Quantification of the Primary Emission Changes in Europe due to the COVID-19 Quarantine Measures

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04/11/2020

IOP webinar - The Impact of COVID19 on the Environment: Observations and Insights

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Outline

- Motivation and objective
- CAMS COVID-19 emission reduction factors
- Emission modelling results
- Take home messages and future works

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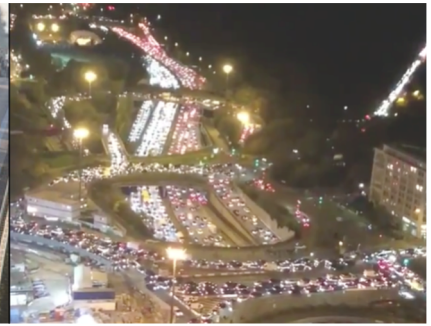
Motivation and objective

To control the spread of the COVID-19 disease, European governments implemented emergency measures going from light social distancing to strict lockdowns, which resulted in an unprecedented drop of anthropogenic emissions.



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Motivation and objective

Most studies are assessing the impact of COVID-19 on air pollution/climate through the use of satellite & ground—based observations. A complete understanding requires also quantifying the reduction of primary emissions.

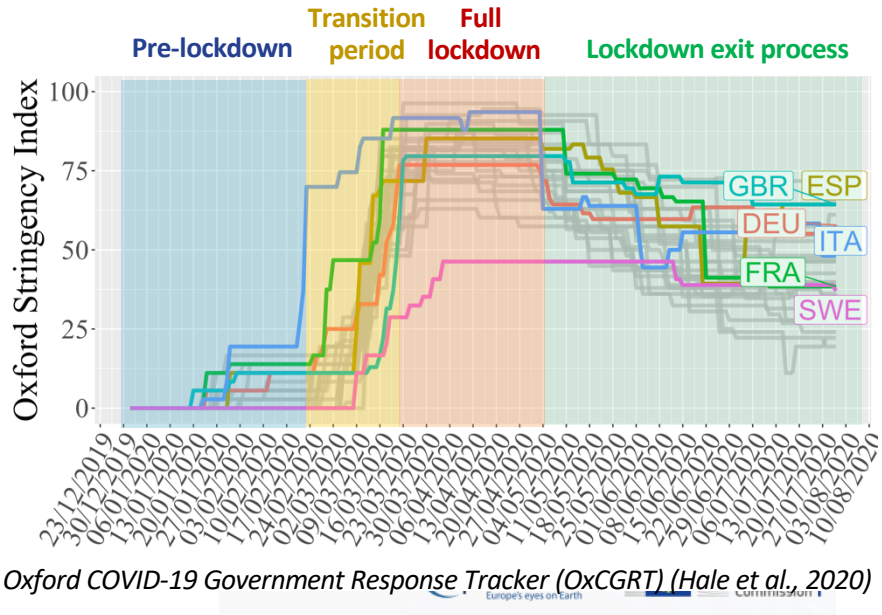
Objective: To develop emission reduction factors attributable to the COVID-19 measures, which can be combined with the Copernicus CAMS European emission inventory for emissions & air quality modelling

Heterogeneous restrictions across EU:

- Different starting dates (e.g. ITA vs. GBR)
- Different levels of restriction (e.g. ESP vs. SWE)
- Changes in time of the restriction levels

Requirements of the reduction factors:

- Country-dependent
- Sector-dependent
- Time-dependent (e.g. daily/weekly/monthly)



Oxford COVID-19 Government Response Tracker (OxCGRT) (Hale et al., 2020)

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Methodology

Sectors considered: Energy and manufacturing industry, residential/commercial combustion activities, road transport, shipping and aviation (LTO cycles)

Temporal coverage: 21/02/2020 until 31/07/2020

Spatial coverage: Europe, giving a special priority to EU28 + Norway + Switzerland

Data-driven approach: Changes in emissions assumed to follow changes observed in measured time-series representing the main activities of each sector.

Construction of reduction factors: Ratio between the activity data for a given day/week/month and the value of this activity over a pre-lockdown period (baseline): 1) Jan-Feb 2020, before lockdown started, 2) same day/month from previous year(s)

Sector	Sources of information
Energy industry	• Electricity demand data: ENTSO-E (2020) • Outdoor temperature: C3S (2017)
Manufacturing industry	• Industrial Production Index: Eurostat (2020)
Residential/Commercial combustion activities	• Movement trend reports: Google (2020) – Groceries, residences, workplaces
Road Transport	• Movement trend reports: Google (2020) – Transit stations
Shipping	• Port call trends: EMSA (2020)
Aviation	• Airport movement statistics: EUROCONTROL (2020)

Emission reduction factors

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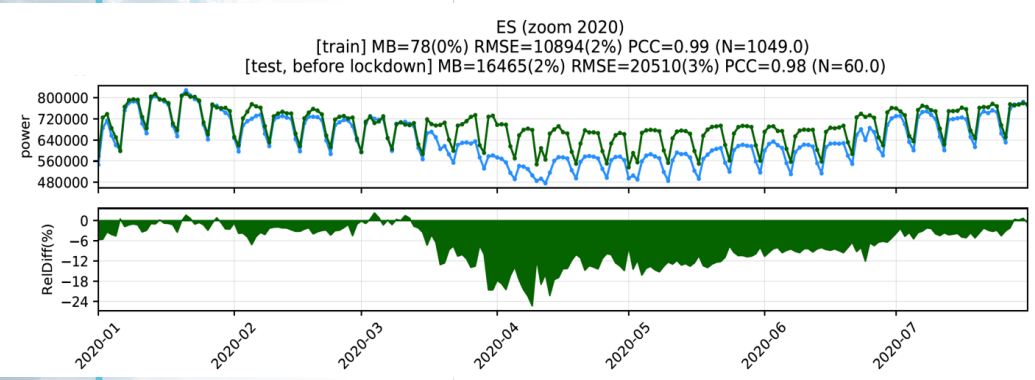
Energy Industry – or the importance of using a robust baseline

