HSLU Lucerne University of Applied Sciences and Arts

The effects of teleworking on CO_2 emissions to commute: Baselining key data in living labs to investigate transformative change

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Overview

Study aim & research questions

Literature review

LL «*Suurstoffi*»

Methodology

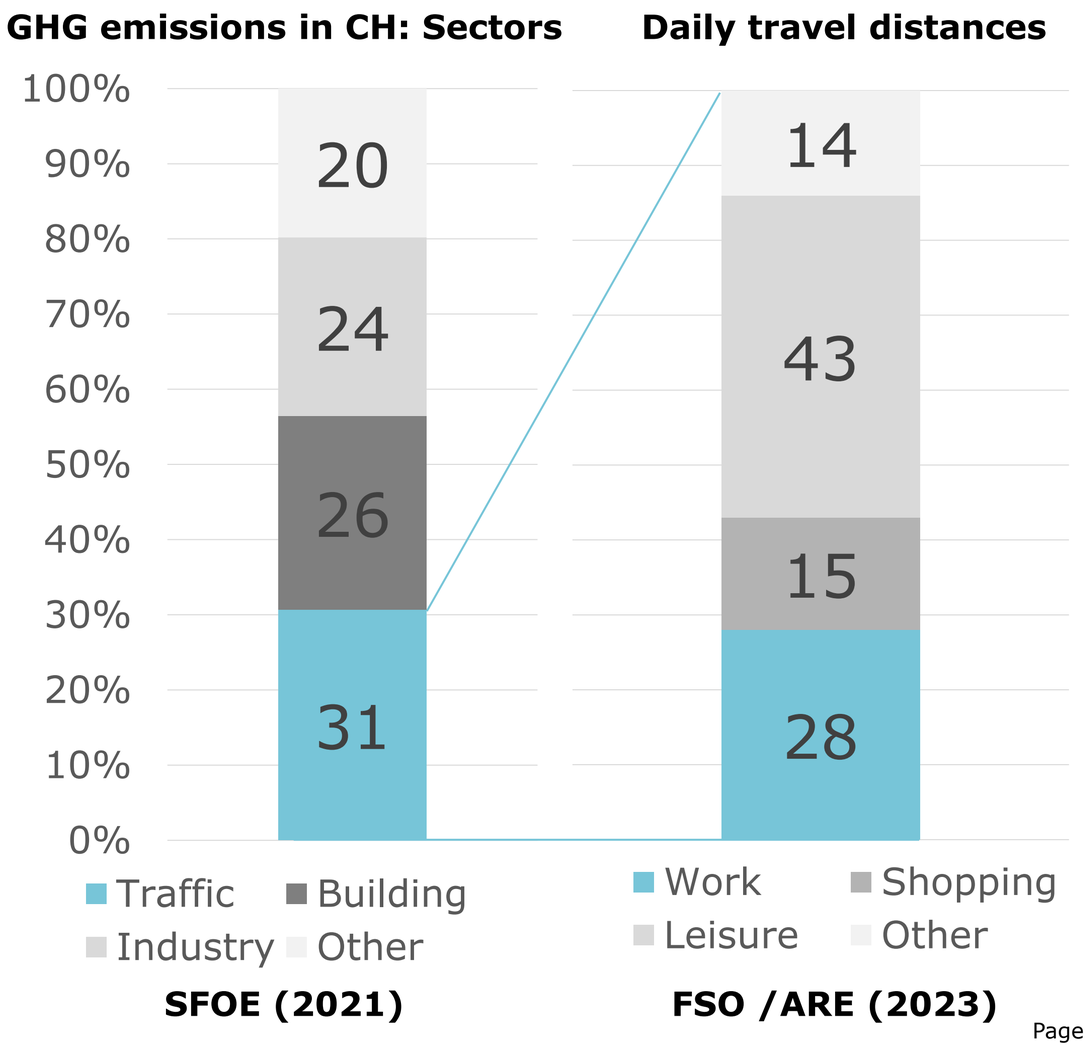
Results: Linear regression model

Summary & outlook

Green house gas (GHG) emission in Switzerland and daily travel distances (2021)

- So far, **GHG reduction** has been achieved **mostly** in the **building** and **industry sector**.
- **One third** of GHG emission is caused **in the traffic sector**.
- **<u>But</u>: No** reduction in emissions since **1990 in the traffic sector** (FOEN 2022; SFOE 2020; 2021, p.5; FSO 2022b, 2022a).
- Traffic caused in 2021 **13.9 mio. tons** of **CO_2**
- **Trip purpose work = 28 %,** equals **3.9 mio. tons of CO_2**
- 5 mio. employees in Switzerland. On average: **761 kg of CO_2 per year.**

How high is this figure in our LL?
Can it be influenced?



Literature Review

Teleworking is understood as work activities that are done outside the traditional workplace (Morganson et al. 2010).

Teleworking is considered as a (transport) **policy** to **reduce** work related **travel CO_2 emissions** (Cass & Faulconbridge 2016; Santos & Azhari 2022)

For Switzerland:

- Ohnmacht et al. (2020) show effects for using **co-working spaces** and
- Wöhner (2022) & Ravalet and Rérat (2019) for **home-office use**

on **reducing distance travelled** on the day of the telework activity.

