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Evaluation of the status of natural resources in the updated Reference Configuration 2014 of the LUISA modelling platform

Methodological framework and preliminary considerations

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Abstract

The impacts of current and planned policy initiatives can be simulated by using modelling tools and indicators, which help determine the effectiveness of policies in attaining targets. The Land Use-based Integrated Sustainability Assessment (LUISA) modelling platform was configured to assess the spatial impact of the "EU Energy Reference scenario 2013" on the efficient use of natural resources in the EU-28 in a short time period (2010-2020) and in a long term vision (2010-2050). A set of Resource Efficiency (RE) indicators were computed to measure [1] the progress towards the efficient use of land and water as a resource and [2] the performance on the actions and milestones on natural capital and ecosystems proposed in the RE roadmap, in particular biodiversity, safeguarding clean air, and land and soils. The modelling results show that by 2050: [1] the share of built-up area in the EU-28 will increase by 1%; [2] the EU-28 will use the land less efficiently; [3] the water productivity is expected to increase on average 8%; [4] the landscape fragmentation in the EU-28 will show no significant changes [5] and the PM10 concentrations in urban air and population exposed will remain constant.

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1. Introduction

Natural capital is often undervalued and mismanaged. Even if natural assets are priced in markets, their scarcity may not be fully reflected in the value of goods and services arising from their exploitation. There is a need to identify methods for measuring the efficiency of resource use, which in turn will provide opportunities for both the economy and human well-being (Organisation for Economic Cooperation and Development, 2011).

To analyse the impact of the current policies on the natural resources, a thorough impact assessment should be performed. The impacts of current and planned policy initiatives can be simulated by using modelling tools and indicators, which help determine the effectiveness of policies in attaining targets. The methodological framework reported here relies on an integrated modelling approach based on LUISA (the 'Land Use-based Integrated Sustainability Assessment' modelling platform). LUISA is a land-function model developed by JRC and primarily used for the ex-ante evaluation of EC policies that have a territorial impact.

This report presents the assessment of the use of land-based natural resources in Europe, according to a simulated scenario in a short time period (2010-2020) and in a long term vision (2010-2050). For this purpose, a set of indicators have been modelled through the LUISA platform to evaluate the use of natural resources in the EU-28 up to 2050 according to an EU Reference Scenario 2014 (Baranzelli et al., 2014).

This report describes the methodology and preliminary results relevant for the evaluation of the natural resources in Europe, using indicators such as share of the built-up areas, water productivity, landscape fragmentation and urban population exposure to air pollutants, calculated for the entire EU-28 domain.

2. Methodology

2.1 Land Use-based Integrated Sustainability Impact Assessment platform (LUISA)

The Land Use-based Integrated Sustainability Impact Assessment platform (LUISA) was developed by the JRC to produce a comprehensive modelling framework to assess the impact of environmental, socio-economic and policy changes in Europe. For the exercise herein, LUISA was configured in compliancy with the "EU Energy, Transport and

GHG emission trends until 2050 – Reference Scenario 2013"[1] (EU Reference Scenario 2013 hereinafter), derived from an earlier implementation (Lavalle et al., 2013). Within the scope of the present report, this new scenario configuration in LUISA is referred to as the Updated Reference Scenario (or EU Reference Scenario 2014), assuming the most likely socio-economic trends and 'business-as-usual' dynamics (i.e. as observed in the recent past). It includes the Cohesion Policy's current legislation (regional and infrastructural investments at regional scale), CAP related measures, biodiversity and habitat protection. According to the EU Reference scenario 2014, the urban area is driven by demographic projections given by EUROPOP from Eurostat and the tourism projections from United Nations World Tourism Organization (UNWTO). The industrial and commercial sectors are driven primarily by the growth of different economic sectors as projected by Directorate-General for Economic and Financial Affairs of the European Commission (DG ECFIN). The economic and demographic assumptions were taken from the Ageing Report 2012 (European Commission/ DG Economic and Financial Affairs, 2011). A detailed description of the EU Reference Scenario 2014 is presented in (Baranzelli et al., 2014)

LUISA is structured in three main modules: the 'demand module', the 'land use allocation module' and 'the indicator module' (Lavalle et al., 2011; Batista e Silva et al., 2013). The demand module takes into account the sector specific land requirements. In this module sector specific models and the historical land use data are used to report the proportion of additional land expected to be required for any given sector and year: agriculture, urban area, industrial/commercial area and forest. The allocation module spatially distributes the regional land use demands to 100m pixel resolution considering bio-physical characteristics, neighborhood factors, the competition for land and policy-based restrictions. The main final output of the allocation module is a time series of yearly land use maps, from 2007 to 2050 at 100 m resolution for EU28. These land use maps in combination with other sector modelling tools which have been coupled with LUISA, allow the computation of a number of relevant indicators.

2.2 Indicators

In this study, the indicators used to assess the efficient use of natural resources in EU under the EU Reference Scenario 2014 were based on the resource efficiency (RE) Roadmap's approach to resource efficiency indicators[2]. The Eurostat RE scoreboard presents a set of 30 statistical indicators that aim to assess the progress towards a resource-efficient EU. The LUISA study aims to assess natural resources according to the EU Reference Scenario 2014 using 4 Resource Efficiency Scoreboards indicators and one additional indicator. The

[1] EU Energy, Transport and GHG Emissions – Trends to 2050 http://ec.europa.eu/energy/observatory/trends_2030/index_en
[2] Eurostat Resource Efficiency scoreboard - http://ec.europa.eu/eurostat/web/environmental-data-centre-on-natural-resources/resource-efficiency-indicators/resource-efficiency-scoreboard

first set of indicators presented in the current report measures the progress towards the efficient use of **land and water as a resource** which corresponds to the dashboard of indicators. The second set of indicators presented in the current report measures the performance on the actions and milestones **on natural capital and ecosystems** proposed in the Resource Efficiency Roadmap (RERM), in particular Biodiversity, Safeguarding clean air and Land.

The indicators presented in this report were adapted to the LUISA framework. Therefore there are some differences with the methods described by Eurostat in the estimation of the indicators. Eurostat provides Resource Efficiency indicators based on official statistics as reported by the MSs, data sources being Eurostat, EEA, JRC and few others. LUISA relies on exogenous models for its input datasets, calibration and validation. The main output of the core model are projected land use maps which in combination with other sector modelling tools (e.g. water, soil) integrated in LUISA, allow the estimation of a set of indicators.In as far as possible the methodologies used in the current report were compliant with those used for the indicators published by Eurostat. However, projected data was used to forecast the indicators, and therefore the interpretation of the results should be made with caution, especially when comparing with the data reported by Eurostat. The reason for this is twofold. First, Eurostat reports observed data, while the indicators published here are obtained from a modelling exercise. Any differences between Eurostat indicators and the indicators reported here can furthermore be attributed to the reference data used to compute the indicators. For instance, Eurostat uses land use and cover data from LUCAS (Land Use and Cover Area frame Survey) to estimate the 'Built-up areas', whereas in this study the data used to estimate the same indicator is based on a refined version of CORINE Land Cover 2006 (CLC2006_r) (Batista e Silva, Lavalle, & Koomen, 2013). A major difference between the data sources is the definition of ‘Built-up areas’.

A detailed list of the indicators used in this study is presented in Table 1. The simulations of these indicators have been made using the LUISA modelling platform for the EU-28 operating at 100-meter resolution. Results are aggregated at national level for the years 2010, 2020 and 2050. The indicators are presented at Member State level, for the year 2010. All the milestones mentioned by the RERM refer to year 2020, while the 'vision' is for the year 2050. Therefore, the net changes for the proposed indicators are computed for a short term period (2010-2020), and for a long term period (2010-2050), which corresponds to the long term vision of the Roadmap.

The indicators and the related assessment methodology are described following the format proposed by the Europe Environmental Agency (EEA) for publishing indicators (European Environment Agency (EEA), 2014). A detailed factsheet for each indicator is available in the Annex B.

Table 1. List of indicators used to assess the efficient use of natural resources in EU according to the EU Reference Scenario 2014

Theme indicators	***Sub-theme***	***Indicator***	***Unit***
Dashboard	Land	Built-up areas as a share of total land	% of land area
		Built-up area per inhabitant	m^2 per person
	Water	Water productivity	EUR per m^3
	Biodiversity	Landscape fragmentation	Number of meshes per 1 000 km^2
Thematic	Safeguarding clean air	Urban population exposure to air pollution by particulate matter	Micrograms per cubic meter
		Urban population exposed to PM10 concentrations exceeding the daily limit value on more than 35 days in a year	% total of urban population

3. Analysis of the indicators

3.1 Dashboard indicators

3.1.1 Built-up areas

<u>*Indicators definition and units*</u>

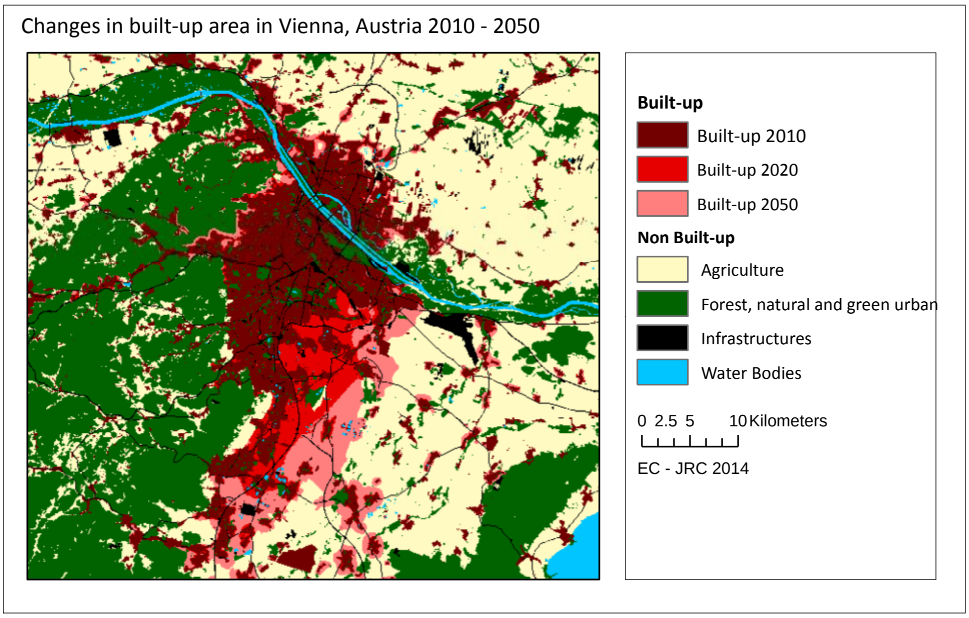
The **'built-up areas'** indicator measures a country's use of land for residential, green urban areas, economic activities, and the growth of these built-up areas over time (land take). It can be expressed as the share of built-up areas in the total land area. In this study the definition of the 'Built-up area' follows the CLC classification, including: the urban fabric (CLC 1.1), industrial / commercial areas (CLC 1.2.1) (excluding transport networks), green areas, sport and leisure facilities (CLC 1.4). This definition is different from the LUCAS dataset used by Eurostat[3].