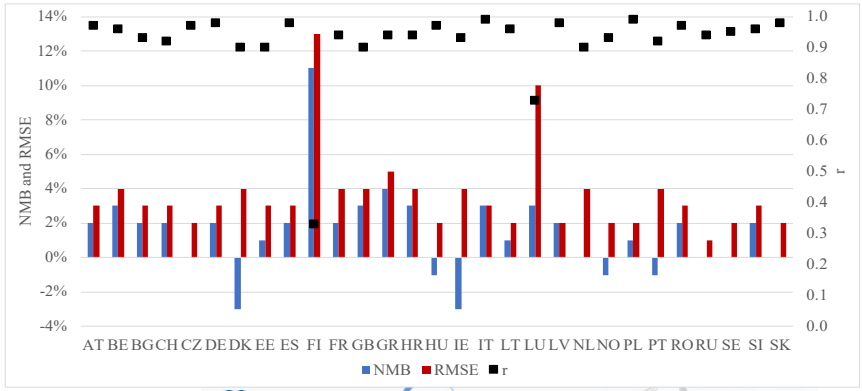
Use of **Machine Learning** to estimate national business-as-usual electricity demand (i.e. without the lockdown effect)

- Features: ENTSO-E electricity demand & population-weighted ERA5 temperature (Jan-Jul 2015-2019), julian date
- Gradient boosting machine model similar to the one used to model Spanish BAU NO_2 (Petetin et al., 2020, ACP)

Reduction factors estimated as the difference between BAU and measured demand



Statistics for test period (Jan-Feb 2020)



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Emission reduction factors

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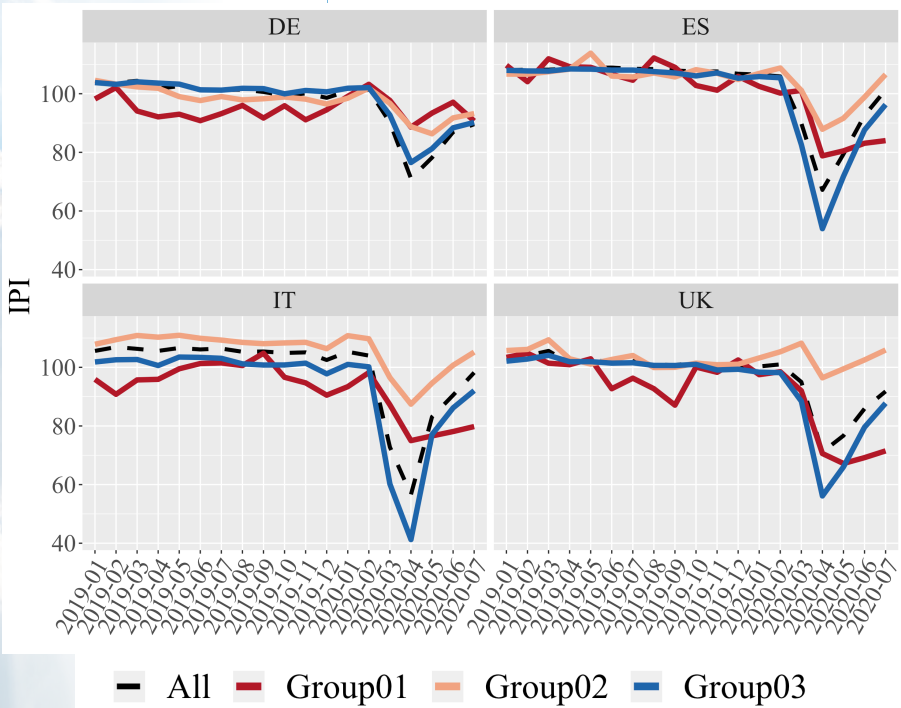
Manufacturing Industry – or the heterogeneous impact of lockdown among industrial branches

Use of Eurostat monthly Industrial Production Index values by economic activity (NACE Rev.2) - 2019 as a baseline



- **Group 1: Petroleum refining** → Essential but affected by the decrease in demand
- **Group 2: Chemistry and food/beverages** → Essential and barely affected during lockdown
- **Group 3: Other industries** → Non-essential and heavily affected during lockdown (e.g. non-metallic mineral products, basic metals) but quick recovery