In general: CO_2 emissions for work commutes are influenced by

- **commuting distance** (i.a. Heinen & Mattioli 2019)
- **mode of transport** (i.a. Pérez-Neira et al. 2020; Sobrino & Arce 2021)
- various **sociodemographic indicators** (gender, income, age, household) (i.a. Brand et al. 2021; Cao & Yang 2017; Cirilli & Veneri 2014, Wang & Zeng 2019)

<u>Research gap</u>: Rebound effects (e.g., more leisure trips on teleworking days) and spillover effects (e.g., increase in individual living space due to separate rooms for home office)

Transformative change within a Living Lab (LL)

<u>Our understanding</u>: In energy studies, a LL introduces a (temporary) **transformative change within a real-life setting**.

To "**encourage people's engagement in new ways of doing**" within the discourse of climate change through a participatory setting (co-creation of interventions) (Sahakian et al. 2021, p.3).

<u>Shortcomings of participatory practices within LLs</u>:

- **Valid population data on consumption patterns** and mobility behavior **is often scarce** especially when the living lab is set up initially.
- **Quantitative monitoring** of **energy savings** and the GHG **mitigation** reduction introduced by interventions is central to a living lab approach (e.g., for the government or policy makers that finance research).
- **Key data** is the backbone **of evaluation studies.**

But how to achieve this key data?

Study aims and research questions (RQ)

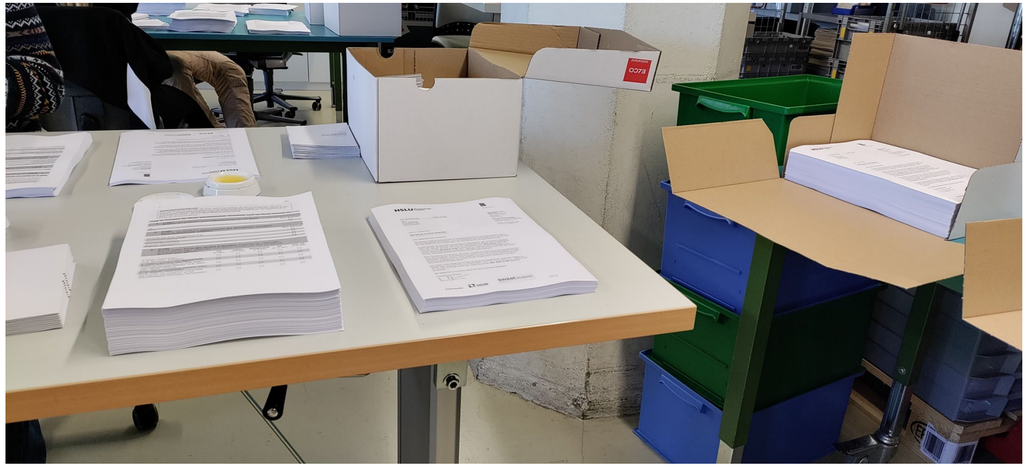
Aim 1: Carrying out a (cross-sectional) base-line-survey, questionnaire before intervention

Aim 2: Including key data to describe the residents of the living lab (socio-demographics, work life characteristic, CO_2-figures for work commutes)

Aim 3: Survey design and methodology is understood as a process of collaboration within the living lab

RQ 1: How can the GHG mitigation potential of the intervention "telework" be analyzed in a LL?

RQ 2: What are the effects of individual characteristics on CO_2 emission for work commutes?



Our LL «Suurstoffi»

The modern “Suurstoffi” Site in the municipality of Risch-Rotkreuz serves as a LL.

- 1500 inhabitants
- 2500 workplaces
- 2600 students

Methodology: Study design

Participative approach

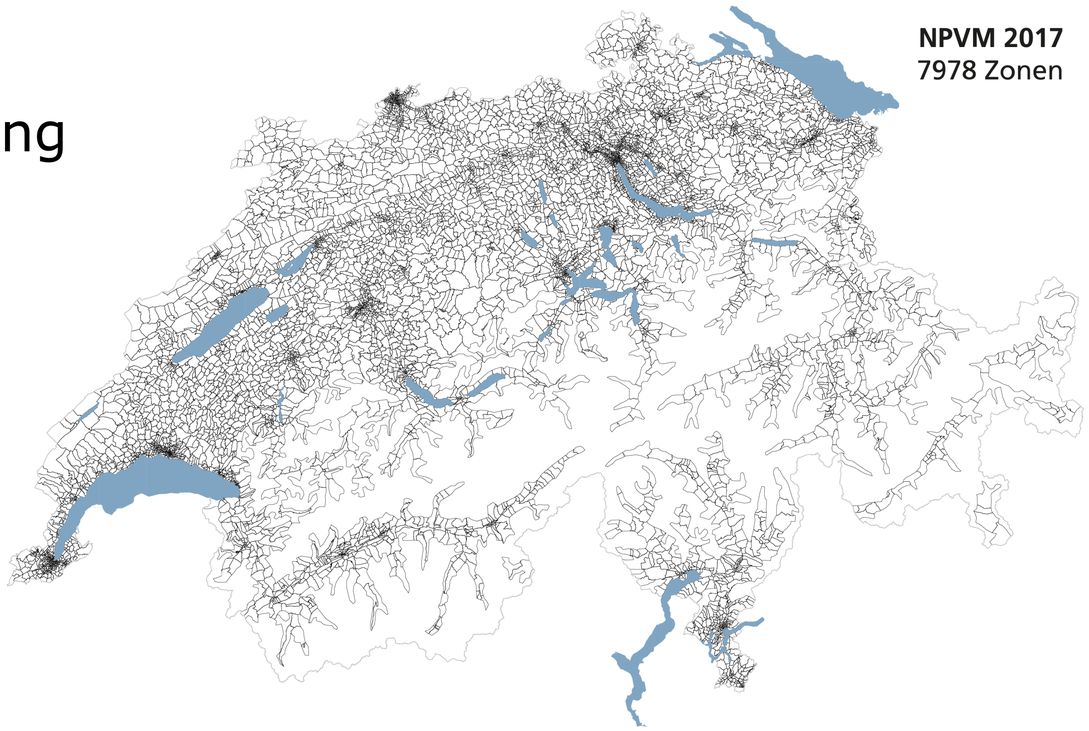
Researchers, public bodies, a real-estate company, industry partners and transport companies have served as a sounding board for the methodological design and content of our study.

