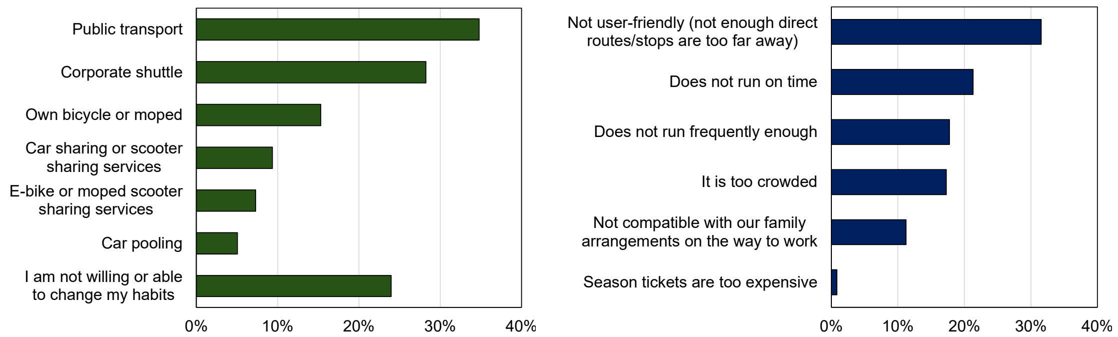


Figure 13

Sharing areas when working remotely

(per cent)

(a) Sharing the home with other people when working remotely — **(b) Sharing the room with other people when working remotely**

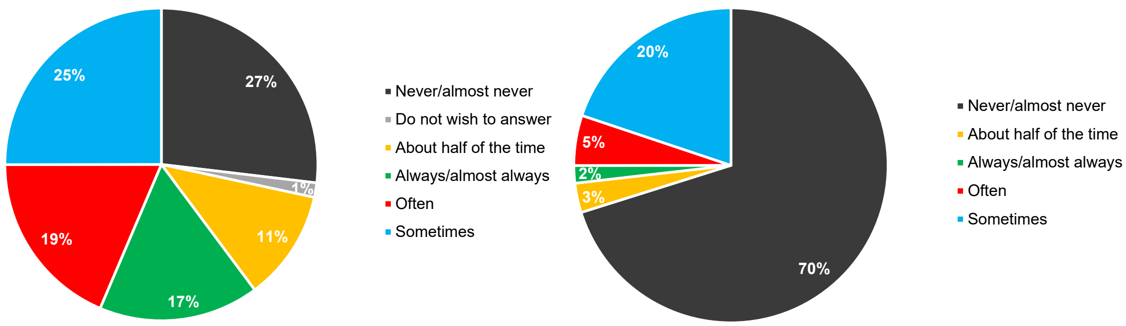


Figure 14

Housing situation of respondents

(per cent)

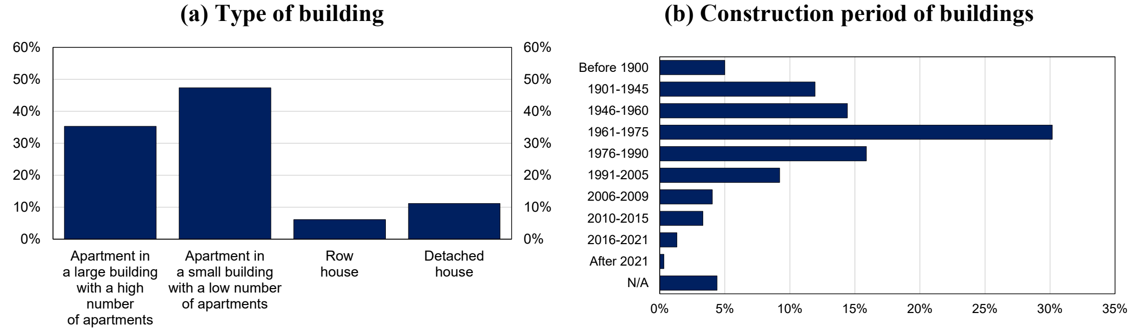


Table 2

Average annual emissions of pollutants from the use of private cars and motorcycles by respondents

(average grams of pollutant per employee using their private motor vehicle)

POLLUTANT	Average quantity
CO	1,096.7334
VOCs	864.9513
NMVOC	814.3922
NO_x	578.9866
Benzene	0.7751
PM2.5	48.6710
PM10	82.5450
PM exhaust	11.9456
Me	5.5087
PAH	0.0028
BaP	0.0007
N_2O	10.5475
CH_4	50.5591

Details on calculating additional household energy consumption and technical assumptions

The tool developed by ENEA, based on a dynamic energy-balance model and on the ‘archetype’ model, is shown below (fig. 15).