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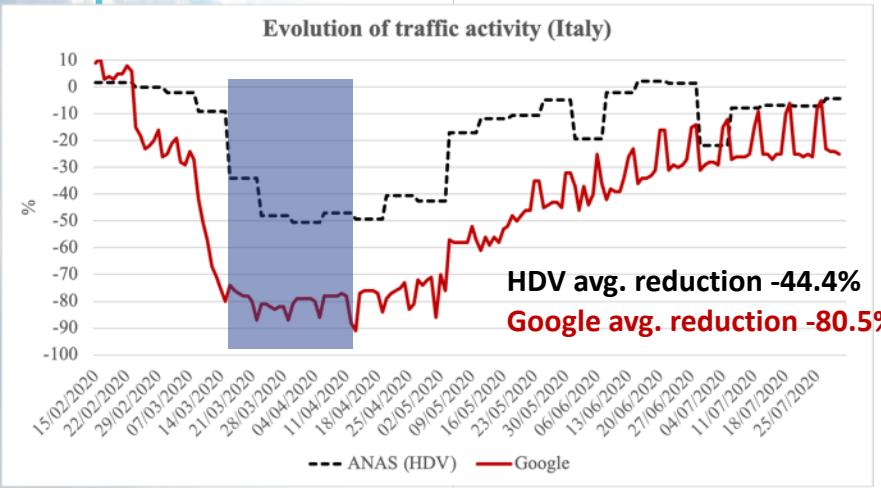
Emission reduction factors

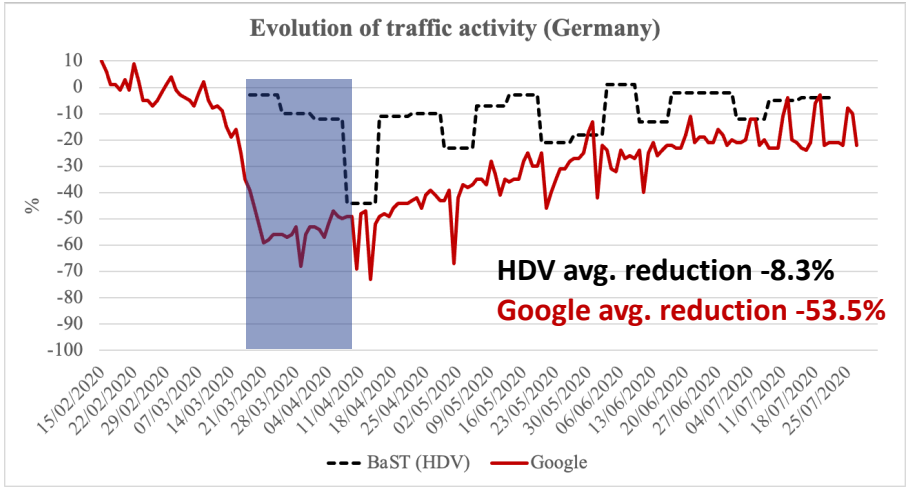
Road transport – or the need to combine new mobility datasets with traditional metrics

Use of the Google COVID-19 Mobility Reports (Google, 2020) - Transit stations category

- Daily movement trends by country across different categories of places.
- Based on anonymized and aggregated mobility trends in public transport hubs
- Widely used within the modelling community: Adams (2020); Forster et al. (2020); Lee et al. (2020);….
- Very useful, complete, homogenous, continuously updated open-access dataset…
- **But when compared with trends derived from measured traffic counts, certain limitations arise**

Limitation 1: Google trends are not representative of the observed changes in heavy-duty vehicle's activity (which were considered essential activity during lockdown)





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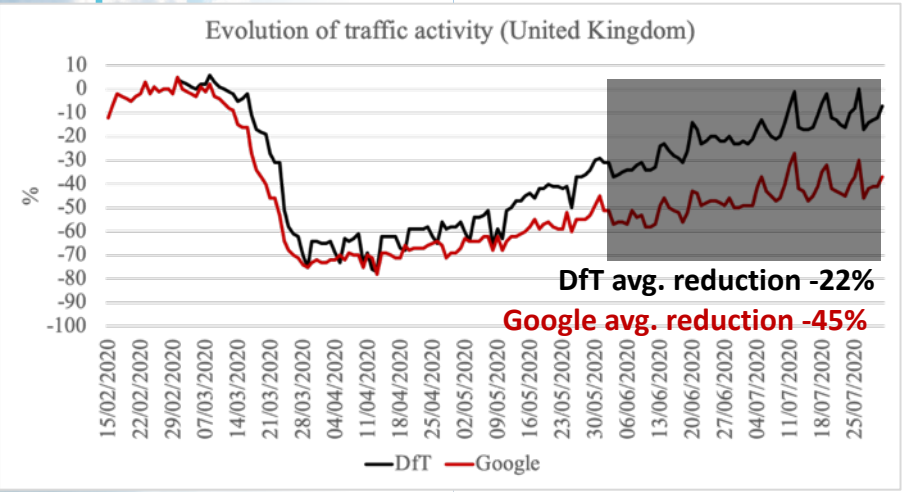
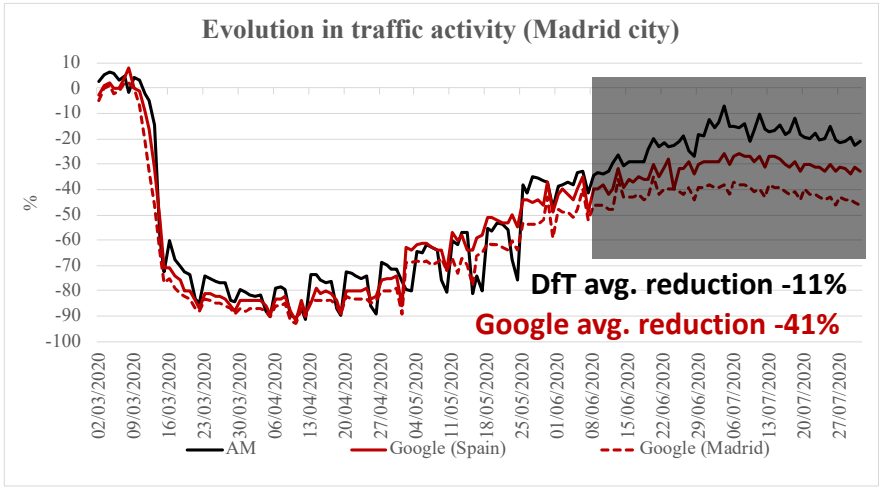
Limitation 2: Data based on mobility trends in public transport hubs, therefore affected by the fact that, with the virus still circulating, people remain wary of using this mode of transport