Addresses were provided by the **municipality** of Risch-Rotkreuz.

- **Quantitative cross-sectional study** with standardized questionnaire
- **Representative survey** of residents with an age of 18 years and older (n = **922 persons**)
- **Personal letter** with paper-pencil-survey and prepaid reply envelope, in parallel **online survey** in German or English
- **Incentive** in form of a **voucher worth 10 Swiss francs** per person from a local bakery after response
- **Reminder** wave with response control & **field support** with hotline and email support
- **Response rate after** date cleaning: **n = 296 : 32%**

Methodology: Generating CO_2 figures for commuting

- Study participants report **workdays of the week**, **postal code of workplace locations**, **mode of transport (MoT)** for commute
- **Matching of living location** and **workplace location via postal codes** with traffic zones of the Swiss federal transport model
- **Imputation** of **commuting distance** to the survey
- Combining the distances per MoT and commute with **CO_2 equivalent factors based on mobitool factors (Swiss standard)**



MoT	CO_2 factors [grams CO_2-equivalents]
Passenger car, diesel, gasoline (fleet average)	186.4
Passenger car, battery electric (fleet average)	89.8
Train, regional transport, s-rail	8.2
By bike	5.6
On foot	0

Descriptives: general

Attribute	% / Mean	Attribute	% / Mean	*Sig.*
Gender	50 % female	MoT for work commute		
Age	41 years	*Car*	46 %	
Household (HH) size	2.4 persons	*PT*	35 %	
HH income	10 140 Swiss Francs	*Bike*	5 %	
		Walk	13 %	
Car use	23 % car free HH			
PT tickets	86 % of HH	Commuting distance (per day, one way)		*
		All	27 km	
Workload	84 %	*Teleworkers*	31 km	
Telework rate	60 %	*No teleworkers*	21 km	
Telework days per week	1.6			

Note: Two sample t-test, * = the difference is significant at the 0.05 level ($p<.05$, 2-sided). n=242
MoT = mode of transport, HH = household, Sig. = Significance, PT = Public Transport

Descriptives: CO_2 emission to commute (kg per year)

Attribute	**Mean**	*Sig.*
Work commute		
Switzerland	761 kg	
LL	742 kg	
MoT for work commute		**
Car	1538 kg	
Public transport (PT)	77 kg	
Bike	28 kg	
Walk	0 kg	
	Correlation	
Income	.125	.

Attribute	**Mean**	*Sig.*
Gender		
Female	622 kg	
Male	819 kg	
Survey language		**
German	805 kg	
English (proxy for "expats")	326 kg	
Teleworking		*
Yes	597 kg	
No	964 kg	

Note: Two sample t-test / ANOVA n=235
** = The difference is significant at the 0.01 level (p<.01, 2-sided).
* = The difference is significant at the 0.05 level (p<.05, 2-sided).
. = The correlation is significant at the 0.10 level (p<.10, 2-sided).
Sig. = Significance

PMA & «Orientations» towards the car and PT

Constructs	**Mean**	*Sig.*	**Constructs**	**Correlation (r)**	*Sig.*
Phase Model of Action (PMA) (based on Bamberg 2013)		**	Orientations (5-point Likert scale)		
Phase 1: no car use reduction planed	1005 kg	.	*Travelling by other MoT than car is good/pleasant*	-.222	*
Phase 2: reduction considered, but impossible	1549 kg	**	*Travelling by other MoT than car is easy/practicable*	-.377	*
Phase 3: reduction planed, first attempts	681 kg	.	*PT is too inflexible for me*	.193	**
Phase 4: is reducing, wants more	463 kg		*I like to travel by PT because I can focus on other things during the journey*	-.182	**
Phase 5: no car is used at all	61 kg	**			