The tool uses the following standards and technical assumptions:

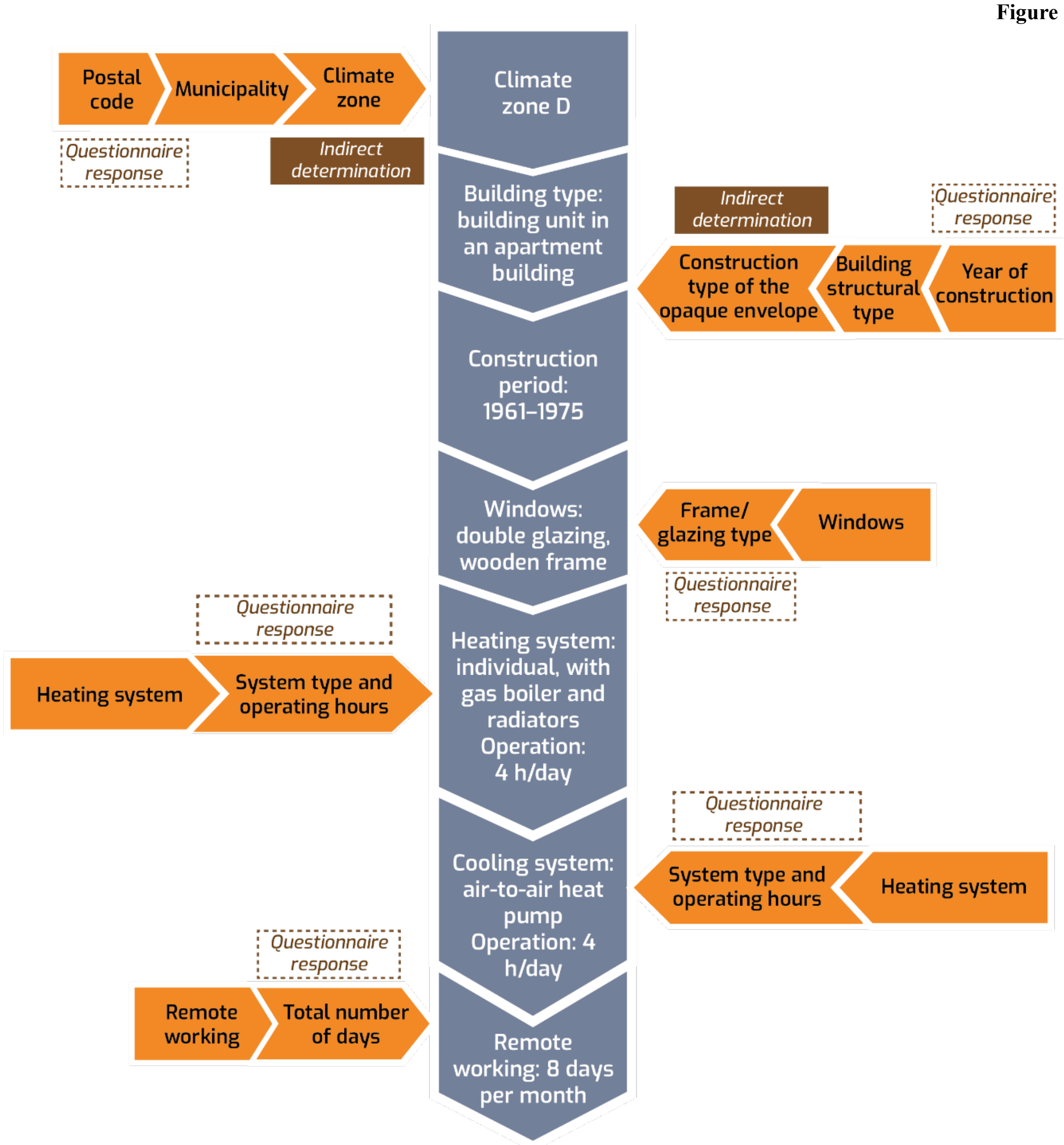
- **Thermo-physical characteristics of the building envelope**: thermal transmittance and areal heat capacity were derived from UNI/TR 11552:2014[24] and UNI EN ISO 6946:2018,[25] with dynamic parameters referred to based on UNI EN ISO 13786:2018.[26]
- **Technical building system**: an individual natural gas heating system with a two-star type B atmospheric boiler and radiators was assumed, with energy efficiency compliant with

[24]See the UNI/TR 11552:2014 standard. ‘Opaque envelope components of buildings - Thermo-physical parameters’.
[25]See UNI EN ISO 6946:2018 standard. ‘Building components and building elements - Thermal resistance and thermal transmittance - Calculation methods’.
[26]See the UNI EN ISO 13786:2018 standard. ‘Thermal performance of building components - Dynamic thermal characteristics - Calculation methods’.