Emission reduction factors

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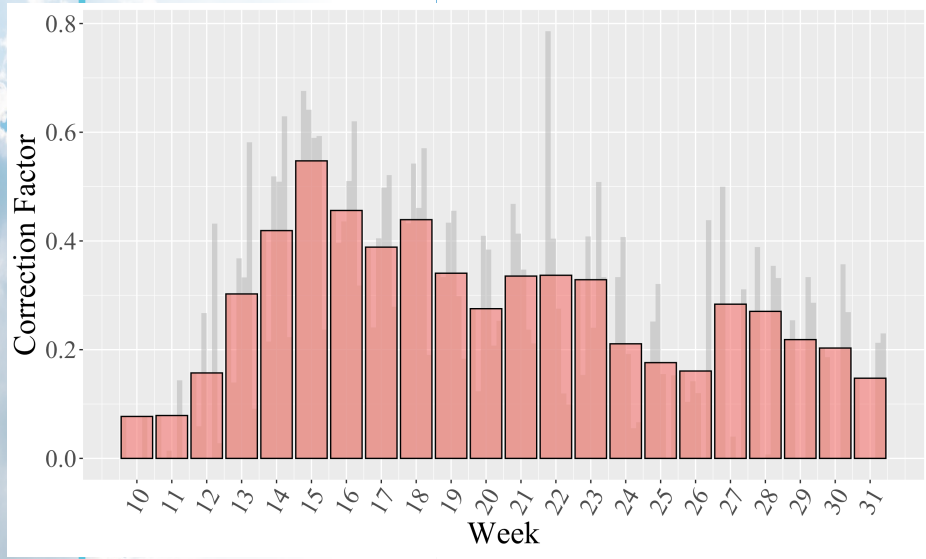
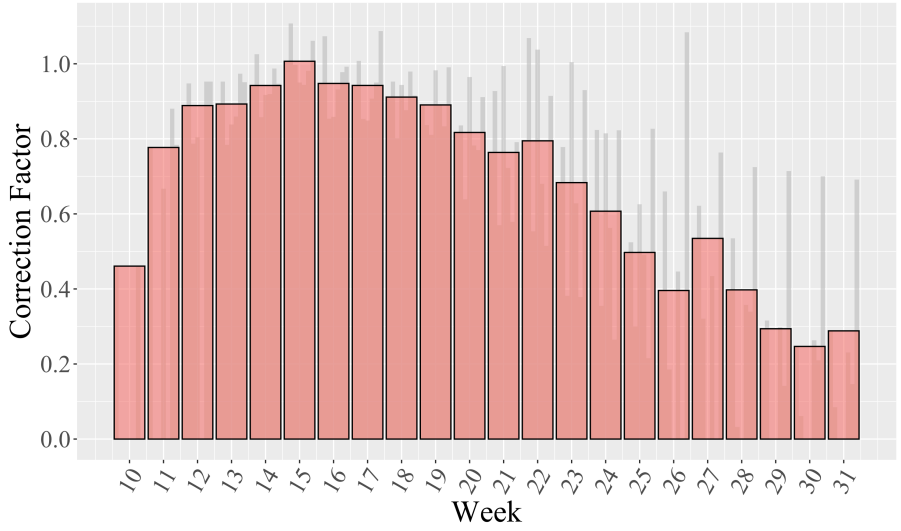
Road transport – or the need to combine new mobility datasets with traditional metrics

Use of measured-based trends to compute two sets of European adjustment factors:

weekly "Google HDV adjustment factors"



weekly "Google lockdown exit process adjustment factors"