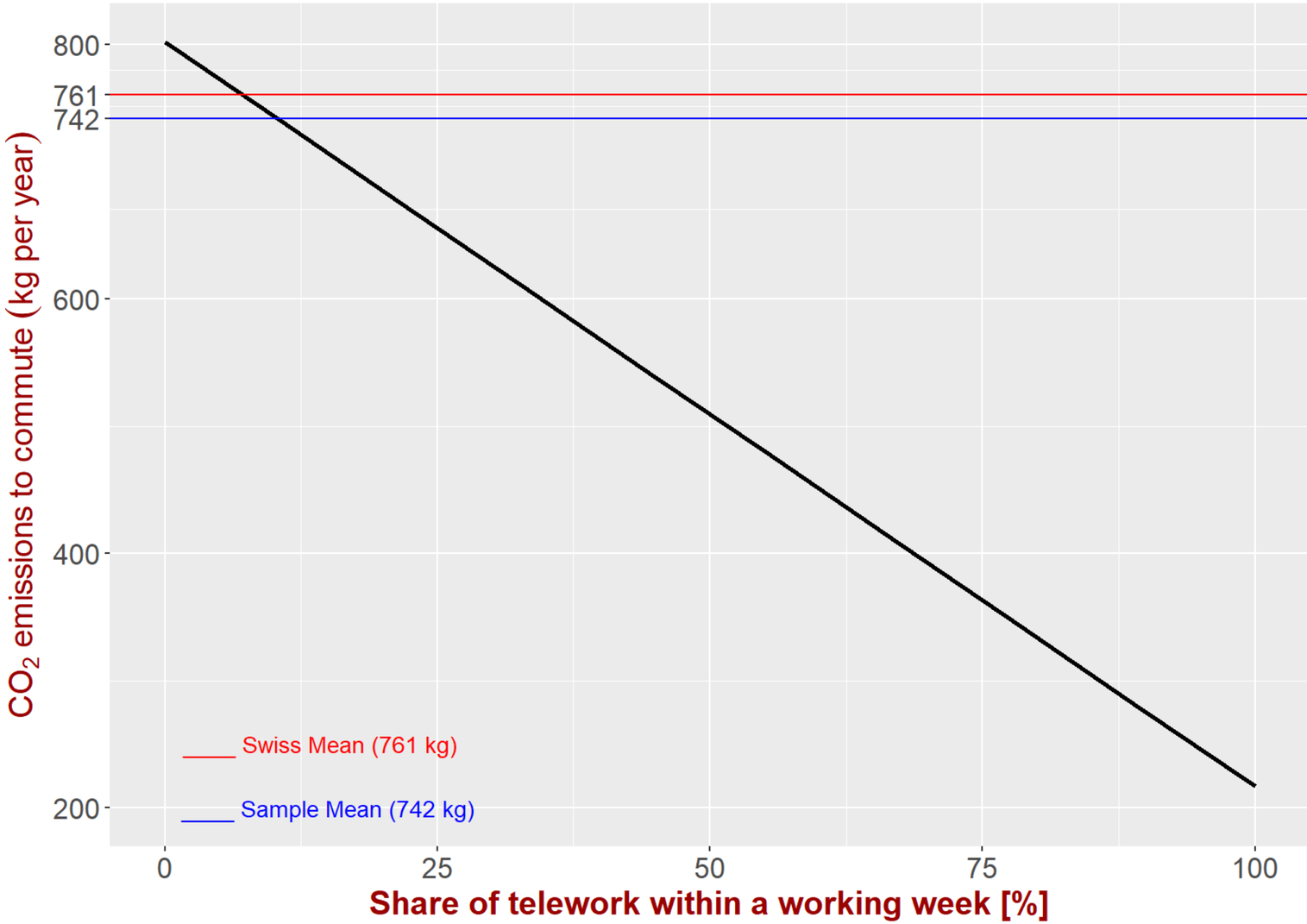
Note: Two sample t-test / ANOVA / Pearson correlation coefficient r n=235
** = The difference/correlation is significant at the 0.01 level ($p<.01$, 2-sided).
* = The difference/correlation is significant at the 0.05 level ($p<.05$, 2-sided).
. = The correlation is significant at the 0.10 level ($p<.10$, 2-sided).
Sig. = Significance

Independent Variables		CO2 emissions to commute (kg per year) b	SE	t values	Pr (>|t|)	Sig.
Intercept		1680.93	556.42	3.02	0.003	**
Share of telework within a working week	percent	-5.86	2.38	-2.46	0.015	*
Workload	fulltime (Ref.: parttime)	341.43	162.82	2.10	0.038	*
Apartment ownership	owner (Ref.: tenant)	-49.65	192.99	-0.26	0.797	
Length of residence	Years	33.20	21.75	1.53	0.129	
Public transport subscription	yes (Ref.: no)	-270.84	168.97	-1.60	0.111	
Cars in household	number (metric)	-55.72	241.14	-0.23	0.818	
Bikes in household	number (metric)	165.18	175.95	0.94	0.349	
MaaS use in a year		-3.24	6.67	-0.49	0.628	
Regular workplace location	suburban	110.69	395.51	-0.28	0.780	
	urban	-944.72	366.25	-2.58	0.011	*
	(Ref.: Rural)					
Phase model of action (PMA)	Phase 2	546.52	188.30	2.90	0.004	**
	Phase 3	17.90	238.00	0.08	0.940	
	Phase 4	-55.40	188.06	-0.30	0.769	
	Phase 5	-247.74	265.51	-0.93	0.352	
	(Ref.: Phase 1)					
Residential location choice	Close to…					
	…highway	61.98	158.54	0.39	0.696	
	…public transport	-272.62	159.18	-1.71	0.089	.
	…workplace	-332.56	129.28	-2.57	0.011	*
Traveling by MoT other than the private car is practicable	yes (Ref.: no)	-316.16	157.58	-2.01	0.047	*
Gender	male (Ref.: female)	108.04	133.27	0.81	0.419	
Age	Years	-4.86	6.55	-0.74	0.459	
Gross household income	Swiss Francs	0.02	0.02	0.80	0.428	
Household size	number (metric)	19.93	65.72	0.30	0.762	
Expats (proxy: English survey)	Yes (Ref.: no)	-244.65	245.48	-1.00	0.321	
n = 235						
Explained Variance = 49 %, adjusted-R^2= 0.49						
F-statistic				6.097	0.000	*

