

RC4S Roegen Centre for Sustainability

BORDERSTEP INSTITUTE

CARBON TRUST

EC-CNECT/2024/OP/0071

Assessing Net Climate Impact of Digital Infrastructures

Initial findings presented at BEREC

16th September 2026

Funded by the European Union

Agenda

01 **Introduction**

02 Results using Emissions Outcome

03 Results using Energy Outcome

04 Methodology & Challenges

05 Conclusions & Next Steps



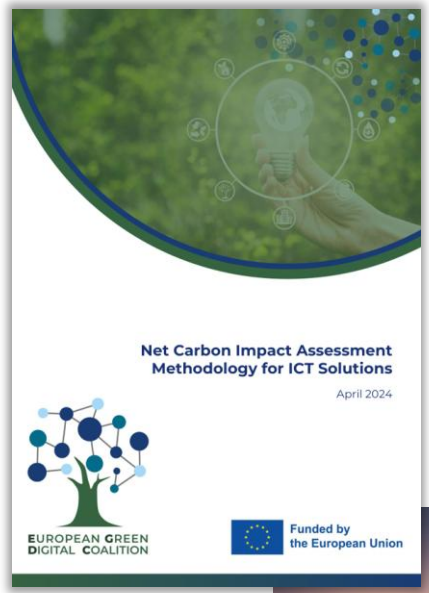
Project Background

Background:

- EGDC methodology assesses specific solution implementations and determined not suitable to assess digital infrastructure
- European Commission funded EC-CNECT/2024/OP/0071 - Assessing Net Climate Impact of Digital Infrastructures

Problem Statements

- Digital infrastructure acts as an enabler to activities across all economic sectors and thus has an indirect impact on sectoral GHG emissions which are far more challenging to assess and are not reasonably assessed by considering the compound impacts of single solutions
- Digital infrastructures, such as data centres or telecommunication networks, act as part of a digital system where it is challenging to allocate effects to individual elements.

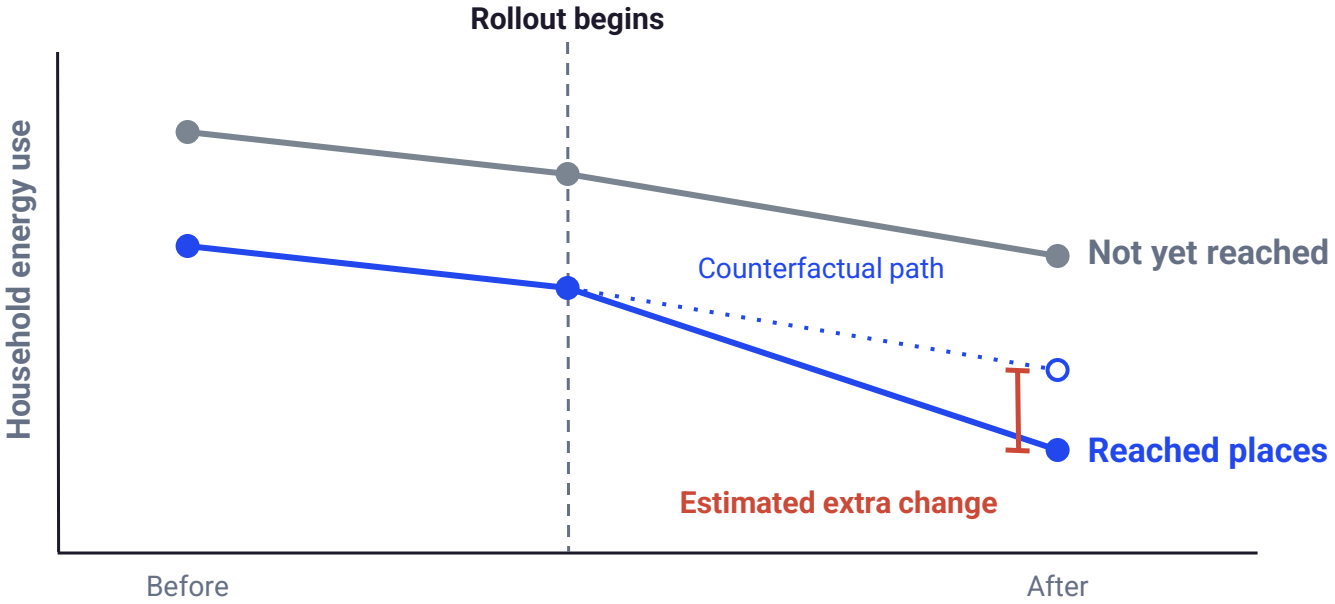






Difference-in-differences

Comparison of reached places versus places not yet reached



Methodology necessary conditions:

Comprehensiveness
Avoidance of selection bias

Causality
Adequate consideration of confounding factors

Granularity
Ability to attribute effects to the local / regional boundary of the rollout

Each place is compared with its own past and with places not yet reached in the same years. The estimate is the extra change in the reached places.