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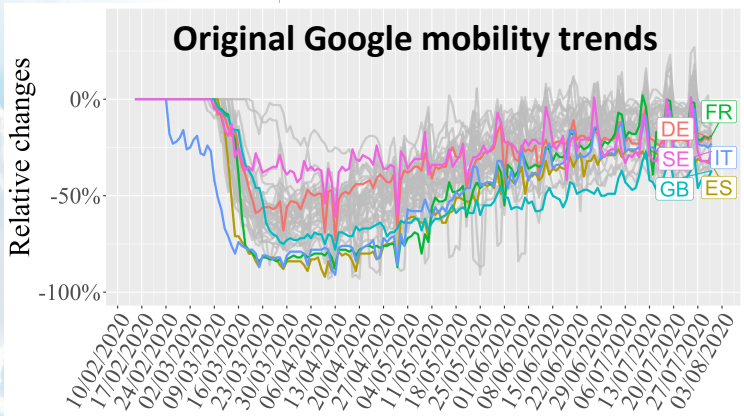
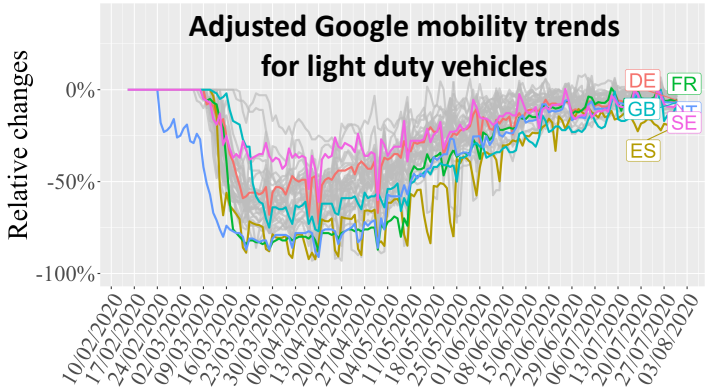
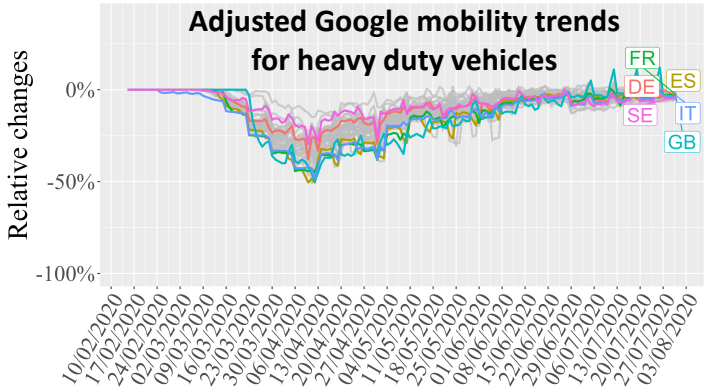
Emission reduction factors

Road transport – or the need to combine new mobility datasets with traditional metrics

Adjustment of the original Google mobility trends







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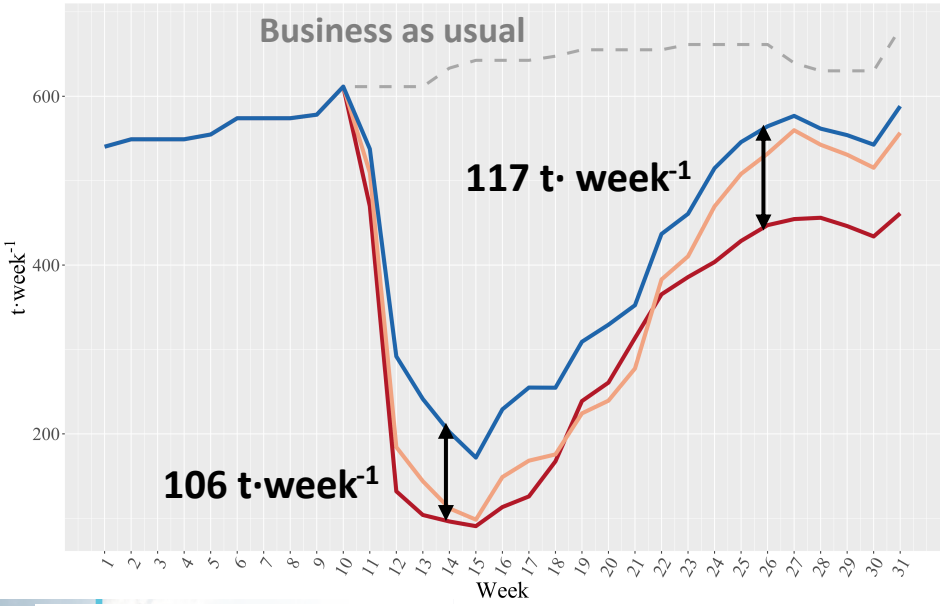
Emission reduction factors

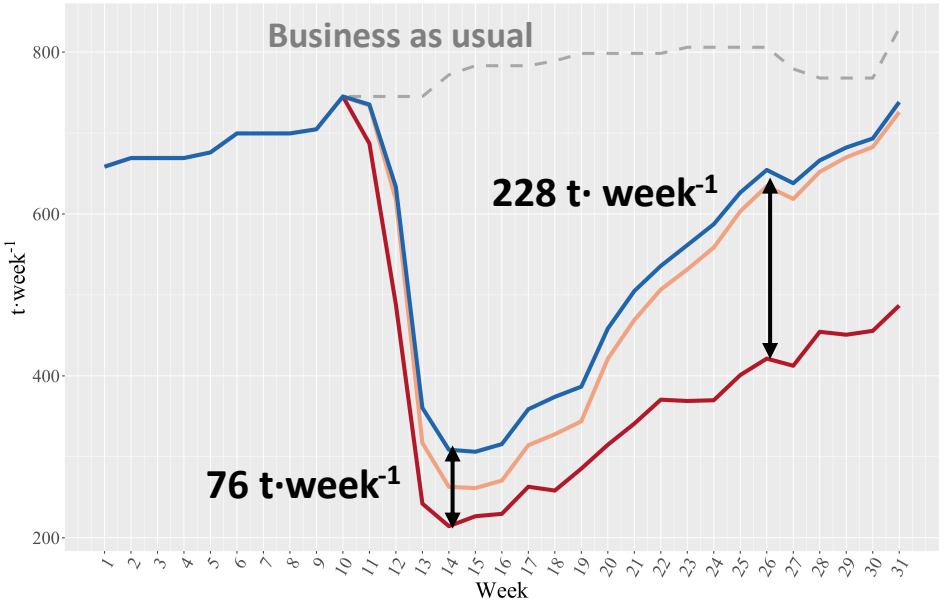
Road transport – or the need to combine new mobility datasets with traditional metrics

