National Observatory of Athens

Department of Informatics and Telecommunications -University of Peloponnese

Master of Science in Space Science Technologies and Applications.

Lamprini Chroni

space18014@uop.gr

2022201803014

Evaluating the Efficacy of Alternative Methodologies to EU and UN SDG Air-Pollution Indicators

MASTER THESIS

Advisory Committee

Evangelos Gerasopoulos, Research Director, Institute for Environmental Research & Sustainable Development, National Observatory of Athens, Advisor

Nikolaos Michalopoulos, Research Director, Institute for Environmental Research & Sustainable Development, National Observatory of Athens, Member.

Keramitsoglou Iphigenia, Research Director, Institute for Astronomy, Astrophysics, Space Applications and Remote Sensing, National Observatory of Athens, Member.

ATHENS 2024

Acknowledgements

First, I would like to thank Evangelos Gerasopoulos who had the supervision of this project. In addition, I would like to thank Orestis Speyer and Jennifer Bailey for their useful feedback and Danai Eleni Michailidou for providing me necessary data. Last but not least, I would like to thank my family and friends for their support throughout all these years.

Abstract

Air pollution and air quality are major issues concerning a big part of Earth's population. In order to address these issues, among others, a global agenda called "Sustainable Development Goals "was established. Under goal 11.6.2 lies a target that implies that countries should reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management. Two approaches by the UN and Eurostat have created two similar indictors, the UN SDG 11.6.2 and the Eurostat sdg_11_50. Both of them examine the annual mean levels of fine particulate matter and are population weighted. Since these approaches are sensitive to the definition of the city, SMURBS suggests a different approach to the indicator, combining EO data and in situ measurements and using objective city definitions. As a result, two indicators arise, using the SMURBS UC approach and the SMURBS FUA approach.

The purpose of this study is to test if the SMURBS indicators provide a sufficient alternative approach to the SDG 11.6.2 indicator, and Eurostat sdg_11_50, focusing on European countries and how these are affected by different city definitions.

At the first chapter we begin by defining air pollution, its sources and what Particulate Matter is. At the second chapter we explore the Global and European policy against air pollution, mentioning the Sustainable Development goals and the Guidelines. At the third chapter we analyze Global and European monitoring and reporting on the indicator 11.6.2, by diving into UN, Eurostat and SMURBS approach. At the fourth chapter we present the Methodology that was used in order to examine the approaches, using statistical tests and a study based upon the Charts and at the final chapter, our conclusion from this study is presented.

Table of Contents

Table of figures

Introduction

Air pollution

What is it and when it began to appear

Air pollution is defined as the contamination of the indoor or outdoor environment by any chemical, physical or biological agent that modifies the natural characteristics of the atmosphere [1]. It can also be described as the presence of toxic compounds in the atmosphere, in a concentration that can be harmful for humans, living beings and the environment [2]. Chemical compounds are naturally present in the atmosphere but human activity causes changes in the air composition. In order to find if a place suffers from air pollution or not, the presence of chemical compounds that are not present naturally is being studied. Also, a comparison is being made between the present air quality, and air quality of a time that was supposed to have little or no air pollution, for example, before the industrial revolution [3]. Air pollution can be categorized as indoor and outdoor which is also known as ambient. Indoor air pollution is generated by household burning of fuels, such as for heating and cooking, while outdoor air pollution can result from a variety of sources [4]. Historically, air quality issues have been found in any large city where people burned wood and worked in crafts or industry, whether or not fossil fuels were used. One of the first air pollution related incidents was recorded in 1157 where “unendurable” air pollution from wood smoke leads Henry II’s wife Eleanor of Aquitaine to move from Tutbury Castle at Nottingham [5].In 1306 coal burning was prohibited in London but this action was never put into effect. The burning of coal and other fossil fuels escalated dramatically during The Industrial Revolution (1760-1820), especially in the big coal and steel cities like Manchester in England and Pittsburgh in Pennsylvania. During that time, smoke was considered an indicator of wealth, however, people soon began to realize that it was also a public health problem [6].

Sources

Air pollution originates from a variety of sources, all of which can be divided into two categories :1) naturally occurring pollutants and 2) pollution resulting from anthropogenic sources, i.e. produced through human activity. Some examples of natural air pollution sources include smoke and carbon dioxide from wildfires, volcanic emissions containing sulfur and particulates, as well as gases like methane, which are emitted from decomposing organic matter in soils and from animals during food digestion [7]. Anthropogenic sources seem to have more impact in urban areas and are mostly related with exhaust fumes produced by internal combustion engines and the burning of fossil fuels. The anthropogenic sources can be categorized as: a) mobile sources such as cars, buses, planes, trucks and trains, b) stationary sources such as fossil fuel power stations, oil refineries, industrial facilities and factories and c) area sources such as agricultural areas, cities, and wood burning fireplaces [8].

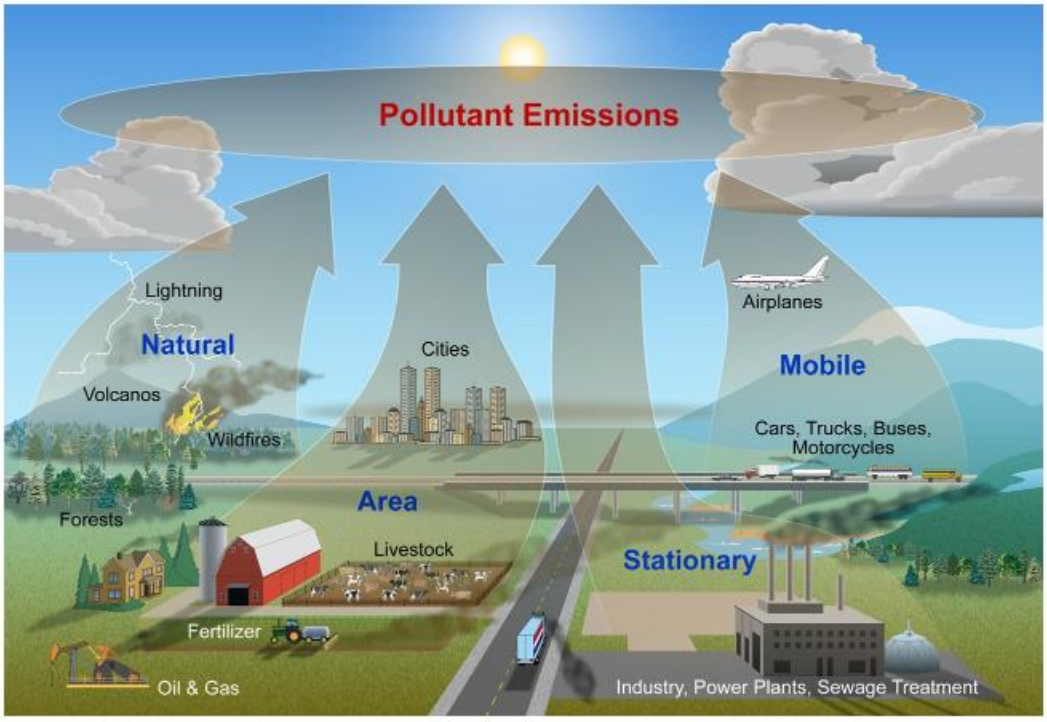

Figure 1: Mobile, stationary, area, and natural sources all emit pollution into the air, Source: https://www.nps.gov/subjects/air/sources.htm

In Europe, in 2020, residential, commercial and institutional energy consumption was the principal source of particulate matter emissions. Agriculture was the main source of ammonia and methane emissions and road transport was the principal source of nitrogen oxides. Also, the energy supply sector was responsible for most of Sulphur dioxide emissions and last, the manufacturing and extractive industries, and the energy supply sector, were the principal sources of heavy metals emissions [9].

Particulate matter

The term Particulate matter (PM) is referred to describe a mixture of solid and liquid inhalable particles that are suspended in the air. For this reason, the term ambient particulate matter is also used [10]. PM is a product of chemical reactions between pollutants composed of sulfate, nitrates, ammonia, sodium chloride, black carbon, mineral dust and water [11]. It is one of the main air pollutants which plays a major role in terms of pollution, especially in urban regions, and has negative impacts to health, since they are inhalable and respirable particles. Furthermore, PM is widely used as an indicator for air pollution broadly to address regulatory policy and health effects from exposure to outdoor air pollution. According to their size PM is categorized into two groups: a) $PM_{2.5}$ are the finer particles whose diameter is 2.5 micrometers (μm) or smaller, and can be derived from primary sources such as combustion of fuels in power generation facilities, industries or vehicles and secondary sources such as chemical reactions between gases b) PM_{10} are the coarse particles whose diameter is between 2.5 μm and 10 μm and mainly consist of pollen,

sea spray and wind-blown dust from erosion, agricultural spaces, roadways and mining operations [11] ,[12].

Environmental impacts

Air pollution can cause a variety of environmental impacts. Some of them are acid rain, ozone depletion and climate change. First, due to air pollution, precipitation containing toxic substances is produced, called acid rain, which can damage plants and trees, along with negative effects on buildings and sculptures. Another impact of air pollution is stratospheric ozone depletion. Ozone is found both at ground level and in the stratosphere. At ground level, ozone is considered a pollutant. However, stratospheric ozone forms a protective layer against the Sun's harmful ultraviolet rays. Unfortunately, stratospheric ozone is being depleted by man-made chemical substances, causing damage to this protective layer, resulting in penetration of ultraviolet rays into the atmosphere causing harmful effects, such as skin damages that can lead also to cancer, in humans and animals [13]. Last but not least, global climate change is intensified due to increased greenhouse gases emissions, whose sources also emit air pollution, contributing to the dramatic rise of the average temperature on Earth's atmosphere resulting in negative impacts to the environment such as longer periods of drought, more intense tropical storms, loss of sea ice and more frequent wildfires [14].
Deposition of PM to vegetated surfaces may cause abrasion, radiative heating and leaf injury and interfere with photosynthesis. Also, PM deposition directly to the soil can influence nutrient cycling and affect the ecosystem [15].

Health impacts

Air pollution has also various negative effects on Health. It is the leading cause of chronic health conditions, including respiratory diseases such as asthma, cardiovascular diseases such as heart attacks and neurological disorders [16]. Particulate matter plays a major role to these impacts since it can penetrate deep into the lungs and enter the bloodstream, causing, among other impacts, cardiovascular and respiratory diseases, as well as cancer. It affects more people than other pollutants and has serious health impacts even at very low concentrations [17]. The ability of PM to penetrate into the human body is dependent on the particle size. PM_{10} can invade the lungs and reach the bloodstream, while particles $PM_{2.5}$ can cause more serious effects due to the fact that they are smaller and can penetrate easily and more deeply into the human body [18]. In 2013, exposure to PM and air pollution in general were classified as a cause of lung cancer by the International Agency for Research on Cancer (IARC) [19].

Global and European policy against air pollution

Air pollution is often considered as a regional problem. However, it also has a global dimension. Some of the reasons that make air pollution a global problem is presented below. Firstly, air pollution emitted in one country can affect people and the environment of another country due to the long-range transport of air pollution. Also, different countries can have similar air pollution problems that can be solved using the same measures and finally, the implementation of national policies might have implications for other countries, as they can lead to shifting environmental problems to another country. It is clear that addressing these pollution problems requires cooperation between countries at the scientific and the policy level [20].

Air pollution is one of the most important environmental risks to human health and people who live in large cities and next to big roads or industrial areas are more likely to face higher exposure to it [21]. Due to urbanization, which is the shift in human's residence from rural to urban areas, a big percentage of Earth's population live in cities. In 2018, 55% of the world's population lived in urban areas and by 2050 this percentage is expected to reach up to 68% [22]. It has also been estimated that the majority of the world's population (87%) live in areas in which WHO air quality guideline for PM2.5 is exceeded [23].

A global framework under the United Nations (UN) is working on facing air pollution. The UN is an intergovernmental organization founded in 1945 and consists of 193 Member States. The UN can take action on the issues such as peace, security, climate change, sustainable development, human rights, disarmament, terrorism, humanitarian and health emergencies, gender equality and more [24].

Sustainable Development Goals

The UN has set an agenda for global sustainable development to address these issues. The 2030 Agenda for Sustainable Development contains 17 goals, the Sustainable Developments Goals (SDGS) that aim to improve the lives and prospects of humans. These goals were adopted by all UN Member States in 2015, as part of the 2030 Agenda for Sustainable Development, which set out a 15-year plan to achieve the Goals. They are designed to balance the three dimensions of sustainable development: the economic, social and environmental. The goals are presented in the infographic below.

Figure 2: Sustainable Development Goals, Source: https://sdgs.un.org/goals

Each of the previous goals that were adopted by the UN consists of some targets, and each target consists of some indicators. The indicator that concerns air pollution is SDG Indicator 11.6.2. This comes from Goal 11, which is about Sustainable Cities and Communities, and Target 6 about reducing the adverse per capita environmental impact of cities by paying special attention to air quality and municipal and other waste management [25].

Indicator 11.6.2 addresses the annual mean levels of fine particulate matter ($PM_{2.5}$ and PM_{10}) in cities. This mean is a population-weighted average and is expressed in micrograms per cubic meter ($\mu g/m^3$) [26].

At the European level, the European Union member states are also taking measures against air pollution. The EU's objective is to achieve levels of air quality that do not impose risks to human health and the environment. EU policies aim to reduce exposure to air pollution by reducing emissions and setting limits and target values for air quality [27].The EU's member states, under the EUs Air Quality Directive and European Environmental Agency (EEA), have to implement and report on the measures they take in areas where air quality limit and target values are exceeded in order to reduce people's exposure to air pollutants. The EEA is an agency of the European Union, whose task is to provide information on the environment, aiming to support sustainable development by helping to achieve significant and measurable improvement in Europe's environment [28]. EU, under the supervision of Eurostat, which is the statistical office of the European Union that provides high quality statistics and data on Europe [29], has adopted the indicator sdg 11_50 in order to regulate and report about air pollution in Europe. This indicator is similar to the one set by the UN and is also population weighted.

Guidelines

The World Health Organization (WHO) has established guidelines on ambient air pollution levels, which are used as reference tools by policymakers across the world in order to set standards and goals for air quality management. These guidelines provide health-based standards for air pollutants that cities are required to adopt as air quality targets. They were initially set in 2005 and they were updated in 2021 with lower values for all pollutants.

The WHO guidelines state that annual average concentrations of $PM_{2.5}$ should not exceed 5 µg/m^3, while 24-hour average exposures should not exceed 15 µg/m^3 more than 3 - 4 days per year.

Interim targets have been set to support the planning of progressive milestones toward cleaner air. For PM2.5 these are:

- Interim Target 1: 35 µg/m^3 annual mean, 75 µg/m^3 24-hour mean.
- Interim Target 2: 25 µg/m^3 annual mean, 50 µg/m^3 24-hour mean.
- Interim Target 3: 15 µg/m^3 annual mean, 37.5 µg/m^3 24-hour mean.
- Interim Target 4: 10 µg/m^3 annual mean, 25 µg/m^3 24-hour mean.

The previous WHO Global Air Quality Guidelines, published in 2005, were that annual average concentrations of PM2.5 should not exceed 10 µg/m^3, while 24-hour average exposures should not exceed 25 µg/m^3 more than 3 times a year [30].

The EU air quality standards for the annual average concentrations of $PM_{2.5}$ are shown in the figure below. They apply over different periods of time because the observed health impacts associated with the various pollutants occur over different exposure times [31].

Pollutant	Concentration	Averaging period	Legal nature	Permitted exceedences each year
Fine particles ($PM_{2.5}$)	25 µg/m^3	1 year	Target value to be met as of 1.1.2010 Limit value to be met as of 1.1.2015	n/a
Fine particles ($PM_{2.5}$)	20 µg/m^3	1 year	Stage 2 limit value to be met as of 1.1.2020 ***	n/a

Figure 3: EU air quality standards Source: https://environment.ec.europa.eu/topics/air/air-quality/eu-air-quality-standards_en

Global and European monitoring and reporting of indicator 11.6.2

In the previous chapter we talked about two indicators that measure human's exposure to air pollution: the SDG Indicator 11.6.2, which is the UN approach and sdg 11_50, which is Eurostat's approach.

A linear regression calibration approach was used in 2013 in the Global Burden of Disease study (referred to as GBD2013) in order to utilize information from satellite remote sensing and chemical transport models. Since the reported indicator value is population–weighted, these estimates of exposure are then combined with population estimates and the value of Indicator 11.6.2 is produced.

The following formula is used to obtain the aggregated mean for each city:

$$Annual\ mean\ levels = \frac{\sum C_n \times P_n}{\sum P_n}$$

where C_n is the estimated mean annual fine particulate matter for the city (or grid(s) corresponding to that city), P_n is the population of the city (or grid(s) corresponding to that city)

The same formula is used to derive country estimates, by aggregating the grid cells that are within the country.

Although the formula is universal, the uneven geographic distribution of measurements combined with different urban air quality monitoring protocols, measurement techniques and different city definitions used by each country, leads to a difficult comparison of the values globally [32].

Urban definitions

In order to examine the different approaches, we first have to explicate the three different Urban definitions that are being used by each approach: Urban center, Functional Urban Area and Agglomerations.

Urban center

Urban center (UC) is a cluster of contiguous grid cells of 1 km² (excluding diagonals) with a population density of at least 1.500 inhabitants per km² and collectively a minimum population of 50.000 inhabitants after gap-filling [33].

FUA

A Functional Urban Area consists of a city and its commuting zone. Functional urban areas therefore consist of a densely inhabited city and a less densely populated commuting zone whose labor market is highly integrated with the city [34].

Agglomerations

Agglomerations are defined as a zone that is a conurbation with a population in excess of 250 .000 inhabitants or, where the population is 250. 000 inhabitants or less, with a given population density per km^2 to be established by the EU Member States [35].

UN approach

As the Custodian Agency, the WHO gathers the necessary data from countries to calculate and report on SDG Indicator 11.6.2 on the country-level. Although measurements are collected by thousands of locations around the world, the density of ground- based monitoring sites vary, with extensive measurements available in North America, Europe, China and India but with less or no measurement data available for Africa, South America and the Middle East [32]. As a result, information from other sources is needed in order to obtain estimates of the indicator for all areas on Earth. The sources of data that are used can be categorized to one of three groups: ground monitoring data, estimates of $PM_{2.5}$ from remote sensing satellites and chemical transport models, and other sources including population, land use and topography [36]. The output is a national aggregate estimate for the indicator, taking into account the 'cities' population and the respective PM values from all the above sources.

Eurostat approach

Eurostat is called to monitor progress towards the SDGs in an EU context. For this purpose, it coordinates the development of the EU SDG indicator set and keeps it up to date and also produces regular monitoring reports on progress towards the SDGs in an EU context. SDG 11 aims to renew and plan cities and other human settlements in a way that offers opportunities for all, with access to basic services, energy, housing, transport and green public spaces, while reducing resource use and environmental impact [37]. The indicator sdg_11_50 measures the population weighted annual mean concentration of particulate matter at urban background stations in agglomerations and can be considered as identical to global SDG indicator 11.6.2 with the only difference being that only agglomerations are used in order to calculate the value [38].

SMURBS approach

SMURBS (SMart URBan Solutions for air quality, disasters and city growth), is a project that aims to promote the "smart city" approach, serving the need for a common approach to enhance environmental and societal resilience to specific urban pressures, through the integration of EO [39]. A part of this project is the SMURBS estimation of SDG 11.6.2 at the Country and City Level across Europe. The SMURBS approach utilizes two objective city definitions (UC and FUA) endorsed by the European Commission and PM data from the Copernicus Atmospheric Monitoring Service (CAMS), as opposed to in situ measurements [40].

For the first city definition, Urban Center (UC), the Joint Research Center 's Global Human Settlement Layer (GHS) initiative was followed, where the Degree of Urbanization (DEGURBA) classifications were re-calculated using both population density criteria and density of built-up area derived from primary databases and not Local Administrative Unit (LAU) data to produce the Urban Centre Database (UCDB), which is agnostic to national definitions [41]. The degree of urbanization classifies local administrative units (LAUs) as cities, towns and suburbs or rural areas based on a combination of geographical contiguity and population density, measured by minimum population thresholds applied to 1 km² population grid cells; each LAU belongs exclusively to one of these three classes [42] . Due to the fact that the definition is driven by satellite information, it is not affected by national definitions of LAUs, so it is more objective.

For the second city definition, Functional Urban Area (FUA), the UC database is used, it is overlayed against the LAUs and categorizes them based off of criteria that labels the units as cities or not. A functional urban area is then defined by incorporating the commuting zone into that city's overall extent based on commuting patterns from Eurostat or country data [43]. FUA database was provided by the Copernicus Land Monitoring Service (CLMS) [44].