The **'built-up area per inhabitant'** indicator is included in this study as an additional indicator to better measure the efficiency of built-up areas. This indicator measures the land consumption by comparing the size

[3] In LUCAS dataset the 'Built-up areas' consist of roofed constructions built for permanent purposes which can be entered by people. They include: i) roofed constructions with one to three floors or less than 10 meters of height in total; ii) roofed constructions with more than three floors or more than 10 meters of height in total and; iii) greenhouses. (Source Built-up areas indicator profile: http://ec.europa.eu/eurostat/cache/metadata/en/tsdnr510_esmsip.htm)

of built-up areas with the population expressed in m^2 per person. The lower the consumption of land the more efficient is the use of the built-up areas.

The surface coverage of built-up areas was estimated from the projected land use maps from LUISA framework, which are based on a refined version of CLC 2006 (CLC2006_r) at 100 meter resolution. An example of the modelling exercise output is presented in Figure 1 for Vienna, Austria. This map shows the



changes in built-up area over time: 2010, 2020 and 2050.

Figure 1. Illustration of the growth of built-up areas in Vienna according to the Reference scenario for the years 2010, 2020 and 2050.

Key messages

The land take might causes irreversible impacts on the ecosystems, contributing to the habitat loss and degradation and compromising biodiversity conservation. The coverage and changes in 'built-up areas' (i.e. land take) is a key indicator that reflects the human intervention in the environment. When contrasted with the population, the 'built-up area per inhabitant' provides more in-depth information on how efficiently the built-up areas have been used per person (European Commission, 2014). In Europe cities use land more efficiently and population density tends to decline the further away from the city center an area is located. This general trend can be reflected by the price of the land and its corresponding use varies according to the distance from the city center (European Commission, 2014). The closer to the city center where services and shops are concentrated, the higher the price of land and density of residential use.

In this study the 'built-up areas', 'built-up area per inhabitant' indicators are a useful tool to monitor the growth of the built-up areas and assess the efficient use of land in Europe from 2010 until 2050 according to the EU Reference Scenario 2014.

Policy context and policy questions

In the Resource Efficiency Roadmap (RERM), the 'built-up areas' indicator itself does not have a specific target goal. However, for the average annual land take indicator, which measures the net changes of the built-up areas in time in km^2, a 'no net land take by 2050' is proposed (EC, 2011a). Other strategic objectives related with built-up areas were reported by a few countries. For instance, in Germany growth in land use for housing, transport and related soil sealing should reduce by 30 ha per day by 2020 and in Switzerland the total built-up area should stabilize at 400 m^2 per head of population (EEA, 2011).

The 'built-up areas' and 'built-up area per inhabitant' aim to answer the following policy questions:

- By how much and in which proportions are built-up areas increasing in Europe?
- Is Europe using land more efficiently?

Key assessment

By 2050 the share of built-up area in the EU-28 will increase by 1% point.

In the EU Reference Scenario 2014, the ratio of the 'built-up areas' over the EU-28 surface was 4.4% in 2010. The scenario foresees an additional 0.2% points of built-up areas in the short term (2010-2020) and 0.7% points in the long term vision (2010-2050) as a consequence of the population increase and economic growth (Figure 2).

At member state level this trend shows significant differences. The countries with the greatest proportion of built-up areas in 2010 are Malta, Belgium and the Netherlands, where more than 14% of the country surface is covered by built-up land. On the other extreme, the countries with the lowest proportion of built-up areas (less than 1.5 %) are Finland and Sweden.

For 2010 to 2020 the largest growth of the share of built-up areas is foreseen in Malta, Belgium and Luxemburg (almost 2% points growth). In the long term (2010 - 2050), Belgium expects an exceptional growth up to 6.2% points, followed by Malta and Luxemburg (more than 5% points). In Luxemburg and Belgium this growth is likely to occur due to the foreseen population and economic growth. On the contrary, Malta expects to lose 4% population and still shows the highest increase in the share of built-up area. Indeed the absolute growth of built-up area between 2010 and 2050 is very low (<20 km^2). However given the little size of the country (only 315 km^2), in relative terms a small growth of the built-up area has a strong effect in the indicator. In contrast Latvia, Bulgaria and Croatia expect to lose population in a short and long term, which is reflected in the smallest amount of growth of built-up area share (<0.1% points) between 2010 and 2050.

Member States	Share of Built-up areas (% of total land) 2010	2020	2050	Changes (% points) 2010-2020	2010-2050
Finland	1.2	1.3	1.4	0.1	0.2
Sweden	1.4	1.6	1.9	0.2	0.5
Latvia	1.7	1.7	1.7	0.0	0.0
Greece	1.7	1.8	2.0	0.1	0.2
Estonia	1.8	1.9	2.0	0.1	0.2
Spain	2.0	2.1	2.5	0.1	0.5
Ireland	2.9	3.1	4.0	0.2	1.1
Croatia	3.3	3.4	3.5	0.0	0.1
Slovenia	3.4	3.6	4.0	0.3	0.6
Lithuania	3.5	3.6	3.7	0.1	0.3
Portugal	4.0	4.1	4.5	0.1	0.5
Bulgaria	4.5	4.5	4.5	0.0	0.1
Austria	4.5	4.7	5.4	0.2	0.8
Poland	4.6	4.9	5.2	0.3	0.6
France	4.7	5.0	5.7	0.3	1.0
Romania	4.7	5.0	5.3	0.2	0.5
Italy	5.4	5.6	6.4	0.3	1.0
Slovakia	5.5	6.0	6.7	0.5	1.2
Hungary	6.2	6.4	6.7	0.1	0.5
Czech Republic	6.7	7.2	7.8	0.5	1.1
Cyprus	7.2	8.1	10.0	0.9	2.9
United Kingdom	8.0	8.6	10.0	0.6	2.0
Denmark	8.1	8.4	9.2	0.3	1.1
Germany	9.0	9.2	9.2	0.1	0.2
Luxemburg	9.1	10.8	14.2	1.7	5.1
Netherlands	14.8	15.5	16.7	0.8	2.0
Belgium	18.4	20.1	24.6	1.7	6.2
Malta	25.4	27.1	30.8	1.7	5.5
EU-28	4.4	4.6	5.1	0.2	0.7

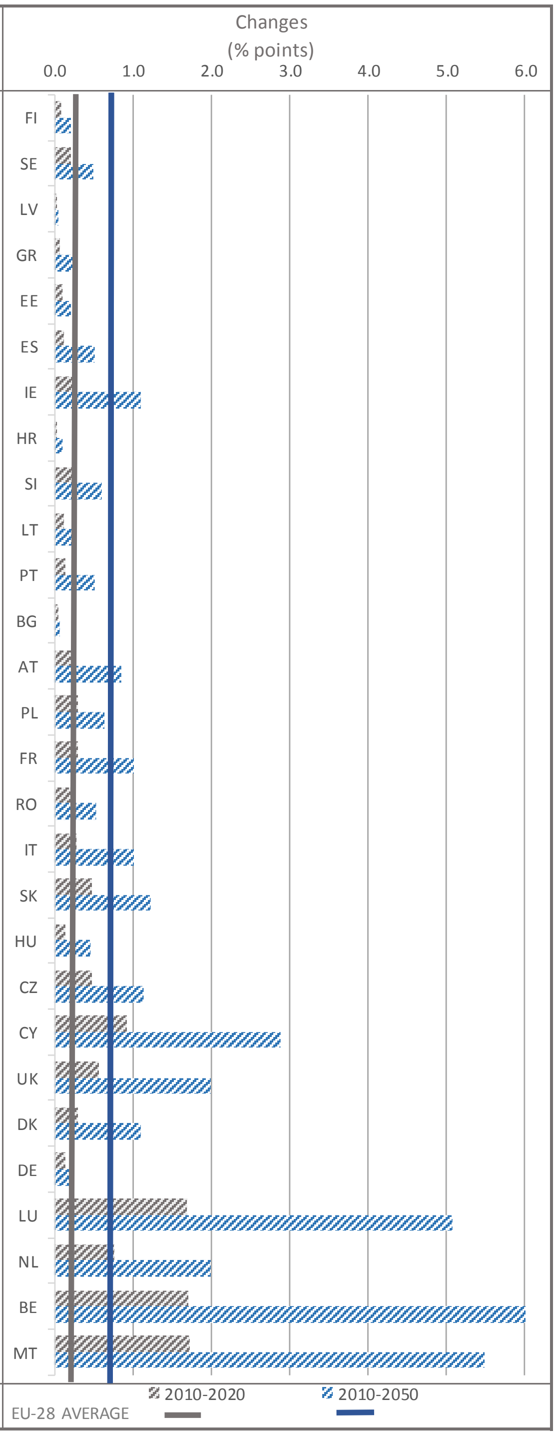


Figure 2.Share of the built-up areas in 2010 and relative changes of the built-up areas in a short term period (2010 -2020) and long term vision (2010-2050), for the 28 EU Member States.

By 2050 the EU-28 will use the land less efficiently

In EU-28, the available built-up area per person was on average 391 m^2 in 2010 (Figure 3). In 2020, the amount of land consumed per person forecasted by the model is expected to increase in the EU-28 by 3% in the short term period and 12% in the long term. According to the modelling results there are clearly different patterns of land use intensity throughout Europe. The amount of land consumed per person in 2010 is lower in Malta, Greece and Spain (less than 300 m^2 per person). In contrast, the highest amount of land consumed per person are in Cyprus (824 m^2 per person) followed by the Scandinavian countries and Bulgaria (more than 600 m^2 per person).

The majority of Member States show an increase in the amount of land consumed per inhabitant, meaning that land use efficiency is declining. In the short and long time period the largest increase of land consumption is foreseen to occur in Bulgaria, Romania, Latvia and Lithuania. In those countries the land efficiency is foreseen to decrease due to the faster pace of growth of built-up areas while those countries are depopulating. The higher consumption of land can be explained by the need for more space per person, the development of commercial areas and transport services, preference for single houses over blocks of flats and the influence of land use policies, either towards compact or sprawled cities (Kasanko et al., 2006). In Ireland and the United Kingdom the changes in land use intensity are very low, meaning that the demand for new built-up area follows the same pace as the population growth.