Note: Ref. = Reference Category, Sig. = Significance, ** = The effect is significant at the 0.01 level (p<.01).
* = The effect is significant at the 0.05 level (p<.05).
. = The effect is significant at the 0.10 level (p<.10).

Effects of **telework** on CO_2 emissions to commute (kg per year)

- CO_2 emission to commute per year
  - **Switzerland: 761 kg**
  - **LL: 742 kg**
- Increase of telework **of 10%** within a working week leads to a reduction of **approximately 60 kg of CO_2 per year**.
- A person who **teleworks 50%** consumes **approx. 500 kg CO_2** per year.

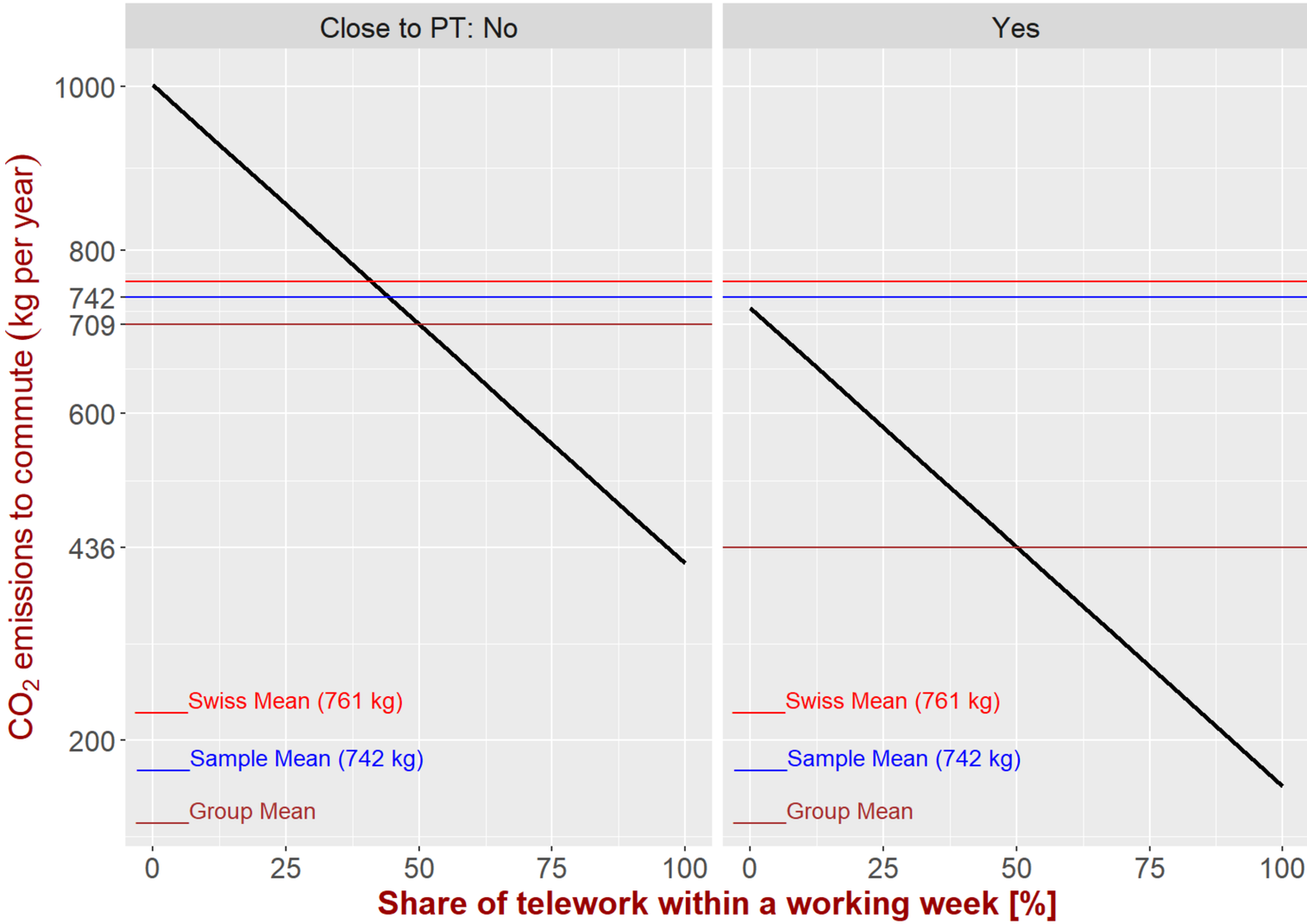


Effects of **regular workplace location** on CO_2 emissions to commute

- Significant difference between regular workplace in
  - **rural area: 1295 kg per year**
  - **urban area: 351 kg per year**
- Significant **higher** CO_2 emissions, if workplace is in a **rural area**, compared to having a workplace in the **urban area**.
- When having a workplace in the city the group mean is **below** Swiss mean and sample mean.