At last, PM annual average concentrations from CAMS [45] are derived from the annual average regional ensemble reanalysis product for the years 2014-2020. This contains modeled information validated with all available in situ or satellite information. The spatial resolution the product is 11km. CAMS values are masked using the shapefiles of the city definitions and then a pixel-weighted concentration average is produced in a GIS environment. Population is then combined with the concentration to produce the indicator value per city and at country level.

The results of the SMURBS approach are presented on an online platform [46], which provides an equivalent to the SDG indicator value for every country in Europe along with city values, using the UC and FUA city definitions [47].

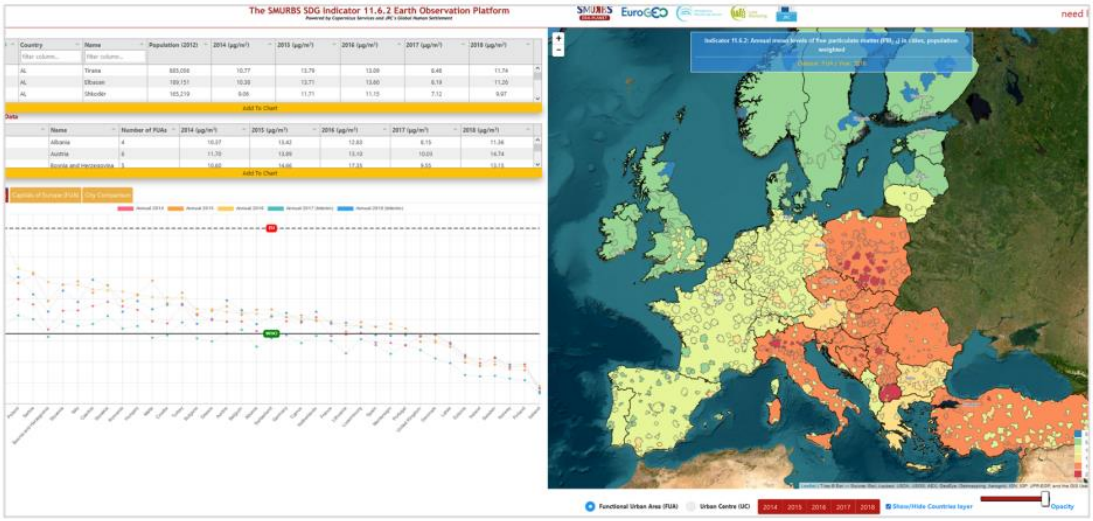

Figure 4:Interface of the SMURBS SDG Indicator 11.6.2 Earth Observation Platform
Source: http://apcg.meteo.noa.gr/sdg1162/

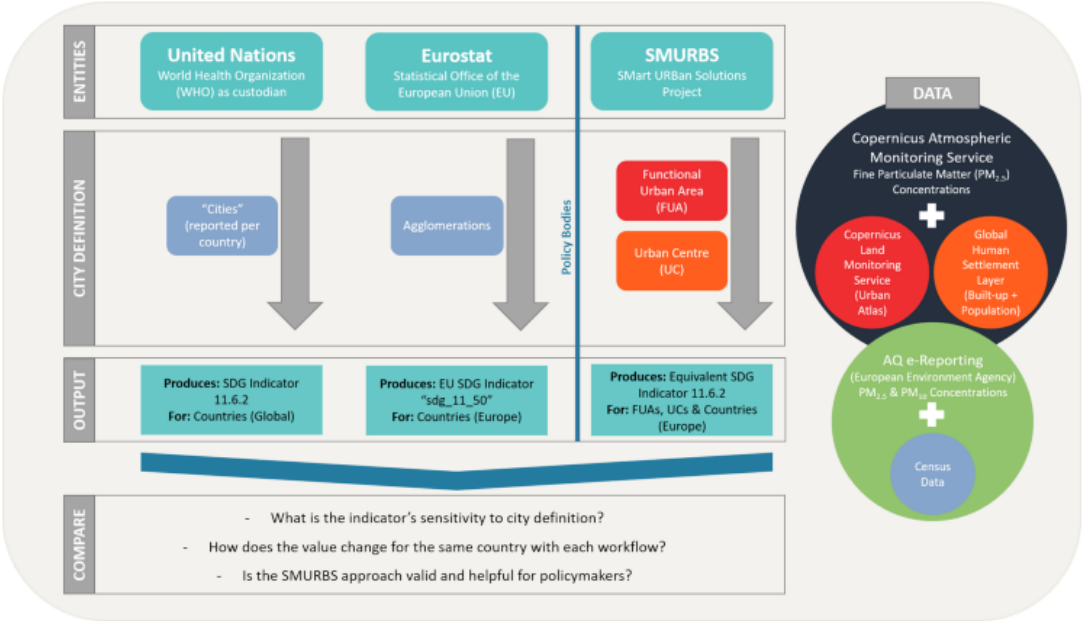

Figure 5: Conceptual workflows for the approaches of the two different policy entities UN, Eurostat and SMURBS approach for producing comparable values of SDG indicator 11.6.2 ,Source: Insights and Policy Implications from a Harmonized Earth Observation Approach to Urban Air Quality (essopenarchive.org)

Purpose of the study

As mention above, there are two different approaches for Indicator SDG 11.6.2, the UN approach and the Eurostat approach. SMURBS suggests a different approach to the indicator, the SMURBS SDG 11.6.2, combining EO data and in situ measurements and using objective city definitions. As a result, two indicators arise, using the SMURBS UC approach and the SMURBS FUA approach. The purpose of this study is to test if the SMURBS indicators provide a sufficient alternative approach to the SDG 11.6.2 indicator, and Eurostat sdg_11_50, focusing on European countries and how these are affected by different city definitions.

Methodology

Data acquisition

The values that are being studied are about 30 European Countries:

Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

For SMURBS approach, (UC and FUA) data for the years 2014-2020 was collected from the online platform: http://apcg.meteo.noa.gr/sdg1162/

For UC values for Cyprus 2017-2020 and Lithuania 2014-2016 were not available.

For FUA values for Lithuania 2014-2016 were not available.

For Eurostat approach data for the years 2014-2019 was collected from the online platform: https://eu-dashboards.sdgindex.org/explorer

Values for Greece 2014, Hungary 2015,2016, Iceland 2014 and Switzerland 2019 were not available.

For UN approach data for the years 2014-2019 was collected from the online platform: https://unstats.un.org/sdgs/dataportal/database . For the purpose of this research, only two values were selected: the UN Total, which is the value for the entire country and UN Urban which is the value for countries' regions that are classified as Urban.

Comparisons

In order to examine which is the correlation between the different Data sets that are derived from each approach, some Statistical tests were used.

Statistical tests

For all the statistical tests, as a data set was used the Eurostat, Un Total, Un Urban, FUA and UC values for years 2014 – 2020, for all the European countries.

t-test

The first statistical test that was conducted was the t-test. The t-test is a statistical test used to compare the means of two groups. The null hypothesis (H0) for a t-test usually states that there is no significant difference between the two group means and that the two means are equal, implying that any observed difference is due to random chance. The alternative hypothesis (H1), on the other hand, suggests that there is a significant difference between the two group means.

The p-value is a measure of the probability of observing the test results under the null hypothesis. A small p-value (typically ≤ 0.05) indicates strong evidence against the null hypothesis, so it is rejected, and it is concluded that there is a significant difference between the groups. A large p-value (> 0.05) indicates weak evidence against the null hypothesis, so it fails to be rejected, suggesting that any observed difference could indeed be due to chance [48].

The t-Test was conducted between each pair of datasets, for each, year assuming unequal variances.

As shown on the Table 1 below, each pair of data set is divided into two categories depending on the p value of each test and whether the mean values of the data sets are statistically significant different or statistically insignificant different. At the left we have the pairs that present p-value<0,05 and at the right we have the pairs that present p-value>0,05.

t-Test Results	
Statistically Significant Difference	**Statistically Insignificant Difference**
Eurostat-FUA-2017	Eurostat-FUA-2016
Eurostat-FUA-2018	Eurostat-FUA-2019
Eurostat-UC-2014	Eurostat-UC-2015
FUA-UN Urban 2014	Eurostat-UC-2016
FUA-UN Urban 2015	Eurostat-UC-2017
FUA-UN Urban 2017	Eurostat-UC-2018
FUA-UN Urban 2018	Eurostat-UC-2019
FUA-UN Total 2014	FUA-UC-2014
FUA-UN Total 2018	FUA-UC-2015
UC - UN Urban 2014	FUA-UC-2016
UC - UN Urban 2018	FUA-UC-2017
	FUA-UC-2018
	FUA-UC-2019
	FUA-UC-2020
	Eurostat-UN Urban 2014
	Eurostat-UN Urban 2015
	Eurostat-UN Urban 2016
	Eurostat-UN Urban 2017
	Eurostat-UN Urban 2018
	Eurostat-UN Urban 2019
	Eurostat-UN Total 2014
	Eurostat-UN Total 2015
	Eurostat-UN Total 2016
	Eurostat-UN Total 2017
	Eurostat-UN Total 2018

Eurostat-UN Total 2019
FUA-UN Urban 2016
FUA-UN Urban 2019
FUA-UN Total 2015
FUA-UN Total 2016
FUA-UN Total 2017
FUA-UN Total 2019
UN Urban-UN Total 2014
UN Urban-UN Total 2015
UN Urban-UN Total 2016
UN Urban-UN Total 2017
UN Urban-UN Total 2018
UN Urban-UN Total 2019
UC - UN Urban 2015
UC - UN Urban 2016
UC - UN Urban 2017
UC - UN Urban 2019
UC - UN Total 2014
UC - UN Total 2015
UC - UN Total 2016
UC - UN Total 2017
UC - UN Total 2018
UC - UN Total 2019

Table 1: t- Test results

As we can observe, 11 data set pairs are statistically significant different and 48 data set pairs are statistically insignificant different. Since the majority of the data set pairs belong in the second category, it is safe to assume that the data sets are statistically insignificant different, so any observed difference is due to random chance.

Relative Percentage difference

Another way of comparing two data sets is by calculating their relative percentage difference. The relative percentage difference between two points is calculated by first finding the relative difference between two quantities across different measurements or samples, then subtract one measurement from the other and take the absolute value of this difference.

The relative percentage difference between two data sets is given by the formula:

$$RPD = \frac{|R1 - R2|}{\left(\frac{R1 + R2}{2}\right)} \times 100,$$

[49]

and the results can be seen on Table2 to Table 11 below.

Relative Percentage Differences: Eurostat - FUA						
Countries / Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Austria	24%	4%	0%	10%	17%	10%
Belgium	20%	6%	2%	1%	8%	1%
Bulgaria	69%	64%	39%	63%	62%	35%
Croatia	54%	42%	30%	46%	48%	25%
Cyprus	39%	31%	18%	29%	16%	-2%
Czechia	31%	10%	10%	15%	17%	6%
Denmark	23%	25%	10%	20%	42%	15%
Estonia	21%	13%	-18%	10%	16%	-16%
Finland	39%	22%	7%	21%	30%	11%
France	26%	14%	8%	15%	21%	11%
Germany	25%	8%	4%	10%	17%	9%
Greece	-	21%	8%	10%	22%	16%
Hungary	41%	-	-	41%	19%	-10%
Iceland	-	106%	65%	107%	118%	92%
Ireland	49%	39%	33%	58%	54%	35%
Italy	28%	23%	13%	26%	13%	-6%
Latvia	73%	65%	57%	66%	78%	37%
Lithuania				-2%	-5%	14%
Luxembourg	13%	0%	26%	28%	20%	26%
Netherlands	12%	6%	-5%	-2%	8%	2%
Norway	48%	43%	39%	53%	31%	34%
Poland	54%	32%	19%	28%	29%	16%
Portugal	18%	-4%	0%	20%	29%	0%
Romania	0%	15%	7%	37%	35%	-5%
Slovakia	21%	12%	-10%	8%	11%	-1%
Slovenia	27%	24%	24%	28%	29%	13%
Spain	26%	17%	3%	23%	32%	22%
Sweden	11%	8%	-8%	11%	17%	7%
Switzerland	16%	-28%	-24%	3%	-9%	
United Kingdom	28%	12%	7%	16%	20%	9%
Total Average	**31%**	**22%**	**13%**	**27%**	**28%**	**14%**

Table 2 :Relative Percentage Difference Eurostat - FUA

We can observe that the Relative Percentage Difference between Eurostat and FUA, range from 13% to 31%. Since it is always positive, we can assume that Eurostat values are greater than FUA values.

Relative Percentage Differences: Eurostat - UC						
Countries / Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Austria	14%	-2%	-5%	27%	41%	-13%
Belgium	15%	2%	-1%	-2%	4%	-4%
Bulgaria	54%	48%	23%	50%	45%	15%
Croatia	48%	37%	25%	42%	38%	10%
Cyprus	36%	28%	16%			
Czechia	28%	6%	7%	10%	11%	-1%
Denmark	17%	17%	4%	11%	36%	7%
Estonia	4%	-2%	-32%	-10%	0%	-37%
Finland	16%	-3%	-16%	-4%	8%	-10%
France	26%	12%	7%	4%	10%	-2%
Germany	20%	3%	0%	3%	11%	1%
Greece		6%	-6%	-3%	9%	1%
Hungary	34%			36%	10%	-21%
Iceland		74%	3%	56%	49%	17%
Ireland	41%	33%	26%	48%	44%	19%
Italy	23%	20%	10%	25%	11%	-10%
Latvia	58%	45%	38%	49%	58%	7%
Lithuania				-10%	-15%	3%
Luxembourg	1%	-13%	11%	17%	5%	13%
Netherlands	12%	6%	-5%	-3%	8%	0%
Norway	11%	3%	-3%	3%	-6%	-5%
Poland	47%	23%	11%	20%	20%	5%
Portugal	7%	-15%	-7%	9%	18%	-13%
Romania	-4%	11%	2%	34%	32%	-8%
Slovakia	18%	6%	-13%	2%	6%	-6%
Slovenia	16%	3%	4%	15%	17%	-4%
Spain	16%	8%	-5%	14%	22%	10%
Sweden	-1%	-5%	-19%	-3%	5%	-9%
Switzerland	14%	-31%	-26%	-1%	-12%	
United Kingdom	23%	8%	2%	11%	14%	3%
Total Average	**22%**	**12%**	**2%**	**16%**	**17%**	**-1%**

Table 3: Relative Percentage Difference Eurostat - UC

We can observe that the Relative Percentage Difference between Eurostat and UC, range from -1% to 22%. For years 2014-2018 the Relative Percentage Difference is positive, so we can assume that Eurostat values are greater than UC values.

Relative Percentage Differences: FUA- UC							
Countries / Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Austria	-10%	-6%	-5%	17%	25%	-24%	-40%
Belgium	-6%	-4%	-4%	-3%	-3%	-4%	-6%
Bulgaria	-17%	-17%	-16%	-14%	-18%	-20%	-31%
Croatia	-6%	-5%	-5%	-5%	-10%	-14%	-19%
Cyprus	-3%	-3%	-3%				
Czechia	-4%	-3%	-3%	-5%	-5%	-7%	-9%
Denmark	-6%	-8%	-6%	-9%	-6%	-8%	-8%
Estonia	-17%	-15%	-15%	-20%	-16%	-21%	-22%
Finland	-24%	-25%	-23%	-25%	-22%	-22%	-19%
France	0%	-2%	-2%	-11%	-11%	-13%	-12%
Germany	-5%	-5%	-4%	-7%	-6%	-8%	-7%
Greece	-17%	-15%	-15%	-13%	-13%	-15%	-21%
Hungary	-7%	-5%	-6%	-5%	-9%	-12%	-15%
Iceland	-65%	-41%	-62%	-60%	-81%	-78%	-72%
Ireland	-8%	-6%	-7%	-11%	-10%	-17%	-14%
Italy	-4%	-3%	-3%	-2%	-2%	-4%	-7%
Latvia	-17%	-21%	-20%	-19%	-22%	-30%	-29%
Lithuania				-8%	-10%	-11%	-12%
Luxembourg	-11%	-13%	-15%	-11%	-14%	-13%	-13%
Netherlands	0%	0%	0%	-1%	-1%	-2%	-3%
Norway	-37%	-40%	-42%	-50%	-37%	-39%	-40%
Poland	-8%	-10%	-8%	-8%	-9%	-10%	-17%
Portugal	-11%	-11%	-7%	-11%	-11%	-13%	-17%
Romania	-4%	-4%	-5%	-4%	-3%	-4%	-8%
Slovakia	-4%	-6%	-3%	-6%	-5%	-5%	-8%
Slovenia	-11%	-21%	-20%	-13%	-13%	-17%	-26%
Spain	-10%	-8%	-8%	-8%	-10%	-12%	-12%
Sweden	-11%	-13%	-12%	-14%	-11%	-16%	-15%
Switzerland	-2%	-2%	-2%	-4%	-3%	-5%	-4%
United Kingdom	-5%	-4%	-4%	-5%	-5%	-6%	-7%
Total Average	**-11%**	**-11%**	**-11%**	**-11%**	**-12%**	**-16%**	**-18%**

Table 4: Relative Percentage Difference FUA - UC

We can observe that the Relative Percentage Difference between FUA and UC, range from -18% to -11%. Since it is always negative, we can assume that FUA values are smaller than UC Values.

Relative Percentage Differences: Eurostat - UN Urban						
Countries / Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Austria	6%	-2%	-1%	6%	13%	-3%
Belgium	6%	-1%	4%	1%	2%	-4%
Bulgaria	13%	13%	-5%	9%	-9%	5%
Croatia	3%	15%	14%	3%	5%	3%
Cyprus	8%	6%	1%	-6%	-22%	-14%
Czechia	0%	-4%	5%	4%	7%	-3%
Denmark	13%	1%	-2%	-13%	13%	-1%
Estonia	5%	-5%	-18%	-15%	-10%	-32%
Finland	22%	-12%	-9%	-23%	0%	-20%
France	-3%	9%	3%	-2%	-4%	-9%
Germany	15%	2%	6%	4%	8%	-2%
Greece	-	-6%	-9%	-18%	-22%	-10%
Hungary	9%	-	-	19%	-1%	-3%
Iceland	-	7%	-20%	0%	-2%	-5%
Ireland	2%	-19%	4%	-7%	0%	1%
Italy	2%	21%	16%	16%	-3%	2%
Latvia	0%	-17%	7%	1%	6%	-15%
Lithuania	-20%	-17%	-22%	-26%	-38%	-5%
Luxembourg	9%	9%	36%	27%	11%	11%
Netherlands	9%	0%	-5%	-4%	1%	-5%
Norway	11%	-3%	8%	-5%	-18%	-10%
Poland	5%	-1%	3%	4%	2%	-3%
Portugal	20%	13%	15%	27%	27%	18%
Romania	-21%	4%	8%	22%	19%	15%
Slovakia	-11%	-3%	-23%	-8%	-14%	-16%
Slovenia	-6%	17%	22%	10%	-1%	5%
Spain	4%	11%	7%	13%	11%	19%
Sweden	8%	-12%	-13%	-17%	-6%	-10%
Switzerland	4%	-15%	-3%	8%	-12%	-
United Kingdom	13%	-12%	0%	-4%	-2%	5%
Total Average	**5%**	**0%**	**1%**	**1%**	**-1%**	**-3%**

Table 5: Relative Percentage Difference Eurostat - UN Urban

We can observe that the Relative Percentage Difference between Eurostat and UN Urban range from -3% to 5%. For years 2014-2017 the Relative Percentage Difference is positive so we can assume that Eurostat values are greater than UN Urban Values.

Relative Percentage Differences: Eurostat - UN Total						
Countries / Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Austria	14%	6%	6%	13%	20%	4%
Belgium	9%	2%	7%	4%	5%	-1%
Bulgaria	21%	20%	3%	16%	-1%	13%
Croatia	5%	16%	15%	4%	7%	5%
Cyprus	14%	12%	7%	1%	-15%	-8%
Czechia	4%	-1%	9%	8%	11%	0%
Denmark	18%	5%	2%	-8%	18%	3%
Estonia	9%	-1%	-14%	-11%	-6%	-28%
Finland	37%	3%	6%	-9%	14%	-7%
France	6%	10%	12%	6%	4%	-1%
Germany	19%	6%	10%	8%	11%	2%
Greece	-	0%	-3%	-12%	-16%	-4%
Hungary	13%	-	-	23%	3%	1%
Iceland	-	14%	-13%	8%	5%	2%
Ireland	8%	-14%	10%	-2%	6%	7%
Italy	5%	24%	20%	20%	0%	6%
Latvia	17%	17%	24%	17%	23%	1%
Lithuania	-8%	-5%	-10%	-14%	-27%	7%
Luxembourg	11%	11%	39%	29%	13%	14%
Netherlands	11%	1%	-4%	-3%	3%	-3%
Norway	25%	11%	22%	10%	-4%	3%
Poland	11%	5%	9%	9%	8%	2%
Portugal	23%	17%	18%	28%	31%	21%
Romania	-14%	10%	15%	28%	25%	21%
Slovakia	-8%	0%	-20%	-6%	-12%	-14%
Slovenia	-2%	21%	25%	14%	3%	8%
Spain	9%	16%	12%	17%	15%	23%
Sweden	16%	-4%	-5%	-9%	2%	-3%
Switzerland	7%	-7%	0%	12%	-8%	-
United Kingdom	16%	-10%	2%	-2%	0%	7%
Total Average	**11%**	**6%**	**7%**	**7%**	**5%**	**3%**

Table 6: Relative Percentage Difference Eurostat - UN Total

We can observe that the Relative Percentage Difference between Eurostat and UN Total range from 3% to 11%. The Relative Percentage Difference is always positive so we can conclude that Eurostat values are greater than UN Total values.