Member States	Buil-up area per inhabitant (m² / pp) 2010	2020	2050	Changes (%) 2010-2020	2010-2050
Malta	194	206	245	6	27
Greece	203	207	226	2	11
Spain	227	232	250	2	10
Italy	267	270	291	1	9
United Kingdom	315	316	320	0	1
Netherlands	316	320	343	1	8
Slovenia	335	344	381	3	14
Portugal	361	369	407	2	13
Poland	375	397	472	6	26
Germany	394	408	466	4	18
Croatia	441	456	518	3	18
Austria	452	463	501	2	11
Ireland	454	453	451	0	-1
France	466	473	500	2	7
Luxemburg	470	488	523	4	11
Latvia	474	507	611	7	29
Slovakia	497	525	619	6	25
Czech Republic	504	524	580	4	15
Belgium	520	532	575	2	11
Romania	525	564	679	7	29
Hungary	577	597	677	3	17
Estonia	600	645	741	7	23
Denmark	632	635	658	0	4
Bulgaria	658	707	856	7	30
Sweden	668	710	755	6	13
Lithuania	674	730	865	8	28
Finland	773	790	845	2	9
Cyprus	824	843	851	2	3
EU-28	391	402	436	3	12

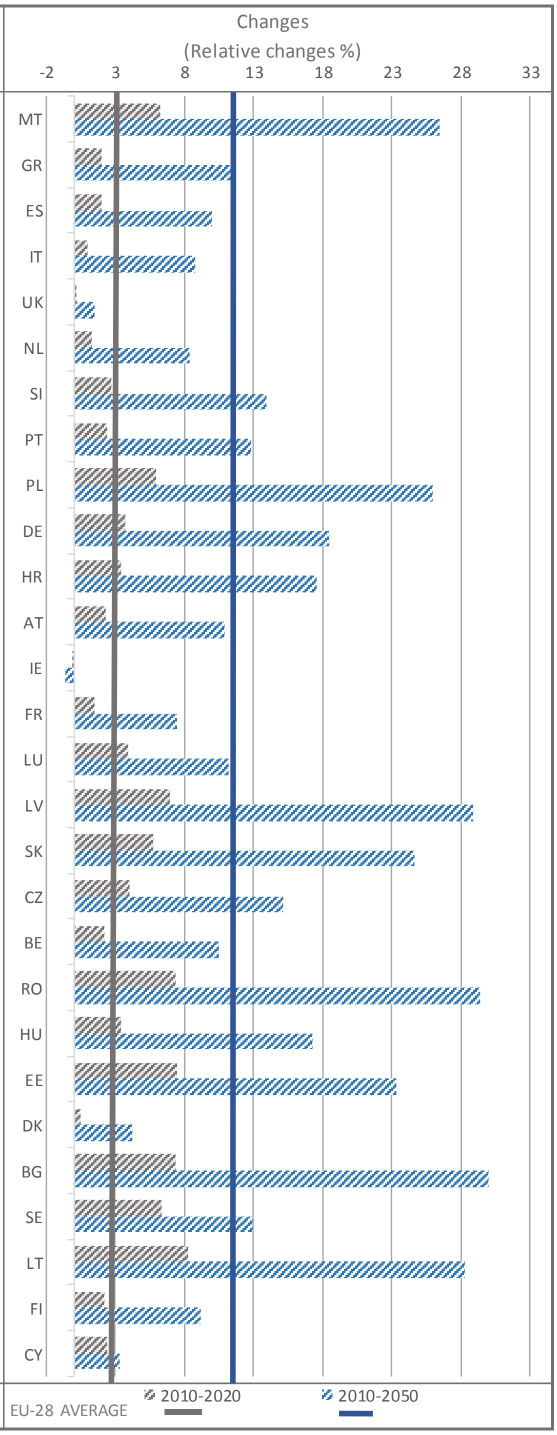


Figure 3. Built-up area per inhabitant in sq. meters per inhabitants in 2010 and relative changes in a short term period (2010 -2020) and long term vision (2010-2050), for the 28 EU Member States.

3.1.2 Water productivity

Indicator definition and units

'Water productivity' is a measure of the monetary value produced by a country per unit of water used. It is essentially the country total annual GDP (GEM-E3 model - National Technical University of Athens, 2010) divided by the total annual freshwater use for all sectors. The higher the value of the indicator, the higher the productivity.

The total annual freshwater use was calculated for the base year 2006 and forecasted to 2010, 2020 and 2050 using the Water Use Model (Vandecasteele et al., 2013; Vandecasteele et al., 2014). The model quantifies water use in the public, industry, energy (cooling water), irrigation, and livestock sectors. Country-level aggregated statistics on water use per sector were derived from Eurostat and verified with the FAO AQUASTAT dataset. These values were disaggregated using proxy data (mostly land use) to produce sectoral water use maps up to 100m resolution. The total country-level sectoral water use is forecasted based on additional proxy data specific to each sector, including, amongst others, population growth, industrial productivity, and energy consumption.

The GDP disaggregated per region is divided by the total water used in all sectors to give the final indicator, which is presented here at country level, in GDP Million euros (volumes in constant prices of year 2010) per m^3 of water used. As presented in the RE Scoreboards Indicators ideally the GDP should be expressed in Purchasing Power Standard (PPS) because this eliminates differences in price levels between countries and enables comparison of water productivity between countries during one time period. However, the projected GDP from GEM-E3 is expressed in Million EUR and the GDP in PPS at market prices is not available in projections. Therefore the results are not meaningful when comparing the Member States water productivity.

Key messages

Water is used as an input to almost all steps involved in the production of goods and services - it is used across all sectors of human activity. The more efficiently this often scarce resource can be used, the better for both the environment and for our own wellbeing.

Policy context and policy questions to be addressed

'Water productivity' has been chosen as a dashboard indicator for water and presented in the Resource Efficiency Scoreboard, for assessing progress towards the objectives and targets of the Europe 2020 flagship initiative on Resource Efficiency.

The indicator aims at answering the following policy question:

• How efficiently is water used for productive purposes?

A target value to be achieved has as yet not been given. This said, it is evident that policy should be directed towards improving both the efficiency of water use for production, and reducing the amount of water lost in distribution. Investment in improved technology for the treatment and recycling of water should also be promoted.

Key assessment

Water productivity is expected to increase on average 8% by 2050

Figure 4 shows the indicator value as calculated for 2010, and the relative changes expected up to 2020 and 2050 for each country. The European average water productivity is 53 Euro/m^3, which is expected to increase by 2% in the short term (2020), and 8% in the long term (2050). There is a high amount of variation in both the absolute values of the indicator and the expected changes over time between countries. Luxembourg has the highest calculated water productivity (662 Euro/m^3), followed closely by Finland and Denmark. Countries at the other end of the spectrum include France (5.4 Euro/m^3), Bulgaria and Spain.

All countries show improvements in the indicator in the long term, with only Spain and Hungary showing some small decreases in the indicator in the short term projections. This effectively means that all countries show positive economic growth over this timeframe, the countries with greatest improvements also have a stabilization or even slight reduction in the total amount of water used.

In the interpretation of these results it is, however important to note that it would be advisable to make a sector-based assessment, rather than calculate the total water productivity. For example, irrigation water use is very high in Southern countries such as France and Spain, meaning they have very low overall water productivities here, whereas they may actually be performing quite well in other sectors (such as industrial productivity).

To date climate change aspects have not been taken into account in computing the water productivity indicator. The methodology used to determine future water use remains under constant development, though, with climatic variation being an important next factor to integrate. The model will be adapted to take into account variations in water availability over time by imposing a maximum threshold of water which can be withdrawn during periods of water scarcity. For the time being, however, we assume that there are no limitations on the amount of water available, and that all water requirements can be met. This means that there may be some overestimations in actual water use in areas which do experience restricted water availability over time.

	Water Productivity (mn EUR/m^3)			Changes (%)	
Member States	2010	2020	2050	2010-2020	2010-2050
France	5	6	9	17	71
Bulgaria	6	7	8	12	22
Spain	7	6	8	-2	27
Estonia	12	15	17	19	38
Lithuania	13	14	16	11	24
Hungary	19	19	21	-3	7
Portugal	20	21	31	4	57
Romania	22	25	28	16	27
Poland	35	42	45	18	28
Slovenia	38	42	49	9	28
Italy	41	44	60	8	48
Netherlands	54	62	84	15	57
Belgium	55	63	96	15	75
Latvia	77	100	142	31	86
Cyprus	77	88	151	14	94
Croatia	79	96	132	21	66
Germany	82	92	101	12	23
Austria	84	97	116	16	38
Slovakia	85	93	118	9	38
Czech Republic	91	101	131	11	44
Sweden	140	171	262	23	88
Ierland	172	210	368	22	114
United Kingdom	178	214	349	21	96
Malta	185	215	344	16	86
Greece	199	233	359	17	80
Denmark	319	368	565	16	77
Finland	642	795	1225	24	91
Luxembourg	662	819	1194	24	80
EU-28	53	54	57	2	8

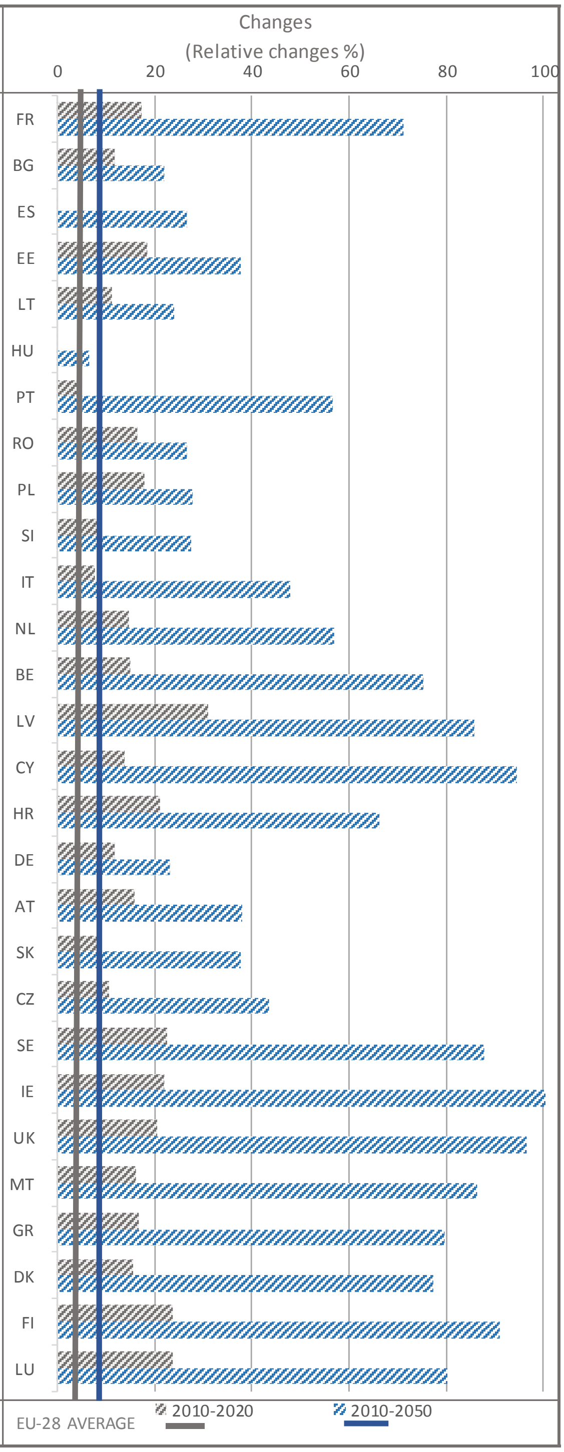


Figure 4. Water Productivity in million EUR per m3 in 2010 and relative changes in the time period 2010 -2020 and 2010-2050 for the 28 EU Member States.

Figure 5 shows the changes in the indicator between 2010 and 2050 for Paris, France. There is an overall decrease of productivity within the city, with the largest decreases on the outskirts of the city, probably due to increasing water withdrawals in new industrial areas. There are also several areas outside the city that show an increase in water productivity, meaning that the increase in GDP between the 2 time periods is greater than the increase in water withdrawals, or even that there may be a reduction of water withdrawals. Areas where no change in the indicator is seen are mostly infrastructure, where no change in water use is modelled.

Again, it should be noted that these results should be interpreted with care, especially since the GDP data used was at country-level and disaggregated at regional level. For a more accurate comparison at the pixel level GDP data should be used at least at regional if not city-level.