Emission sensitivity test after adjusting original Google mobility trends

NOx road transport average weekly emissions (Spain)



NOx road transport average weekly emissions (United Kingdom)



BAU COVID-19 (Google) COVID-19 (Traffic counts) COVID-19 (Traffic counts + HDV)

Significant impact on the emission reduction results (both during lockdown and exit process)

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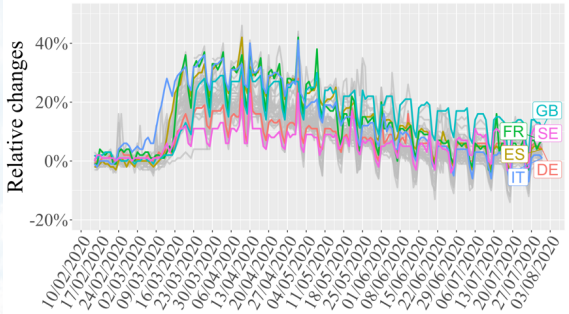
Emission reduction factors

Residential/Commercial combustion activities – or translating mobility changes into energy demand changes

Use of the Google COVID-19 Mobility Reports (Google, 2020) – residences & workplaces/groceries categories

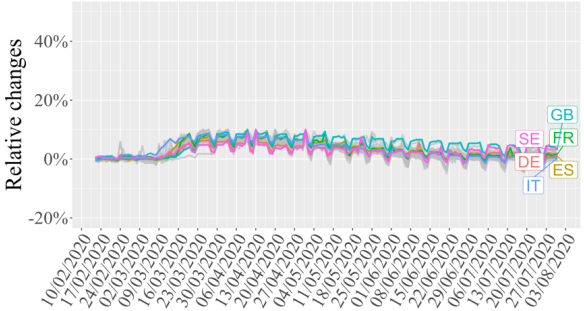
Residential - Original Google trends



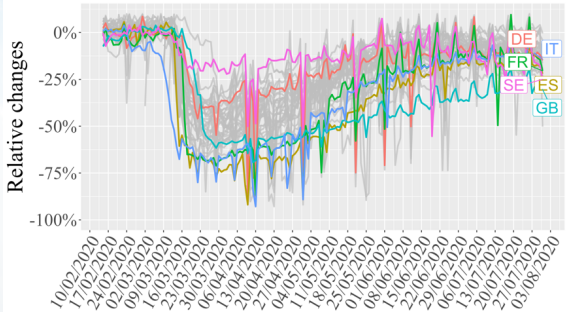
Scaling down

Fit max. of 10%
Le Quéré et al. (2020)

Residential - Adjusted Google trends



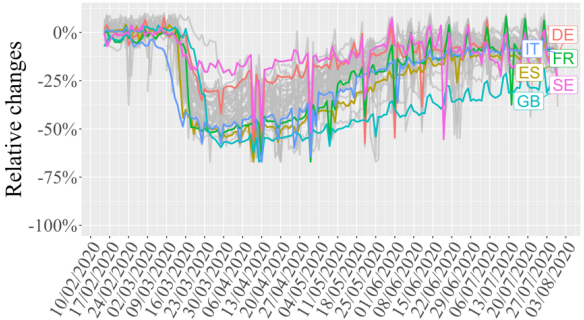
Commercial - Original Google trends



Scaling up

Fit min. of -66.9%
Based on IDAE (2018)

