Technical validation of CoM dataset 2019

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Introduction

The procedure to verify and improve the coherence of the dataset starts with the extraction of complete emission inventories stored in a PostgreSQL database. At the closing date of this study, (September 2019) 6,239 climate action plans with complete inventories had been submitted by cities in the EU27, EFTA countries and UK, Western Balkans, Eastern and Southern EU neighbourhoods. Inventories and other data are self-reported to the online platform and must accurately reflect the content of the official climate action plan %(SECAP) document. The SECAP document is a separated file, usually in PDF format and publicly available that represents the official action plan endorsed and signed by the local council.

The CoM dataset analysis

As a first step to address the quality of the data reported, yearly GHG emission per capita are plotted for each signatory. Let's first upload and reorganise the CoM dataset 2019.

```
%  Let's first upload and reorganise the CoM dataset 2019.

CoM_dataset2019_all=readtable('CoM_dataset2019_allinitial.xlsx');
CoM_dataset2019_all.type_of_emission_inventory=categorical(CoM_dataset2019_all.type_of_emi
ssion_inventory);
CoM_dataset2019_all.emission_inventory_sector=categorical(CoM_dataset2019_all.emission_inv
entory_sector);
CoM_dataset2019_all.city=categorical(CoM_dataset2019_all.city);

CoM_dataset2019_all.type_of_emissions=categorical(CoM_dataset2019_all.type_of_emissions);
CoM_dataset2019_all.GCoM_ID=categorical(CoM_dataset2019_all.GCoM_ID);

EDGAR_RCO_TCO_2005=readtable('EDGAR_RCO_TCO_20052.csv','delimiter',',');

CoM_dataset2019=(CoM_dataset2019_all(:,1:7));
CoM_dataset2019 = removevars(CoM_dataset2019, 'emission_inventory_sector');
CoM_dataset2019 = removevars(CoM_dataset2019, 'type_of_emissions');
CoM_dataset2019=unique(CoM_dataset2019);

% create the variable of activity and emission per capita in the
% Energy in buildings sector residential/municipal/istitutional, Transportation and Waste
sector
```

```
CoM_dataset2019_all.activity_data(isnan(CoM_dataset2019_all.activity_data))=0;
CoM_dataset2019_all.emissions(isnan(CoM_dataset2019_all.emissions))=0;

CoM_dataset2019_all.PC_emissions=CoM_dataset2019_all.emissions;
```

```
CoM_dataset2019_all.PC_emissions=CoM_dataset2019_all.emissions./CoM_dataset2019_all.popula
tion_in_the_inventory_year;

CoM_dataset2019_all.PC_activity_data=CoM_dataset2019_all.PC_emissions;
CoM_dataset2019_all.PC_activity_data=CoM_dataset2019_all.activity_data./CoM_dataset2019_al
l.population_in_the_inventory_year;
```

```
rows=(CoM_dataset2019_all.emission_inventory_sector~={'Manufacturing and construction indu
stries'}& CoM_dataset2019_all.type_of_emission_inventory=={'baseline_emission_inventory'})
;

T = CoM_dataset2019_all(rows,{'GCoM_ID','emission_inventory_id','city'});  %'emission_inve
ntory_id'
[G,total] = findgroups(T);
total.PC_emissions=splitapply(@sum,CoM_dataset2019_all.PC_emissions(rows),G);
total.PC_activity_data=splitapply(@sum,CoM_dataset2019_all.PC_activity_data(rows),G);

PC_emissions2=total.PC_emissions(total.PC_emissions<50);
```