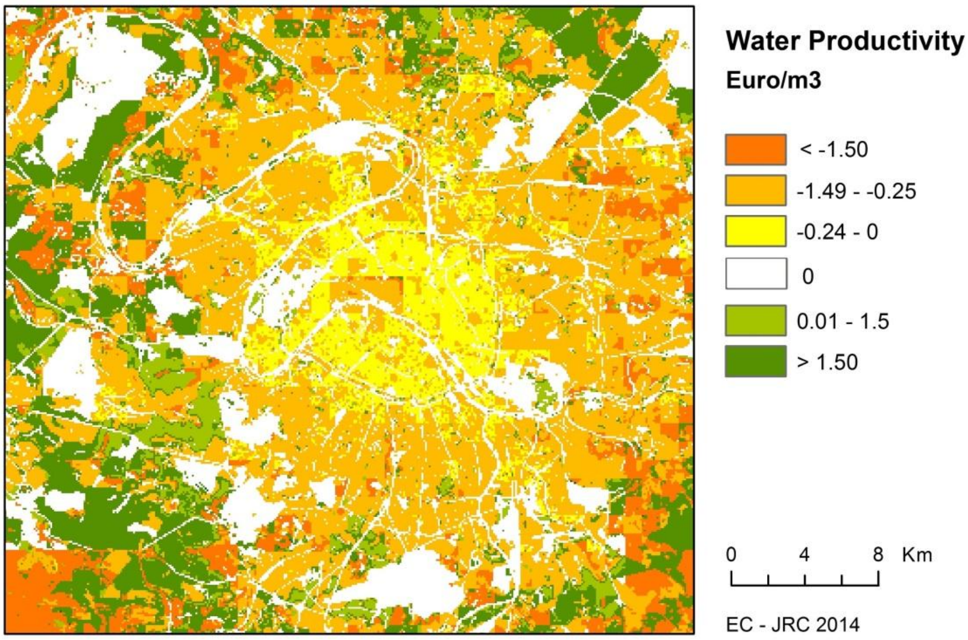


Figure 5. Detail of the change in Water Productivity in EUR per m^3 between 2010 and 2050 for Paris, France.

3.2 Thematic indicators

3.2.1 Landscape Fragmentation

Indicator definition and units

The indicator of **'Landscape fragmentation'** presented here reflects the degree to which species movements between different parts of the landscape are interrupted by barriers. The more barriers fragmenting the landscape, the more difficult will be the species movement through the landscape.

In this sense, all natural and semi-natural habitats (including farmlands with high natural value, see Annex B for further details) were considered as element of interest in the landscape, since all of them may provide habitat for some species. On the other hand, motorways, national roads, urban fabric, industry/commercial uses, infrastructures and intensive agriculture were considered as land uses contributing to break up Europe's landscapes into smaller pieces. These last land uses are contributing to the habitat loss for many species and constraining the species movement throughout the landscape acting as barriers. The **'Landscape fragmentation'** is measured by the effective mesh density ($S_{eff)}$ and includes the so-called 'cross-boundary connections' procedure that eliminates the bias arising from the patches shared by two or more reporting units (i.e. administrative boundaries) (Jaeger, 2000; Moser, Jaeger, Tappeiner, Tasser, & Eiselt, 2007; Jaeger & Madrinan, 2011). It is expressed in the number of meshes per 1,000 km^2 - the more fragmented is the landscape, the higher the number of meshes a given region will have per unit area.

Key Messages

Landscape fragmentation is the result of the transformation of large habitat patches into smaller and more isolated fragments. The fragmentation of natural and semi-natural landscapes due to the spread of artificial areas, expanding transport network and intensive agricultural practices is a general trend across Europe, reducing the integrity of terrestrial ecosystems (Jaeger & Madrinan, 2011). Ecosystems getting their extent reduced and more isolated become less able to support biodiversity in the long term compromising the achievement of the 2020 Biodiversity target. In addition, the ecosystem fragmentation will also decrease their resilience to environmental changes, an issue of special concern under a global climate change context.

In this sense, the 'landscape fragmentation' indicator is a useful tool to monitor and assess this pressure on ecosystems, spatially (in the EU territory) and temporally (under LUISA scenarios).

Policy context and policy questions to be addressed

The indicator of 'Landscape fragmentation' has been included in the Resource Efficiency Scoreboard as an indicator for assessing the progress towards the objectives of the Roadmap to a Resource Efficient Europe.

The importance of landscape fragmentation was also reflected in the 5th 'Aichi Biodiversity Target', stating that '*by* 2020, the rate of loss of all natural habitats, (...), is at least halved, (...), and degradation and fragmentation is significantly reduced' (United Nations Environment Programme, 2010).

The landscape fragmentation indicator aims to answer the following policy questions:

- To what extent are natural and semi-natural lands fragmented in EU-28?
- How may landscape fragmentation change under future scenarios in response to urban and industrial sprawl and agricultural intensification?

Key assessment

By 2050, the negative trends of landscape fragmentation in some regions of Europe are practically compensated with positive changes in others

On average in the EU-28, landscape fragmentation is not expect to change significantly, neither in the short term (between 2010 and 2020) or in the long term (till 2050). However, this general pattern of landscape fragmentation at European level shows important variability among member states (Figure 6), as a consequence of the different patterns of urban sprawl and agricultural intensification.

In the base year 2010, the countries with the largest fragmentation indices are Malta, Denmark, The Netherlands and Luxembourg. While in Malta the main barriers are shaped by intensive agriculture, in the other countries the main barriers are artificial land uses (urban and services and industrial) and roads. At the other extreme, Sweden, Finland and Bulgaria are the countries with the lowest landscape fragmentation given the limited presence of elements acting as barriers for species movement in these countries (Figure 6).

The simulated scenario shows 6 countries undergoing a decrease in landscape fragmentation for both the long and short term, especially notable in Luxembourg. However, in spite of this large reduction of landscape fragmentation in this country, Luxembourg will still be among the most fragmented in Europe, most likely due to the exceptional urban development.

On the other hand, 15 countries show an increase of the landscape fragmentation for both time periods analysed. Malta, Latvia and Estonia are the countries with the largest increases of landscape fragmentation, which may compromise the integrity of their terrestrial ecosystems in the future.

Member States	n. of meshes per 1,000 km² 2010	Changes (%) 2010-2020	Changes (%) 2010-2050
Malta	>150	1	23
Denmark	98.0	-2	-4
Netherlands	69.6	0	0
Luxembourg	52.2	-23	-42
Belgium	17.6	0	1
Germany	11.2	1	0
Lithuania	9.2	9	0
Ireland	7.7	2	6
Hungary	5.7	3	4
Czech Republic	4.7	2	2
Croatia	3.8	-2	-1
Latvia	3.7	8	19
Poland	2.6	0	-7
France	2.5	-1	0
Estonia	2.3	9	25
Italy	1.9	-2	-4
Cyprus	1.8	-1	2
Slovakia	1.5	4	5
Romania	1.2	1	3
Slovenia	1.2	1	1
United Kingdom	1.2	0	0
Austria	1.2	0	1
Portugal	0.8	-7	1
Spain	0.8	-1	2
Greece	0.6	-3	-4
Bulgaria	0.5	1	-1
Finland	0.2	0	2
Sweden	0.1	-3	2
EU-28	0.5	-2	2

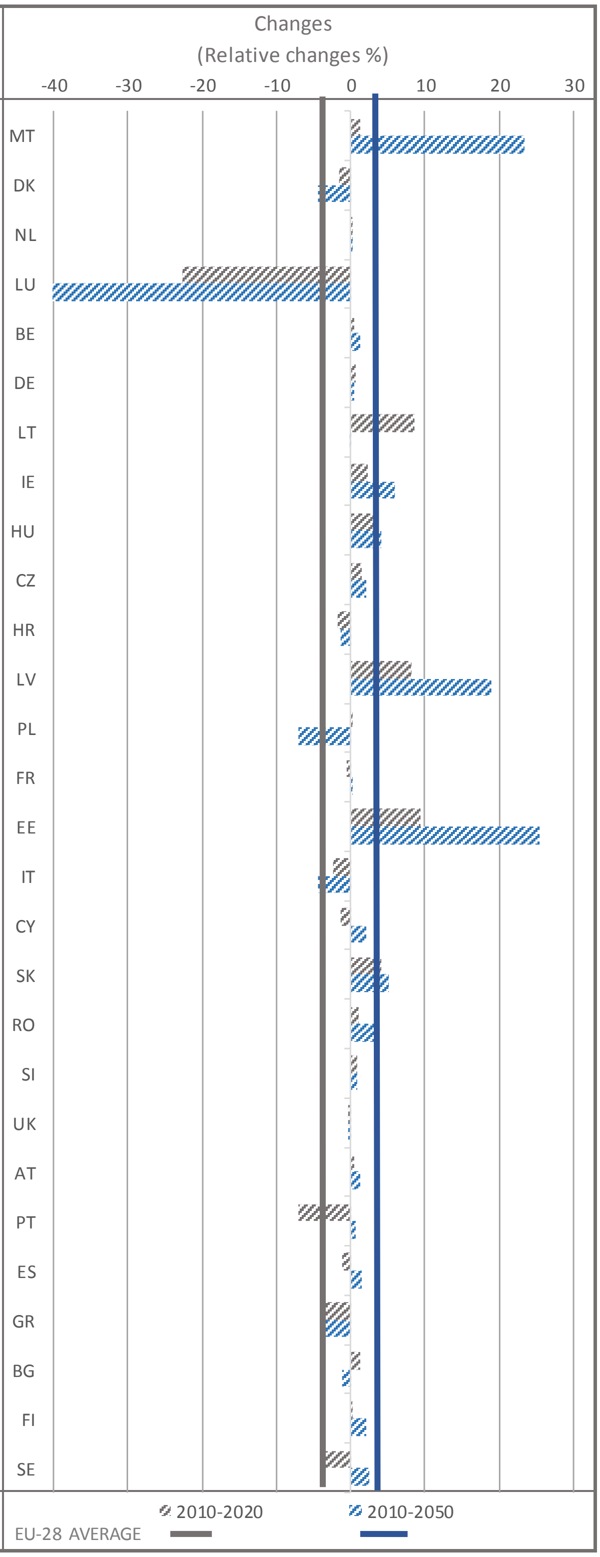


Figure 6. Effective mesh density in 2010 at Member State level and changes in the medium (2010-2020) and long term (2020-2050)

Causes behind changes in landscape fragmentation are very different among regions given the complexity of land use changes. In general, increase of the landscape fragmentation arises from a reduction in habitat extent (i.e. conversion of forest into new energy crops). However, the effective mesh density also captures the way different land uses are configured to shape the landscape. For instance, small patches of new energy crops embedded in a forest area would result in higher fragmentation than two big patches of energy crops and forest with the same extent than in the previous example. This was the case in Lithuania, where landscape fragmentation increase in the short term because of the expansion of new energy crops into natural habitats (transitional woodland shrub and forest) and this fragmentation is compensated in the long term by changes in the spatial configuration of coexisting land uses showing more homogeneous patches of natural habitats. Opposing trends in landscape fragmentation in the short- and long term can also be found in Portugal. In this country, the abandonment of agricultural areas in the short term give rise to the formation of natural land and forests yielding decreases in landscape fragmentation. However, this trend in the long term is inverted by the large increase of built-up areas taking place in the long term around the largest cities.

Figure 7 shows an illustration on how the landscape fragmentation will have decreased between 2010 and 2050 in Luxembourg. The conversion of intensive arable land and intensive pastures to natural land and transitional woodland have favoured the decrease of landscape fragmentation, given rise to an increase in habitat extent and therefore, a decrease of landscape fragmentation.