Relative Percentage Differences: FUA - UN Urban						
Countries / Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Austria	-18%	-7%	-1%	-4%	-4%	-14%
Belgium	-14%	-7%	2%	0%	-5%	-5%
Bulgaria	-58%	-53%	-44%	-55%	-69%	-30%
Croatia	-51%	-28%	-17%	-44%	-42%	-22%
Cyprus	-31%	-24%	-18%	-34%	-37%	-13%
Czechia	-31%	-14%	-6%	-11%	-9%	-10%
Denmark	-10%	-24%	-12%	-32%	-29%	-16%
Estonia	-16%	-17%	0%	-25%	-26%	-16%
Finland	-18%	-34%	-16%	-44%	-30%	-31%
France	-29%	-5%	-5%	-17%	-25%	-19%
Germany	-10%	-7%	2%	-5%	-9%	-11%
Greece	-33%	-28%	-18%	-28%	-43%	-26%
Hungary	-32%	-14%	-8%	-22%	-21%	7%
Iceland	-99%	-101%	-82%	-107%	-119%	-96%
Ireland	-46%	-57%	-29%	-65%	-53%	-34%
Italy	-26%	-2%	3%	-10%	-17%	8%
Latvia	-73%	-80%	-51%	-66%	-72%	-52%
Lithuania	-	-	-	-24%	-33%	-19%
Luxembourg	-4%	9%	11%	-1%	-8%	-15%
Netherlands	-2%	-7%	0%	-2%	-7%	-6%
Norway	-37%	-46%	-31%	-57%	-48%	-44%
Poland	-50%	-33%	-16%	-24%	-27%	-19%
Portugal	1%	17%	14%	7%	-1%	17%
Romania	-21%	-12%	1%	-15%	-16%	19%
Slovakia	-32%	-14%	-13%	-16%	-25%	-16%
Slovenia	-33%	-7%	-2%	-18%	-30%	-8%
Spain	-21%	-5%	4%	-10%	-21%	-3%
Sweden	-3%	-20%	-5%	-28%	-22%	-17%
Switzerland	-12%	14%	20%	6%	-3%	0%
United Kingdom	-14%	-24%	-7%	-20%	-21%	-4%
Total Average	**-28%**	**-22%**	**-11%**	**-26%**	**-29%**	**-16%**

Table 7: Relative Percentage Difference FUA - UN Urban

We can observe that the Relative Percentage Difference between FUA and UN Urban range from -28% to -11%. Since the Relative Percentage Difference is always negative, we can conclude that FUA values are smaller than UN Urban values.

Relative Percentage Differences: FUA - UN Total						
Countries / Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Austria	-10%	2%	6%	4%	3%	-6%
Belgium	-11%	-5%	5%	2%	-3%	-2%
Bulgaria	-50%	-46%	-37%	-48%	-63%	-23%
Croatia	-50%	-26%	-16%	-42%	-41%	-20%
Cyprus	-25%	-19%	-11%	-28%	-31%	-6%
Czechia	-27%	-10%	-2%	-7%	-6%	-6%
Denmark	-6%	-20%	-8%	-28%	-24%	-12%
Estonia	-12%	-13%	4%	-21%	-22%	-12%
Finland	-2%	-19%	-2%	-30%	-17%	-18%
France	-20%	-4%	4%	-9%	-17%	-11%
Germany	-6%	-2%	6%	-1%	-6%	-8%
Greece	-27%	-21%	-12%	-22%	-37%	-20%
Hungary	-28%	-10%	-4%	-18%	-17%	11%
Iceland	-94%	-96%	-76%	-101%	-115%	-91%
Ireland	-41%	-52%	-23%	-59%	-48%	-28%
Italy	-23%	1%	7%	-7%	-13%	12%
Latvia	-57%	-49%	-35%	-51%	-58%	-37%
Lithuania	-	-	-	-12%	-22%	-7%
Luxembourg	-2%	11%	13%	1%	-6%	-12%
Netherlands	-1%	-5%	1%	-1%	-6%	-5%
Norway	-23%	-32%	-17%	-44%	-35%	-31%
Poland	-44%	-27%	-10%	-19%	-22%	-13%
Portugal	5%	21%	18%	9%	2%	21%
Romania	-14%	-5%	7%	-9%	-10%	25%
Slovakia	-29%	-12%	-11%	-14%	-23%	-13%
Slovenia	-30%	-3%	1%	-14%	-26%	-4%
Spain	-16%	-1%	9%	-6%	-17%	1%
Sweden	5%	-13%	3%	-21%	-15%	-10%
Switzerland	-9%	22%	24%	9%	0%	3%
United Kingdom	-12%	-22%	-5%	-18%	-19%	-2%
Total Average	**-23%**	**-16%**	**-5%**	**-20%**	**-24%**	**-11%**

Table 8: Relative Percentage Difference FUA - UN Total

We can observe that the Relative Percentage Difference between FUA and UN Total range from -24% to -11%. Since the Relative Percentage Difference is always negative, we can conclude that FUA values are smaller than UN Total values.

Relative Percentage Differences: UN Urban - UN Total						
Countries / Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Austria	8%	8%	8%	7%	7%	8%
Belgium	3%	3%	3%	3%	3%	3%
Bulgaria	8%	8%	7%	7%	7%	7%
Croatia	1%	1%	1%	1%	1%	1%
Cyprus	6%	5%	7%	6%	6%	6%
Czechia	4%	4%	4%	4%	4%	4%
Denmark	5%	4%	5%	5%	5%	5%
Estonia	4%	4%	4%	4%	4%	4%
Finland	15%	15%	15%	14%	14%	13%
France	9%	1%	9%	9%	8%	8%
Germany	4%	4%	4%	4%	4%	4%
Greece	6%	6%	6%	6%	6%	6%
Hungary	4%	4%	4%	4%	4%	4%
Iceland	7%	7%	7%	7%	7%	7%
Ireland	6%	6%	6%	6%	6%	6%
Italy	4%	4%	4%	3%	3%	4%
Latvia	17%	34%	17%	16%	17%	16%
Lithuania	12%	12%	12%	12%	12%	12%
Luxembourg	2%	2%	2%	2%	2%	2%
Netherlands	1%	1%	1%	1%	1%	1%
Norway	14%	14%	14%	14%	14%	13%
Poland	6%	6%	6%	6%	6%	6%
Portugal	4%	4%	4%	2%	4%	4%
Romania	7%	7%	7%	7%	6%	6%
Slovakia	2%	2%	2%	2%	2%	2%
Slovenia	4%	4%	4%	4%	4%	4%
Spain	5%	5%	5%	4%	4%	5%
Sweden	8%	8%	8%	8%	7%	7%
Switzerland	3%	8%	3%	3%	3%	3%
United Kingdom	2%	2%	2%	2%	2%	2%
Total Average	**6%**	**6%**	**6%**	**6%**	**6%**	**6%**

Table 9: Relative Percentage Difference UN Urban - UN Total

We can observe that the Relative Percentage Difference between UN Urban and UN Total is always 6%. So, UN Urban is always greater than UN total.

Relative Percentage Differences: UC - UN Urban						
Countries / Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Austria	-8%	0%	3%	-21%	-29%	10%
Belgium	-8%	-3%	6%	3%	-2%	0%
Bulgaria	-42%	-36%	-28%	-42%	-54%	-9%
Croatia	-45%	-22%	-12%	-39%	-33%	-7%
Cyprus	-28%	-21%	-15%	-	-	-
Czechia	-27%	-11%	-2%	-6%	-4%	-3%
Denmark	-4%	-16%	-6%	-23%	-22%	-8%
Estonia	2%	-2%	15%	-5%	-11%	5%
Finland	7%	-8%	7%	-19%	-8%	-9%
France	-29%	-3%	-3%	-7%	-14%	-6%
Germany	-5%	-2%	6%	1%	-4%	-4%
Greece	-15%	-12%	-3%	-15%	-30%	-11%
Hungary	-25%	-9%	-2%	-17%	-11%	18%
Iceland	-41%	-68%	-23%	-56%	-51%	-22%
Ireland	-38%	-51%	-22%	-55%	-44%	-17%
Italy	-22%	1%	6%	-8%	-14%	12%
Latvia	-58%	-61%	-32%	-48%	-53%	-23%
Lithuania	-	-	-	-16%	-24%	-8%
Luxembourg	8%	22%	25%	10%	6%	-2%
Netherlands	-3%	-7%	0%	-1%	-6%	-5%
Norway	-1%	-7%	11%	-8%	-12%	-5%
Poland	-43%	-23%	-8%	-16%	-18%	-8%
Portugal	12%	28%	21%	18%	9%	30%
Romania	-16%	-7%	6%	-12%	-13%	23%
Slovakia	-28%	-8%	-10%	-10%	-20%	-11%
Slovenia	-22%	14%	18%	-5%	-18%	9%
Spain	-11%	3%	12%	-1%	-11%	9%
Sweden	9%	-8%	7%	-14%	-11%	-1%
Switzerland	-10%	16%	23%	10%	0%	5%
United Kingdom	-9%	-20%	-3%	-15%	-16%	2%
Total Average	**-17%**	**-11%**	**0%**	**-14%**	**-18%**	**-1%**

Table 10: Relative Percentage Difference UC - UN Urban

We can observe that the Relative Percentage Difference between UC and UN Urban ranges from -18% to 0%. Since the Relative Percentage Difference is always negative, we can conclude that UC values are smaller than UN Urban values.

Relative Percentage Differences: UC - UN Total						
Countries / Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Austria	0%	8%	11%	-13%	-22%	18%
Belgium	-6%	0%	9%	6%	1%	2%
Bulgaria	-34%	-29%	-21%	-35%	-47%	-2%
Croatia	-44%	-21%	-10%	-38%	-31%	-6%
Cyprus	-22%	-16%	-8%	-	-	-
Czechia	-23%	-7%	2%	-2%	0%	1%
Denmark	0%	-12%	-2%	-19%	-18%	-4%
Estonia	6%	1%	19%	-1%	-7%	9%
Finland	22%	6%	22%	-5%	6%	3%
France	-21%	-2%	6%	2%	-5%	2%
Germany	-1%	3%	10%	5%	0%	0%
Greece	-9%	-6%	3%	-9%	-24%	-5%
Hungary	-20%	-5%	2%	-13%	-7%	22%
Iceland	-34%	-61%	-16%	-49%	-44%	-15%
Ireland	-33%	-46%	-16%	-49%	-39%	-12%
Italy	-18%	4%	10%	-5%	-11%	15%
Latvia	-42%	-29%	-15%	-32%	-37%	-7%
Lithuania	-	-	-	-4%	-12%	3%
Luxembourg	10%	24%	28%	12%	8%	1%
Netherlands	-2%	-5%	1%	0%	-5%	-3%
Norway	14%	8%	25%	7%	2%	8%
Poland	-37%	-17%	-2%	-10%	-12%	-3%
Portugal	16%	32%	25%	19%	13%	34%
Romania	-9%	-1%	12%	-5%	-8%	29%
Slovakia	-26%	-6%	-7%	-8%	-18%	-8%
Slovenia	-19%	18%	21%	-1%	-14%	13%
Spain	-6%	7%	17%	3%	-7%	14%
Sweden	17%	0%	15%	-7%	-4%	6%
Switzerland	-7%	24%	26%	13%	4%	8%
United Kingdom	-7%	-18%	0%	-13%	-14%	4%
Total Average	**-12%**	**-5%**	**6%**	**-9%**	**-12%**	**4%**

Table 11: Relative Percentage Difference UC - UN Total

We can observe that the Relative Percentage Difference between UC and UN Total ranges from -12% to -4%. Since the Relative Percentage Difference is always negative, we can conclude that UC values are smaller than UN Total values.

Average differences

The average difference is defined as the difference between the average value of one data set minus the average value of another data set and is given by the formula:

Average (data set 1) – Average (data set 2)

By calculating the Average difference, we can observe which data set has values that are bigger than the values of the other data set.

The result can be seen on Table 12 below.

Average Differences								
	2014	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	
Eurostat-FUA	4,26	2,49	1,35	3,03	3,07	1,33		always positive : Eurostat> FUA
Eurostat-UC	3,27	1,40	0,25	2,16	2,20	0,04		always positive : Eurostat> UC
FUA- UC	-0,99	-1,10	-1,10	-0,88	-0,87	-1,30	-1,49	always negative : UC> FUA
Eurostat-UN Urban	0,70	0,07	0,20	0,42	-0,10	-0,16		most times: Eurostat>UN Urban
Eurostat-UN Total	1,48	0,90	0,90	1,10	0,60	0,47		always positive: Eurostat> UN Total
FUA-UN Urban	-3,56	-2,43	-1,15	-2,61	-3,17	-1,49		always negative: UN Urban> FUA
FUA-UN Total	-2,78	-1,59	-0,45	-1,93	-2,47	-0,86		always negative: UN Total>FUA
UN Urban-UN Total	0,78	0,84	0,70	0,68	0,70	0,63		always positive: UN Urban> UN Total
UC - UN Urban	-2,57	-1,33	-0,06	-1,74	-2,30	-0,20		always negative: UN Urban> UC
UC - UN Total	-1,79	-0,49	0,64	-1,06	-1,60	0,44		always negative: UN Total> UC

Table 12: Average Differences

We observe that the values derived by SMURBS approach are lower than the other values. Also, the relation FUA < UC is expected since UC includes the most densely lived and more polluted areas and FUA incudes the commuting zone which is a larger area and less inhabited, so the average concentration is lower.

By combing the results from Relative Percentage Difference and Average Difference, we can see that they follow a pattern of **FUA< UC< UN Total< UN Urban <Eurostat**.

Absolute differences

The Absolute Difference comparison determines how close two number values are to each other, in order to allow two numbers that are close to each other to be considered as matches, or possible matches [50]. The absolute difference between two data sets is given by the formula: ABS (data set 1- data set 2).

An empirical classification was made so if the Absolute difference is greater than 2,5 (that corresponds to approximately 20% difference), then the values are not close, if the Absolute difference is between 1,5 and 2,5 (that corresponds to approximately 10% to 20% difference) then the values are slightly close and if the Absolute difference is 1,5 and below then the values are close.

The results can be seen below on Tables 13 to 22.

Absolute Differences: Eurostat- FUA						
Countries / Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Austria	3,2	0,61	0	1,31	2,41	1,16
Belgium	2,66	0,83	0,3	0,17	0,96	0,06
Bulgaria	13,46	12,17	6,66	11,38	9,47	5,82
Croatia	8,54	7,57	5,44	7,15	7,81	3,53
Cyprus	5,63	4,58	2,48	3,69	1,96	0,22
Czechia	5,16	1,58	1,78	2,64	2,98	0,88
Denmark	2,57	2,52	0,93	1,67	4,15	1,41
Estonia	1,62	0,79	1,06	0,51	0,93	0,86
Finland	2,76	1,19	0,4	0,94	1,68	0,55
France	2,91	1,77	1,03	1,66	2,21	1,07
Germany	3,34	1,05	0,55	1,16	2,04	0,95
Greece		3,14	1,19	1,27	2,65	2,11
Hungary	6,81			7,09	3,09	1,46
Iceland		5,14	2,44	4,32	4,61	3,72
Ireland	3,71	2,61	2,49	3,59	3,72	2,63
Italy	4,29	4,54	2,36	4,49	2,01	0,86
Latvia	9,76	7,76	6,86	6,78	9,00	3,81
Lithuania				0,18	0,42	1,47
Luxembourg	1,39	0,05	3,32	3,23	1,98	2,35
Netherlands	1,55	0,77	0,57	0,23	0,94	0,20
Norway	3,27	2,67	2,56	2,91	1,66	1,89
Poland	11,17	6,61	4,02	5,87	6,19	2,78
Portugal	1,69	0,42	0,02	2,14	2,71	0,03
Romania	0,01	2,44	1,2	6,37	5,92	0,76
Slovakia	3,47	2,09	1,48	1,36	1,76	0,09
Slovenia	4,22	4,61	4,63	4,87	4,68	1,82
Spain	2,56	1,99	0,33	2,48	3,20	2,32
Sweden	0,76	0,48	0,44	0,58	0,96	0,39
Switzerland	1,65	3,35	2,67	0,28	0,83	
United Kingdom	3,1	1,13	0,68	1,49	1,80	0,86
Total Average	**4,12**	**3,02**	**2,07**	**3,06**	**3,16**	**1,59**

Table 13: Absolute Differences: Eurostat- FUA

We can observe that the Absolute Differences between Eurostat and FUA range from 1,59 to 4,12 so, the values are not close to each other.

Absolute Differences: Eurostat- UC						
Countries / Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Austria	1,95	0,28	0,64	3,32	5,30	1,73
Belgium	1,98	0,25	0,19	0,25	0,55	0,41
Bulgaria	11,14	9,74	4,24	9,57	7,42	2,70
Croatia	7,8	6,79	4,62	6,56	6,47	1,59
Cyprus	5,26	4,18	2,14			
Czechia	4,65	1,02	1,2	1,83	2,08	0,08
Denmark	1,98	1,77	0,37	0,92	3,63	0,68
Estonia	0,3	0,15	2,09	0,55	0,03	2,18
Finland	1,21	0,21	1	0,19	0,49	0,55
France	2,93	1,53	0,8	0,51	1,06	0,23
Germany	2,73	0,43	0	0,36	1,39	0,16
Greece		0,95	0,94	0,40	1,13	0,13
Hungary	5,8			6,35	1,69	3,41
Iceland		3,98	0,15	2,72	2,45	0,93
Ireland	3,21	2,27	2,05	3,08	3,19	1,50
Italy	3,69	4	1,9	4,21	1,71	1,51
Latvia	8,21	5,87	4,97	5,34	7,26	0,84
Lithuania				0,92	1,37	0,37
Luxembourg	0,16	1,61	1,53	2,10	0,56	1,23
Netherlands	1,6	0,78	0,57	0,32	0,86	0,00
Norway	0,92	0,24	0,28	0,20	0,37	0,35
Poland	9,97	4,83	2,33	4,28	4,43	0,96
Portugal	0,72	1,67	0,71	1,05	1,77	1,23
Romania	0,63	1,78	0,4	5,86	5,53	1,39
Slovakia	2,93	1,06	2,04	0,37	0,99	0,84
Slovenia	2,66	0,65	0,89	2,79	2,87	0,69
Spain	1,63	1,03	0,6	1,63	2,28	1,10
Sweden	0,05	0,29	1,2	0,16	0,32	0,52
Switzerland	1,46	3,66	2,99	0,12	1,18	
United Kingdom	2,61	0,74	0,25	1,06	1,34	0,29
Total Average	**3,27**	**2,21**	**1,47**	**2,31**	**2,40**	**0,98**

Table 14: Absolute Differences: Eurostat- UC

We can observe that the Absolute Differences between Eurostat and UC range from 0,98 to 3,27 so the values are slightly close to each other.