Prepare figure 2

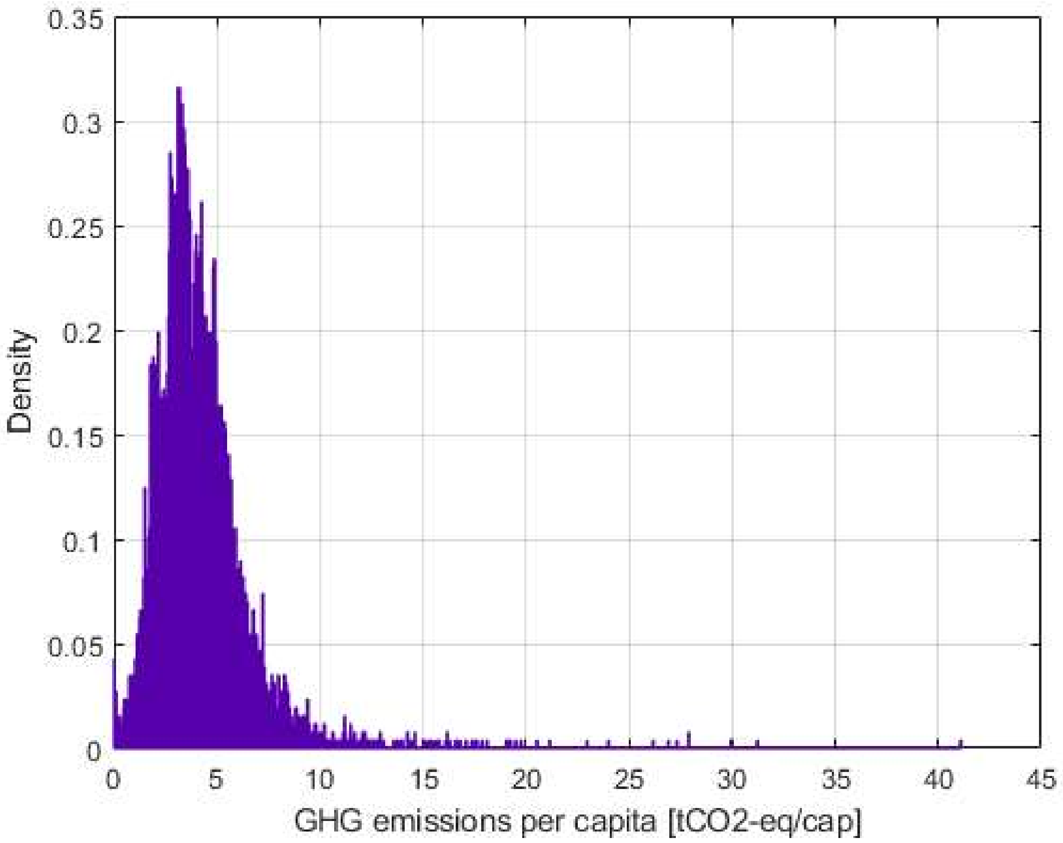
```
clf;
hold on;
LegHandles = []; LegText = {};

% --- Plot data originally in dataset "PC_emissions2 data"
[CdfF,CdfX] = ecdf(PC_emissions2,'Function','cdf');  % compute empirical cdf
BinInfo.rule = 5;
BinInfo.width = 0.01;
BinInfo.placementRule = 1;
[~,BinEdge] = internal.stats.histbins(PC_emissions2,[],[],BinInfo,CdfF,CdfX);
[BinHeight,BinCenter] = ecdfhist(CdfF,CdfX,'edges',BinEdge);
hLine = bar(BinCenter,BinHeight,'hist');
set(hLine,'FaceColor','none','EdgeColor',[0.333333 0 0.666667],...
    'LineStyle','-', 'LineWidth',1);
xlabel('GHG emissions per capita [tCO2-eq/cap]');
ylabel('Density')
LegHandles(end+1) = hLine;
%LegText{end+1} = 'PC_emissions2 data';
% set(axes1,'FontSize',24,'XGrid','on','YGrid','on','YTickLabel',...
%     {'0','0.1','0.2','0.3'});

% Create grid where function will be computed
XLim = get(gca,'XLim');
XLim = XLim + [0 1] * 0.01 * diff(XLim);
XGrid = linspace(XLim(1),XLim(2),100);


% Adjust figure
box on;
grid on;
hold off;
```

```
Warning: Cannot compute centers that are consistent with EDGES.
```