Effects of **residential location choice** on CO_2 emissions to commute (close to PT)

- Significant difference between importance of closeness to PT
  - **no: 709 kg per year**
  - **yes: 436 kg per year**
- Significant **higher** CO_2 emissions, if closeness to PT is **not** important for residential location choice, compared to the group for which it is.
- Both group means are **lower** than the Swiss mean and the sample mean.

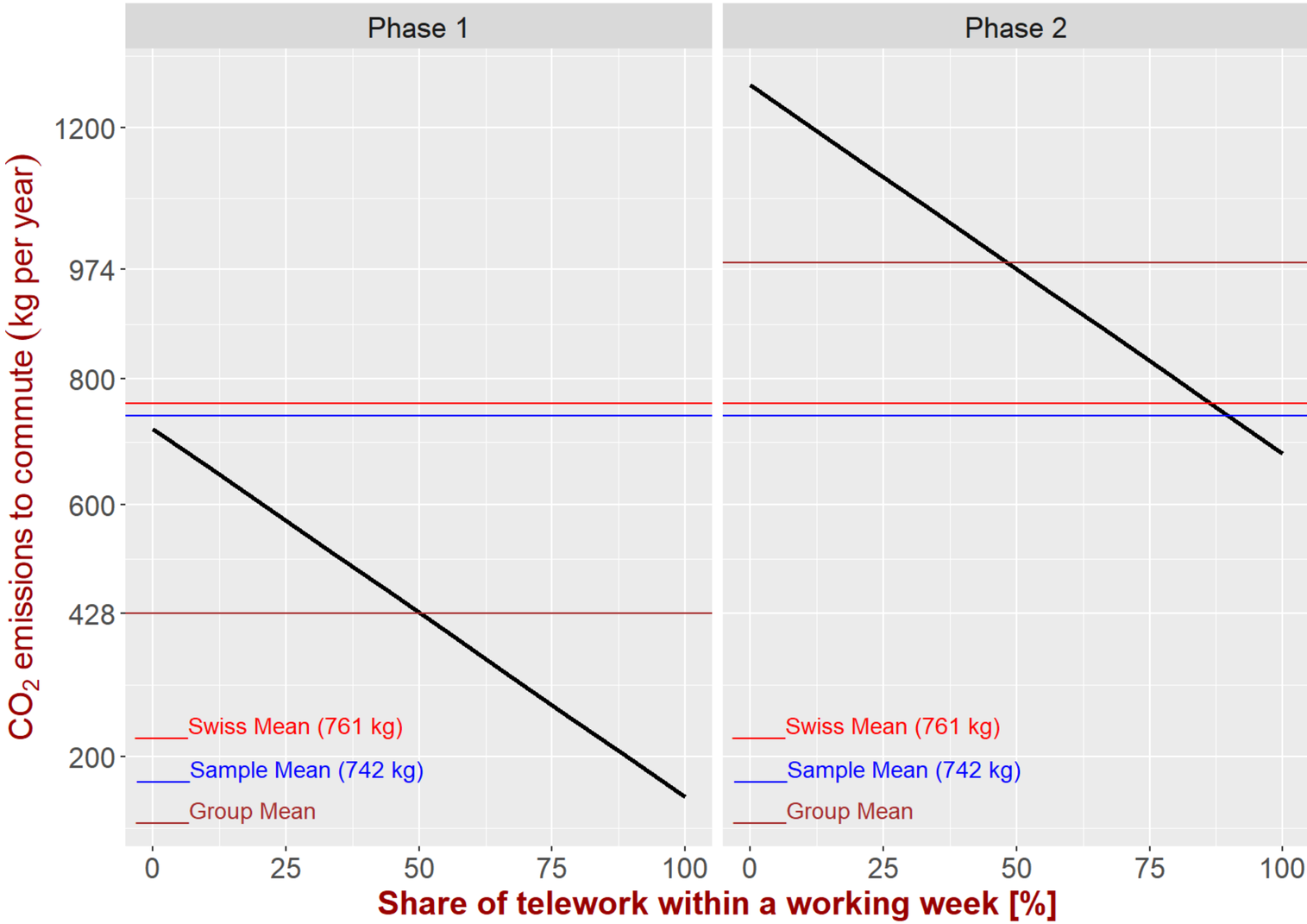


Effects of **residential location choice** on CO_2 emissions to commute (close to regular workplace)

- Significant difference between importance of closeness to the regular workplace
  - **no: 673 kg per year**
  - **yes: 340 kg per year**
- Significant **higher** CO_2 emissions, if closeness to workplace is **not** important for residential location choice, compared to the group for which it is.
- Both group means are **lower** than the Swiss mean and the sample mean.