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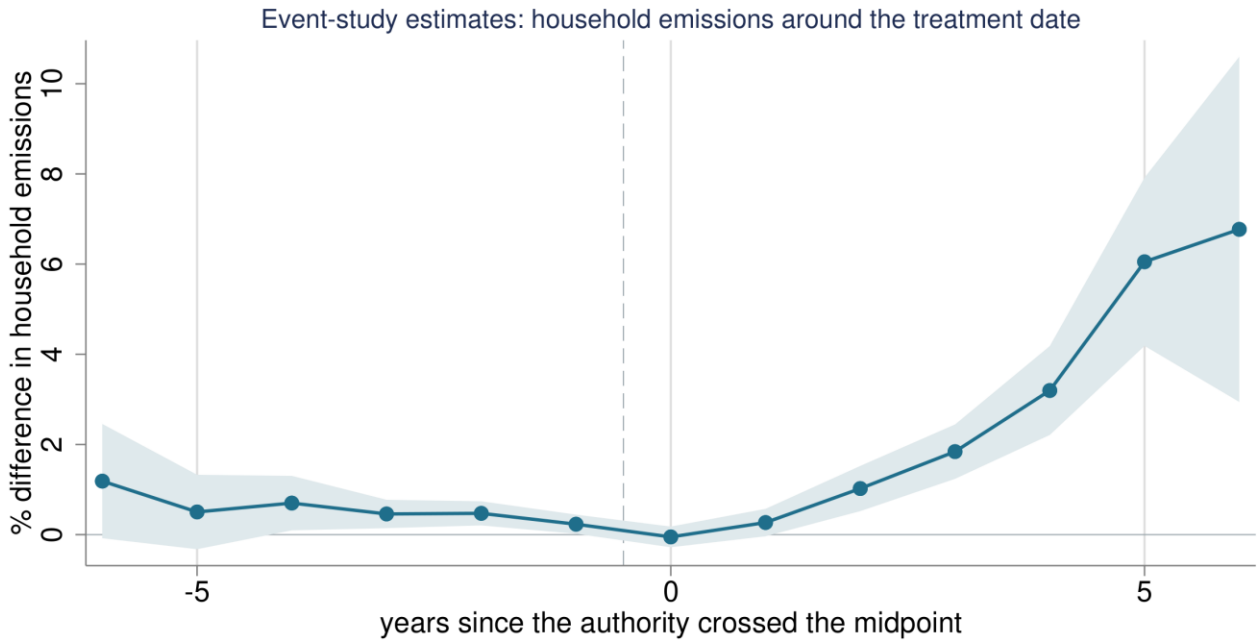
Initial results: Emissions Outcome

Method Overview

Side	Published measure	Measure used
Treatment	**UK:** Ofcom Connected Nations, coverage by tier, superfast ≥30, ultrafast ≥300 and gigabit ≥1,000 Mbit/s	**UK:** an index of the three Ofcom tiers, (superfast % × 1 + ultrafast % × 1.5 + gigabit % × 2.5) ÷ 250, scaled 0–1, by local authority and year 2016–23.
	EU: Eurostat, share of households with broadband, NUTS-2 regions, 2008–2021; Ookla median fixed download speed, NUTS-3 regions and 0.1-degree cells, 2019–2024	**EU:** at NUTS-2, the share of households with broadband, 2008–21, per +10 points. At NUTS-3 and on the 0.1° grid, Ookla median download speed, 2019–24, per +10 Mbit/s.
Outcome	**UK:** DESNZ local-authority territorial CO_2e by sector	**UK**: log of DESNZ CO_2e by sector, local authority × year, read as % changes; authority and year effects, then authority trends.
	EU: 244 EDGAR CO_2 by sector, version 8, allocated from national totals to 244 NUTS-2 and 1,408 NUTS-3 regions	**EU**: log of EDGAR CO_2 by sector (residential, road transport, power). EDGAR allocates national totals to regions, so little regional movement remains.