Extreme studentized deviate procedure - ESD

```
% In this section we describe the automatic routine implemented to detect and treat the
% outliers in inventories from small medium towns (number of inventories = (5,538)


% The procedure starts with dividing the data into two groups based on the normalization process:
% the activity data in the residential/municipal/institutional/tertiary buildings and transport sector and Waste
% were normalised with the population size, whereas the activity data in manufacturing and construction industries
% were normalised with the GDP values.
```

```
CoM_dataset2019_all.PC_activity_data=CoM_dataset2019_all.activity_data;
rows=(CoM_dataset2019_all.emission_inventory_sector~={'Manufacturing and construction industries'}& CoM_dataset2019_all.type_of_emission_inventory=={'baseline_emission_inventory'}& CoM_dataset2019_all.city~={'City or Greater city'});
CoM_dataset2019_all.PC_activity_data(rows)=CoM_dataset2019_all.activity_data(rows)./CoM_dataset2019_all.population_in_the_inventory_year(rows);
```

```
rows=(CoM_dataset2019_all.emission_inventory_sector~={'Manufacturing and construction industries'}& CoM_dataset2019_all.type_of_emission_inventory=={'baseline_emission_inventory'}& CoM_dataset2019_all.city~={'City or Greater city'});
T = CoM_dataset2019_all(rows,{'GCoM_ID','emission_inventory_id','city'});  %'emission_inventory_id'
[G,total] = findgroups(T);
total.population_in_the_inventory_year=splitapply(@max,CoM_dataset2019_all.population_in_the_inventory_year(rows),G);
total.PC_emissions=splitapply(@sum,CoM_dataset2019_all.PC_emissions(rows),G);
total.PC_activity_data=splitapply(@sum,CoM_dataset2019_all.PC_activity_data(rows),G);
total.emissions=splitapply(@sum,CoM_dataset2019_all.emissions(rows),G);
total.activity_data=splitapply(@sum,CoM_dataset2019_all.activity_data(rows),G);

total_initial=total;

Median=median(total_initial.PC_activity_data);
Mean=mean(total_initial.PC_activity_data);
SDs=std(total_initial.PC_activity_data); %standard deviation
S=skewness(total_initial.PC_activity_data);%the skewness
%
% The method is based on a generalised ESD (extreme studentized deviate) procedure for the
 detection of
% abnormal energy consumptions

% The procedure starts considering the whole data set of GHG emissions per capita. The mea
n, the standard deviation,
% the skewness and the ESD (extreme studentized deviate)  (the second, the third moment ab
out the mean) are calculated at the beginning for each set of data

total=total_initial;
total.ESD=(total.PC_activity_data-mean(total.PC_activity_data))/std(total.PC_activity_data
);

alpha=0.01;
out=total;

while ~isempty(out.PC_activity_data)
p_upper=1-alpha./(2*(n-1));% the upper limit
t_upper=tinv(p_upper, n-1-1); %this is the inverse of tstudent distribution

lambda_upper=t_upper*(n-1-1)/((((n-1)*(n-1-2+t_upper^2)))^0.5); %the critical value
rows=(total.ESD>=lambda_upper);
out=total(rows,:);

rows=(total.ESD<lambda_upper);
total=total(rows,:);

n=length(total.PC_activity_data);
total.ESD=(total.PC_activity_data-mean(total.PC_activity_data))/std(total.PC_activity_data
);
end
```

Median Absolute Deviation (MAD)

```
% To conclude, also a non-parametric statistical procedure, i.e. the Median Absolute Devia
tion (MAD),
% has been applied to identify outliers in dataset that are non normal distributed.
% This method is more robust than the ESD, but less efficient, and its validity increases
% as data approach normal distribution. Similarly to the ESD, the choice of a critical
% value is motivated by the reasoning that if the observations other than outliers
% have an approximately normal distribution, it picks up as an outlier any observations
% more than about three standard deviations from the means

MAD1=sum(abs(total.PC_activity_data-median(total.PC_activity_data)))/length(total.PC_activ
ity_data);
total.MAD=((total.PC_activity_data-median(total.PC_activity_data)))/MAD1;
```