Absolute Differences: FUA- UC							
Countries / Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Austria	1,25	0,89	0,64	2,01	2,89	2,89	4,83
Belgium	0,68	0,58	0,49	0,42	0,41	0,47	0,61
Bulgaria	2,32	2,43	2,42	1,82	2,05	3,12	4,36
Croatia	0,74	0,78	0,82	0,59	1,34	1,94	2,55
Cyprus	0,37	0,40	0,34				
Czechia	0,51	0,56	0,58	0,81	0,90	0,96	1,12
Denmark	0,59	0,75	0,56	0,75	0,52	0,73	0,53
Estonia	1,32	0,94	1,03	1,05	0,90	1,32	1,25
Finland	1,55	1,40	1,40	1,13	1,19	1,10	0,86
France	0,02	0,24	0,23	1,16	1,14	1,30	1,04
Germany	0,61	0,62	0,55	0,81	0,65	0,79	0,64
Greece	2,29	2,19	2,13	1,67	1,52	1,98	2,34
Hungary	1,01	0,87	0,95	0,74	1,40	1,95	2,07
Iceland	2,08	1,16	2,29	1,59	2,16	2,79	2,22
Ireland	0,50	0,34	0,44	0,51	0,53	1,13	0,79
Italy	0,60	0,54	0,46	0,29	0,31	0,65	1,03
Latvia	1,55	1,89	1,89	1,44	1,74	2,97	2,38
Lithuania				0,74	0,95	1,10	1,12
Luxembourg	1,23	1,66	1,79	1,13	1,41	1,13	0,98
Netherlands	0,05	0,01	0,00	0,08	0,08	0,20	0,27
Norway	2,35	2,43	2,84	2,71	2,03	2,24	1,98
Poland	1,20	1,78	1,69	1,58	1,77	1,82	2,65
Portugal	0,97	1,25	0,73	1,10	0,94	1,25	1,52
Romania	0,62	0,66	0,80	0,51	0,39	0,63	1,28
Slovakia	0,54	1,03	0,56	0,99	0,77	0,75	1,09
Slovenia	1,56	3,96	3,74	2,08	1,82	2,51	3,43
Spain	0,93	0,96	0,93	0,85	0,92	1,22	1,12
Sweden	0,81	0,77	0,76	0,74	0,63	0,91	0,75
Switzerland	0,19	0,31	0,32	0,40	0,35	0,51	0,37
United Kingdom	0,49	0,39	0,43	0,43	0,46	0,57	0,54
Total Average	**1,00**	**1,10**	**1,10**	**1,04**	**1,11**	**1,41**	**1,58**

Table 15: Absolute Differences: FUA- UC

We can observe that the Absolute Differences between FUA and UC range from 1 to 1,58 so the values are close to each other.

Absolute Differences: Eurostat - UN Urban						
Countries / Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Austria	0,84	0,33	0,17	0,82	1,84	0,42
Belgium	0,9	0,15	0,58	0,13	0,31	0,47
Bulgaria	3,24	2,98	0,93	1,99	1,84	1,04
Croatia	0,66	3	2,64	0,53	1,08	0,51
Cyprus	1,33	1,07	0,1	0,87	3,21	2,06
Czechia	0,07	0,8	0,81	0,74	1,34	0,5
Denmark	1,52	0,08	0,24	1,23	1,51	0,12
Estonia	0,43	0,32	1,05	0,84	0,68	1,81
Finland	1,67	0,75	0,55	1,27	0,02	1,11
France	0,38	1,19	0,43	0,3	0,5	0,94
Germany	2,09	0,22	0,75	0,54	0,95	0,25
Greece	-	1,1	1,43	2,65	3,26	1,48
Hungary	1,77	-	-	3,61	0,25	0,43
Iceland	-	0,49	1,11	0,03	0,11	0,3
Ireland	0,22	1,7	0,35	0,61	0,01	0,12
Italy	0,3	4,1	2,91	2,92	0,52	0,37
Latvia	0,03	2,99	0,99	0,11	0,95	2,03
Lithuania	2,63	1,98	2,29	2,56	4	0,57
Luxembourg	1	1,02	4,44	3,15	1,17	1,09
Netherlands	1,25	0,05	0,56	0,48	0,17	0,48
Norway	0,86	0,26	0,59	0,33	1,17	0,69
Poland	1,2	0,13	0,65	0,85	0,48	0,6
Portugal	1,78	1,28	1,37	2,81	2,59	1,47
Romania	3,2	0,61	1,31	4,04	3,46	2,29
Slovakia	2,01	0,52	3,73	1,43	2,63	2,47
Slovenia	1,1	3,38	4,23	1,95	0,15	0,7
Spain	0,47	1,37	0,79	1,47	1,18	2,03
Sweden	0,59	0,79	0,75	1	0,36	0,6
Switzerland	0,44	1,6	0,32	0,9	1,13	-
United Kingdom	1,6	1,33	0,02	0,41	0,18	0,49
Total Average	**1,20**	**1,23**	**1,24**	**1,35**	**1,24**	**0,95**

Table 16: Absolute Differences: Eurostat - UN Urban

We can observe that the Absolute Differences between Eurostat and UN Urban range from 0,95 to 1,35, so the values are close to each other.

Absolute Differences: Eurostat - UN Total						
Countries / Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Austria	1,92	0,87	0,82	1,78	2,82	0,49
Belgium	1,27	0,22	0,93	0,47	0,64	0,16
Bulgaria	4,93	4,59	0,57	3,50	0,30	2,31
Croatia	0,90	3,25	2,87	0,78	1,32	0,71
Cyprus	2,32	1,89	1,03	0,10	2,18	1,12
Czechia	0,82	0,12	1,48	1,41	2,00	0,06
Denmark	2,01	0,57	0,22	0,77	1,98	0,34
Estonia	0,75	0,05	0,80	0,60	0,40	1,55
Finland	2,63	0,17	0,31	0,47	0,83	0,37
France	0,72	1,29	1,46	0,71	0,47	0,06
Germany	2,63	0,76	1,24	1,02	1,40	0,17
Greece	-	0,05	0,47	1,70	2,29	0,52
Hungary	2,52	-	-	4,28	0,45	0,16
Iceland	-	0,97	0,69	0,45	0,31	0,11
Ireland	0,76	1,16	0,82	0,13	0,49	0,60
Italy	0,91	4,72	3,48	3,47	0,03	0,88
Latvia	2,91	2,50	3,25	2,14	3,26	0,08
Lithuania	1,02	0,54	1,00	1,31	2,62	0,73
Luxembourg	1,23	1,25	4,65	3,36	1,39	1,31
Netherlands	1,41	0,11	0,40	0,33	0,31	0,34
Norway	1,88	0,78	1,57	0,64	0,23	0,20
Poland	2,65	1,21	1,96	2,14	1,79	0,47
Portugal	2,10	1,62	1,68	2,96	2,90	1,76
Romania	2,06	1,69	2,35	5,08	4,40	3,10
Slovakia	1,52	0,05	3,28	0,99	2,18	2,09
Slovenia	0,41	4,05	4,86	2,62	0,53	1,22
Spain	0,99	1,89	1,26	1,89	1,62	2,46
Sweden	1,10	0,27	0,28	0,53	0,11	0,16
Switzerland	0,79	0,72	0,01	1,21	0,81	-
United Kingdom	1,85	1,08	0,21	0,19	0,03	0,68
Total Average	**1,68**	**1,33**	**1,52**	**1,57**	**1,34**	**0,83**

Table 17: Absolute Differences: Eurostat - UN Total

We can observe that the Absolute Differences between Eurostat and UN Total range from 0,83 to 1,68, so the values are close to each other.

Absolute Differences: FUA - UN Urban						
Countries / Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Austria	2,36	0,94	0,17	0,49	0,57	1,58
Belgium	1,76	0,98	0,28	0,04	0,65	0,53
Bulgaria	10,22	9,19	7,59	9,39	11,31	4,78
Croatia	7,88	4,57	2,80	6,62	6,73	3,02
Cyprus	4,30	3,51	2,38	4,56	5,17	1,84
Czechia	5,09	2,38	0,97	1,90	1,64	1,38
Denmark	1,05	2,44	1,17	2,90	2,64	1,53
Estonia	1,19	1,11	0,01	1,35	1,61	0,95
Finland	1,09	1,94	0,95	2,21	1,66	1,66
France	3,29	0,58	0,60	1,96	2,71	2,01
Germany	1,25	0,83	0,20	0,62	1,09	1,20
Greece	4,67	4,24	2,62	3,92	5,91	3,59
Hungary	5,04	2,40	1,26	3,48	3,34	1,03
Iceland	4,30	4,65	3,55	4,29	4,72	4,02
Ireland	3,49	4,31	2,14	4,20	3,71	2,51
Italy	3,99	0,44	0,55	1,57	2,53	1,23
Latvia	9,73	10,75	5,87	6,67	8,05	5,84
Lithuania	-	-	-	2,38	3,58	2,04
Luxembourg	0,39	0,97	1,12	0,08	0,81	1,26
Netherlands	0,30	0,82	0,01	0,25	0,77	0,68
Norway	2,41	2,93	1,97	3,24	2,83	2,58
Poland	9,97	6,74	3,37	5,02	5,71	3,38
Portugal	0,09	1,70	1,35	0,67	0,12	1,44
Romania	3,19	1,83	0,11	2,33	2,46	3,05
Slovakia	5,48	2,61	2,25	2,79	4,39	2,38
Slovenia	5,32	1,23	0,40	2,92	4,83	1,12
Spain	2,09	0,62	0,46	1,01	2,02	0,29
Sweden	0,17	1,27	0,31	1,58	1,32	0,99
Switzerland	1,21	1,75	2,35	0,62	0,30	0,03
United Kingdom	1,50	2,46	0,70	1,90	1,98	0,37
Total Average	**3,55**	**2,77**	**1,64**	**2,70**	**3,17**	**1,94**

Table 18: Absolute Differences: FUA - UN Urban

We can observe that the Absolute Differences between FUA and UN Urban range from 1,64 to 3,55, so the values are not close to each other.

Absolute Differences: FUA - UN Total						
Countries / Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Austria	1,28	0,26	0,82	0,471422	0,410378	0,671219
Belgium	1,39	0,61	0,63	0,297222	0,31958	0,221673
Bulgaria	8,53	7,58	6,09	7,884241	9,767766	3,512645
Croatia	7,64	4,32	2,57	6,373782	6,489335	2,823119
Cyprus	3,31	2,69	1,45	3,5851	4,136394	0,90404
Czechia	4,34	1,7	0,3	1,227516	0,983842	0,823627
Denmark	0,56	1,95	0,71	2,439347	2,170812	1,06562
Estonia	0,87	0,84	0,26	1,105415	1,330118	0,691076
Finland	0,13	1,02	0,09	1,414026	0,853053	0,916996
France	2,19	0,48	0,43	0,952368	1,737256	1,128714
Germany	0,71	0,29	0,69	0,143033	0,644483	0,776415
Greece	3,66	3,19	1,66	2,970741	4,941491	2,633953
Hungary	4,29	1,69	0,59	2,811086	2,640995	1,619497
Iceland	3,85	4,17	3,13	3,869165	4,295567	3,61011
Ireland	2,95	3,77	1,67	3,721543	3,229423	2,029931
Italy	3,38	0,18	1,12	1,022239	1,984762	1,736489
Latvia	6,85	5,26	3,61	4,641044	5,738055	3,728217
Lithuania	-	-	-	1,129936	2,201542	0,739263
Luxembourg	0,16	1,2	1,33	0,125147	0,588446	1,044811
Netherlands	0,14	0,66	0,17	0,09607	0,628	0,537539
Norway	1,39	1,89	0,99	2,274894	1,885259	1,692557
Poland	8,52	5,4	2,06	3,725267	4,403816	2,309738
Portugal	0,41	2,04	1,66	0,819135	0,188699	1,733588
Romania	2,05	0,75	1,15	1,292628	1,523546	3,856762
Slovakia	4,99	2,14	1,8	2,349485	3,937069	2,004376
Slovenia	4,63	0,56	0,23	2,252544	4,153535	0,596289
Spain	1,57	0,1	0,93	0,588626	1,579528	0,136532
Sweden	0,34	0,75	0,16	1,11413	0,84541	0,54838
Switzerland	0,86	2,63	2,68	0,92889	0,019158	0,253244
United Kingdom	1,25	2,21	0,47	1,683261	1,771208	0,178167
Total Average	**2,84**	**2,08**	**1,36**	**2,11**	**2,51**	**1,48**

Table 19: Absolute Differences: FUA - UN Total

We can observe that the Absolute Differences between FUA and UN Total range from 1,36 to 2,48 so the values are slightly close to each other.

Absolute Differences: UN Urban - UN Total						
Countries / Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Austria	1,08	1,2	0,99	0,96	0,98	0,91
Belgium	0,37	0,37	0,35	0,34	0,33	0,31
Bulgaria	1,69	1,61	1,5	1,51	1,54	1,27
Croatia	0,24	0,25	0,23	0,25	0,24	0,2
Cyprus	0,99	0,82	0,93	0,97	1,03	0,94
Czechia	0,75	0,68	0,67	0,67	0,66	0,56
Denmark	0,49	0,49	0,46	0,46	0,47	0,46
Estonia	0,32	0,27	0,25	0,24	0,28	0,26
Finland	0,96	0,92	0,86	0,8	0,81	0,74
France	1,1	0,1	1,03	1,01	0,97	0,88
Germany	0,54	0,54	0,49	0,48	0,45	0,42
Greece	1,01	1,05	0,96	0,95	0,97	0,96
Hungary	0,75	0,71	0,67	0,67	0,7	0,59
Iceland	0,45	0,48	0,42	0,42	0,42	0,41
Ireland	0,54	0,54	0,47	0,48	0,48	0,48
Italy	0,61	0,62	0,57	0,55	0,55	0,51
Latvia	2,88	5,49	2,26	2,03	2,31	2,11
Lithuania	1,61	1,44	1,29	1,25	1,38	1,3
Luxembourg	0,23	0,23	0,21	0,21	0,22	0,22
Netherlands	0,16	0,16	0,16	0,15	0,14	0,14
Norway	1,02	1,04	0,98	0,97	0,94	0,89
Poland	1,45	1,34	1,31	1,29	1,31	1,07
Portugal	0,32	0,34	0,31	0,15	0,31	0,29
Romania	1,14	1,08	1,04	1,04	0,94	0,81
Slovakia	0,49	0,47	0,45	0,44	0,45	0,38
Slovenia	0,69	0,67	0,63	0,67	0,68	0,52
Spain	0,52	0,52	0,47	0,42	0,44	0,43
Sweden	0,51	0,52	0,47	0,47	0,47	0,44
Switzerland	0,35	0,88	0,33	0,31	0,32	0,28
United Kingdom	0,25	0,25	0,23	0,22	0,21	0,19
Total Average	**0,78**	**0,84**	**0,70**	**0,68**	**0,70**	**0,63**

Table 20: Absolute Differences: UN Urban - UN Total

We can observe that the Absolute Differences between UN Urban and UN Total range from 0,63 to 0,84, so the values are close to each other.

Absolute Differences: UC - UN Urban						
Countries / Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Austria	1,11	0,05	0,47	2,502038	3,464449	1,306954
Belgium	1,08	0,4	0,77	0,378819	0,23896	0,057036
Bulgaria	7,9	6,76	5,17	7,575702	9,260899	1,661621
Croatia	7,14	3,79	1,98	6,029768	5,391503	1,083171
Cyprus	3,93	3,11	2,04	-	-	-
Czechia	4,58	1,82	0,39	1,089338	0,73917	0,422254
Denmark	0,46	1,69	0,61	2,151688	2,119005	0,798378
Estonia	0,13	0,17	1,04	0,292944	0,705212	0,365766
Finland	0,46	0,54	0,45	1,07974	0,468934	0,55684
France	3,31	0,34	0,37	0,806754	1,562321	0,713287
Germany	0,64	0,21	0,75	0,182482	0,443067	0,409377
Greece	2,38	2,05	0,49	2,253447	4,392473	1,610837
Hungary	4,03	1,53	0,31	2,738163	1,937845	2,975724
Iceland	2,22	3,49	1,26	2,694236	2,555796	1,226584
Ireland	2,99	3,97	1,7	3,692322	3,1761	1,378616
Italy	3,39	0,1	1,01	1,287153	2,225073	1,876196
Latvia	8,18	8,86	3,98	5,232337	6,311359	2,866729
Lithuania	-	-	-	1,643419	2,633689	0,938702
Luxembourg	0,84	2,63	2,91	1,048783	0,605188	0,138432
Netherlands	0,35	0,83	0,01	0,161299	0,691499	0,481439
Norway	0,06	0,5	0,87	0,530434	0,796098	0,339475
Poland	8,77	4,96	1,68	3,432265	3,945432	1,559043
Portugal	1,06	2,95	2,08	1,764804	0,816345	2,695382
Romania	2,57	1,17	0,91	1,820848	2,069037	3,677532
Slovakia	4,94	1,58	1,69	1,80001	3,621626	1,634885
Slovenia	3,76	2,73	3,34	0,841141	3,016095	1,388852
Spain	1,16	0,34	1,39	0,156501	1,09853	0,927782
Sweden	0,64	0,5	0,45	0,844502	0,68069	0,077196
Switzerland	1,02	2,06	2,67	1,023063	0,050059	0,484086
United Kingdom	1,01	2,07	0,27	1,471239	1,523692	0,203746
Total Average	**2,76**	**2,11**	**1,42**	**1,95**	**2,29**	**1,17**

Table 21: Absolute Differences: UC - UN Urban

We can observe that the Absolute Differences between UC and UN Urban range from 1,17 to 2,76 so the values are slightly close to each other.

Absolute Differences: UC - UN Total						
Countries / Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Austria	0,03	1,15	1,46	1,542038	2,484449	2,216954
Belgium	0,71	0,03	1,12	0,718819	0,09104	0,252964
Bulgaria	6,21	5,15	3,67	6,065702	7,720899	0,391621
Croatia	6,9	3,54	1,75	5,779768	5,151503	0,883171
Cyprus	2,94	2,29	1,11	-	-	-
Czechia	3,83	1,14	0,28	0,419338	0,07917	0,137746
Denmark	0,03	1,2	0,15	1,691688	1,649005	0,338378
Estonia	0,45	0,1	1,29	0,052944	0,425212	0,625766
Finland	1,42	0,38	1,31	0,27974	0,341066	0,18316
France	2,21	0,24	0,66	0,203246	0,592321	0,166713
Germany	0,1	0,33	1,24	0,662482	0,006933	0,010623
Greece	1,37	1	0,47	1,303447	3,422473	0,650837
Hungary	3,28	0,82	0,36	2,068163	1,237845	3,565724
Iceland	1,77	3,01	0,84	2,274236	2,135796	0,816584
Ireland	2,45	3,43	1,23	3,212322	2,6961	0,898616
Italy	2,78	0,72	1,58	0,737153	1,675073	2,386196
Latvia	5,3	3,37	1,72	3,202337	4,001359	0,756729
Lithuania	-	-	-	0,393419	1,253689	0,361298
Luxembourg	1,07	2,86	3,12	1,258783	0,825188	0,081568
Netherlands	0,19	0,67	0,17	0,011299	0,551499	0,341439
Norway	0,96	0,54	1,85	0,439566	0,143902	0,550525
Poland	7,32	3,62	0,37	2,142265	2,635432	0,489043
Portugal	1,38	3,29	2,39	1,914804	1,126345	2,985382
Romania	1,43	0,09	1,95	0,780848	1,129037	4,487532
Slovakia	4,45	1,11	1,24	1,36001	3,171626	1,254885
Slovenia	3,07	3,4	3,97	0,171141	2,336095	1,908852
Spain	0,64	0,86	1,86	0,263499	0,65853	1,357782
Sweden	1,15	0,02	0,92	0,374502	0,21069	0,362804
Switzerland	0,67	2,94	3	1,333063	0,370059	0,764086
United Kingdom	0,76	1,82	0,04	1,251239	1,313692	0,393746
Total Average	**2,24**	**1,69**	**1,42**	**1,45**	**1,70**	**1,02**

Table 22: Absolute Differences: UC - UN Total

We can observe that the Absolute Differences between UC and UN Total range from 1,02 to 2,24 so the values are slightly close to each other.

We can also conclude that there is a general agreement between the values

Percent change

Recent change is used in order to compare one value relative to another value. In order to perform this, one value is used as a reference value and it indicates the variation between two data sets. The relative percentage difference can be found from the formula:

((Value – reference value)/reference value) *100%

An empirical classification was made so if the Percent Change is greater than 20% then the values are not close, if the Percent Change is between 10% to 20% then the values are slightly close and if the Percent Change is 10% and below then the values are considered close.

The results can be seen below on Tables 23 to 33.

Percent Change : Eurostat-FUA						
Countries / Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Austria	21%	4%	0%	9%	16%	10%
Belgium	18%	6%	2%	1%	7%	1%
Bulgaria	52%	49%	33%	48%	47%	30%
Croatia	43%	35%	26%	38%	38%	22%
Cyprus	33%	27%	17%	25%	15%	2%
Czechia	27%	9%	10%	14%	15%	6%
Denmark	21%	22%	9%	18%	35%	14%
Estonia	19%	12%	20%	10%	15%	18%
Finland	33%	20%	7%	19%	26%	11%
France	23%	13%	8%	14%	19%	10%
Germany	22%	8%	4%	9%	16%	9%
Greece		19%	8%	9%	20%	15%
Hungary	34%			34%	17%	10%
Iceland		69%	49%	70%	74%	63%
Ireland	39%	33%	28%	45%	42%	30%
Italy	24%	21%	12%	23%	13%	6%
Latvia	53%	49%	45%	50%	56%	31%
Lithuania				2%	5%	13%
Luxembourg	12%	0%	23%	25%	18%	23%
Netherlands	11%	6%	5%	2%	8%	2%
Norway	38%	35%	32%	42%	27%	29%
Poland	43%	28%	17%	24%	25%	14%
Portugal	17%	4%	0%	18%	25%	0%
Romania	0%	14%	7%	31%	30%	5%
Slovakia	19%	11%	10%	8%	10%	1%
Slovenia	24%	21%	21%	25%	26%	12%
Spain	23%	15%	3%	20%	27%	20%
Sweden	10%	8%	8%	11%	15%	7%
Switzerland	15%	33%	27%	3%	9%	
United Kingdom	24%	11%	7%	15%	18%	8%
Total Average	**26%**	**21%**	**16%**	**22%**	**24%**	**15%**

Table 23: Percent Change: Eurostat-FUA

The Percent Change between Eurostat-FUA Range from 15% to 26%, so the values are not close.