Initial results: Emissions Outcome

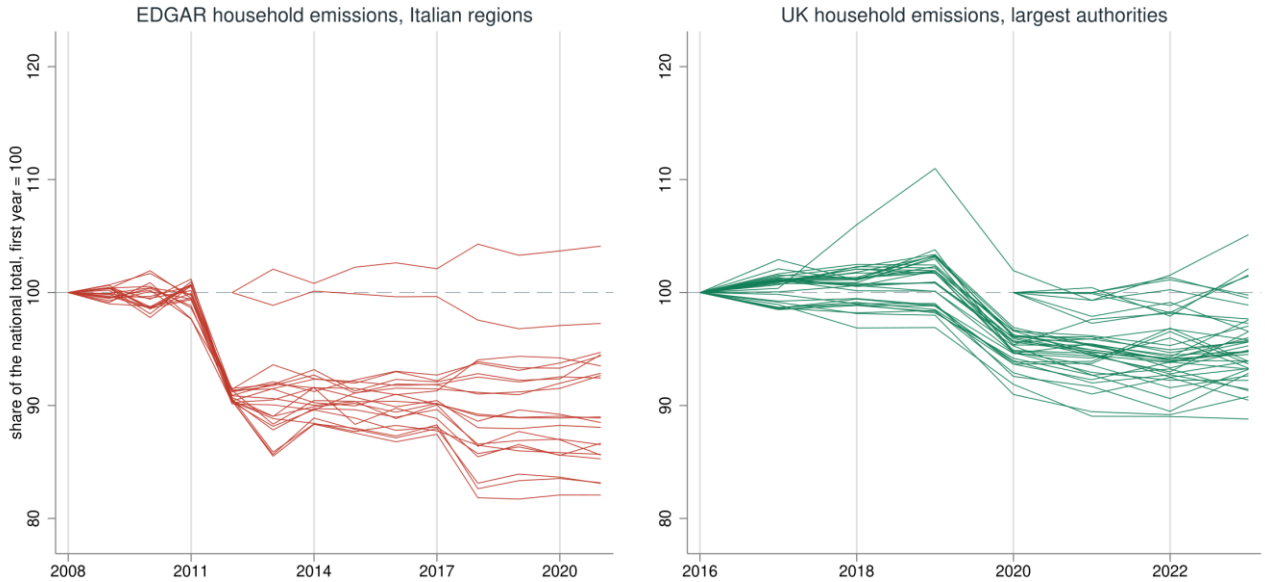
UK Household emissions results



- 361 local authorities; 2019–23 cohorts compared with authorities not yet crossing the midpoint.
- Shaded band: 95% interval. This early design cannot separate broadband from other changes in the same authorities.

Initial results: Emissions Outcome

Data & Design Checks - Step changes in regional emissions shares



Each regional share is indexed to 100 in its first year; periods differ across panels

- Left: EDGAR emissions data show common steps in 2012 and 2018 consistent with alike revisions to allocation
- Right: UK emissions data show some individual path variation, alongside a common shift around 2020.
- DiD assessment of staggered rollout require region-specific changes > **Very little of this variation remains in the downscaled household and transport inventories.**

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Matched coverage and household energy data

Why the main analysis focuses on households

Area	Coverage	Metered energy
United Kingdom	Ofcom postcode and local-authority coverage, 2014–25 Superfast, ultrafast and gigabit tiers	DESNZ gas and electricity at postcode or LSOA level
France and selected EU	ARCEP FTTH at commune and IRIS level, 2019–24 National registers for selected countries	Enedis, GRDF and national metered-energy registers

Households are the only sector for which metered consumption can be matched to broadband coverage at the same local unit. Firm data exist, but their pre-treatment trends do not support causal interpretation; we retain them for the report.

Results in one view

Preliminary results, 13 September 2026

1. **Small estimates in the finest data**
   UK and French local data give gas estimates below two-tenths of one per cent per 10 percentage points of coverage. Electricity is close to zero.

2. **Small against the background fall**
   Household gas use fell 16% in the UK and 24% in France over the same periods. The coverage-linked estimate is a small fraction of that fall.

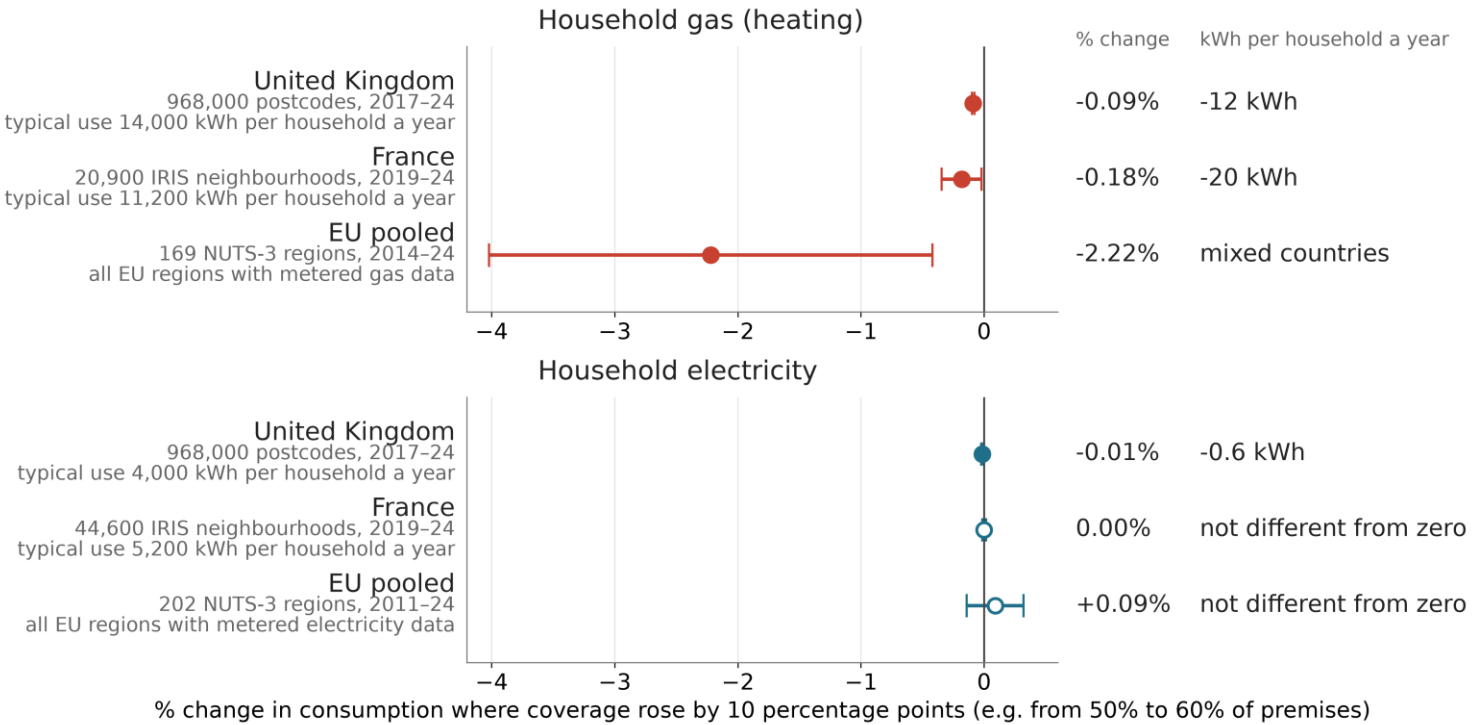
3. **Method and measurement change size and sign**
   Coarser units, different outcome measures and rollout sequences correlated with place type produce larger or less stable estimates.