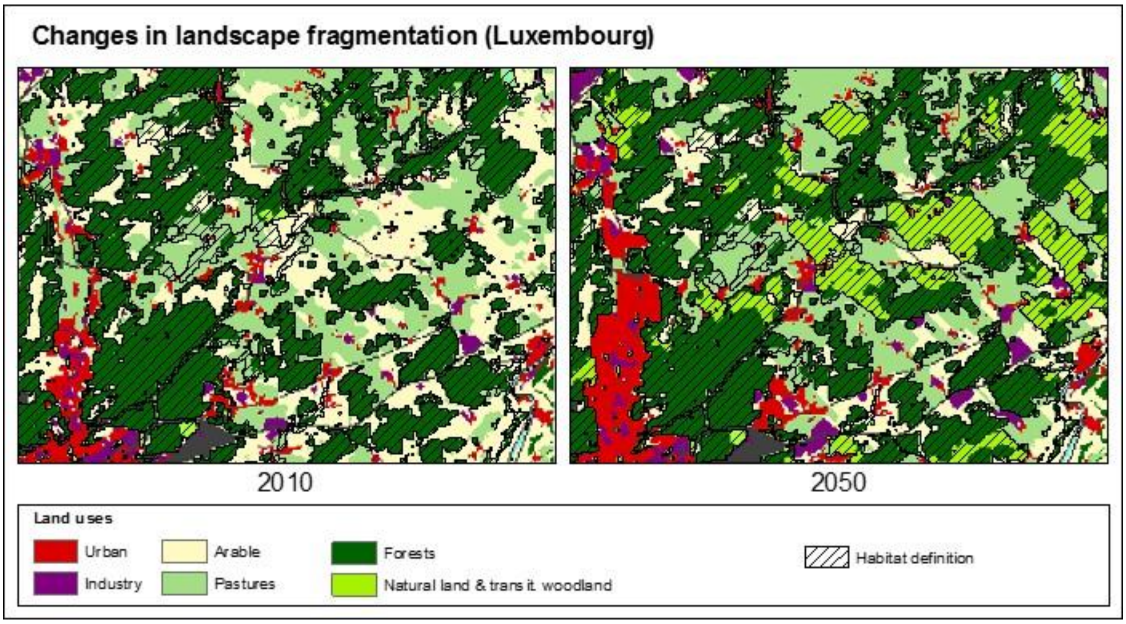


Figure 7. Illustration of the differences in landscape fragmentation between 2010 and 2050 in Luxemburg according to the simulated land use scenarios

In addition, urban and industrial sprawl, especially evident when comparing the bottom left corner in Figure 7 is taking place in areas classified as intensive agriculture in 2010. Therefore, the habitat extent and its fragmentation does not undergo any change in this region because both land uses, intensive agriculture in 2010 and urban area in 2050, are considered as barriers for the species movement. In this sense, the 'Effective mesh density' is not able to discriminate the differences of the barrier effect between the analyzed land uses (see 'Uncertainties' section in the Annex B).

3.2.2 Urban population exposed to air pollution

Indicator definition and units

The **Urban population exposure to air pollution by particulate matter** indicator shows the population-weighted annual mean concentration of PM10 in urban areas, expressed in $\mu g/m^3$. PM10 are fine particles whose diameters are less than 10 micrometers, and that can be carried deep into the lungs where they can cause inflammation and a worsening of the condition of people with heart and lung diseases. When considered at the local scale, this indicator provides information on how the population is affected by PM10 concentrations according to their spatial distribution. At national scale, this indicator provides information on the evolution over time of total urban concentrations of PM10 for each country.

The **urban population exposed to PM10 concentrations exceeding the daily limit value on more than 35 days in a year** measures the percentage of the population in urban areas exposed to PM10 concentrations exceeding the daily limit value (50 µg/m3) established by the Air Quality Directive (2008/50/EC) on more than 35 days in a calendar year. The indicator presents the percentage of population living in urban areas where the daily limit is exceeded for 0 days, 1-7 days, 8-35 days and more than 35 days per year.

The exposure to PM10 pollution is estimated based on the PM10 annual mean concentration maps at European scale for urban areas. These maps are derived from Land Use Regression (LUR) models built with the available monitored data and several model predictor variables defined within a Geographic Information System (GIS). Monitoring station data were retrieved from the AIRBASE database for the baseline year 2010. The predictor variables included five major categories: climatic variables, physic-geographical variables, land use characteristics, population density and transportation systems. In order to forecast the indicator, projected maps of land use characteristics and population density from the LUISA framework were used; the rest of the predictor variables were assumed to remain invariant over time.

The results of the evaluation of both safeguard-clean air indicators were exposure scenarios based on monitored data for 2010, and predicted exposure for the short (2020) and long-term (2050) scenarios.

Key Messages

The high density of population and economic activities in urban areas results in increased emissions, ambient concentrations, and exposure to air pollutants. In particular, PM10 exposure is the main component responsible for health problems due to air pollution: chronic exposure to PM contributes to the risk of developing cardiovascular and respiratory diseases, as well as lung cancer. In urban areas, important local sources of particulate matter include vehicle exhausts, road dust re-suspension, and the burning of wood, fuel or coal for domestic heating. As these are all low emitters, below 20 meters, they lead to significant impacts on the concentration levels close to ground within urban areas.

The evaluation of results derived from both safeguard-clean air indicators, are useful tools to monitor the amount of people exposed to levels over the established limit and to spot areas where more people are affected by higher annual levels of PM10 concentrations. It also explains how changes in land use and redistribution of people over time according to efficient use of the land in Europe from 2010 until 2050 will affect urban air quality levels.

Policy context and policy questions to the addressed

Both indicators have been included in the Resource Efficiency Scoreboard as indicators for the assessment of the progress towards the objectives of the Roadmap to a Resource Efficient Europe.

The indicator 'Urban population exposure to air pollution by particulate matter' is also included in the EU Sustainable Development Indicators (SDI).[4] It has been chosen for the assessment of the progress towards the objectives and targets of the EU Sustainable Development Strategy.

The EU Air Quality Directive (2008/50/EC) have set forth legally binding limit values for ground- level concentrations of PM10, for daily and annual exposure: the short-term limit establishes a limit value on daily mean concentrations of 50 µg/m3 not to be exceeded more than 35 times per year. The long-term objective establishes a limit on annual mean concentrations on 20µg/m3. The annual target limit is more easily attained and for this reason, an indicator based on the more restrictive daily mean concentrations provides more information on real achievements to improve air quality levels.

[4] Sustainable Development Indicators: http://ec.europa.eu/eurostat/web/sdi/indicators/public-health

The two indicators aim to answer the following policy question:

• What progress is being made towards the targets for reducing the concentration of particulate matter smaller than 10 micrometers in urban areas?

Key assessment

As presented in Figure 8 and Figure 9, on average in the EU-28, the modeling projects that urban population exposure and population exposed to PM10 concentrations will remain almost fix in the short or in the long term. Most of the countries will experience slight deterioration in both indicators, especially those countries where total built-up area is expected to increase and population within newly built-up areas will increase as well, as is the case of Slovakia, Romania and Bulgaria.

In most of the cases, both indicators tendencies have the same sign, meaning that both mean population weighted concentrations and population exposed to high concentrations, are increasing along time (Slovakia, Latvia, Luxemburg, Denmark) or decreasing (Finland, Cyprus, Ireland). Still some of the countries (Greece, Estonia) have opposite tendencies with less people exposed to values over the limit, but greater concentrations. Still in this case the total changes are so slight that can be ascribed to redistribution of population within cities.

It must be highlighted that the applied Land Use Regression (LUR) models do not consider country specific compliance with the Air quality legislation and information on trends on traffic flows as predictor variables of the model due to lack of information (see 'Uncertainties' section in the annex). Only land-use and population distribution changes were considered as variable along the time, and consequently predicted variations on air quality parameters can be attributed only to those reasons.

We selected two examples that illustrate the two indicators. The first example presented in Figure 10 represents the city of Milan. Besides the fact that total population within the city is expected to decrease according to projections (1.7 million inhabitants in 2010 and 1.3 million inhabitants in 2050), there will be also a net increase on total PM10 concentrations. On the other side, people within the city will redistribute with increasing population in the peripheral areas and less people living in the core of the city. As a result, the model predicts a net increase on the population weighted annual mean concentration indicator along the time, located in the areas where population will increase, and a slight or no reduction in areas where population will decrease or remain constant (city centre).

Member States	(µg/m3) 2010	Changes (%) 2010-2020	2010-2050
Slovakia	28.1	1.6	2.6
Poland	26.7	0.1	0.1
Czech Republic	25.4	0.5	0.4
Hungary	25.2	-1.7	-1.6
Romania	23.9	1.7	2.6
Bulgaria	23.4	1.8	1.9
Netherlands	23.2	0.2	0.4
Malta	22.7	0.4	2.0
Luxemburg	22.7	1.1	1.4
Cyprus	22.5	1.5	-1.3
Austria	22.4	0.0	-0.5
Spain	22.2	-0.1	0.0
Germany	22.2	0.5	0.4
Italy	22.0	0.7	1.0
Finland	22.0	0.4	-13.4
Latvia	22.0	1.4	1.2
Slovenia	21.9	1.2	1.5
Greece	21.9	0.6	0.8
Lithuania	21.9	1.2	0.8
Portugal	21.7	1.8	2.7
Belgium	21.1	0.2	0.2
Denmark	21.0	0.3	1.3
Sweden	20.7	0.3	0.1
Ireland	20.7	-0.2	0.1
United Kingdom	20.7	0.3	0.5
Estonia	20.1	0.8	0.7
France	19.2	0.2	14.9
Croatia	18.7	1.2	9.9
EU-28	21.8	0.0	0.0

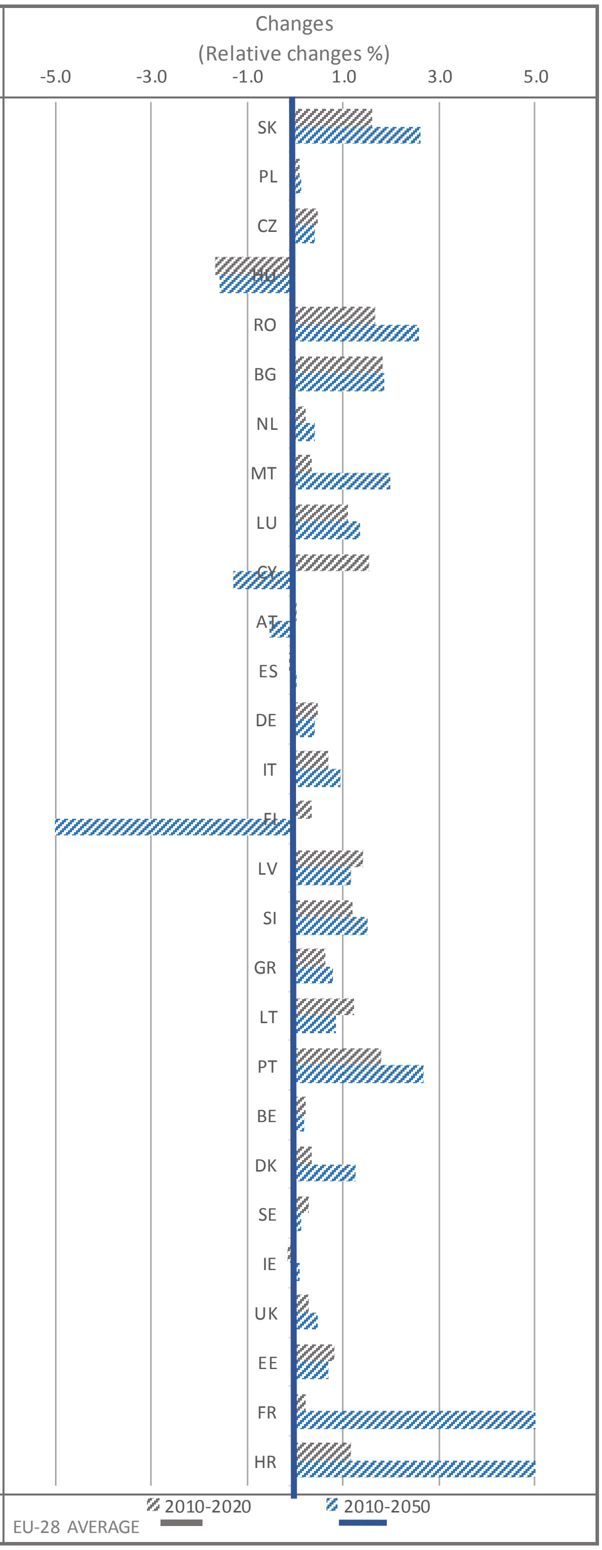


Figure 8.Urban population exposure to air pollution by particulate matter (ßg/mS) and changes in the medium (2010-2020) and long term (2020-2050)