Percent Change: Eurostat-UC						
Countries / Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Austria	13%	2%	5%	24%	34%	14%
Belgium	14%	2%	1%	2%	4%	4%
Bulgaria	43%	39%	21%	40%	37%	14%
Croatia	39%	31%	22%	35%	32%	10%
Cyprus	31%	24%	15%			
Czechia	24%	6%	7%	10%	11%	1%
Denmark	16%	16%	4%	10%	30%	7%
Estonia	3%	2%	39%	10%	0%	45%
Finland	14%	4%	18%	4%	8%	11%
France	23%	11%	6%	4%	9%	2%
Germany	18%	3%	0%	3%	11%	1%
Greece		6%	6%	3%	8%	1%
Hungary	29%			30%	10%	24%
Iceland		54%	3%	44%	39%	16%
Ireland	34%	28%	23%	39%	36%	17%
Italy	21%	18%	10%	22%	11%	10%
Latvia	45%	37%	32%	39%	45%	7%
Lithuania				11%	16%	3%
Luxembourg	1%	14%	11%	16%	5%	12%
Netherlands	12%	6%	5%	3%	7%	0%
Norway	11%	3%	4%	3%	6%	5%
Poland	38%	20%	10%	18%	18%	5%
Portugal	7%	16%	7%	9%	16%	13%
Romania	5%	10%	2%	29%	28%	8%
Slovakia	16%	6%	14%	2%	6%	6%
Slovenia	15%	3%	4%	14%	16%	5%
Spain	14%	8%	5%	13%	19%	9%
Sweden	1%	5%	21%	3%	5%	9%
Switzerland	13%	36%	30%	1%	13%	
United Kingdom	20%	7%	2%	11%	13%	3%
Total Average	**19%**	**15%**	**12%**	**16%**	**17%**	**9%**

Table 24: Percent Change: Eurostat-UC

The Percent Change between Eurostat and UC ranges from 9% to 19%, so, the values are slightly close.

Percent Change: FUA-UC							
Countries / Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Austria	11%	6%	5%	16%	22%	27%	51%
Belgium	6%	5%	4%	3%	3%	4%	7%
Bulgaria	18%	19%	18%	15%	19%	23%	37%
Croatia	6%	5%	5%	5%	11%	16%	21%
Cyprus	3%	3%	3%				
Czechia	4%	4%	4%	5%	5%	7%	10%
Denmark	6%	9%	6%	10%	7%	8%	8%
Estonia	19%	16%	16%	22%	17%	23%	25%
Finland	27%	29%	26%	29%	25%	24%	21%
France	0%	2%	2%	11%	12%	14%	13%
Germany	5%	5%	4%	7%	6%	8%	8%
Greece	19%	17%	16%	14%	14%	17%	23%
Hungary	8%	6%	6%	5%	10%	12%	16%
Iceland	95%	51%	89%	85%	135%	128%	113%
Ireland	9%	6%	7%	12%	10%	18%	15%
Italy	5%	3%	3%	2%	2%	4%	7%
Latvia	18%	23%	22%	21%	24%	36%	34%
Lithuania				8%	11%	11%	13%
Luxembourg	12%	14%	16%	11%	15%	14%	14%
Netherlands	0%	0%	0%	1%	1%	2%	3%
Norway	45%	49%	53%	66%	46%	49%	50%
Poland	8%	10%	9%	9%	10%	11%	18%
Portugal	12%	12%	7%	11%	12%	14%	19%
Romania	4%	5%	5%	4%	3%	4%	9%
Slovakia	4%	6%	3%	6%	5%	5%	9%
Slovenia	12%	23%	22%	14%	13%	19%	29%
Spain	11%	9%	8%	9%	11%	13%	13%
Sweden	12%	14%	13%	15%	12%	17%	16%
Switzerland	2%	2%	3%	4%	3%	6%	4%
United Kingdom	5%	4%	4%	5%	6%	6%	7%
Total Average	**13%**	**12%**	**13%**	**15%**	**16%**	**19%**	**21%**

Table 25: Percent Change: FUA -UC

The Percent Change between FUA and UC ranges from 12% to 21%, so, the values are slightly close.

Percent Change: Eurostat - UN Urban						
Countries / Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Austria	6%	2%	1%	6%	12%	4%
Belgium	6%	1%	4%	1%	2%	4%
Bulgaria	12%	12%	5%	8%	9%	5%
Croatia	3%	14%	13%	3%	5%	3%
Cyprus	8%	6%	1%	6%	24%	15%
Czechia	0%	5%	4%	4%	7%	3%
Denmark	12%	1%	2%	13%	13%	1%
Estonia	5%	5%	19%	16%	11%	38%
Finland	20%	13%	10%	26%	0%	22%
France	3%	9%	3%	3%	4%	9%
Germany	14%	2%	6%	4%	7%	2%
Greece	-	7%	10%	20%	24%	10%
Hungary	9%	-	-	17%	1%	3%
Iceland	-	7%	22%	0%	2%	5%
Ireland	2%	21%	4%	8%	0%	1%
Italy	2%	19%	15%	15%	3%	2%
Latvia	0%	19%	6%	1%	6%	17%
Lithuania	22%	18%	25%	30%	47%	5%
Luxembourg	9%	9%	31%	24%	11%	11%
Netherlands	9%	0%	5%	4%	1%	5%
Norway	10%	3%	7%	5%	19%	11%
Poland	5%	1%	3%	4%	2%	3%
Portugal	18%	12%	14%	23%	24%	16%
Romania	23%	4%	8%	20%	17%	14%
Slovakia	11%	3%	25%	8%	16%	18%
Slovenia	6%	16%	20%	10%	1%	5%
Spain	4%	11%	7%	12%	10%	17%
Sweden	8%	13%	13%	19%	6%	10%
Switzerland	4%	16%	3%	8%	12%	-
United Kingdom	13%	13%	0%	4%	2%	5%
Total Average	**9%**	**9%**	**10%**	**11%**	**10%**	**9%**

Table 26: Percent Change: Eurostat-UN Urban

The Percent Change between Eurostat and UN Urban ranges from 9% to 11%, so the values are close.

Percent Change: Eurostat - UN Total						
Countries / Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Austria	13%	6%	6%	13%	18%	4%
Belgium	9%	2%	7%	4%	5%	1%
Bulgaria	19%	18%	3%	15%	1%	12%
Croatia	4%	15%	14%	4%	7%	4%
Cyprus	13%	11%	7%	1%	17%	8%
Czechia	4%	1%	8%	8%	10%	0%
Denmark	16%	5%	2%	8%	17%	3%
Estonia	9%	1%	15%	11%	6%	32%
Finland	31%	3%	5%	10%	13%	7%
France	6%	10%	11%	6%	4%	1%
Germany	17%	6%	10%	8%	11%	2%
Greece	-	0%	3%	13%	17%	4%
Hungary	12%	-	-	20%	3%	1%
Iceland	-	13%	14%	7%	5%	2%
Ireland	8%	15%	9%	2%	6%	7%
Italy	5%	21%	18%	18%	0%	6%
Latvia	16%	16%	21%	16%	20%	1%
Lithuania	9%	5%	11%	15%	31%	7%
Luxembourg	11%	11%	32%	25%	13%	13%
Netherlands	10%	1%	4%	3%	3%	3%
Norway	22%	10%	20%	9%	4%	3%
Poland	10%	5%	8%	9%	7%	2%
Portugal	21%	16%	17%	25%	27%	19%
Romania	15%	10%	14%	25%	22%	19%
Slovakia	8%	0%	22%	6%	13%	15%
Slovenia	2%	19%	23%	13%	3%	8%
Spain	9%	15%	11%	16%	14%	21%
Sweden	15%	4%	5%	10%	2%	3%
Switzerland	7%	7%	0%	11%	9%	-
United Kingdom	14%	11%	2%	2%	0%	7%
Total Average	**12%**	**9%**	**11%**	**11%**	**10%**	**7%**

Table 27: Percent Change: Eurostat-UN Total

The Percent Change between Eurostat and UN Total ranges from 7% to 12%, so the values are close.

Percent Change: FUA - UN Urban						
Countries / Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Austria	20%	7%	1%	4%	4%	15%
Belgium	15%	8%	2%	0%	5%	5%
Bulgaria	81%	72%	56%	76%	106%	35%
Croatia	69%	32%	18%	56%	54%	24%
Cyprus	37%	28%	19%	41%	46%	14%
Czechia	37%	15%	6%	12%	10%	10%
Denmark	11%	28%	13%	39%	34%	18%
Estonia	17%	19%	0%	28%	30%	17%
Finland	19%	40%	18%	56%	35%	36%
France	34%	5%	5%	19%	29%	22%
Germany	11%	7%	2%	5%	10%	12%
Greece	39%	32%	19%	32%	55%	30%
Hungary	38%	16%	8%	25%	23%	6%
Iceland	197%	206%	139%	228%	296%	184%
Ireland	60%	80%	33%	95%	73%	41%
Italy	30%	3%	3%	11%	18%	8%
Latvia	114%	132%	69%	98%	113%	70%
Lithuania	-	-	-	27%	40%	21%
Luxembourg	4%	8%	10%	1%	9%	16%
Netherlands	2%	7%	0%	2%	7%	7%
Norway	46%	59%	37%	79%	64%	56%
Poland	67%	39%	17%	28%	32%	20%
Portugal	1%	16%	13%	7%	1%	16%
Romania	23%	12%	1%	17%	18%	18%
Slovakia	38%	15%	14%	17%	29%	17%
Slovenia	40%	7%	2%	20%	35%	8%
Spain	24%	6%	4%	10%	24%	3%
Sweden	3%	23%	5%	33%	25%	18%
Switzerland	13%	13%	19%	6%	3%	0%
United Kingdom	15%	28%	7%	23%	24%	4%
Total Average	**38%**	**33%**	**19%**	**36%**	**42%**	**25%**

Table 28: Percent Change: FUA - UN Urban

The Percent Change between FUA and UN Urban ranges from 19% to 42%, so the values are not close.

Percent Change: FUA - UN Total						
Countries / Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Austria	11%	2%	6%	4%	3%	6%
Belgium	12%	5%	5%	2%	3%	2%
Bulgaria	67%	59%	45%	64%	92%	25%
Croatia	67%	30%	17%	54%	52%	23%
Cyprus	29%	21%	12%	33%	37%	7%
Czechia	31%	11%	2%	8%	6%	6%
Denmark	6%	22%	8%	32%	28%	12%
Estonia	12%	14%	4%	23%	25%	12%
Finland	2%	21%	2%	36%	18%	20%
France	23%	4%	4%	9%	18%	12%
Germany	6%	2%	6%	1%	6%	8%
Greece	31%	24%	12%	24%	46%	22%
Hungary	32%	11%	4%	20%	18%	10%
Iceland	177%	185%	122%	206%	269%	166%
Ireland	51%	70%	26%	84%	64%	33%
Italy	25%	1%	7%	7%	14%	11%
Latvia	80%	65%	42%	68%	81%	45%
Lithuania	-	-	-	13%	25%	8%
Luxembourg	2%	10%	12%	1%	6%	13%
Netherlands	1%	6%	1%	1%	6%	5%
Norway	27%	38%	19%	56%	42%	37%
Poland	57%	31%	11%	20%	24%	14%
Portugal	5%	19%	16%	8%	2%	19%
Romania	15%	5%	7%	9%	11%	22%
Slovakia	34%	13%	11%	15%	26%	14%
Slovenia	35%	3%	1%	15%	31%	4%
Spain	18%	1%	8%	6%	19%	1%
Sweden	5%	13%	3%	23%	16%	10%
Switzerland	9%	20%	21%	9%	0%	3%
United Kingdom	13%	25%	5%	20%	21%	2%
Total Average	**30%**	**25%**	**15%**	**29%**	**34%**	**19%**

Table 29: Percent Change: FUA - UN Total

The Percent Change between FUA and UN Total ranges from 15% to 34%, so the values are not close.

Percent Change: UN Urban - UN Total						
Countries / Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Austria	8%	8%	7%	7%	7%	7%
Belgium	3%	3%	3%	3%	3%	3%
Bulgaria	7%	7%	7%	7%	7%	7%
Croatia	1%	1%	1%	1%	1%	1%
Cyprus	6%	5%	6%	6%	6%	6%
Czechia	4%	4%	4%	4%	4%	4%
Denmark	5%	4%	4%	4%	4%	5%
Estonia	4%	4%	4%	4%	4%	4%
Finland	14%	14%	14%	13%	13%	12%
France	8%	1%	8%	8%	8%	8%
Germany	4%	4%	4%	4%	4%	4%
Greece	6%	6%	6%	6%	6%	6%
Hungary	4%	4%	4%	4%	4%	4%
Iceland	7%	7%	7%	7%	7%	7%
Ireland	6%	6%	5%	6%	5%	6%
Italy	4%	3%	3%	3%	3%	3%
Latvia	16%	29%	16%	15%	15%	15%
Lithuania	11%	11%	11%	11%	11%	11%
Luxembourg	2%	2%	2%	2%	2%	2%
Netherlands	1%	1%	1%	1%	1%	1%
Norway	13%	13%	13%	13%	13%	12%
Poland	6%	6%	6%	6%	5%	5%
Portugal	4%	4%	4%	2%	4%	4%
Romania	7%	7%	7%	6%	6%	6%
Slovakia	2%	2%	2%	2%	2%	2%
Slovenia	4%	4%	4%	4%	4%	4%
Spain	5%	4%	4%	4%	4%	4%
Sweden	7%	8%	7%	7%	7%	7%
Switzerland	3%	8%	3%	3%	3%	3%
United Kingdom	2%	2%	2%	2%	2%	2%
Total Average	**6%**	**6%**	**6%**	**6%**	**6%**	**5%**

Table 30: Percent Change: UN Urban - UN Total

The Percent Change between Un Urban and UN Total is always 6%, so the values are close.

Percent Change: UC - UN Urban						
Countries / Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Austria	9%	0%	3%	23%	34%	10%
Belgium	9%	3%	6%	3%	2%	0%
Bulgaria	53%	44%	32%	53%	73%	10%
Croatia	59%	25%	12%	48%	39%	8%
Cyprus	33%	24%	16%	-	-	-
Czechia	32%	11%	2%	7%	4%	3%
Denmark	4%	18%	6%	26%	25%	9%
Estonia	2%	2%	14%	5%	11%	5%
Finland	6%	9%	7%	21%	8%	10%
France	34%	3%	3%	7%	15%	7%
Germany	5%	2%	6%	1%	4%	4%
Greece	17%	13%	3%	16%	36%	12%
Hungary	28%	9%	2%	19%	12%	17%
Iceland	52%	102%	26%	78%	68%	25%
Ireland	48%	69%	25%	75%	57%	19%
Italy	24%	1%	6%	9%	16%	11%
Latvia	81%	88%	38%	63%	71%	25%
Lithuania	-	-	-	17%	27%	9%
Luxembourg	7%	20%	23%	9%	6%	2%
Netherlands	3%	7%	0%	1%	6%	5%
Norway	1%	7%	11%	8%	12%	5%
Poland	54%	26%	8%	17%	20%	9%
Portugal	11%	25%	19%	16%	9%	26%
Romania	18%	8%	5%	13%	14%	21%
Slovakia	33%	9%	10%	11%	23%	11%
Slovenia	25%	13%	16%	5%	20%	9%
Spain	12%	3%	12%	1%	12%	9%
Sweden	9%	8%	7%	15%	12%	1%
Switzerland	10%	15%	21%	9%	0%	5%
United Kingdom	10%	22%	3%	17%	17%	2%
Total Average	**24%**	**20%**	**12%**	**20%**	**22%**	**10%**

Table 31: Percent Change: UC - UN Urban

The Percent Change between UC - UN Urban ranges from 10% to 24%, so the values are slightly close.

Percent Change: UC - UN Total						
Countries / Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Austria	0%	8%	11%	14%	24%	16%
Belgium	6%	0%	8%	6%	1%	2%
Bulgaria	42%	34%	23%	43%	61%	2%
Croatia	57%	23%	11%	46%	37%	6%
Cyprus	25%	18%	9%	-	-	-
Czechia	27%	7%	2%	3%	0%	1%
Denmark	0%	13%	2%	20%	20%	4%
Estonia	5%	1%	17%	1%	7%	9%
Finland	20%	6%	20%	5%	6%	3%
France	23%	2%	6%	2%	6%	2%
Germany	1%	3%	10%	5%	0%	0%
Greece	10%	6%	3%	9%	28%	5%
Hungary	23%	5%	2%	14%	8%	20%
Iceland	42%	88%	17%	65%	57%	16%
Ireland	39%	60%	18%	65%	48%	12%
Italy	20%	4%	9%	5%	12%	14%
Latvia	53%	34%	16%	39%	45%	7%
Lithuania	-	-	-	4%	13%	3%
Luxembourg	9%	21%	24%	11%	8%	1%
Netherlands	2%	6%	1%	0%	5%	3%
Norway	13%	7%	23%	6%	2%	8%
Poland	45%	19%	2%	11%	13%	3%
Portugal	15%	27%	22%	17%	12%	29%
Romania	10%	1%	12%	5%	8%	25%
Slovakia	30%	6%	7%	8%	20%	9%
Slovenia	21%	16%	19%	1%	15%	12%
Spain	7%	7%	16%	3%	7%	13%
Sweden	15%	0%	14%	7%	4%	6%
Switzerland	7%	21%	23%	12%	4%	8%
United Kingdom	7%	20%	0%	14%	15%	4%

Table 32: Percent Change: UC - UN Total

The Percent Change between UC - UN Total ranges from 0% to 20%, so the values are slightly close.

We can also conclude that there is an agreement between the values.

Charts

Firstly, the plots for each approach, for all the countries, for all years are going to be presented. In all the plots the WHO Guideline, including Interim Targets 1-4 and EU limit values are depicted. The goal is to examine the trend of each approach and which years have the biggest values. In figures 6 through 10 the plots are presented.

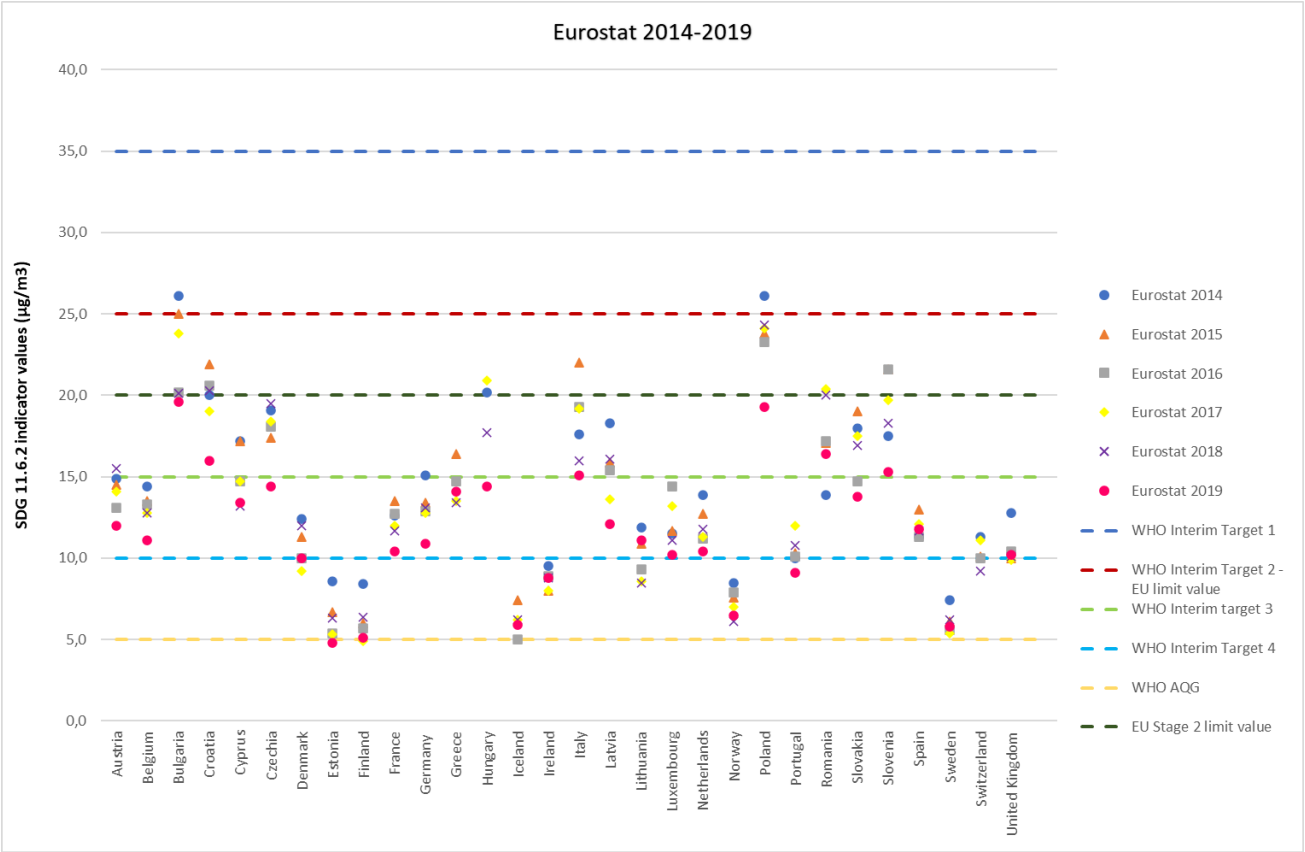

Figure 6 :SDG Indicator 11.6.2 (Eurostat approach) for years 2014-2019.