Why the estimates still move

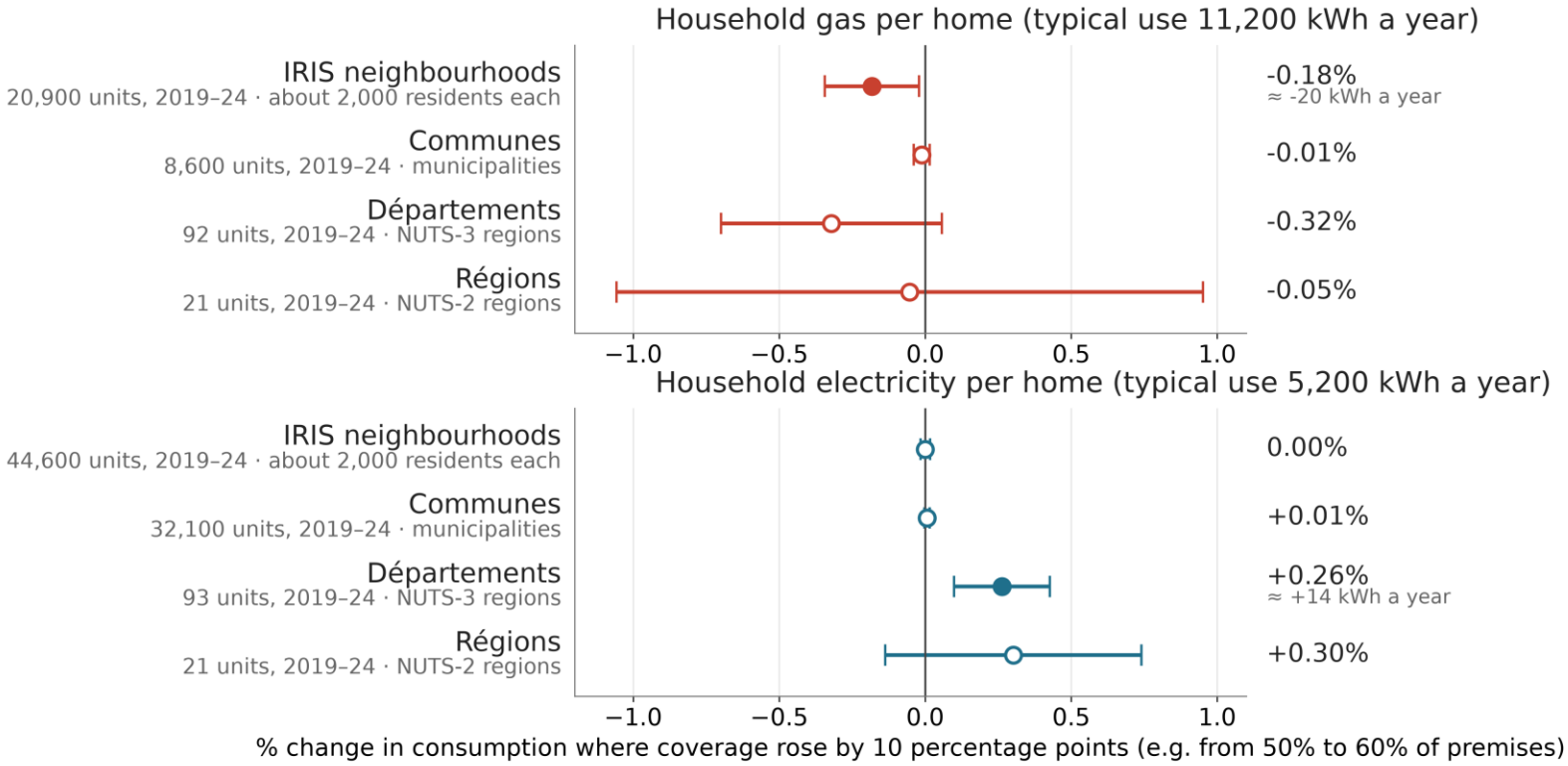
These are working estimates, not final impact factors. Each iteration aligns coverage definitions, outcome units, samples and time windows more closely, then tests rollout order. The movement shows which results are design-sensitive.