UNI/TS 11300-2:2019. For cooling, an air-to-air[27] single-split system with an EER of 3.74[28] was considered, modelled according to UNI/TS 11300-3:2010.

- **Operating conditions and load profiles**: assessed on an hourly basis using the lumped parameter approach (RC model) defined in UNI EN ISO 52016-1:2018.[29] Representative locations of climate zones B, C, D, and E were used, imposing the operating limits and switch-on periods envisaged by Presidential Decree 412/1993, proportional to the degree-days of the respective locations.[30]

Figure 15



[27]See the UNI/TS 11300-2:2019 standard. 'Energy performance of buildings - Part 2: Evaluation of primary energy need and of system efficiencies for space heating, domestic hot water production, ventilation and lighting for non-residential buildings'.
[28]See the UNI/TS 11300-3:2010 standard. 'Energy performance of buildings - Part 3: Evaluation of primary energy and system efficiencies for space cooling'.
[29]See the UNI EN ISO 52016-1:2018 standard. 'Energy performance of buildings - Energy needs for heating and cooling, internal temperatures and sensible and latent heat loads - Part 1: Calculation procedures'.
[30] See Presidential Decree of 26 August 1993, No. 412. 'Regulation containing standards for the design, installation, operation and maintenance of heating systems in buildings for the purpose of reducing energy consumption'.

- **Estimation of useful heat requirements**: for heating and cooling, the following were considered:[31]
  - heat transfer through the building envelope;
  - ventilation and infiltration (reference airflow of $0.3h^{-1}$ under standard conditions);
  - internal thermal heat gain from occupants and equipment (4.4 W / m²);
  - average monthly solar heat gains of transparent components, as a function of the *g* glass factor and the air-light ratio;
  - thermal inputs from incident solar radiation on opaque envelope components, depending on the solar absorption factor of an opaque component (0.6 per medium colour).
- **Thermal set points**: assumed at 20°C for heating and 26°C for space cooling during working hours, in line with the questionnaire responses.
- **Inter-individual variability corrections:** correction factors were applied for efficiency interventions on the building envelope (replacement of windows frames, external wall thermal insulation, combination of the two), with reductions in needs estimated by pre/post-intervention simulated comparison, consistent with the requirements of the reference building of the Ministerial Decree of 26 June 2015.[32]
- **Conversion of energy consumption to emissions**:
  - for natural gas, average coefficients of the national UNFCCC inventory have been adopted (2019-2021 average),
  - for electricity, the national average emission factor published by ISPRA,[33] ensuring temporal and accounting consistency with official inventories.

The tool is based on an overall useful surface of the archetype of approximately 100 m² (whole dwelling) for estimating heating energy need and a surface of 34 m² (an environment in which each employee performs work remotely) for estimating space cooling energy need.

Finally, it should be noted that the calculation of additional energy consumption was carried out also taking into account natural ventilation conditions and established consumption patterns on working days in which the remote worker was absent. These elements were considered in the definition of the baseline scenario (E_{base}), based on the responses to the questionnaire administered to employees, avoiding assuming a priori on these days that the dwelling has zero energy consumption and recognizing the presence of potential consumption related to residual comfort or the presence of other occupants.

Greenhouse gas emissions include CO_2 emitted as a result of direct combustion of fossil fuels (methane gas) and indirect emissions (Scope 2, location-based) associated with the electricity used and calculated using the emission factor of the national energy mix. Emissions of other greenhouse gases (CH_4, N_2O) are negligible under the conditions examined.

The technical parameters used in the estimation are as follows (Table 3):

[31] See UNI / TS 11300-1:2014. ‘Energy performance of buildings - Part 1: Determination of heating energy requirements of the building for summer and winter air conditioning’.

[32] See Interministerial Decree of 26 June 2015. ‘Application of energy performance calculation methodologies and definition of minimum building requirements and requirements’. Updated by the Ministerial Decree of 28 October 2025.

[33] See ISPRA, *Efficiency and decarbonization indicators in Italy and in the biggest European Countries (Report 386/2023)*, ISPRA Editions, 2023.