As we can observe, the majority of the countries have their largest Eurostat value for the year 2014, following the year 2015, then 2017 and last only two countries have the largest value for 2016 and 2018.

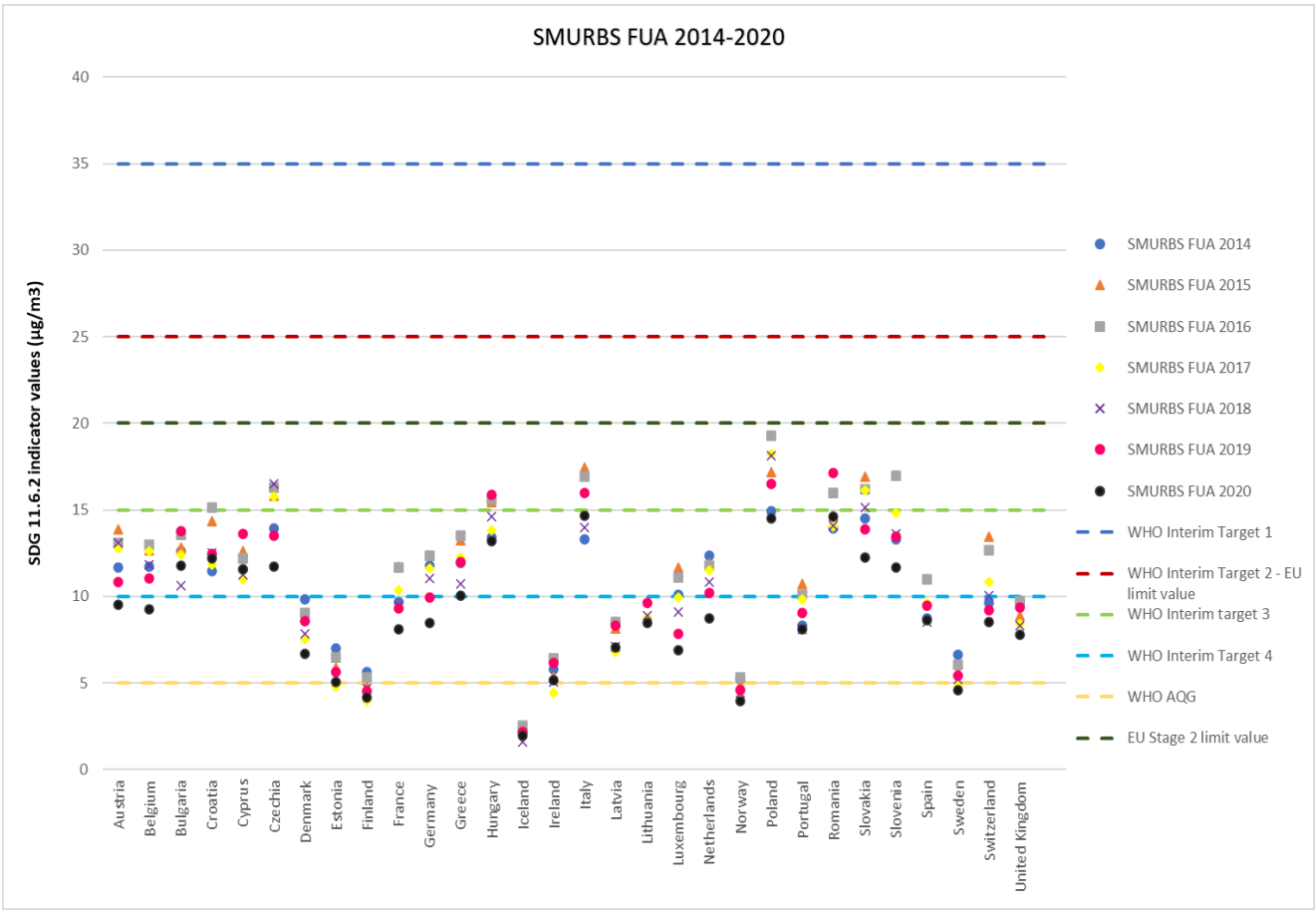

Figure 7 :SDG Indicator 11.6.2 (FUA approach) for years 2014-2020

As we can observe, the majority of the countries have their largest FUA value for the year 2016, following the year 2015, then 2014,2019 and last 2018 with only one country.

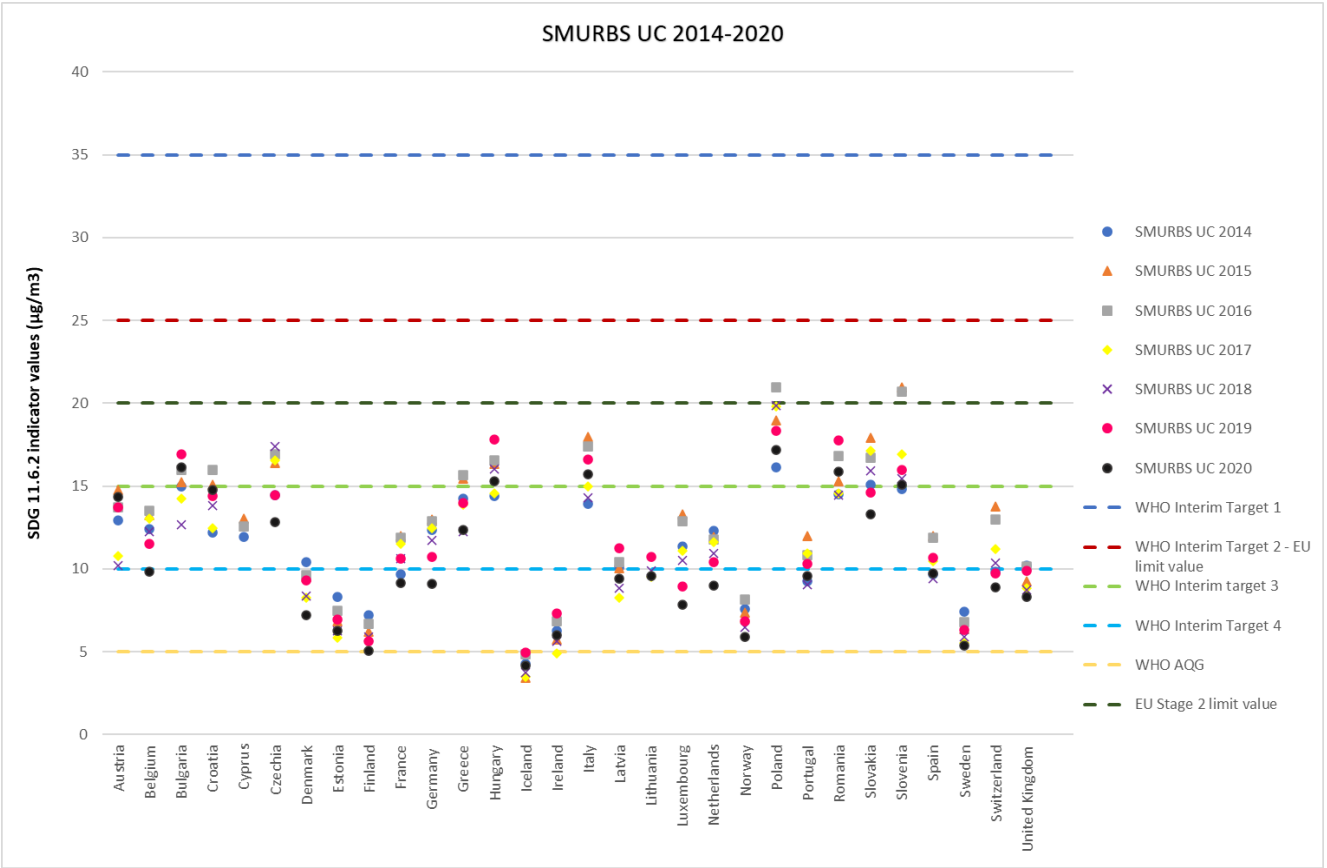

Figure 8: SDG Indicator 11.6.2 (SMURBS UC approach) for years 2014-2020

As we can observe, the majority of the countries have their largest UC value for the year 2016, following the year 2015 and 2019, then 2014, and last 2018 with only one country.

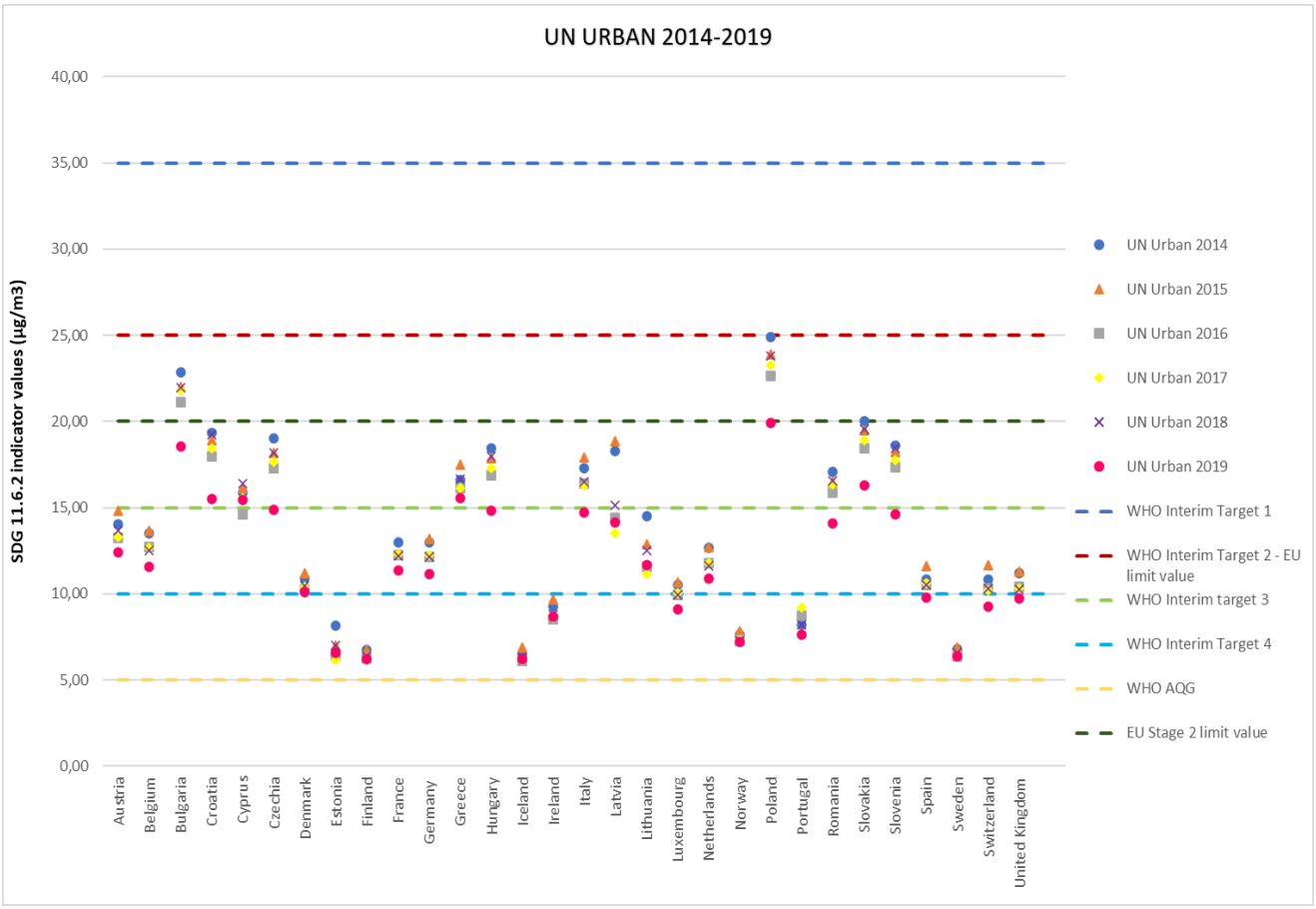

Figure 9 : SDG Indicator 11.6.2 (UN Urban approach) for years 2014-2019

As we can observe, the majority of the countries have their largest UN Urban value for the year 2015, following the year 2014and 2019, and last 2018 with only one country.

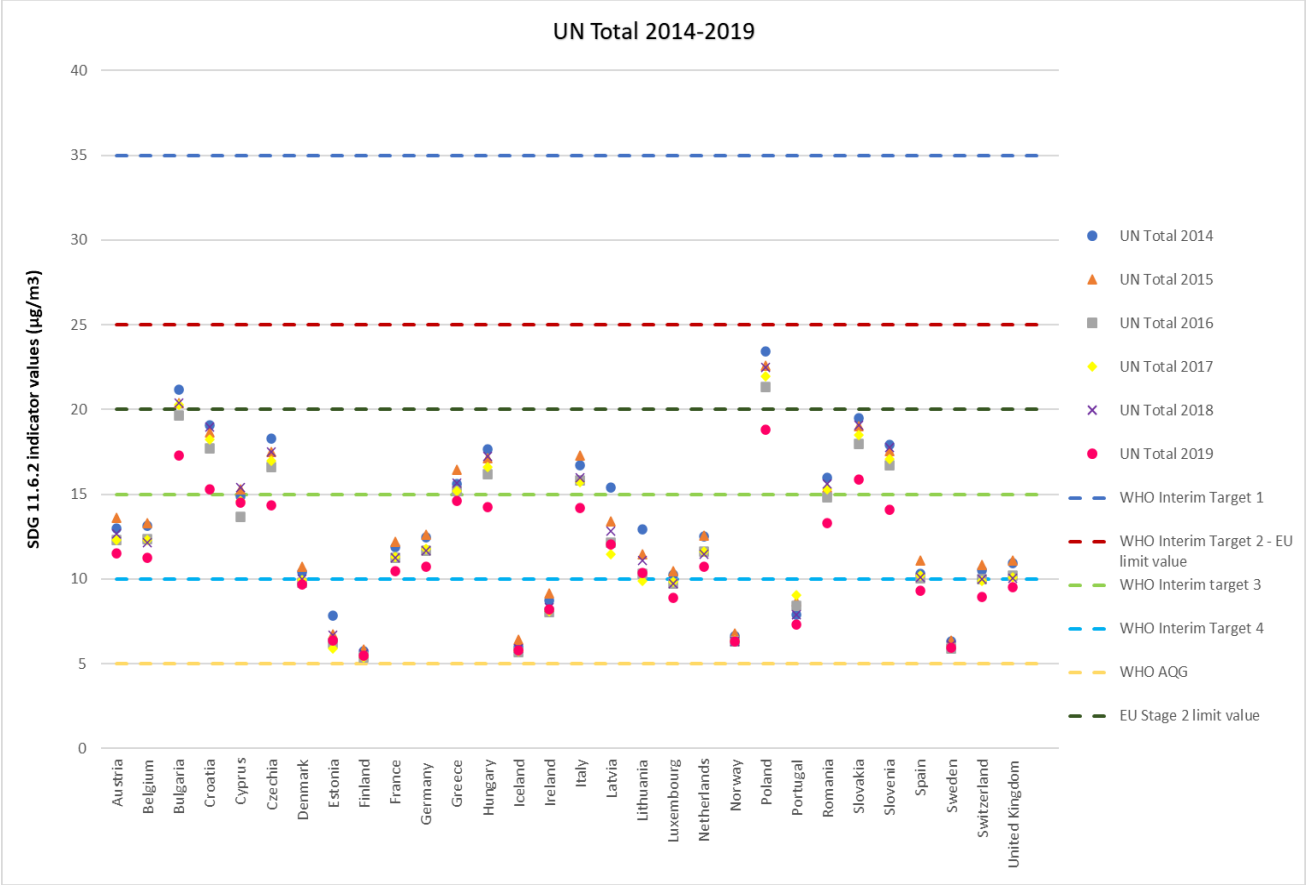

Figure 10: SDG Indicator 11.6.2 (UN Total approach) for years 2014-2019

As we can observe, the majority of the countries have their largest UN Total value for the year 2015, following the year 2014 and last 2018 and 2017 with only one country each.

Based on the above observations we can conclude that the years 2014, 2015 and 2016 present the biggest values and the following years a deduction is being noticed. This can happen due to the fact that the 2030 Agenda for Sustainable Development was adopted in year 2015 and after that the countries members took action in order to reduce air pollution.

Furthermore, for a more detailed study, the plots for each year for all the approaches are presented in figures 11 to 17 in order to find differences between them. For this purpose, the countries are categorized in three different groups each carrying distinct policy implications: a) general agreement between all approaches for each, country, b) approach-driven limit exceedances (either WHO or EU), c) wide divergence between values or have major outlier values which are presented in tables 33 to 38 below.