Results: Energy Outcome

More broadband coverage: lower gas use while electricity unchanged



Results for France: higher resolution, more precise results



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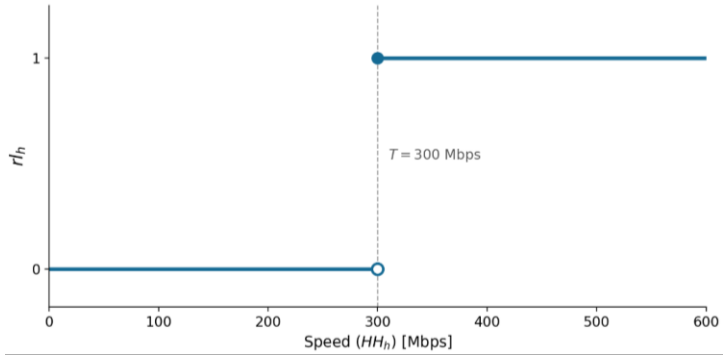
04 **Methodology & Challenges**

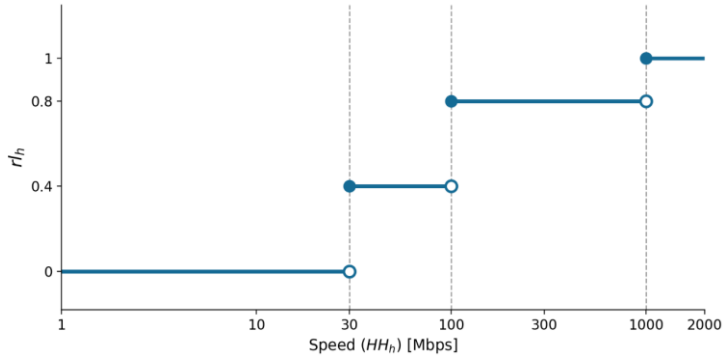
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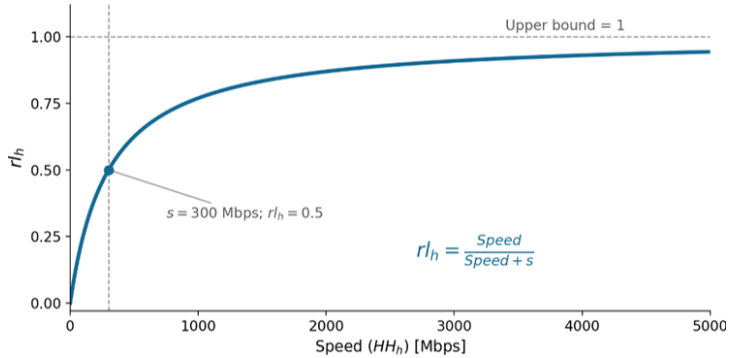


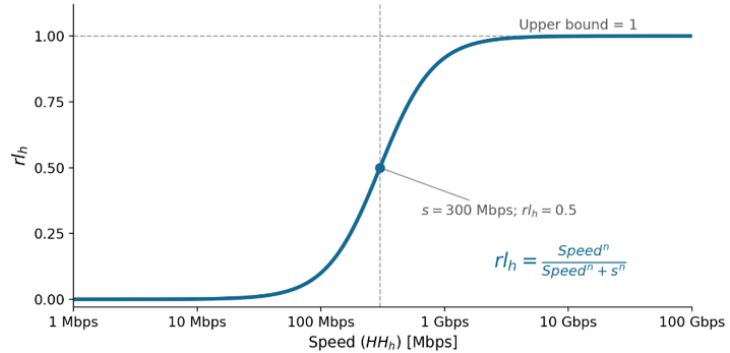
What is the correct regional rollout measure?

Per-household *rollout level* rl [0, 1] adding up to *regional rollout level* (which is always continuous ← results based on RL)



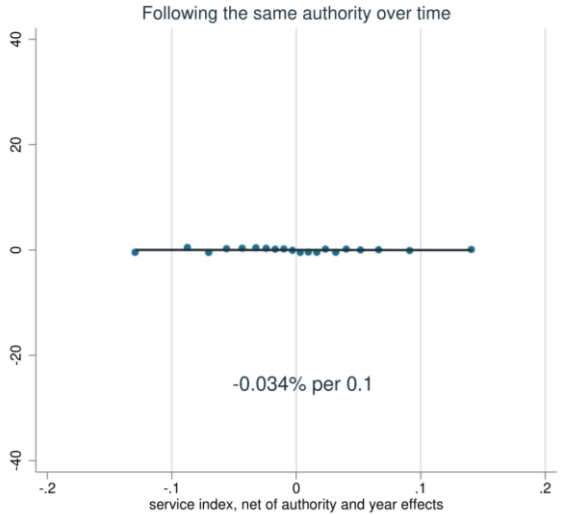






Measuring the outcome (i.e., emissions)

Outcome variations need to be reflected by the data, otherwise DiD analysis impossible



Emissions never measured directly, but estimated from proxies (such as fuel sales, electricity consumption, etc)

Period-by-period variation can be reflected if

- bottom-up / **regional data collection**
- top-down / national data collection & **allocation according to changing keys**, reflecting the changing ratios of underlying proxies