Member States	% of urban population 2010	Changes (% points) 2010-2020	Changes (% points) 2010-2050
Slovakia	49	4.0	5.6
Poland	44	1.3	0.4
Malta	39	2.1	6.0
Bulgaria	36	5.9	7.4
Netherlands	30	2.6	5.1
Cyprus	27	13.6	-32.4
Czech Republic	25	1.2	-2.9
Croatia	24	0.7	0.1
Hungary	20	5.0	-3.8
Romania	20	5.6	16.4
Greece	13	-5.6	-9.4
Italy	10	3.9	5.7
Austria	8	1.4	1.9
Spain	8	4.1	9.7
Portugal	7	4.0	1.2
Germany	7	6.0	8.0
France	6	2.9	-0.7
Lithuania	5	9.8	-2.2
Luxemburg	4	17.2	20.5
Latvia	4	36.9	34.1
Slovenia	3	8.2	-1.5
Denmark	2	16.6	51.7
Sweden	2	3.1	13.4
Belgium	2	6.9	16.3
United Kingdom	2	5.5	8.1
Finland	1	-2.2	-43.1
Estonia	1	2.0	-43.0
Ireland	0	-100.0	-100.0
EU-28	16	0.1	0.0

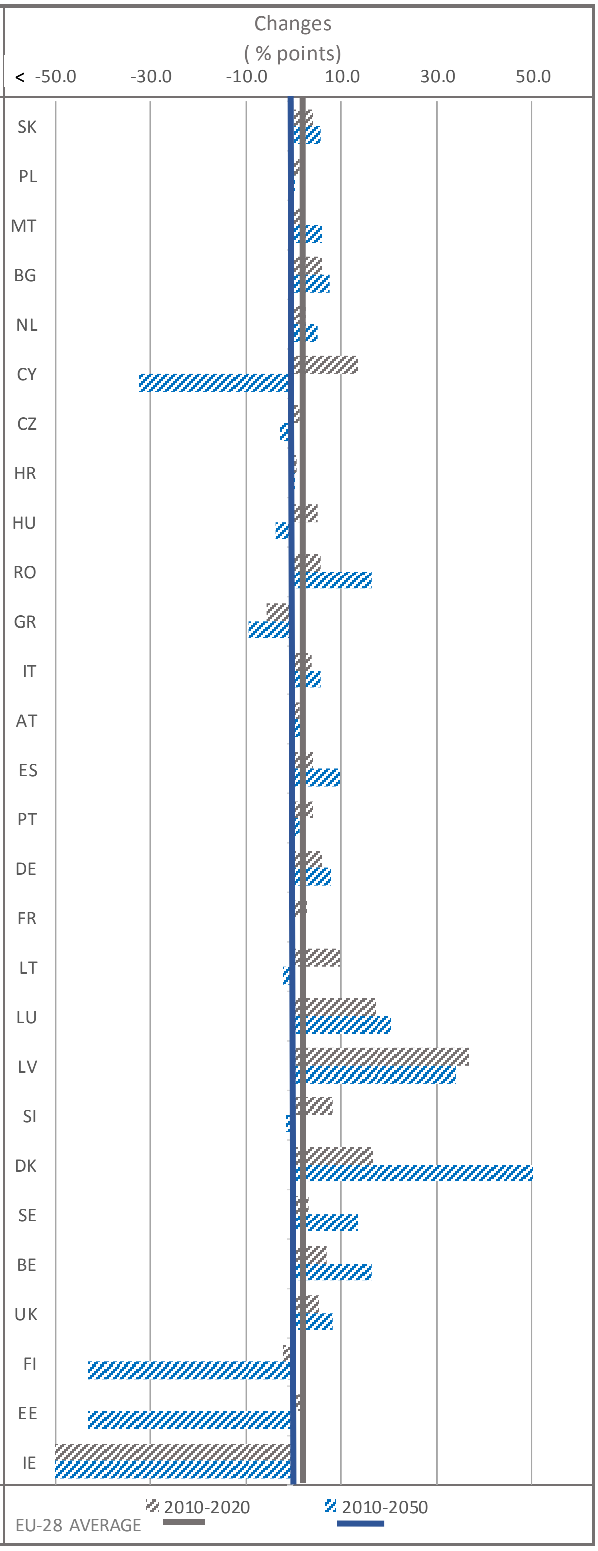


Figure 9.EU urban population. exposed to PM10 concentrations exceeding the daily limit value on more than 35 days in a year (%)and changes in the medium (2010-2020) and long term (2020-2050).

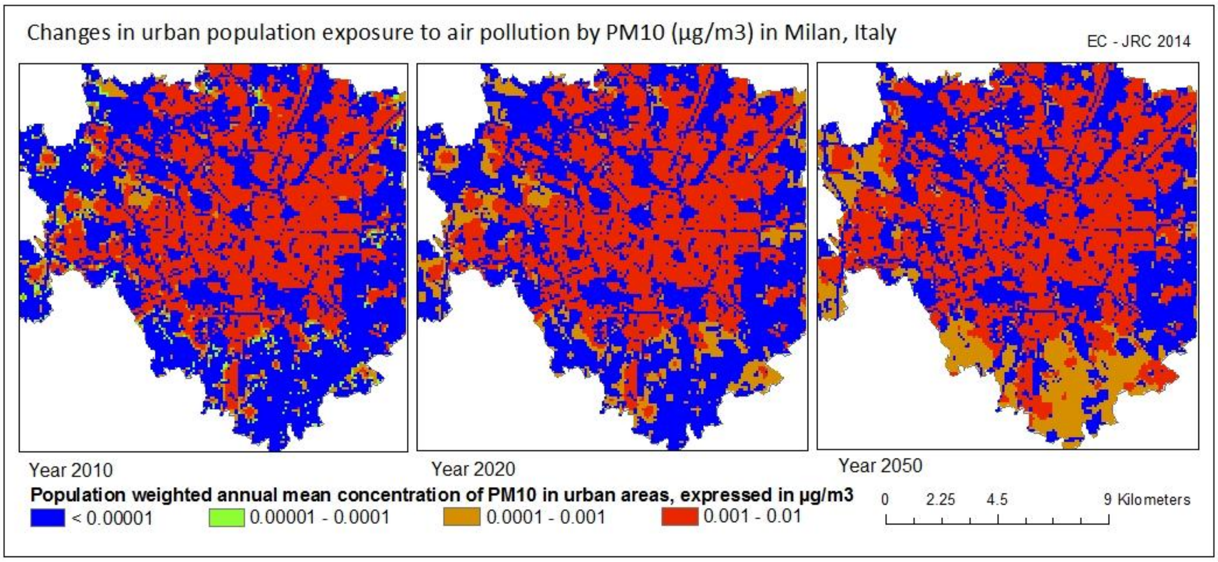
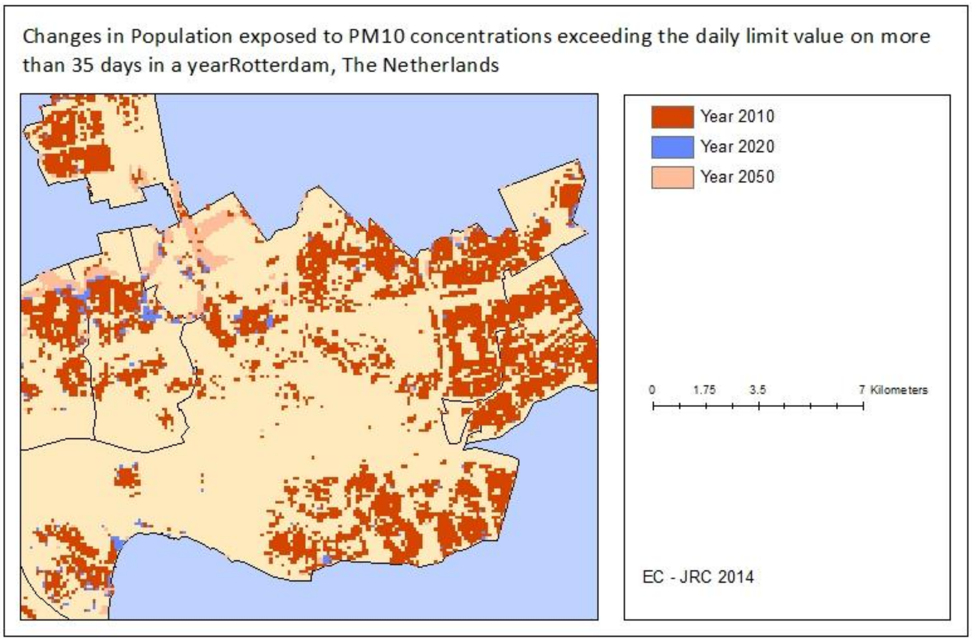


Figure 10. Population annual mean concentration of PM10 in urban areas in the city of Milan (Italy), expressed in µg/m3

The second example presented in Figure 11 represents changes in population exposed to PM10 concentrations exceeding the daily limit value on more than 35 days in a year for the city of Rotterdam (Netherlands). This increase is due to the combination of two factors: in one side, a net increase of PM10



concentrations, but overall, to the redistribution of the population.

Figure 11.Changes in population exposed to PM10 concentrations exceeding the daily limit value on more than 35 days in a year in Rotterdam, the Netherlands.

4. Conclusion

This study aims to evaluate the status of some natural resources in the EU-28 according to the LUISA configuration of the EU Reference Scenario 2014. Projecting forward the indicators allows us to explore the progress made towards the efficient use of land and water as resources and the performance with respect to the landscape fragmentation and safeguarding clean air. The modelling results answered the following questions:

By how much and in which proportions are built-up areas increasing in Europe?

According to the EU Reference Scenario 2014, by 2050 the share of the built-up area in the EU-28 will increase from 4% in 2010 to 5% in 2050. This corresponds to an increase by 16% of the built-up areas in Europe.

Is Europe using land more efficiently?

According to the EU Reference Scenario 2014, land will be used less efficiently in the future. Modelling results shown that the amount of land consumed per person will increase by about 12% in the EU-28 between 2010 and 2050, which means that on average the built-up area will grow at a faster rate (16% growth in 2010-2050 period) than the population (4% growth in 201-2050 period).

How efficiently is water used for productive purposes?

The use of water in Europe is expected to become more efficient by 2050. According to the modelling results and projected GDP (in million EUR) the productivity of water will increase by 8% between 2010 and 2050. The effects of climate change are not included in the reference scenario.