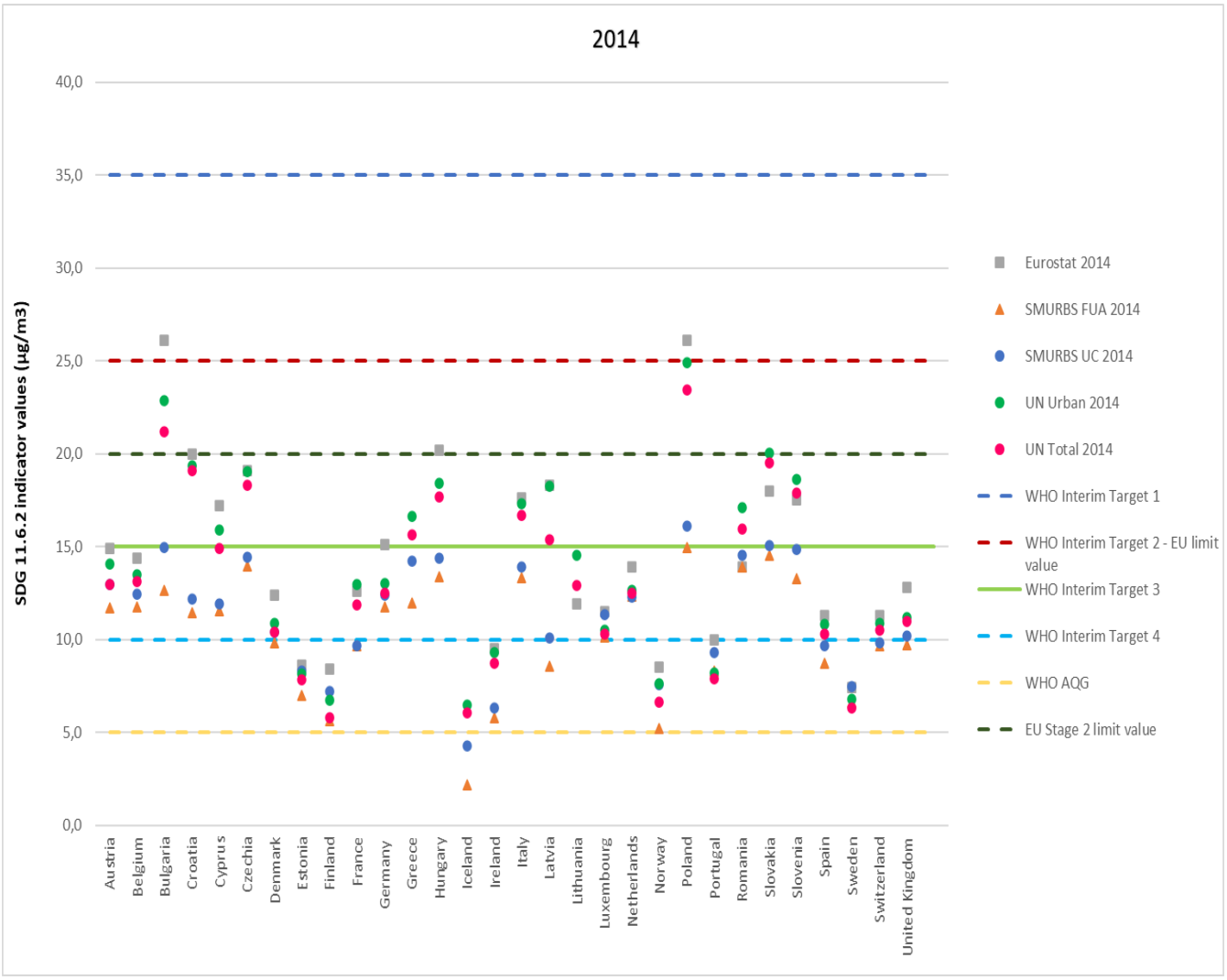

Figure 11 : SDG Indicator 11.6.2 for all approaches, for year 2014

Policy Relevant Groups 2014	Countries	Description
General Agreement All values are similar	Austria	Eurostat slightly higher
	Belgium	Eurostat slightly higher
	Denmark	Eurostat slightly higher
	Estonia	Values are almost similar
	Finland	Values are almost similar
	France	UN slightly higher
	Germany	Eurostat slightly higher
	Greece	UN slightly higher
	Iceland	UN slightly higher
	Ireland	Eurostat slightly higher
	Lithuania	UN slightly higher
	Luxembourg	Values are almost similar
	Netherlands	Values are almost similar
	Norway	Values are almost similar
	Portugal	Values are almost similar
	Romania	UN slightly higher
	Spain	Values are almost similar
	Sweden	Values are almost similar
	Switzerland	Values are almost similar
	United Kingdom	Eurostat slightly higher
Approach Driven Limit Exceedances WHO or EU Values are above or below a certain limit depending on the approach	Bulgaria	Eurostat slightly above the EU limit
	Poland	Eurostat slightly above the EU limit, with UN on the limit
	Iceland	FUA and UC below the WHO limit
Wide Divergence	Croatia	Data between different indicators show wide divergence
	Cyprus	Data between different indicators show wide divergence
	Czechia	Data between different indicators show wide divergence
	Italy	Data between different indicators show wide divergence
	Latvia	Data between different indicators show wide divergence
	Slovakia	Data between different indicators show wide divergence
	Slovenia	Data between different indicators show wide divergence

Table 33: Policy relevant groups for year 2014

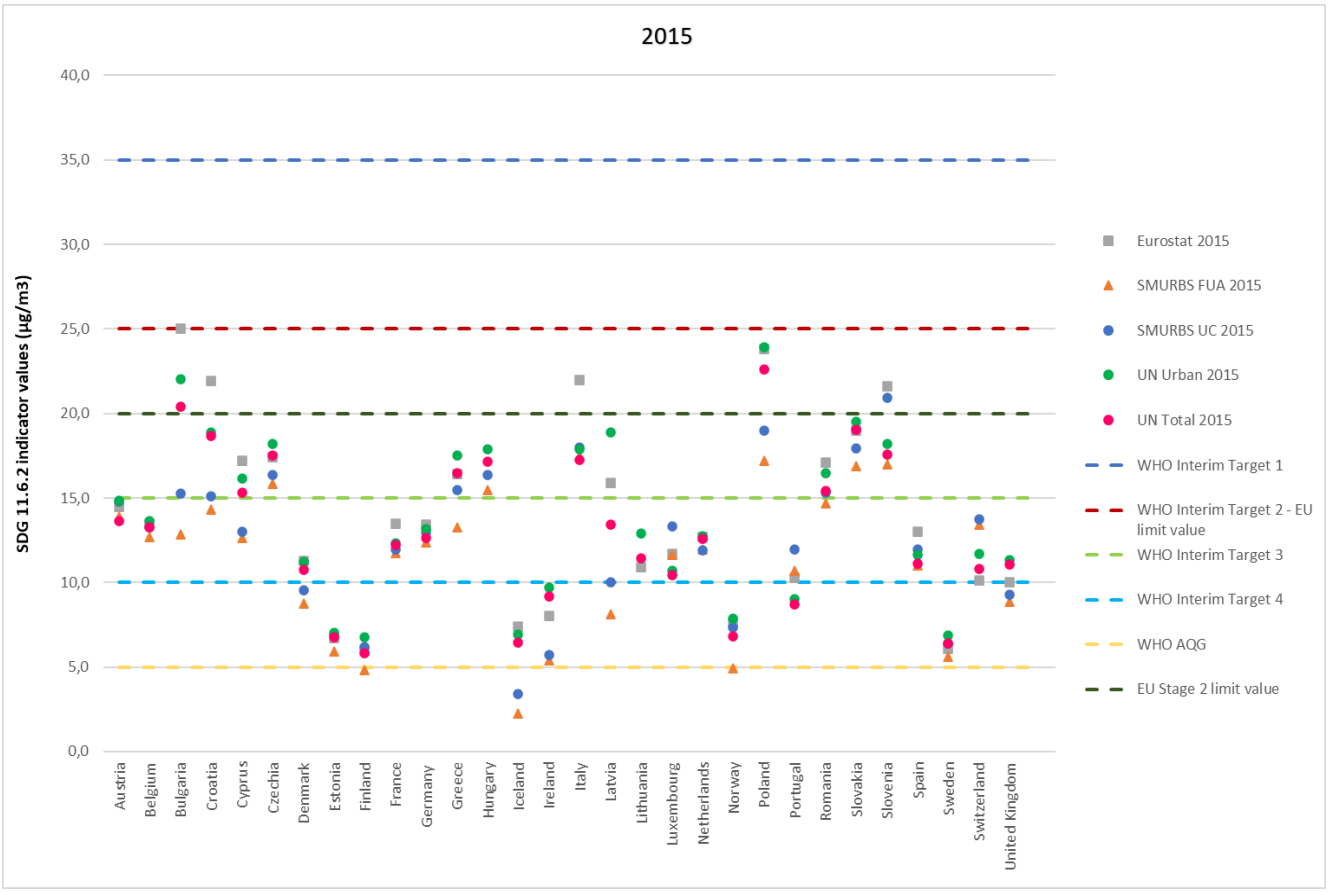

Figure 12: SDG Indicator 11.6.2 for all approaches, for year 2015

Policy Relevant Groups 2015	Countries	Description
General Agreement All values are similar	Austria	Values are almost similar
	Belgium	Values are almost similar
	Cyprus	Eurostat slightly higher
	Czechia	UN slightly higher
	Denmark	Values are almost similar
	Estonia	Values are almost similar
	Finland	Values are almost similar
	France	Eurostat slightly higher
	Germany	Values are almost similar
	Hungary	UN slightly higher
	Ireland	UN slightly higher
	Italy	Eurostat slightly higher
	Lithuania	UN slightly higher
	Luxembourg	UC slightly higher
	Netherlands	Values are almost similar
	Norway	Values are almost similar
	Portugal	UC slightly higher
	Romania	Eurostat slightly higher
	Slovakia	Values are almost similar
	Slovenia	Eurostat and UC slightly higher
	Spain	Values are almost similar
	Sweden	Values are almost similar
	Switzerland	UC and FUA slightly higher
	UK	UN slightly higher
Approach Driven Limit Exceedances WHO or EU Values are above or below (or extremely close) to a certain limit depending on the approach	Iceland	FUA and UC below the WHO limit
	Bulgaria	Eurostat on the EU limit
Wide Divergence	Croatia	Data between different indicators show wide divergence
	Greece	Data between different indicators show wide divergence
	Poland	Data between different indicators show wide divergence

Table 34: Policy relevant groups for year 2015

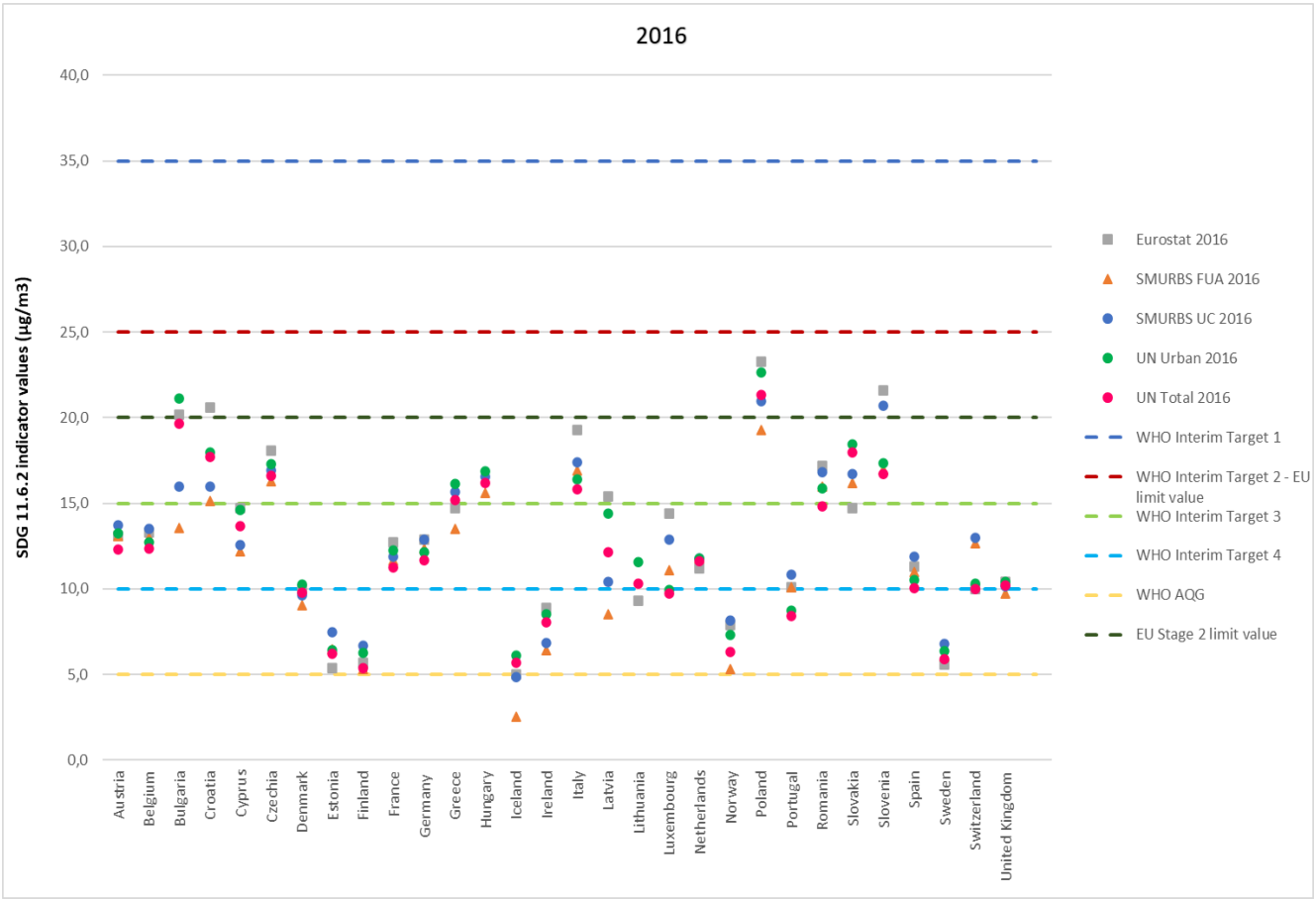

Figure 13: SDG Indicator 11.6.2 for all approaches, for year 2016

Policy Relevant Groups 2016	Countries	Description
General Agreement All values are similar	Austria	Values are almost similar
	Belgium	Values are almost similar
	Cyprus	UN slightly higher
	Czechia	Eurostat slightly higher
	Denmark	Values are almost similar
	Estonia	UC slightly higher
	Finland	Values are almost similar
	France	Eurostat slightly higher
	Germany	Values are almost similar
	Hungary	UN slightly higher
	Ireland	UN slightly higher
	Italy	Eurostat slightly higher
	Lithuania	UN slightly higher
	Greece	Values are almost similar
	Netherlands	Values are almost similar
	Norway	Values are almost similar
	Portugal	Values are almost similar
	Romania	Values are almost similar
	Slovakia	Values are almost similar
	Slovenia	Eurostat and UC slightly higher
	Spain	Values are almost similar
	Sweden	Values are almost similar
	Switzerland	UC and FUA slightly higher
	UK	Values are almost similar
Approach Driven Limit Exceedances WHO or EU Values are above or below (or extremely close) to a certain limit depending on the approach	Iceland	FUA and UC below the WHO limit
	Poland	4 out of 5 indicators near EU limit
Wide Divergence	Bulgaria	Data between different indicators show wide divergence
	Croatia	Data between different indicators show wide divergence
	Latvia	Data between different indicators show wide divergence

Table 35: Policy relevant groups for year 2016

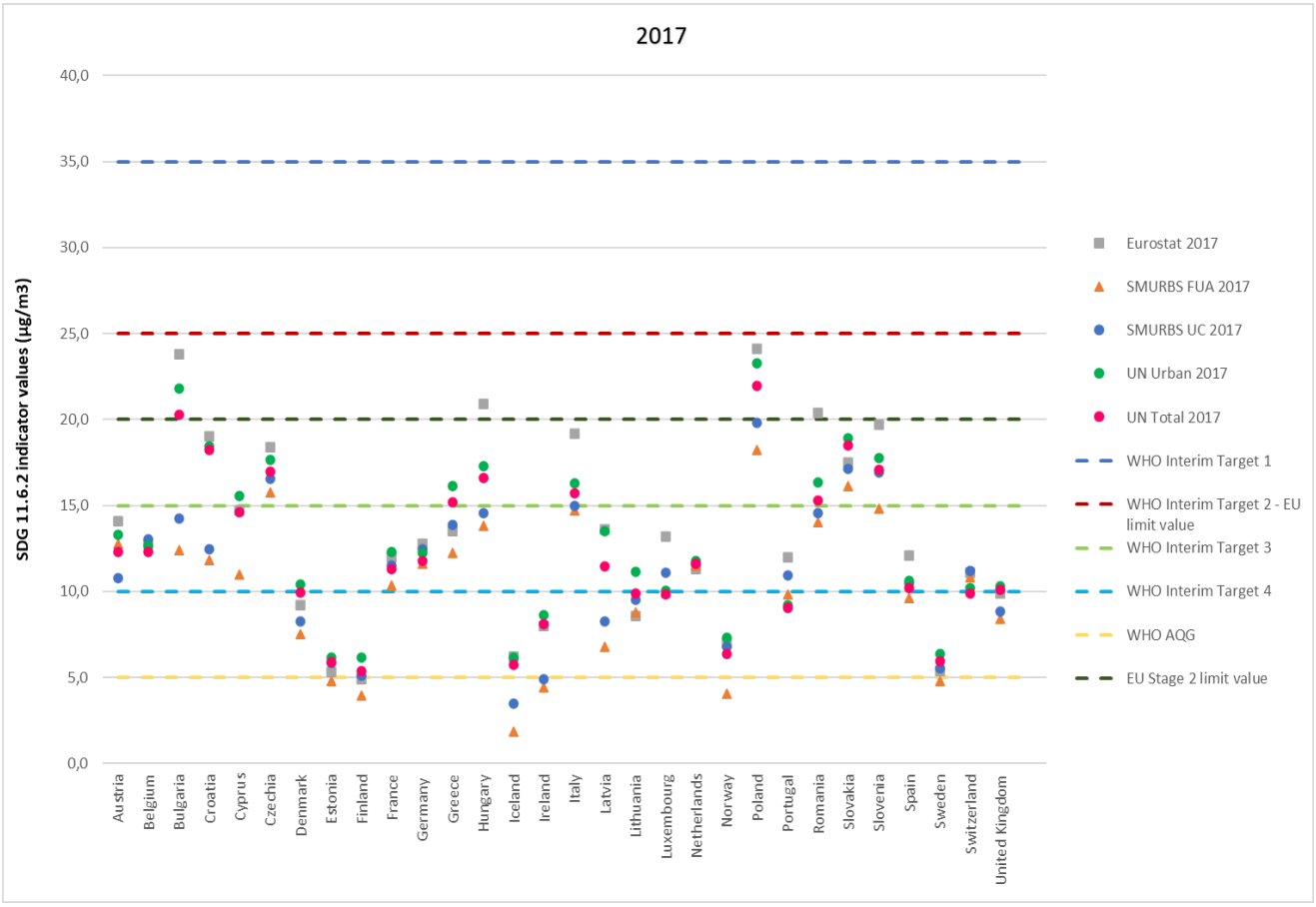

Figure 14: SDG Indicator 11.6.2 for all approaches, for year 2017

Policy Relevant Groups 2017	Countries	Description
General Agreement All values are similar	Austria	Values are almost similar
	Belgium	Values are almost similar
	Czechia	Eurostat slightly higher
	Denmark	UN slightly higher
	Estonia	Values are almost similar
	Finland	Values are almost similar
	France	Values are almost similar
	Germany	Values are almost similar
	Greece	UN slightly higher
	Italy	Eurostat slightly higher
	Lithuania	UN slightly higher
	Luxembourg	Eurostat slightly higher
	Netherlands	Values are almost similar
	Portugal	Eurostat slightly higher
	Slovakia	Values are almost similar
	Slovenia	Eurostat slightly higher
	Spain	Eurostat slightly higher
	Sweden	Values are almost similar
	Switzerland	UC and FUA slightly higher
	UK	Values are almost similar
Approach Driven Limit Exceedances WHO or EU Values are above or below (or extremely close) to a certain limit depending on the approach	Iceland	FUA and UC below the WHO limit
	Ireland	FUA and UC below the WHO limit
	Bulgaria	Eurostat close to EU limit
	Poland	Eurostat close to EU limit
	Norway	FUA below the WHO limit
Wide Divergence	Croatia	Data between different indicators show wide divergence
	Cyprus	Data between different indicators show wide divergence
	Hungary	Data between different indicators show wide divergence

Table 36: Policy relevant groups for year 2017

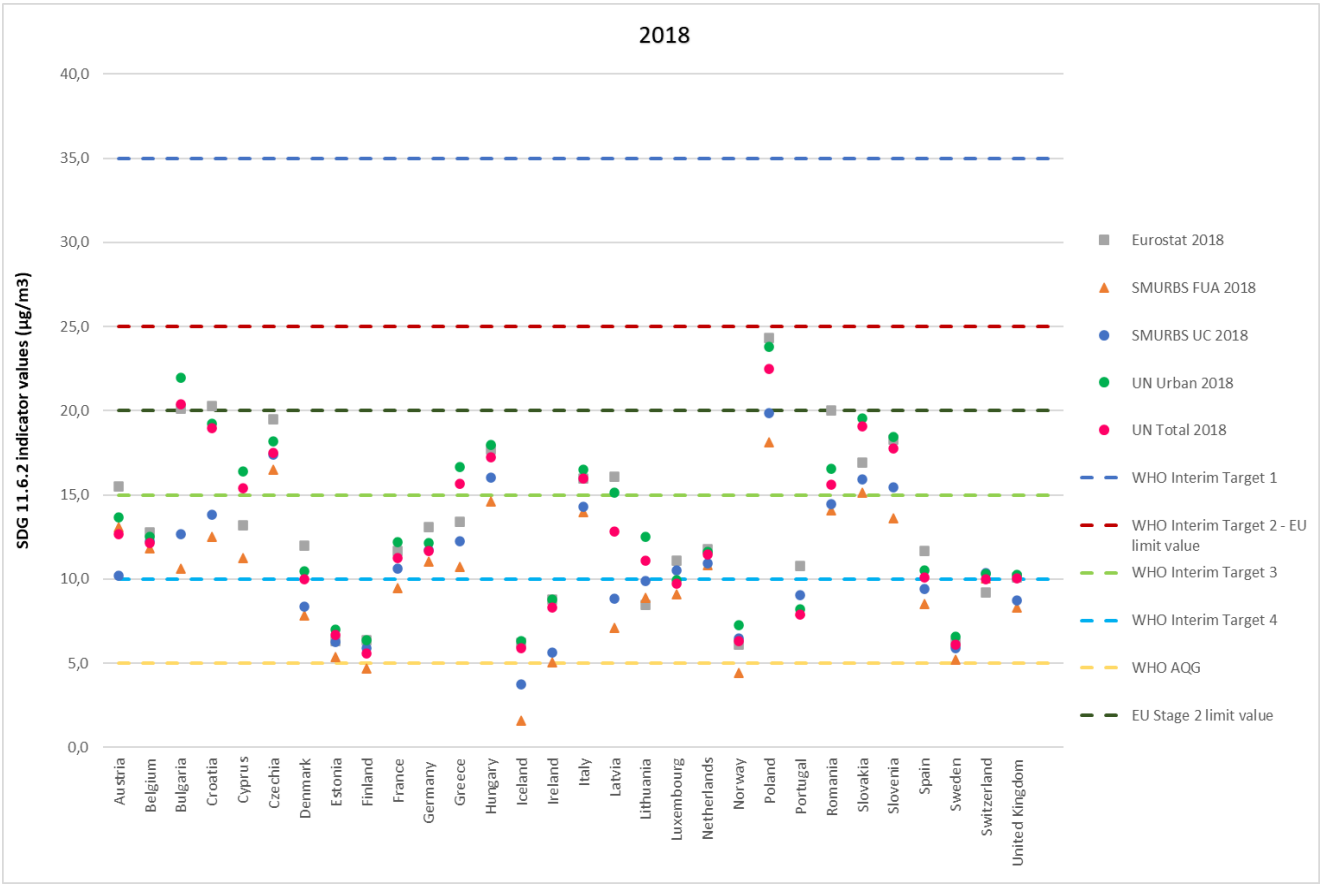

Figure 15: SDG Indicator 11.6.2 for all approaches, for year 2018

Policy Relevant Groups 2018	Countries	Description
General Agreement All values are similar	Austria	Eurostat slightly higher
	Belgium	Values are almost similar
	Cyprus	UN slightly higher
	Czechia	Values are almost similar
	Denmark	Eurostat slightly higher
	Estonia	Values are almost similar
	Finland	Values are almost similar
	France	Values are almost similar
	Germany	Eurostat slightly higher
	Greece	UN slightly higher
	Hungary	Values are almost similar
	Italy	Eurostat slightly higher
	Ireland	Values are almost similar
	Lithuania	UN slightly higher
	Luxembourg	Values are almost similar
	Netherlands	Values are almost similar
	Portugal	Eurostat slightly higher
	Romania	Values are almost similar
	Slovakia	UN slightly higher
	Slovenia	UN and Eurostat slightly higher
	Spain	Eurostat slightly higher
	Sweden	Values are almost similar
	Switzerland	Values are almost similar
	UK	Values are almost similar
Approach Driven Limit Exceedances WHO or EU Values are above or below (or extremely close) to a certain limit depending on the approach	Iceland	FUA and UC below the WHO limit
	Poland	Eurostat close to EU limit
	Norway	FUA below the WHO limit
Wide Divergence	Bulgaria	Data between different indicators show wide divergence
	Croatia	Data between different indicators show wide divergence