Commercial - Adjusted Google trends



Emission reduction factors

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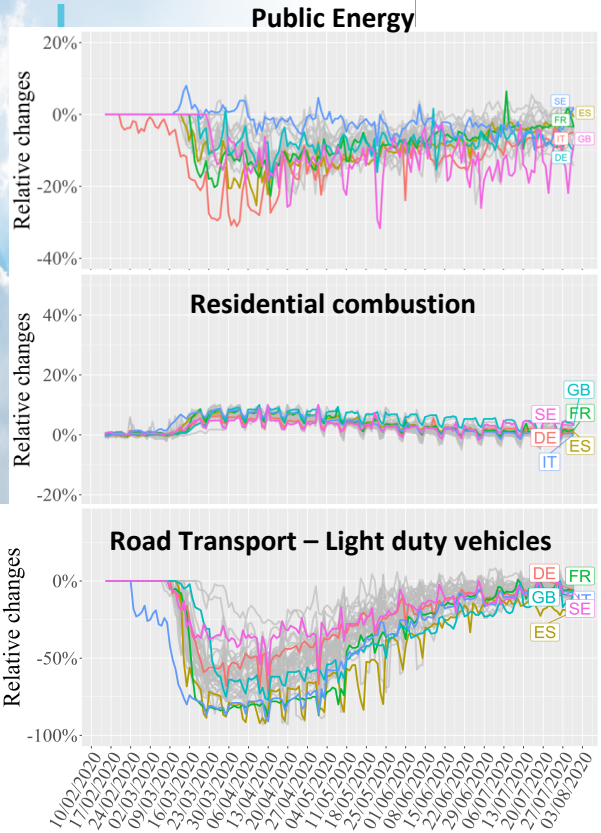
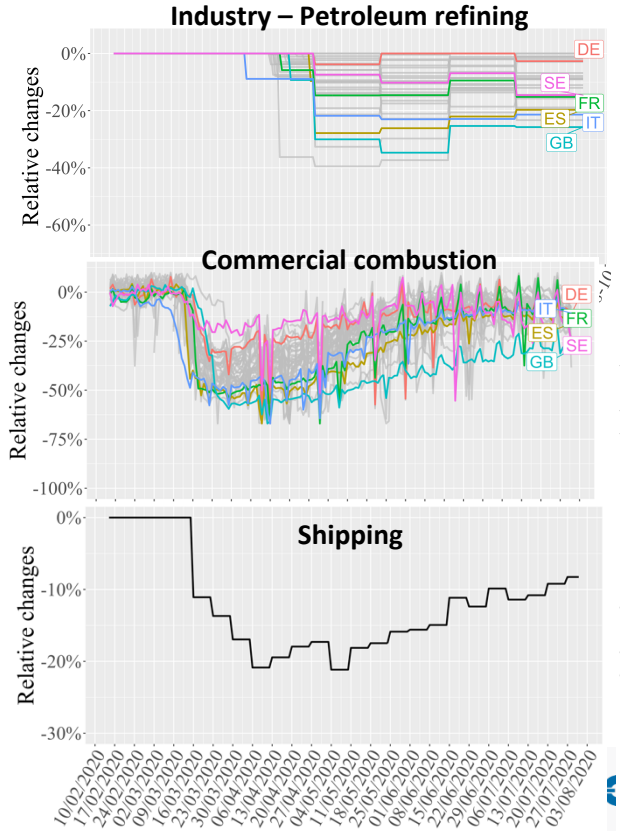
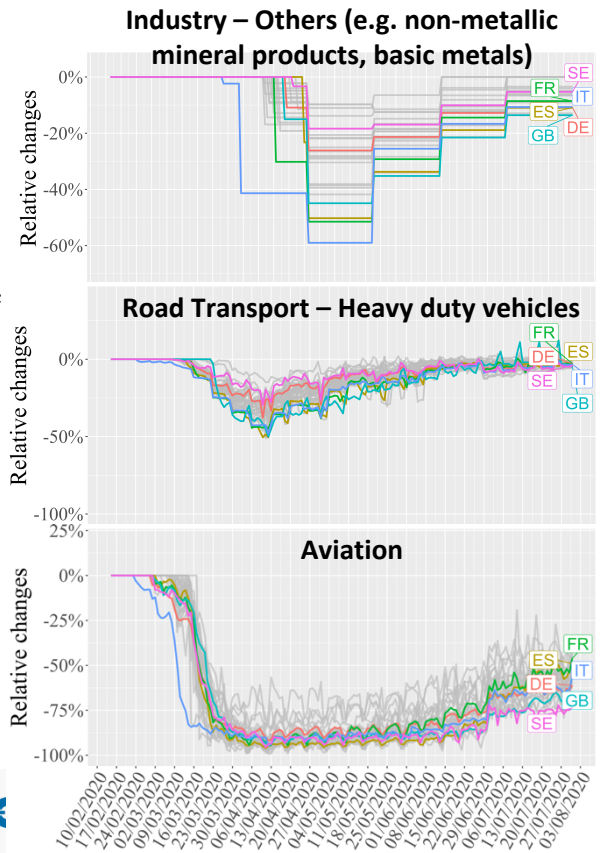
The big picture







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Emission modelling results for EU

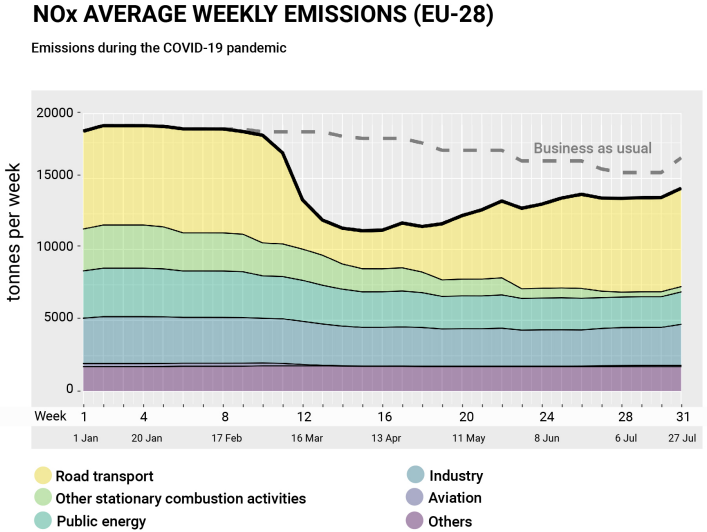
Combination of the emission reduction factors with the CAMS-REG European emission inventory