How may landscape fragmentation change in EU-28 under the EU Reference Scenario 2014?

Landscape fragmentation will show no significant changes at EU-28 level since the negative trends of landscape fragmentation in some regions of Europe are compensated by positive changes in others. For a proper assessment of landscape fragmentation as a consequence of land consumption, variability between regions should therefore be accounted for.

What progress is being made towards the targets for reducing the concentration of particulate matter smaller than 10 micrometers in urban areas?

The PM10 concentrations in urban air and the population exposed to this matter over the limits established due to changes in land use or population distribution will remain more or less the same in the short and longer term.

The methodology used in this study is highly suitable for the simulation of the EU policies and evaluation of their territorial impacts on natural resource. A further step of the current assessment includes the modelling of policy measures and implementation of goals which look at optimizing the efficient use of the resources and promoting nature-based solutions in Europe. The indicators derived for the EU reference scenario 2014 could then be used as 'benchmark' to compare the impacts of different options. The analysis presented in this report is part of a broader project which aims to assess the impact of the EU-Reference Scenario 2014 on land and their functions (Barbosa et al., 2014).

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Annex A: Resource Efficiency Scoreboard

Division		Indicator	Unit
LEAD INDICATOR	Resource	Resource productivity	EUR per kg
DASHBOARD INDICATORS	Materials	Domestic material consumption per capita	Tonnes
	Land	Productivity of artificial land	Millions PPS per km²
		Built-up areas *	km² or % of total land area
	Water	Water exploitation index	%
		Water productivity *	EUR per m3
	Carbon	Greenhouse gas emissions per capita	Tonnes of CO2 equivalent
		Energy productivity	EUR per kg of oil equivalent
		Energy dependence	%
		Share of renewable energy in gross final energy consumption	%
THEMATIC INDICATORS			
Transforming the economy	Turning waste into a resource	Generation of waste excluding major mineral wastes	Kilograms per capita
		Landfill rate of waste excluding major mineral wastes	%
		Recycling rate of municipal waste	%
		Recycling rate of e-waste	%
	Supporting research and innovation	Eco-innovation index	Index (EU=100)
	Getting the prices right	Total environmental tax revenues as a share of total revenues from taxes and social contributions	%
		Energy taxes by paying sectors - Households	%
Nature and ecosystems	Biodiversity	Index of common farmland bird species	Index (1990=100)
		Area under organic farming	%
		Landscape fragmentation*	Number of meshes per 1000 km²
	Safeguarding clean air	**Urban population exposure to air pollution by particulate matter - PM2.5 ***	Micrograms per cubic meter

		Urban population exposed to PM10 concentrations exceeding the daily limit value (50 µg/m3 on more than 35 days in a year) *	%
	Land and soils	Soil erosion by water – area eroded by more than 10 tonnes per hectare per year	%
		Gross nutrient balance in agricultural land - nitrogen	Kilograms per hectare
		Gross nutrient balance in agricultural land - phosphorus	Kilograms per hectare
	Marine resources	---	
Key Areas	Addressing food	Daily calorie supply per capita by source - total	Kilocalories
	Improving buildings	Final energy consumption in households by fuel - total petroleum products	%
	Ensuring efficient mobility	Average carbon dioxide emissions per km from new passenger cars	Gram of CO2/km
		Pollutant emissions from transport - NOx	Index (2000=100)
		Modal split of passenger transport - passenger cars	% in total inland passenger-km
		Modal split of freight transport - by road	% in total inland freight tonne-km

Annex B: Indicator Metadata

Built-up area

1. Identification (title; code) and classification (DPSIR; typology)

- EUROSTAT: Eurobase > Tables on EU policy> Europe 2020 Indicators > Resource efficiency > Dashboard indicators > Land > Built-up areas in km^2 / as a share of total land (t2020_rd110)
- LUISA Framework: LF_431
- EEA (related indicator): Biodiversity/Threats to biodiversity: habitat loss and degradation/Land take
- DPSIR typology: descriptive indicator of Pressure.

2. Rationale — justification for indicator selection;

The built-up areas indicator was selected in the context of the RERM to reflect the production of land as resource. This indicator aimed to be used in conjunction with the lead indicator and has the advantage that it focused on built-up stock and flows of the land as a resource. Thus it can be easily understood, measured and communicated.

List of references used in this work:

Batista e Silva, F., Lavalle, C. & Koomen, E. (2012) A procedure to obtain a refined European land use/cover map. *Journal of Land Use Science*, 8, 255-283.

European Commission (a) (2011). COM (2011) 571 - Roadmap to a Resource Efficient Europe, European Commission, Documentation and data. Retrieved from: [http://ec.europa.eu/environment/resource_efficiency/pdf/com2011_571.pdf] (accessed 30.07.2014).

European Commission (b) (2011). SEC (2011) 10 67 - Commission Staff Working Paper. Analysis associated with the Roadmap to a Resource Efficient Europe Part II. European Commission, Documentation and data. URL: http://ec.europa.eu/environment/resource_efficiency/pdf/working_paper_part2.pdf] (accessed 04.08.2014)

Eursotat (2013). Built-up areas metadata. Retrived from: [http://epp.eurostat.ec.europa.eu/cache/ITY_SDDS/EN/t2020_rd110_esmsip.htm] accessed 30/09/2014

Lavalle, C.; Barbosa,A.; Mubareka S.; Jacobs C.; Baranzelli C.; Pernina C. (2013) Land Use Related Indicators for Resource Efficiency - Part I Land Take Assessment. An analytical framework for assessment of the land milestone proposed in the road map for resource efficiency. Luxemboug, Publications Office of the European Union. .[http://bookshop.europa.eu/pt/land-use-related-indicators-for-resource-efficiency-pbLBNA26083/]

3. Indicator definition — definition; units;

Built-up areas measures the [1] total built-up area in a country in km^2 and [2] the total built-up area as a share of the total surface area of land in the country expressed in percentage.

The indicator presents data for the year 2010, and the net changes in a short term period (2010 -2020) and in a long term period (2010 – 2050), for all EU 28 Member States.

4. Policy context and targets — context description; targets; related policy documents;

The indicator of ‘built-up areas’ has been included in the Dashboard indicators of the Resource Efficiency Scoreboard to measure progress towards the efficient use of land (European Commission (a) (2011). The ‘built-up areas’ indicator itself does not have a specific goal. However the average annual land take indicator which measures the net changes of the built-up areas in time in km^2 has a policy goal proposed in the 2020 land milestone of the RERM. This target is measurable and has a specific time limit to achieve: ‘no net land take by 2050’ (EC, 2011).

5. Policy questions — key policy questions; specific policy questions;

The built-up area indicator aims to answer the following policy questions:

- By how much and in which proportions are built-up areas increasing in Europe?

6. Methodology (indicator calculation; gap filling; references)

The ‘built-up area in km^2 is the total sum of the land uses classified as urban fabric including, CLC11X residential (continuous and discontinuous), CLC121 industrial/commercial land, and CLC 14X green urban areas, sport and leisure facilities.

The ‘share of built-up area’ is the result of the division of the ‘built-up area in Km$^{2'}$ by the total surface of the administrative unit (NUTSx).

7. Data specifications — data references; external data references; data sources;

- Refined CORINE land cover 2006 (Batista e Silva *et al.*, 2012), base year for the Baseline Scenario.
- Baseline Scenario projected land use maps from LUISA (urban & industrial/commercial land uses classes)
- EU-28 administrative regions: EuroBoundaryMap v81

8. Uncertainties — methodology uncertainty; data set uncertainty; rationale uncertainty

The main uncertainty from this indicator arises from the spatial resolution of the source data (100 m^2). Therefore, only built-up areas with a minimum width of 100 meters were considered in the indicator.

9. Responsibility and ownership (indicator manager; ownership)

Joint research Center, Institute for Environment and Sustainability, Sustainability Assessment Unit (H08)

10. Further work (short-term work; long-term work)

Short-term: built-up by NUTS2, NUTS3 , LAU 1 and 2, Large Urban Zones (LUZ) and other relevant classification groups such as:

- Urban – rural topology (NUTS3 3 category levels);
- Less developed regions (GDP per capita < 75% of EU average), transition regions (GDP per capita between 75% and 90%) and more developed regions (GDP per capita > 90%).

Built-up area per inhabitant

1. Identification (title; code) and classification (DPSIR; typology)

LUISA Framework: LF_433

2. Rationale — justification for indicator selection;

The ‘built-up area per inhabitant’, measures the land consumption by comparing the size of the built-up areas with the population expressed in sq. m per inhabitant (m^2 per person). This indicator is not part of the RE indicators. It was included in this study since it provides useful information on the efficiency of land used for residential, sport and leisure, and economic activities. Thus it can be easily understood, measured and communicated.

List of references used in this work:

European Commission (a) (2011). COM (2011) 571 - Roadmap to a Resource Efficient Europe, European Commission, Documentation and data. Retrieved from: [http://ec.europa.eu/environment/resource_efficiency/pdf/com2011_571.pdf] (accessed 30.07.2014).

European Commission (d) (2011). The 2012 Ageing Report - Underlying Assumptions and Projection Methodologies. ISBN 978-92-79-19298-2 doi: 10.2765/15373 Retrieved from: [http://europa.eu/epc/pdf/2012_ageing_report_en.pdf] (accessed 31.07.2014).

European Commission / Eurostat (2013) Europop2010 (Eurostat Population Projections 2010-based). Last update 06.03.12, Extracted 10.01.13 Retrieved from: [http://epp.eurostat.ec.europa.eu/tgm/table.do?tab=table&init=1&language=en&pcode=tps00002&plugin=1]

Prokop, G., Jobstmann, H., Jobstmann, A. (2011) Overview of best practices for limiting soil sealing or mitigating its effects in EU-27. Environment Agency Austria. Retrieved from: [http://ec.europa.eu/environment/soil/pdf/sealing/Soil%20sealing%20-%20Final%20Report.pdf] (accessed 20.07.2014).

Lavalle, C.; Barbosa,A.; Mubareka S.; Jacobs C.; Baranzelli C.; Pernina C. (2013) Land Use Related Indicators for Resource Efficiency - Part I Land Take Assessment. An analytical framework for assessment of the land milestone proposed in the road map for resource efficiency. Luxemboug, Publications Office of the European Union. .[http://bookshop.europa.eu/pt/land-use-related-indicators-for-resource-efficiency-pbLBNA26083/**]**

3. Indicator definition — definition; units;

The built-up area per inhabitant measure the land consumption by comparing the size of the built-up areas with the population expressed in sq. m per mn inhabitants (m^2 per person).

The indicator presents data for the year 2010, and the net changes in a short term period (2010 -2020) and in a long term period (2010 – 2050), for all EU 28 Member States.

4. Policy context and targets — context description; targets; related policy documents;

The ‘built-up areas per inhabitant’ indicator was presented in the “Sixth report on economic, social and territorial cohesion” (EC/DG Regional and Urban Policy, 20104) to measure the efficiency use of land in Europe.

5. Policy questions — key policy questions; specific policy questions (optional)

The built-up area per inhabitant indicator aims to answer the following policy questions:

- Are Europe using land more efficiently?
- Do the land-use intensities improve or follow an unsustainable trend?