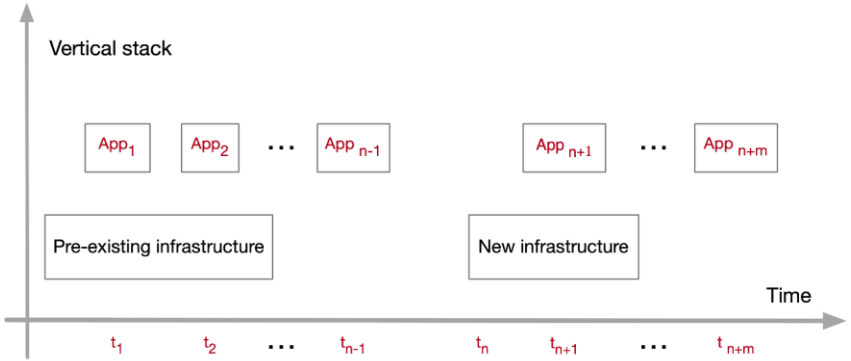
EDGAR / EU NUTS-2 data has neither

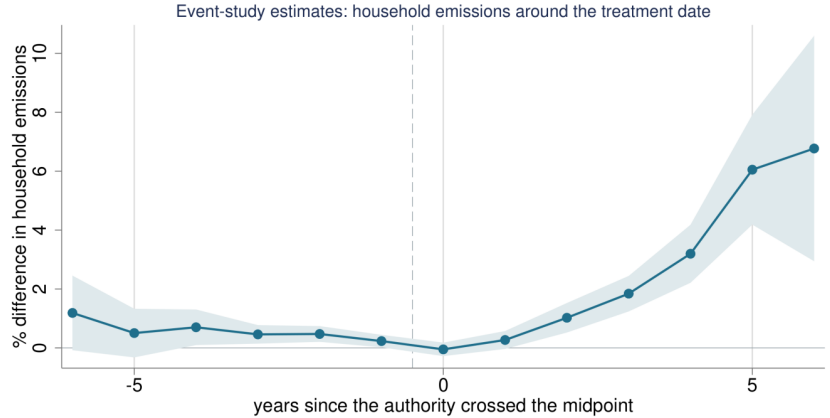
- it is national collection, regional allocation via fixed keys

Different challenge to rollout

- Rollout: **Conceptually challenging**, measurement simple
- Emissions: Conceptually simple, **measurement challenging**

Outcome: Rollouts develop effects indirectly & over time





Exploring causality

What we need	How we check
Data that preserve local changes. The outcome must capture changes where rollout occurs.	**Inspect data construction.** Check which local changes the records capture, and allocation rules may omit.
A credible comparison. Places with different rollout timing must provide a meaningful comparison.	**Examine rollout order.** Assess why some places were reached earlier. Compare results across suitable designs.
Comparable changes without rollout. Other events must not explain the estimated difference between groups.	**Check trends and shocks.** Examine earlier trends, false rollout dates and different exposure to the pandemic and energy prices.

Causality is a hypothesis that can only be rejected, not proven. Failure to reject several tests

Estimating effects and assessing a rollout

Historical evidence informs a proposed assessment

Estimate the response from past rollout

$$\log(\text{Energy}_{it}) = \beta\,\text{Coverage}_{it} + \alpha_i + \lambda_t + u_{it}$$

Energy: metered use in place i, year t

Coverage: share of premises covered

β: response to a coverage change

α_i, λ_t: place and year effects

u_{it}: remaining influences

Apply it to proposed rollout

Projected energy change:

$$\widehat{\Delta\text{Energy}} = \text{Energy}_0 \times \left[e^{\hat{\beta}\,\Delta\text{Coverage}} - 1\right]$$

Energy$_0$: baseline use **Δ**: proposed change

Projected emissions change:

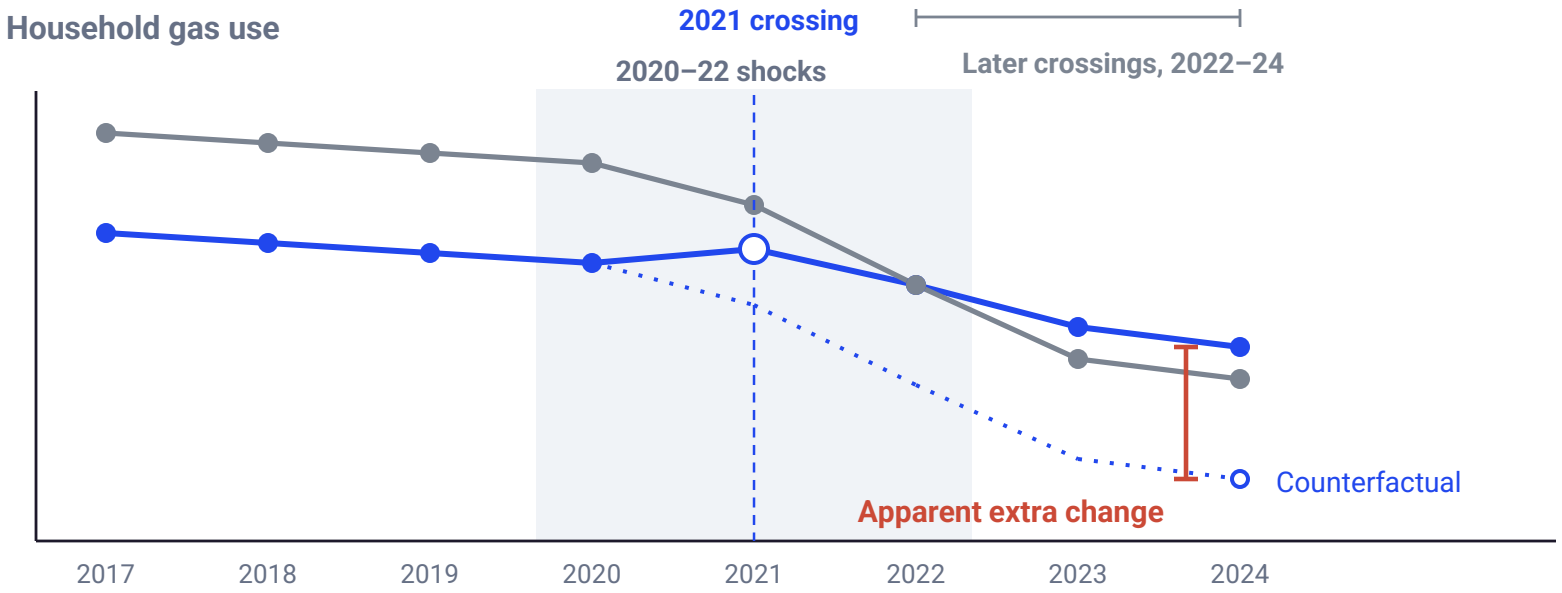
$$\widehat{\Delta\text{CO}_2\text{e}} = \widehat{\Delta\text{Energy}} \times \text{EF}$$