Assessment of performance indicators

```
rows=(CoM_dataset2019_all.type_of_emission_inventory=={'baseline_emission_inventory'} & Co
M_dataset2019_all.city=={'City or Greater city'});
total_cities=CoM_dataset2019_all(rows,:);

T = total_cities(:,{'emission_inventory_id'});  %'emission_inventory_id'
[G,total_cities2] = findgroups(T);
total_cities2.population_in_the_inventory_year=splitapply(@max,total_cities.population_in_
the_inventory_year,G);
total_cities2.activity_data=splitapply(@sum,total_cities.activity_data,G);
total_cities2.emissions=splitapply(@sum,total_cities.emissions,G);

rows=(CoM_dataset2019_all.type_of_emission_inventory=={'baseline_emission_inventory'} & Co
M_dataset2019_all.city~={'City or Greater city'});
total_towns=CoM_dataset2019_all(rows,:);

T = total_towns(:,{'emission_inventory_id'});  %'emission_inventory_id'
[G,total_towns2] = findgroups(T);
total_towns2.population_in_the_inventory_year=splitapply(@max,total_towns.population_in_th
e_inventory_year,G);
total_towns2.activity_data=splitapply(@sum,total_towns.activity_data,G);
total_towns2.emissions=splitapply(@sum,total_towns.emissions,G);
sum(total_towns2.population_in_the_inventory_year)
total_towns3=innerjoin(total_towns2, total(:,2));

total3=union(total_cities2,total_towns3);

total3.PC_activity_data=total3.activity_data./total3.population_in_the_inventory_year;
total3.PC_emissions=total3.emissions./total3.population_in_the_inventory_year;
all_data_clean=total3;
Mean_clean=mean(total3.PC_emissions);
Median_clean=median(total3.PC_emissions);
SDs_clean=std(total3.PC_emissions); %standard deviation of the robust sample
S_clean=skewness(total3.PC_emissions);%the skewness

total_initial = removevars(total_initial, {'PC_emissions','PC_activity_data','city'});
population_in_the_inventory_year=sum(total_initial.population_in_the_inventory_year)+sum(t
otal_cities2.population_in_the_inventory_year);

% population1=sum(all_initial.population_in_the_inventory_year);
% population2=sum(all_data_clean.population_in_the_inventory_year);

all_initial=union (total_cities2, total_initial(:,2:5));
all_initial.PC_emissions=all_initial.emissions./all_initial.population_in_the_inventory_ye
ar;

Mean_all=mean(all_initial.PC_emissions);
Median_all=median(all_initial.PC_emissions);
SDs_all=std(all_initial.PC_emissions); %standard deviation of the robust sample
S_all=skewness(all_initial.PC_emissions);%the skewness

Mean_final=mean(all_data_clean.PC_emissions);
Median_final=median(all_data_clean.PC_emissions);
SDs_finall=std(all_data_clean.PC_emissions); %standard deviation of the robust sample
S_final=skewness(all_data_clean.PC_emissions);%the skewness


CoM_dataset2019_clean=innerjoin(CoM_dataset2019_all,all_data_clean(:,1));
```

```
rows=(CoM_dataset2019_clean.type_of_emissions=={'direct_emissions'}&(CoM_dataset2019_clean.emission_inventory_sector=={'Institutional/tertiary buildings and facilities'}|CoM_dataset2019_clean.emission_inventory_sector=={'Residential buildings and facilities'}|CoM_dataset2019_clean.emission_inventory_sector=={'Municipal buildings and facilities'}));
T = CoM_dataset2019_clean(rows,{'emission_inventory_id'});  %'emission_inventory_id'
[G,totalbd] = findgroups(T);
totalbd.emissions_BD=splitapply(@sum,CoM_dataset2019_clean.emissions(rows),G);% direct emission in buildings


rows=(CoM_dataset2019_clean.type_of_emissions=={'direct_emissions'}&CoM_dataset2019_clean.emission_inventory_sector=={'Transportation'});
T = CoM_dataset2019_clean(rows,{'emission_inventory_id'});  %'emission_inventory_id'
[G,totaltd] = findgroups(T);
totaltd.emissions_TD=splitapply(@sum,CoM_dataset2019_clean.emissions(rows),G);% direct emission in transport

totald=outerjoin(totalbd,totaltd,'MergeKeys',true);

totald.emissions_BD(isnan(totald.emissions_BD))=0;
totald.emissions_BD=totald.emissions_BD*10^-6;
totald.emissions_TD(isnan(totald.emissions_TD))=0;
totald.emissions_TD=totald.emissions_TD*10^-6;
```

```
ans =

    45963551
```

Technical Validation with EDGAR

```
EDGAR_RCO_TCO_2005=EDGARRCOTCO20052;

EDGAR_RCO_TCO_2005.RCO_LAU2_2005(isnan(EDGAR_RCO_TCO_2005.RCO_LAU2_2005))=0;
EDGAR_RCO_TCO_2005.TCO_LAU2_2005(isnan(EDGAR_RCO_TCO_2005.TCO_LAU2_2005))=0;

Tech_Valid=innerjoin (EDGAR_RCO_TCO_2005,CoM_dataset2019 );

rows=(Tech_Valid.RCO_LAU2_2005==0 & Tech_Valid.TCO_LAU2_2005==0);
Tech_Valid(rows,:)=[];

rows=(Tech_Valid.inventory_year==2005);
Tech_Valid2=Tech_Valid(rows,:);
Tech_Valid3=innerjoin(Tech_Valid2,totald);

Tech_Valid3.RSME_BUILD=(Tech_Valid3.RCO_LAU2_2005-Tech_Valid3.emissions_BD).^2;
RSME_BUILD=(sum(Tech_Valid3.RSME_BUILD)/length(Tech_Valid3.RCO_LAU2_2005))^0.5;
RSQ_BUILD=corr(Tech_Valid3.RCO_LAU2_2005,Tech_Valid3.emissions_BD);

Tech_Valid3.RSME_TRANSP=(Tech_Valid3.TCO_LAU2_2005-Tech_Valid3.emissions_TD).^2;
RSME_TRANSP=(sum(Tech_Valid3.RSME_TRANSP)/length(Tech_Valid3.RCO_LAU2_2005))^0.5;
RSQ_TRANSP=corr(Tech_Valid3.TCO_LAU2_2005,Tech_Valid3.emissions_BD);
```

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