Table 37: Policy relevant groups for year 2018

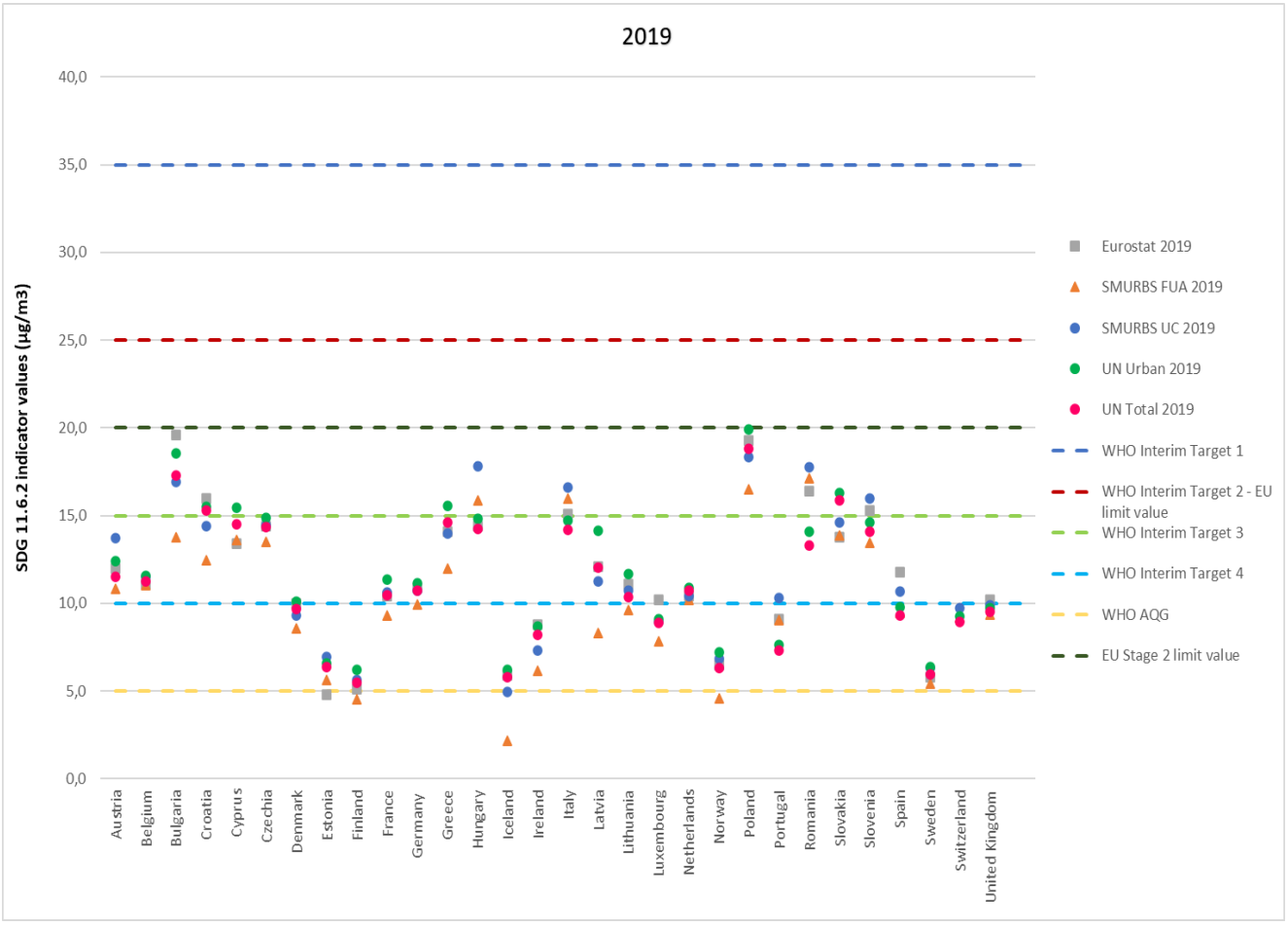

Figure 16 : SDG Indicator 11.6.2 for all approaches, for year 2019

Policy Relevant Groups 2019	Countries	Description
General Agreement All values are similar	Austria	UC slightly higher
	Belgium	Values are almost similar
	Croatia	FUA slightly lower
	Cyprus	Values are almost similar
	Czechia	Values are almost similar
	Denmark	Values are almost similar
	Estonia	Values are almost similar
	France	Values are almost similar
	Germany	Values are almost similar
	Greece	FUA slightly lower
	Hungary	UC slightly higher
	Italy	Values are almost similar
	Ireland	Values are almost similar
	Lithuania	Values are almost similar
	Luxembourg	Values are almost similar
	Netherlands	Values are almost similar
	Portugal	UC slightly higher
	Poland	FUA slightly lower
	Slovakia	Values are almost similar
	Slovenia	Values are almost similar
	Spain	Eurostat slightly higher
	Switzerland	Values are almost similar
	UK	Values are almost similar
Approach Driven Limit Exceedances WHO or EU Values are above or below (or extremely close) to a certain limit depending on the approach	Iceland	FUA and UC below the WHO limit
	Finland	FUA below the WHO limit
	Norway	FUA below the WHO limit
	Sweden	All indexes very close to the WHO limit
Wide Divergence	Latvia	Data between different indicators show wide divergence

Table 38: Policy relevant groups for year 2019

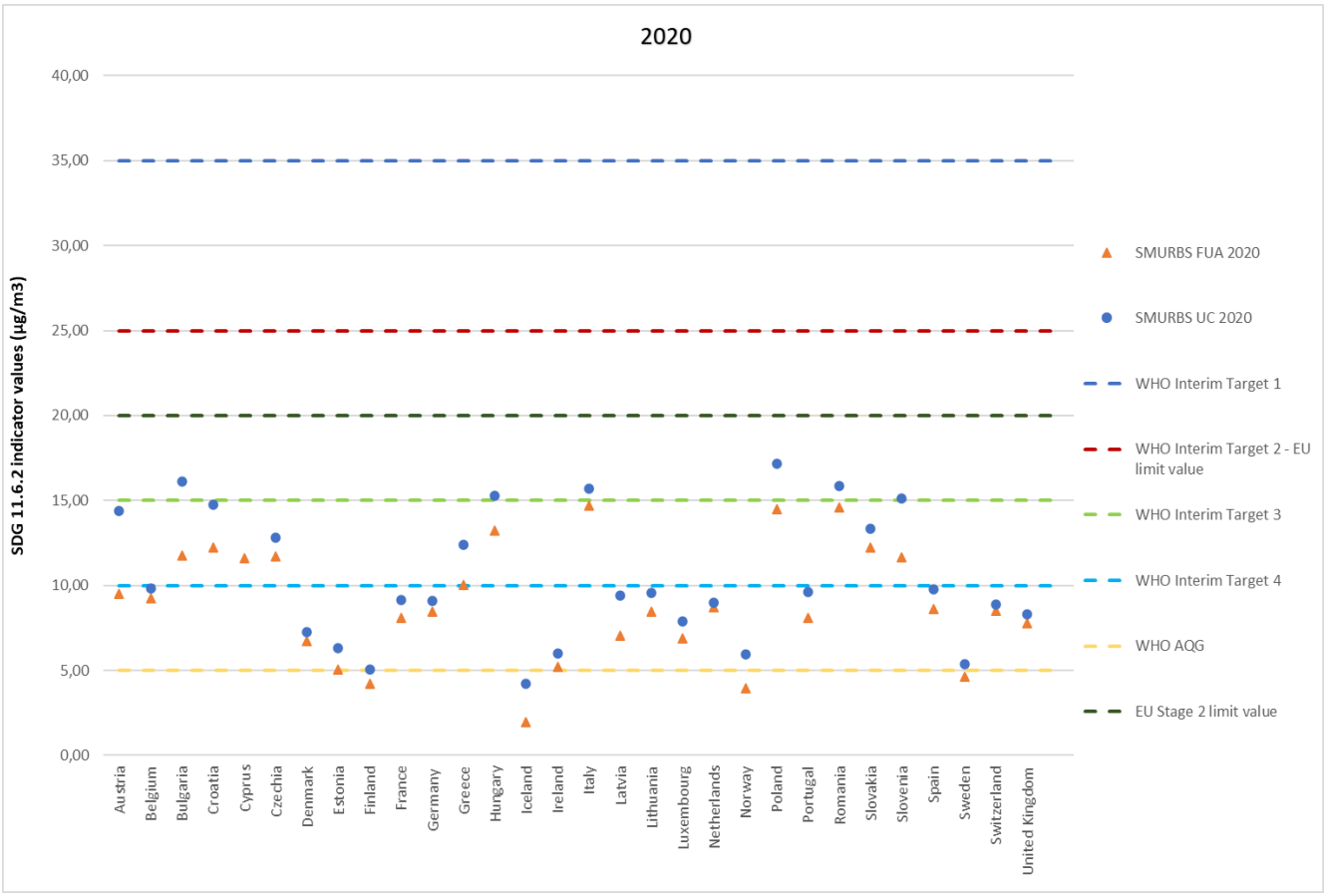

Figure 17: SDG Indicator 11.6.2 for SMURBS approaches, for year 2020

For the year 2020, a table was not created due to the fact that the only available values were the ones from SMURBS FUA and UC and it is clearly seen from the plot that UC values are always bigger than the values for FUA. This comes to agreement with the results of the statistical test.

From the above tables (33 – 38) we can observe that Austria, Belgium, Denmark, Estonia, France, Germany, Ireland, Italy, Lithuania, Luxemburg, Netherlands, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom fall into the first group most of the times and as a result we can conclude that there is a general agreement between the different approaches. Agreement is expected since most of the have well distributed air quality monitoring network, as it appears in the European Environmental Agency portal [51]. On the other hand, Bulgaria, Croatia and Latvia fall into the third group and present wide divergence between the different approaches. This may be due to the fact that they have poor air quality monitoring network and the values are influenced by different city definitions and pollution hot spots.

Generally, there is an agreement between the SMURBS FUA, SMURBS UC, UN and Eurostat approaches. However, some differences exist due to different city

definitions adopted by each approach and inconsistent monitoring network. Moreover, UC values tend to be higher than FUA values by 12%- 21% as seen on Table 24 and this should be taken into consideration if the reporting systems begin to use these city definitions.

Conclusion

Due to the fact that different city definitions exist and are being utilized by each SDG 11.6.2 approach, we end up with different policy frameworks that are not globally harmonized. There is an agreement between different approaches for most of the countries, but some countries appear to have wide divergences concerning these approaches.

Since air pollution and air quality are vital subjects concerning a big part of the global population, especially the ones that live in big cities and urban areas, the reduction of PM concentration and the improvement of air quality in general is a major goal for national authorities. Better monitoring of the SDG's helps to achieve those goals. Provided that UN and Eurostat approaches are mostly based on in situ data collection, they suffer from absence of diversity.

A solution to this problem comes with the use of Earth Observation (EO) platforms which are being utilized on the SMURBS approach, because data from in situ, satellite and models are used, combined with objective city boundary definitions, in order to provide more representative values for the SDG 11.6.2.

In conclusion, SMURBS platform offers a sustainable methodology and provides an opportunity for countries that are uncappable for dense and representative air quality monitoring networks, to have a more objective SDG indicator and therefor, a better knowledge while they monitor their progress towards the SDG 11.6.2.

References

(1) https://www.who.int/health-topics/air-pollution#tab=tab_1

(2) www.esa.int

(3) Vallero, D. Fundamentals of Air pollution, 2014.

(4) Dennis Y.C. Leung, Outdoor-indoor air pollution in urban environment: Challenges and opportunity, Frontiers in Environmental Science, 2015.

(5) Boubel, R., Fundamentals of Air Pollution, 1994

(6) https://environmentalhistory.org/about/airpollution/

(7) https://www.niehs.nih.gov/health/topics/agents/air-pollution

(8) https://www.nps.gov/subjects/air/sources.htm

(9) https://www.eea.europa.eu/publications/air-quality-in-europe-2022/sources-and-emissions-of-air

(10) Adams, K., Greenbaum, D. S., Shaikh, R., van Erp, A. M., & Russell, A. G. ,2015, Particulate matter components, sources, and health: Systematic approaches to testing effects. Journal of the Air & Waste Management Association, 65(5), 544–558. https://doi.org/10.1080/10962247.2014.1001884

(11) https://www.who.int/teams/environment-climate-change-and-health/air-quality-and-health/health-impacts/types-of-pollutants

(12) Harrison Roy M.,2020, Airborne particulate matter, Phil. Trans. R. Soc. A.378:20190319 http://doi.org/10.1098/rsta.2019.0319

(13) https://scied.ucar.edu/learning-zone/air-quality/effects-air-pollution

(14) https://science.nasa.gov/climate-change/effects/

(15) D.A Grantz, J.H.B Garner, D.W Johnson,Ecological effects of particulate matter,Environment International,Volume 29, Issues 2–3,2003, https://doi.org/10.1016/S0160-4120(02)00181-2

(16) Narhar.J. Biraris, Pravin.B.Thakare, International Journal of Engineering Applied Sciences and Technology, 2024,Vol. 8, Issue 12, ISSN No. 2455-2143, Pages 64-67, https://ijeast.com/papers/64-67,%20Tesma0812,IJEAST.pdf

(17) https://www.c40knowledgehub.org/s/article/WHO-Air-Quality-Guidelines?language=en_US

(18) Manisalidis Ioannis , Stavropoulou Elisavet , Stavropoulos Agathangelos , Bezirtzoglou Eugenia, Environmental and Health Impacts of Air Pollution: A Review, Frontiers in Public Health, 8, 2020, https://www.frontiersin.org/journals/public-health/articles/10.3389/fpubh.2020.00014

(19) Turner MC, Andersen ZJ, Baccarelli A, Diver WR, Gapstur SM, Pope CA 3rd, Prada D, Samet J, Thurston G, Cohen A. Outdoor air pollution and cancer: An overview of the current evidence and public health recommendations. CA Cancer J Clin. 2020 Aug 25:10.3322/caac.21632. doi: 10.3322/caac.21632. Epub ahead of print. PMID: 32964460; PMCID: PMC7904962. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7904962/

(20) https://unece.org/international-cooperation

(21) https://www.eea.europa.eu/publications/air-quality-in-europe-2020-report
(22) https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html
(23) Brauer M, Freedman G, Frostad J, van Donkelaar A, Martin RV, Dentener F, van Dingenen R, Estep K, Amini H, Apte JS, Balakrishnan K, Barregard L, Broday D, Feigin V, Ghosh S, Hopke PK, Knibbs LD, Kokubo Y, Liu Y, Ma S, Morawska L, Sangrador JL, Shaddick G, Anderson HR, Vos T, Forouzanfar MH, Burnett RT, Cohen A. Ambient Air Pollution Exposure Estimation for the Global Burden of Disease 2013. Environ Sci Technol. 2016 Jan 5;50(1):79-88. doi: 10.1021/acs.est.5b03709. Epub 2015 Dec 4. PMID: 26595236.
(24) https://www.un.org/en/about-us
(25) https://sdgs.un.org/goals
(26) https://unstats.un.org/wiki/display/SDGeHandbook/Indicator+11.6.2
(27) https://eur-lex.europa.eu/EN/legal-content/summary/cleaner-air-for-europe.html
(28) https://www.eea.europa.eu/en/about/who-we-are
(29) https://ec.europa.eu/eurostat/web/main/about-us/who-we-are
(30) https://www.c40knowledgehub.org/s/article/WHO-Air-Quality-Guidelines?language=en_US
(31) https://environment.ec.europa.eu/topics/air/air-quality/eu-air-quality-standards_en
(32) Gavin Shaddicki , Matthew L. Thomasi , Amelia Joblingi , Michael Brauerii, Aaron van Donkelaariii, Rick Burnettiv, Howard H. Changv , Aaron Cohenvi, Rita Van Dingenenvii, Carlos Doraviii, Sophie Gumyviii, Yang Liuix, Randall Martiniii, Lance A. Wallerv , Jason Westx , James V. Zidekxi and Annette Prüss-Ustünvii, Data Integration Model for Air Quality: A Hierarchical Approach to the Global Estimation of Exposures to Ambient Air Pollution, 2016, 1609.00141 (arxiv.org)
(33) https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Urban_centre
(34) https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Functional_urban_area
(35)https://dd.eionet.europa.eu/vocabularyconcept/aq/zonetype/agg/view?facet=HTML+Representation
(36) https://unstats.un.org/wiki/display/SDGeHandbook/Indicator+11.6.2
(37) https://ec.europa.eu/eurostat/statistics-explained/index.php?title=SDG_11_-_Sustainable_cities_and_communities&oldid=567291
(38) (ec.europa.eu/eurostat/cache/metadata/en/sdg_11_50_esmsip2.htm)
(39) http://www.era-planet.eu/index.php/the-projects
(40) https://smurbs.eu/solutions/sdg11-6-2/

(41) Airaghi, D.; Corbane, C.; Ehrlich, D.; Florczyk, A.J.; Freire, S.; Kemper, T.; Maffenini, M.; Melchiorri, M.; Pesaresi, M.; Politis, P., Description of the GHS Urban Centre Database 2015: Public Release 2019: Version 1.0; Publications Office of the European Union:Luxembourg, 2019; ISBN 9789279997532

(42) https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Territorial_typologies_manual_-_degree_of_urbanisation

(43) Dijkstra, L.; Poelman, H.; Veneri, P. The EU-OECD Definition of a Functional Urban Area; OECD Publishing: Paris, France, 2019.

(44) https://land.copernicus.eu/en

(45) https://atmosphere.copernicus.eu/regional-air-quality-production-systems

(46) http://apcg.meteo.noa.gr/sdg1162/

(47) Jennifer Bailey, Orestis Speyer, Evangelos Gerasopoulos, et al. Insights and Policy Implications from a Harmonized Earth Observation Approach to Urban Air Quality. ESS Open Archive. January 24, 2020. DOI: 10.1002/essoar.10502027.1

(48) https://researchbasics.education.uconn.edu/t-test/

(49) https://docs.oracle.com/en/cloud/saas/planning-budgeting-cloud/pfusu/insights_metrics_RPD.html

(50) https://www.oracle.com/webfolder/technetwork/data-quality/edqhelp/content/processor_library/matching/comparisons/absolute_difference.htm

(51) Up-to-date air quality data — European Environment Agency (europa.eu)