EF: emissions per unit of energy

Method versatility: Operator assessment and regional assessment identical

Earlier parallel trends do not guarantee ongoing ones

A different response to the same shocks can look like a rollout effect

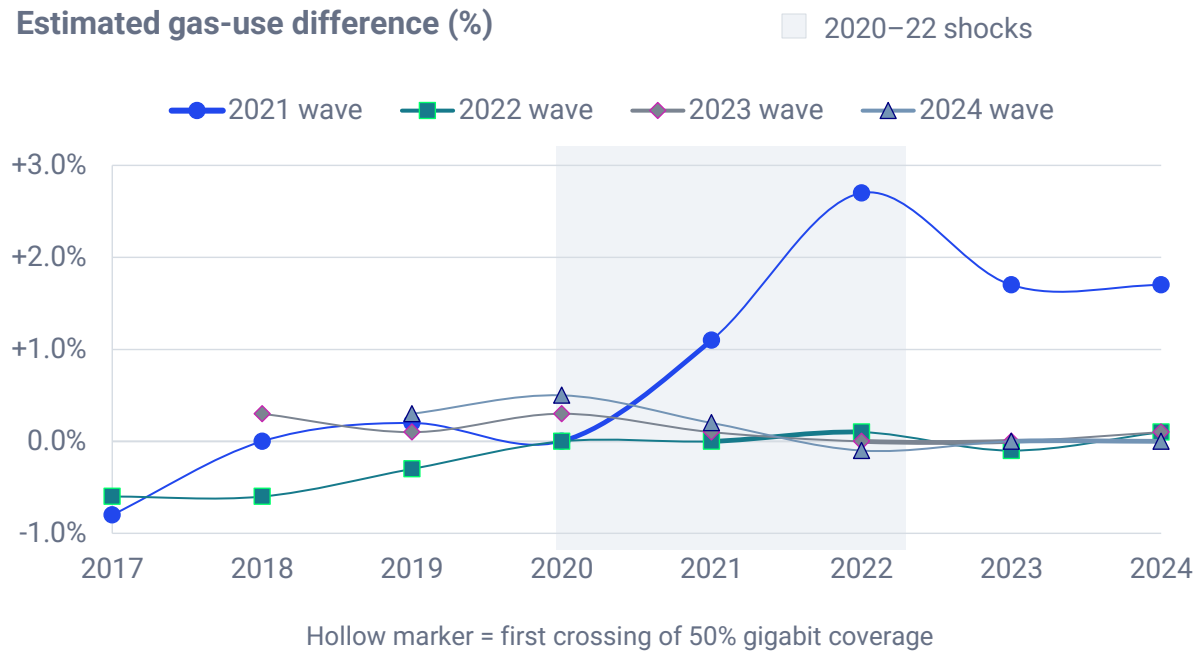


Parallel movement before rollout does not rule out different responses to later shocks.

Schematic only. The counterfactual preserves the early–late gap before the 2021 crossing.

The first rollout wave has a different gas path

All 627,000 commercial-route postcodes with gas meters



Hollow marker = first crossing of 50% gigabit coverage

2021 wave

+1.1% in 2021
+2.7% in 2022
+1.7% in 2023–24

Cable-upgrade wave
68% in conurbations

2022–24 waves

Within ±0.1% after their own crossing

The pattern is consistent with rollout sorting. Different broadband effects across waves remain possible.

Relative to not-yet-reached postcodes. Each wave's year before crossing = 0. Point estimates. Preliminary results.