Table 3

Type	Parameter	Value	Unit of measurement	Source / Calculation method
Thermo-physical characteristics of the opaque envelope elements	Masonry (MLP03) Thermal transmittance - U	1.18	W / m² K	EN ISO 6946:2018 UNI/TR 11552:2014
	Masonry (MLP03) - Indoor air heating capacity - κ_i	57.055	kJ / m² K	EN ISO 13786:2018 UNI/TR 11552:2014
	Under-roof wall - Thermal transmittance - U	1.88	W / m² K	EN ISO 6946:2018 UNI/TR 11552:2014
	Under-roof wall - Indoor areic thermal capacity - κi	63.764	kJ / m² K	EN ISO 13786:2018 UNI/TR 11552:2014
Thermo-physical characteristics of the transparent envelope elements	Window glass (zone B) - U_g	5.75	W / m² K	UNI / TS 11300-1:2014 (Prosp. B.2, B.5)
	Window frames (zone B) - U_f	2.20	W / m² K	UNI / TS 11300-1:2014 (Prosp. B.2, B.5)
	Window (zone B) - $U_{w,a}$	3.55	W / m² K	UNI / TS 11300-1:2014 (Prosp. B.2, B.5)
	Window glass (Zone B) - $g_{gl,n}$	0.85	–	UNI EN ISO 10077-1:2018
	Window glass (zones C-D-E-F) - U_g	2.85	W / m² K	UNI / TS 11300-1:2014 (Prosp. B.2, B.5)
	Window frames (zones C-D-E-F) - U_f	2.20	W / m² K	UNI / TS 11300-1:2014 (Prosp. B.2, B.5)
	Window (zones C-D-E-F) - $U_{w,a}$	2.38	W / m² K	UNI / TS 11300-1:2014 (Prosp. B.2, B.5)
	Window glass (zones C-D-E-F) - $g_{gl,\ n}$	0.75	–	UNI EN ISO 10077-1:2018
	Uninsulated roller shutter box - U	6	W / m² K	UNI / TS 11300-1:2014 (Paragraph 11.1.1)
Location representative of the climate zone of the tool	Zone B - Palermo - Degree-days	751	GG	Presidential Decree 412/1993
	Zone B - Palermo - Operating limit	8	h / g	Presidential Decree 412/1993
	Zone B - Palermo - Switch-on period	01/12–31/03	–	Presidential Decree 412/1993
	Zone C - Lecce - Degree-days	1,153	GG	Presidential Decree 412/1993
	Zone C - Lecce - Operating limit	10	h / g	Presidential Decree 412/1993
	Zone C - Lecce - Switch-on period	15/11–31/03	–	Presidential Decree 412/1993
	Zone D - Rome - Degree-days	1,415	GG	Presidential Decree 412/1993
	Zone D - Rome - Operating limit	12	h / g	Presidential Decree 412/1993
	Zone D - Rome - Switch-on period	01/11–15/04	–	Presidential Decree 412/1993
	Zone E - Milan - Degree-days	2,404	GG	Presidential Decree 412/1993
	Zone E - Milan - Operating limit	14	h / g	Presidential Decree 412/1993
	Zone E - Milan - Switch-on period	15/10–15/04	–	Presidential Decree 412/1993
	Zone F - Cuneo - Degree-days	3,012	GG	Presidential Decree 412/1993
	Zone F - Cuneo - Operating limit	All year round	h / g	Presidential Decree 412/1993
	Zone F - Cuneo - Switch-on period	No limits	–	Presidential Decree 412/1993
Correction factors used for the assessment of additional consumption from LAG	Degree of occupancy of areas - Shared with another user (frequent)	50	%	ENEA estimate based on questionnaire data
	Degree of occupancy of areas - Shared with another user (≈ half the time)	75	%	ENEA estimate based on questionnaire data
	Energy efficiency interventions - Window replacement - Zones A and B	89	%	ENEA simulations; reference building Ministerial Decree of 26 June 2015, App. A
	Energy efficiency interventions - Window replacement - Zone C	87	%	ENEA simulations; reference building Ministerial Decree of 26 June 2015, App. A
	Energy efficiency interventions - Window replacement - Zone D	87	%	ENEA simulations; reference building Ministerial Decree of 26 June 2015, App. A