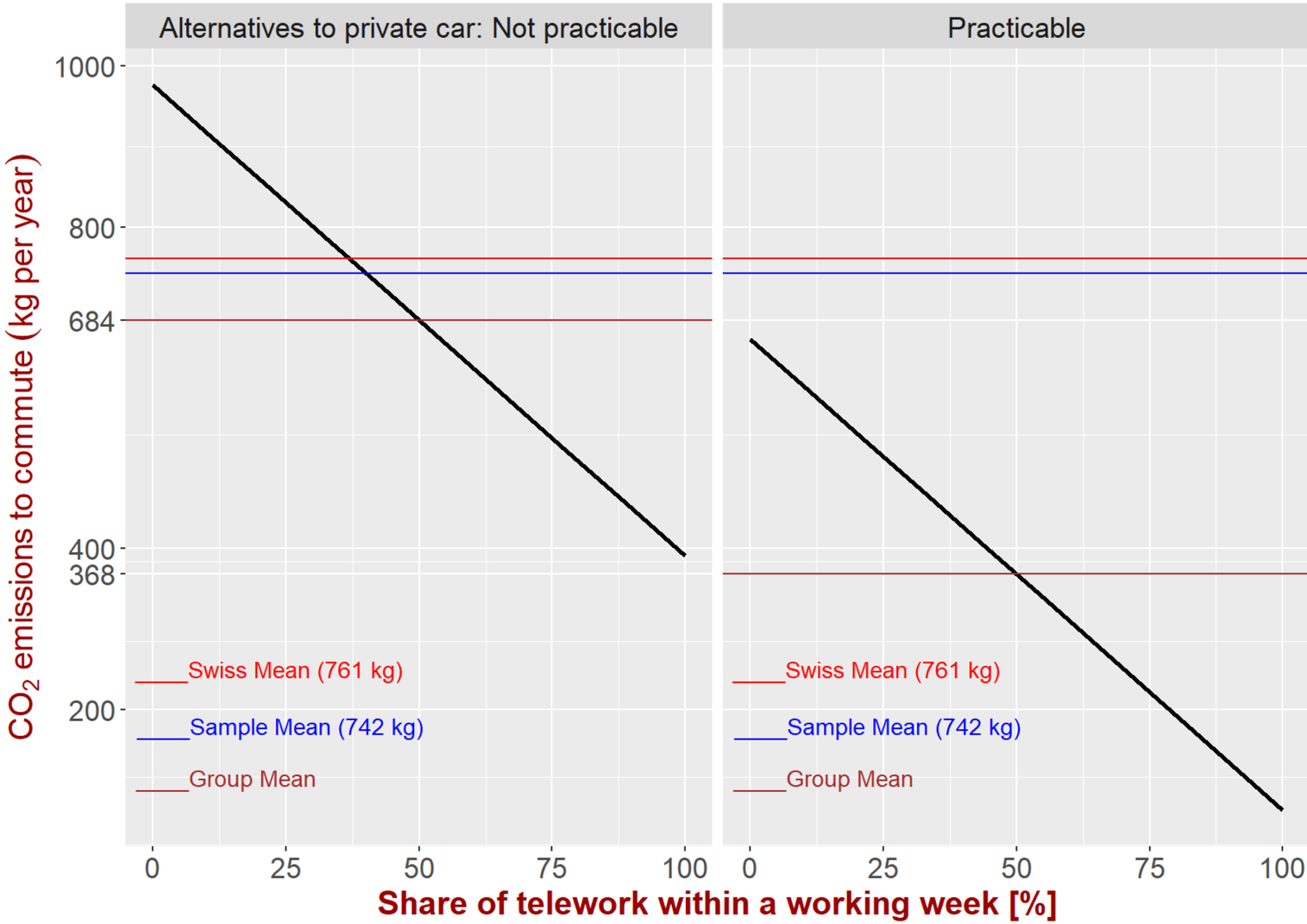
Effects of **phase model of action** (PMA) on CO_2 emissions to commute

- *PMA (based on Bamberg)*
  - *Phase 1:* no car use reduction planed
  - *Phase 2:* reduction considered, but impossible
- Significant difference between phases of PMA 1 and 2
  - **Phase 1: 428 kg per year**
  - **Phase 2: 974 kg per year**
- Significant **higher** CO_2 emissions, if a person is in phase 2, compared to the person who is in phase 1.
- When self-attributed phase 1: group mean is **below** Swiss mean and sample mean.