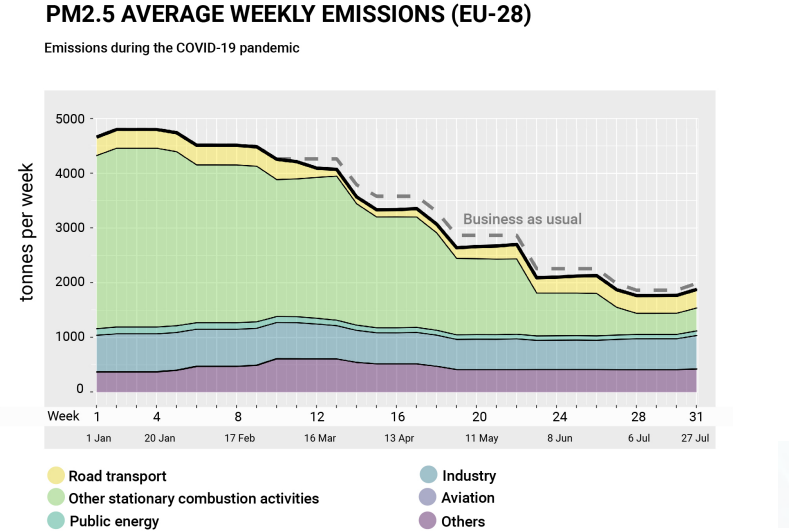
Heterogeneous impact on total emission changes as a function of the pollutant:

- **NO_x** average reduction: -15.2% ; maximum reduction: -36.5% (week 15)
- **$PM_{2.5}$** average reduction: -3.2% ; maximum reduction: -7.9% (week 19)

Emissions changes mainly driven by road transport sector and its contribution to total emissions

Emissions reaching almost pre-lockdown levels during the last week of July (but a new drop is expected soon…)





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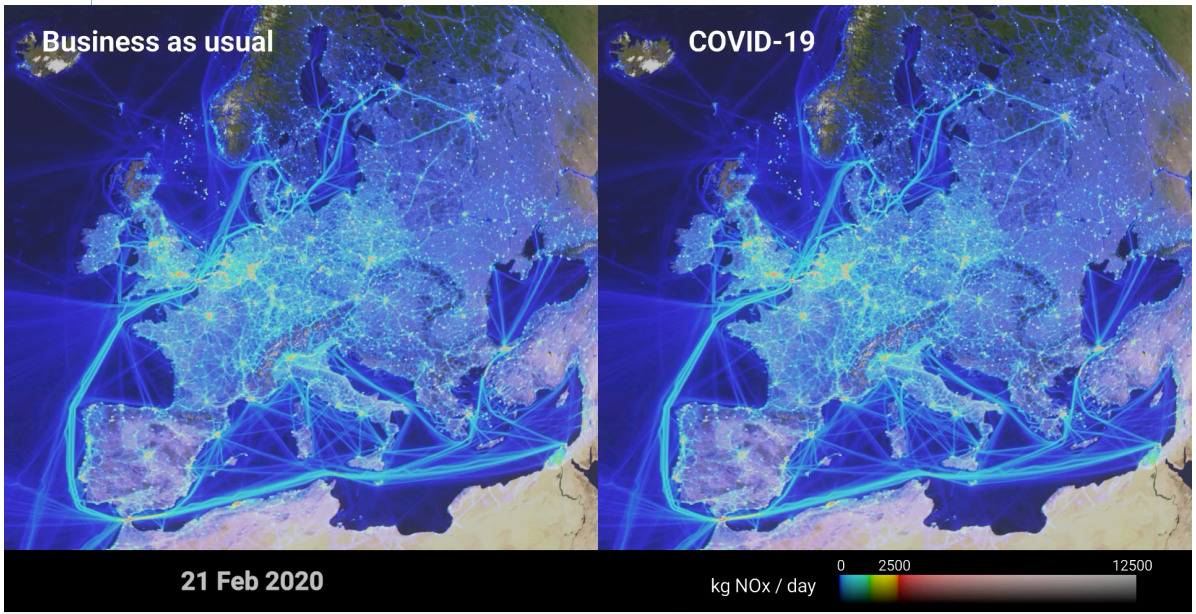
Emission modelling results for EU

Combination of the emission reduction factors with the CAMS-REG European emission inventory

- Heterogeneous impact on total emission changes across countries (up to -50% in Italy/France/Spain)
- Gridded and temporally disaggregated results to be used for air quality modelling



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Conclusions & Future works

- We constructed a dataset of daily-, sector-, pollutant- and country-dependent emission reduction factors to quantify the impact of the COVID-19 measures on EU primary emissions and perform AQ modelling exercises (Guevara et al., 2020, ACPD)

- EU emission reductions during lockdowns were primarily driven by changes in road transport, and the contribution of this sector to total emissions of each pollutant.

- Large contrast between NO_x and $PM_{2.5}$ emission reductions were observed, which is in line with results found through the analysis of air quality ground-based and satellite observations

- Large variations were observed between countries, depending on the level of restrictions imposed on mobility.

- Mobility data has proved to be a very powerful proxy to qualitatively understand the drop in activities, but:
  - Quantitively speaking, significant discrepancies appear when compared to traditional metrics (e.g. traffic counts, energy demand) → Adjustment factors should be considered
  - Certain aspects of the methods used to produce the trends remain unknown → An engagement with data providers would allow a better understating.

- **Future works**: Evaluation of the constructed emission reduction factors in reproducing observed changes in European air pollutants (NO_2, O_3 , PM)
  - CAMS Policy Service recently launched a multi-model experiment devoted to quantify the impact of COVID-19 on air quality levels

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