	Energy efficiency interventions - Window replacement - Zone E	86	%	ENEA simulations; reference building Ministerial Decree of 26 June 2015, App. A
	Energy efficiency interventions - Window replacement - Zone F	86	%	ENEA simulations; reference building Ministerial Decree of 26 June 2015, App. A
	Energy efficiency interventions - External wall insulation - Zones A and B	31	%	ENEA simulations; reference building Ministerial Decree of 26 June 2015, App. A
	Energy efficiency interventions - External wall insulation - Zone C	37	%	ENEA simulations; reference building Ministerial Decree of 26 June 2015, App. A
	Energy efficiency interventions - External wall insulation - Zone D	40	%	ENEA simulations; reference building Ministerial Decree of 26 June 2015, App. A
	Energy efficiency interventions - External wall insulation - Zone E	43	%	ENEA simulations; reference building Ministerial Decree of 26 June 2015, App. A
	Energy efficiency interventions - External wall insulation - Zone F	44	%	ENEA simulations; reference building Ministerial Decree of 26 June 2015, App. A
	Energy efficiency interventions - external wall insulation + replacement of window frames - Zones A and B	20	%	ENEA simulations; reference building Ministerial Decree of 26 June 2015, App. A
	Energy efficiency interventions - external wall insulation + replacement of window frames - Zone C	25	%	ENEA simulations; reference building Ministerial Decree of 26 June 2015, App. A
	Energy efficiency interventions - external wall insulation + replacement of window frames - Zone D	28	%	ENEA simulations; reference building Ministerial Decree of 26 June 2015, App. A
	Energy efficiency interventions - external wall insulation + replacement of window frames - Zone E	31	%	ENEA simulations; reference building Ministerial Decree of 26 June 2015, App. A
	Energy efficiency interventions - external wall insulation + replacement of window frames - Zone F	31	%	ENEA simulations; reference building Ministerial Decree of 26 June 2015, App. A
Thermal characteristics of the envelope in simulated energy efficiency interventions of the real estate unit	Zones A and B - Perimeter walls - U	0.43	W / m² K	Ministerial Decree of 26 June 2015, App. A
	Zone B - Window - U_w	3.00	W / m² K	Ministerial Decree of 26 June 2015, App. A
	Zone C - Perimeter walls - U	0.34	W / m² K	Ministerial Decree of 26 June 2015, App. A
	Zone C - Window - U_w	2.20	W / m² K	Ministerial Decree of 26 June 2015, App. A
	Zone D - Perimeter walls - U	0.29	W / m² K	Ministerial Decree of 26 June 2015, App. A
	Zone D - Window - U_w	1.80	W / m² K	Ministerial Decree of 26 June 2015, App. A
	Zone E - Perimeter walls - U	0.26	W / m² K	Ministerial Decree of 26 June 2015, App. A
	Zone E - Window - U_w	1.40	W / m² K	Ministerial Decree of 26 June 2015, App. A
	Zone F - Perimeter walls - U	0.24	W / m² K	Ministerial Decree of 26 June 2015, App. A
	Zone F - Window - U_w	1.10	W / m² K	Ministerial Decree of 26 June 2015, App. A
U_g = Thermal transmittance of glazing component; U_f = Thermal transmittance of window frames, doors, and window doors; $g_{gl,n}$ = Total solar energy transmittance of glass; U_w = Average thermal transmittance of window.				

Table 4

Daily emission factors linked to additional household energy consumption for heating (1)

(kgCO2e per day of remote working)

Climate zone (Decree of the President of the Republic 412/1993)	GHG emissions linked to heating in case of additional household energy consumption	Multiplicative correction factors linked to energy efficiency interventions			Multiplicative (optional) correction factors for the occupancy of the areas	
		Replacement of existing windows	External wall thermal insulation (EWI)	Both measures (windows and EWI)	Sharing areas with another person (always, almost always, often)	Sharing areas with another person (for about half of the time)
A and B	2.365	0.89	0.31	0.20	0.5	0.75
C	2.760	0.87	0.37	0.25	0.5	0.75
D (2)	2.610	0.87	0.40	0.28	0.5	0.75
E	3.926	0.86	0.43	0.31	0.5	0.75
F	4.250	0.86	0.44	0.31	0.5	0.75

(1) Data are averaged over the heating-system operating period. – (2) The trend of the emission factors is not always increasing from climate zone A to F, since energy consumption is relative to the operating periods of the heating systems that are wider in colder climate zones.

Table 5

Daily emission factors related to additional household energy consumption for cooling (1)

(kgCO2e per day of remote working)

Climate zone (Decree of the President of the Republic 412/1993)	GHG emissions linked to cooling in case of additional household energy consumption	Multiplicative (optional) correction factors for the occupancy of the areas	
		Sharing areas with another person (always, almost always, often)	Sharing areas with another person (for about half of the time)
A and B	0.428	0.5	0.75
C	0.301	0.5	0.75
D (2)	0.355	0.5	0.75
E	0.293	0.5	0.75
F	0.182	0.5	0.75

(1) The data are averaged over the year; the effects of energy efficiency measures on the cooling factor were considered negligible for the model. – (2) The trend of the emission factors is not always decreasing from climate zone A to F, since energy consumption is compared with the operating periods of the cooling systems, which are longer in the warmer climate zones.