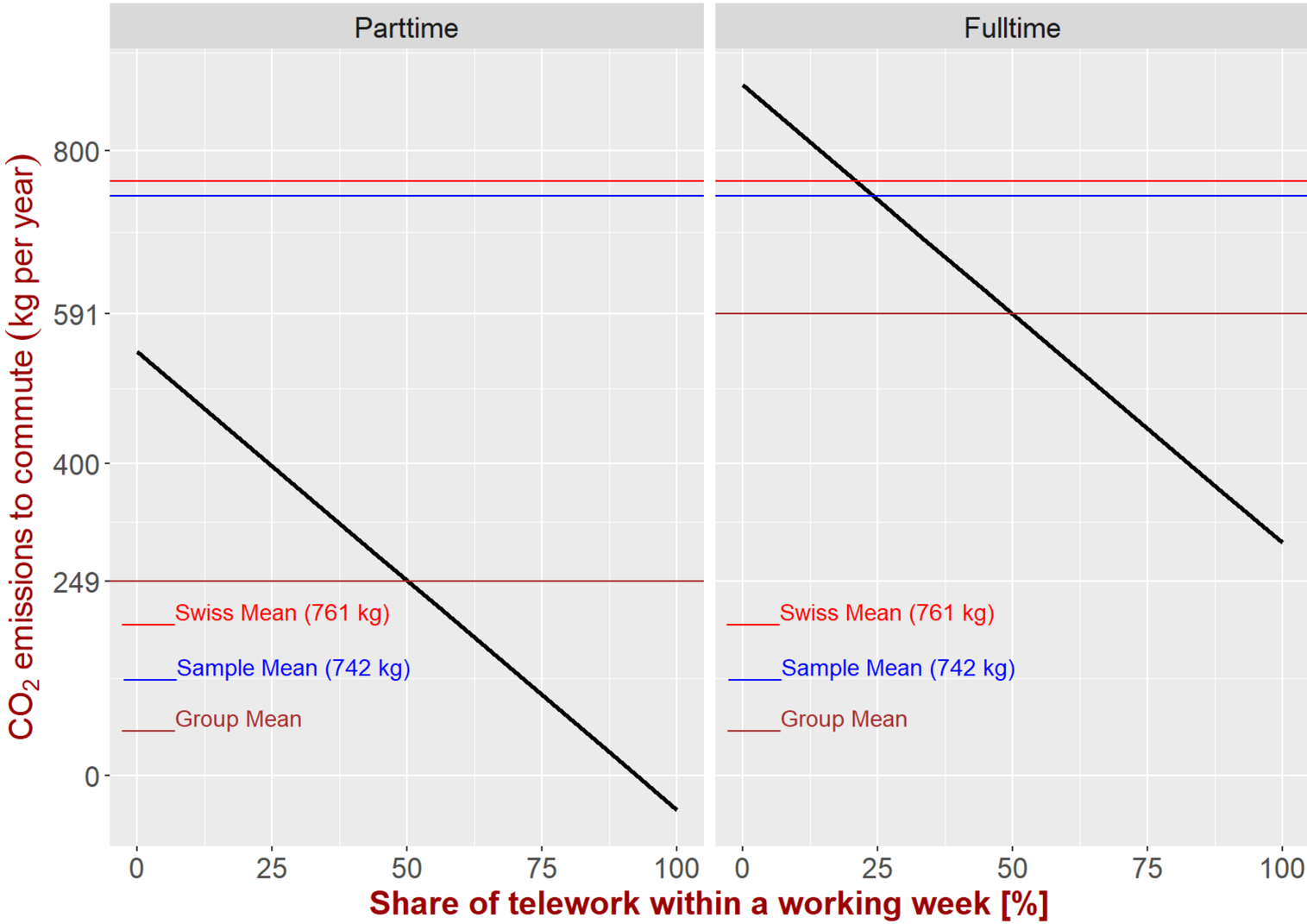
Effects of **mobility orientations** on CO_2 emissions to commute (alternatives to private cars)

- Significant difference between orientations to alternatives to private cars
  - **not practicable: 684 kg per year**
  - **Practicable: 368 kg per year**
- Significant **higher** CO_2 emissions, if alternatives to private car are not practicable, compared to the group for which it is practicable.
- Both group means are **lower** than the Swiss mean and the sample mean.



Effects of workload on CO_2 emissions to commute

- Workload
  - parttime = less than 90%
  - fulltime = more 90%
- Significant difference between parttime or fulltime workload
  - **fulltime: 591 kg per year**
  - **parttime: 249 kg per year**
- Significant **higher** CO2 emissions, a person is working fulltime, compared to a person who is working parttime.
- Both group means are **lower** than the Swiss mean and the sample mean.



Trip purposes: some hints on rebound effects

Working…	***Shopping*** *(e.g., errands, going to the pharmacy)*	***Leisure*** *(e.g., sports, visiting friends)*	***Bringing and picking up*** *(e.g., children to music lessons, grandparents to the doctor)*	***Total***
… at the <u>regular workplace</u> (n=244, multiple answers)	51.6% [45.4% ; 57.9%]	29.1% [22.8% ; 35.4%]	19.3% [13.0% ; 25.5%]	100%
… during <u>teleworking days</u> (n=302, multiple answers)	38.1% [31.8% ; 44.4%]	36.1% [29.8% ; 42.4%]	25.8% [19.6% ; 32.1%]	100%

Note: n=235, [95% confidence interval for the shares]

→ Lower shares for shopping trips & higher shares for leisure and accompanying trips on teleworking days in comparison to working days at the regular workplace.

Summary & Outlook

- **Key data** was produced with a survey that was supported and feedbacked by members of the LL (e.g., public bodies, companies, transportation companies).
- A **T_0-measurement** was produced: The people in the LL consume 742 kg CO_2 a year for commutes

This CO_2 emissions to commute (kg per year) in the LL are influenced by:

- share of telework within a working week
- workload
- regular workplace location
- reasons for residential location choices (e.g., closeness to PT, workplace)
- phase model of action (PMA) towards car use
- mobility orientations (e.g., alternatives to private car are practicable)

<u>Outlook on further RQs</u>:

- How does this figure change when we introduce interventions in the LL? (e.g., new co-working spaces as shared space in LL)
- Rebound effects regarding leisure trips need to be considered more in detail. **But**: First indications that the share of leisure trips increase on the teleworking days.

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Thank you for your attention!

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