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What the current evidence supports

Five conclusions from the current analysis

- **Heating energy**: UK gas use is about 12 kWh lower per domestic meter per year for 10 additional percentage points of coverage. The French estimate is also small.
- **Electricity**: UK and French estimates are around 1 kWh per connection per year for 10 additional percentage points. Results vary with specification.
- **Comparison design**: cross-sectional estimates are 10–30 times larger and can have either sign. Multiple confounding factors, such as rollout order, strongly shapes them and suggests analysis should be at the household level.
- **Availability vs adoption**: Our treatment assesses the former, not the later. In the UK in 2022, ultrafast covered 70% of premises, but only 9% of lines exceeded 300 Mbit/s. Superfast covered 97%, with 84% of lines.
- **Difficult country transfer**: Within the EU, heating fuels, take-up, rollout order and resolution differ. Each Member State requires re-estimation.

Next steps

Data and designs needed for a transferable estimate

- **Case studies**: Our final report will assess two case studies of individual operator rollouts based on estimated regional market share. Correct attribution to operators would require market insight data from operator engagement or paid-for datasets.
- **Better future data** for full sectoral analysis:
  i. Gather precise **adoption data** on NUTS 3/local-authority level observations.
  ii. Generate **bottom-up emissions' inventories** at NUTS 3/local-authority level to describe sector totals to assess across all sectors
  iii. Targeted use of public-programme rollouts as **comparison designs**.
- For **targeted policymaking**, explore **covariates** (e.g., urban/rural, GDP?) **and root causes** that have strongest influence on result

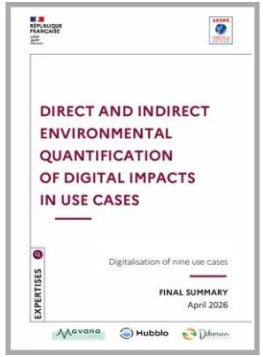
The immediate priority is take-up and timing data: they separate availability from adoption and strengthen the assignment argument.

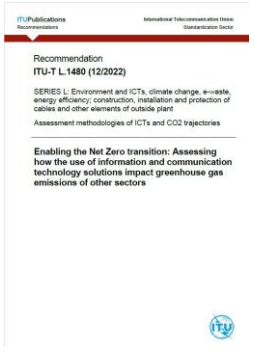
Many frameworks, little coordination and comprehensiveness efforts

Bottom-up methods aimed mostly at individual case studies / Comprehensiveness is key

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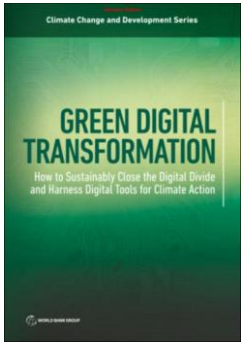
What is the carbon handprint of DigiFinland's services? – Case

12.6.2025 Anna Kemppainen Articles, Carbon handprint, Case, Climate, Consulting

DigiFinland promotes the digitalization of public sector and offers various digital services. The company examined the carbon handprint of its digital services in collaboration with experts from OpenCO2net. DigiFinland is owned by the wellbeing services counties, the City of Helsinki, HUS Group, and the Finnish government. In this project, the focus was c the Omaolo and Medical helpline 116117, and the positive carbon handprint they generate.

Carbon handprint – a measure of positive climate impact





Backup

Results: Energy Outcome

Each row uses a different register, outcome unit and coverage definition

dataset	outcome, in logs	per …	estimate	95% CI
UK, 968k postcodes	gas electricity per domestic meter	+10 pp ultrafast	−0.036% −0.013%	[−0.041, −0.032] [−0.019, −0.007]
UK postcodes, 2017–24 change	gas electricity	+10 pp ultrafast	−0.089% −0.015%	[−0.098, −0.079] [−0.024, −0.005]
UK, 361 authorities	household CO_2e below midpoint commercial	0.1 of UK index	−0.327% −0.916%	[−0.540, −0.114] [−1.670, −0.162]
UK authorities, pandemic	household CO_2e	1 SD of 2019 exposure	+1.018%	[0.552, 1.484]

Rows are not directly comparable: both the treatment and the outcome unit change across specifications.

Energy outcome estimates — continued

Each row uses a different register, outcome unit and coverage definition

dataset	outcome, in logs	per …	estimate	95% CI
Poland, 2,433 gminas	gas per inhabitant	+10 pp gigabit	−1.27%	[−2.00, −0.53]
Denmark, 98 municipalities	electricity: all electrically heated	+10 pp gigabit	−1.75% −1.97%	[−3.02, −0.48] [−3.49, −0.46]
France, 32k communes	electricity per site	+10 pp FTTH, dép. × year	−0.016% [1]	[−0.027, −0.004]
EU, 1,408 NUTS-3	residential transport power CO_2	+10 Mbit/s	−0.035% +0.015% −0.77%	[−0.080, 0.010] [0.004, 0.025] [−1.72, 0.19]
EU, 56k 0.1° cells	residential CO_2 (EDGAR)	+10 Mbit/s: levels logs	−0.132% +0.219% [1]	[−0.147, −0.117] [0.121, 0.317]

Rows are not directly comparable: both the treatment and the outcome unit change across specifications.

Method Selection

DiD introduction & appropriateness to provide evidence of causality

Necessary conditions:

- Comprehensiveness =

  Avoidance of selection bias
- Causality =

  Adequate consideration of confounding factors
- Granularity =

  Ability to attribute effects to the local / regional boundary of the rollout