6. Methodology (indicator calculation; gap filling; references)
The ‘built-up areas’ in km^2 is the total sum of the land uses classified as urban fabric including, CLC11X residential (continuous and discontinuous), CLC121 industrial/commercial land, and CLC 14X green urban areas, sport and leisure facilities.
7. Data specifications — data references; external data references; data sources in latest figures
• Refined CORINE land cover 2006 (Batista e Silva *et al.*, 2012), base year for the Baseline Scenario. • Baseline Scenario projected land use maps from LUISA (urban & industrial/commercial land uses classes) • EUROPOP2010, population projections from Eurostat. • EU-28 administrative regions: EuroBoundaryMap v81
8. Uncertainties — methodology uncertainty; data set uncertainty; rationale uncertainty
The main uncertainty from this indicator arises from the spatial resolution of the source data (100 m^2). Therefore, only built-up areas with a minimum width of 100 meters were considered in the indicator.
9. Responsibility and ownership (indicator manager; ownership)
Joint research Center, Institute for Environment and Sustainability, Sustainability Assessment Unit (H08)
10. Further work (short-term work; long-term work)
Short-term: built-up by NUTS2, NUTS3 , LAU 1 and 2, Large Urban Zones (LUZ) and other relevant classification groups such as: - Urban – rural topology (NUTS3 3 category levels); Less developed regions (GDP per capita < 75% of EU average), transition regions (GDP per capita between 75% and 90%) and more developed regions (GDP per capita > 90%).

Water Productivity

1. Identification (title; code) and classification (DPSIR; typology)

Resource efficiency > Dashboard indicators > Water > Water Productivity (t2020_rd210)

DPSIR typology: Pressure.

2. Rationale — justification for indicator selection; scientific references

The indicator reflects productivity in terms of water use, so gives a measure of a country's water use efficiency.

European Commission (a) (2011). COM (2011) 571 - Roadmap to a Resource Efficient Europe, European Commission, Documentation and data. [http://ec.europa.eu/environment/resource_efficiency/pdf/com2011_571.pdf] (accessed 10/11/2014).

Eursotat (2013). Productivity of built-up areas metadata.

[http://epp.eurostat.ec.europa.eu/cache/ITY_SDDS/EN/t2020_rd210_esmsip.htm] (accessed 10/11/2014).

3. Indicator definition — definition; units

Water productivity is a measure of the monetary value produced by a country per unit of water used. It is essentially the country total annual GDP (GEM-E3) divided by the total annual freshwater use for all sectors. The higher the value of the indicator, the higher the productivity. The indicator is given in euros per m3 of water used.

4. Policy context and targets — context description; targets; related policy documents

Water Productivity is a 'Resource Efficiency indicator' It has been chosen as a dashboard indicator presented in the Resource Efficiency Scoreboard for the assessment of progress towards the objectives and targets of the Europe 2020 flagship initiative on Resource Efficiency (Eurostat - metadata, 2013).

5. Policy questions — key policy questions; specific policy questions (optional)

The indicator aims at answering the following question:

- How efficiently is water used for productive purposes?

6. Methodology (indicator calculation; gap filling; references)

The total annual freshwater use was calculated for the base year 2006 and forecasted to 2010, 2020 and 2050 using the Water Use Model. The model quantifies water use in the public, industry, energy (cooling water), irrigation, and livestock sectors. Country-level aggregated statistics on water use per sector were derived from Eurostat and verified with the FAO AQUASTAT dataset. These values were disaggregated using proxy data (mostly land use) to produce sectoral water use maps up to 100m resolution. The total country-level sectoral water use is forecasted based on additional proxy data specific to each sector, including, amongst others, population growth, industrial productivity, and energy consumption. The GDP per region is divided by the total water used in all sectors to give the final indicator, which is presented here at country level.

References used:

Vandecasteele, I., Bianchi, A., Batista e Silva, F., Lavalle, C., Batelaan, O., 2014. Mapping Current and Future European Public Water Withdrawals and Consumption. Hydrology and Earth System Sciences, 18, 407-416, doi: 10.5194/hess-18-407-2014.

Vandecasteele, I., Bianchi, A., Mubareka, S., De Roo, A., Burek, P., Bouraoui, F., Lavalle, C., Batelaan, O., 2013, Mapping of current and projected Pan-European water withdrawals, UNCCD 2nd Scientific Conference, proceedings, 9-12 April 2013

De Roo, A., Bouraoui, F., Burek, P., Bisselink, B., Vandecasteele, I., Mubareka, S., Salamon, P., Pastori, M., Zambrano, H., Thiemig, V., Bianchi, A., Lavalle, C., 2012. Current water resources in Europe and Africa - Matching water supply and water demand - JRC Technical Report EUR 25247 EN.

7. Data specifications — data references; external data references; data sources in latest figures

- Baseline Scenario projected land use maps (LUISA, urban, industrial and arable land uses classes)
- Freshwater abstractions by source and sector (EUROSTAT)
- Water withdrawals (FAO - AQUASTAT)
- Thermal power stations (EPRTR dataset)
- Projected energy consumption (POLES model)
- Projected GVA for industry (GEM-E3 model)
- Population density maps (Batista et al., 2013)
- Tourism statistics (EUROSTAT), and forecasts (UNWTO, 2014)
- Irrigation water requirements (FAO)
- Livestock density map (FAO)
- EU-28 administrative regions
- GDP in Million Euros from the GEM-E3 model (National Technical University of Athens, 2010)

8. Uncertainties — methodology uncertainty; data set uncertainty; rationale uncertainty

The mapping of sectoral water use requires input from several models (LUISA, POLES, GEM-E3) which all have their own uncertainties. The projection of water use per sector assumes that water use will increase linearly with specific 'driving forces' per sector. Although we do take into account that there will be a certain degree of improvement in water use efficiency over time for all sectors, there may be additional factors which are not taken into account.

9. Responsibility and ownership (indicator manager; ownership)

IES- Sustainability Assessment Unit (H-08)

10. Further work (short-term work; long-term work)

The water use model is continuously being updated and refined to improve dynamic computation of sectoral water use and to reduce uncertainties.

Landscape Fragmentation

1. Identification (title; code) and classification (DPSIR; typology)

EUROSTAT: Resource Efficiency Scoreboard > Natural capital and ecosystem services > Biodiversity > Landscape fragmentation (Resource Efficiency Framework: t2020_rn110, LUISA Framework: LF_622)
EEA: Biodiversity/Ecosystem integrity and ecosystem goods and services/Fragmentation of natural and semi-natural habitats. DPSIR typology: descriptive indicator of pressure.

2. Rationale — justification for indicator selection; scientific references

Landscape fragmentation, usually also associated to habitat loss, is becoming a central issue in land and conservation planning since is a key process with negative impacts on biodiversity. Habitats which are highly degraded or fragmented are less likely to be able to support species in the long term or provide the same level of ecosystem services as by intact habitats. In this sense, an indicator of landscape fragmentation is required to assess likely changes and provide support to policy development. The effective mesh density is the indicator of landscape fragmentation included in the Resource efficiency Scoreboard given the advantages it presents over other landscape metrics (Jaeger, 2000; Moser *et al.*, 2007).

References used:

EEA - European Environmental Agency (2012) Urban adaptation to climate change in Europe: Cities' challenges, opportunities, and supportive national and European policies. In:

EEA - European Environmental Agency & FOEN - Swiss Federal Office for the Environment (2011) Landscape fragmentation in Europe. In. European Environmental Agency. , Luxembourg.

Forman, R.T.T., Sperling, D., Bissonette, J.A., Clevenger, A.P., Cutshall, C.D., Dale, V.H., Fahrig, L., France, R., Goldman, C.R., Heanue, K., Jones, J.A., Swanson, F.J., Turrentine, T. & Winter, T.C. (2003) *Road Ecology*. Island Press, Covelo, CA.

Jaeger, J. (2000) Landscape division, splitting index, and effective mesh size: new measures of landscape fragmentation. *Landscape Ecology*, 15, 115-130.

Moser, B., Jaeger, J.G., Tappeiner, U., Tasser, E. & Eiselt, B. (2007) Modification of the effective mesh size for measuring landscape fragmentation to solve the boundary problem. *Landscape Ecology*, 22, 447-459.

Paracchini, M.L., Petersen, J.E., Hoogeveen, Y., Bamps, C., Burfield, I. & van Swaay, C. (2008) High Nature Value Farmland in Europe: An estimate of the distribution patterns on the basis of land cover and biodiversity data. In: JRC Scientific and technical reports. JRC, EEA., Luxembourg.

3. Indicator definition — definition; units

The indicator presented here measures the degree to which species movements between different parts of the landscape are interrupted by barriers. The more barriers fragmenting the landscape, the more difficult will be the species movement through the landscape. This is measured by the effective mesh density (S_{eff}) and includes the so called 'cross-boundary connections' procedure that eliminates the bias arising from the patches shared by two or more reporting units (i.e. administrative boundaries) (Jaeger, 2000; Moser et al., 2007; EEA & FOEN, 2011). It is expressed in number of meshes per 1,000 km² - the more fragmented in the landscape, the higher the effective mesh density of a given region.

4. Policy context and targets — context description; targets; related policy documents

The indicator of 'Landscape fragmentation' has been included in the Resource Efficiency Scoreboard as indicator for the assessment of the progress towards the objectives of the Roadmap to a Resource Efficient Europe.

In addition, the 'Aichi Biodiversity Target' number 5, established by the parties to the Convention on Biological Diversity, states that '*by 2020, the rate of loss of all natural habitats, (…), is at least halved, (…), and degradation and fragmentation is significantly reduced*'. However, specific targets would be needed to implement measurements towards a better protection of the environment. As discusses in the report 'Landscape Fragmentation in Europe' benchmarks and limits could be distinguished for different types of landscapes. In this sense, priority habitats which have strategic national or global ecological importance should be identified for the implementation of specific fragmentation targets.

5. Policy questions — key policy questions; specific policy questions (optional)

The landscape fragmentation indicator aims to answer the following policy questions:

• To what extent are natural and semi-natural lands fragmented in Europe?

• How may landscape fragmentation change in future scenarios in response to urban and industrial sprawl and bioenergy crops?

6. Methodology (indicator calculation; gap filling; references)

The 'Landscape fragmentation' indicator based on the effective mesh density (number of meshes per 1,000 km^2) is based in the methodology described by Jaeger (2000) and Moser et al. (2007). First, we calculated the effective mesh size (m_{eff}), which estimates the probability that two points chosen randomly in a region are connected. We also accounted for the 'cross-boundary connections' of the habitat patches that are shared by two different regions (i.e. countries, regions, provinces) applying equation 1 (Moser et al., 2007):

$$\mathbf{m_{eff}^{CBC}} = \frac{\mathbf{1}}{\mathbf{Atotal}} \sum_{\mathbf{i=1}}^{\mathbf{n}} \left(\mathbf{Ai \ x \ Ai^{cmpl}}\right) \qquad \textit{(Equation 1)}$$

where $\mathbf{n}$ is the number of patches in a given study region, $\mathbf{Ai}$ is the size of the patch inside the region and $\mathbf{Ai^{cmpl}}$ is the complete area of the patch including also the area outside the study region. $\mathbf{Ai}$ will be equal to $\mathbf{Ai^{cmpl}}$ when the patch is completely located in the study region. Then, the effective mesh size was converted to effective mesh density (S_{eff}) according to equation 2 (Jaeger, 2000):

$$\mathbf{S_{eff}} = \frac{\mathbf{1}}{\mathbf{m_{eff}^{CBC}}} \qquad \textit{(Equation 2)}$$

The interpretation of this indicator largely depends on the definition of the elements that are considered as being habitat areas (i.e. natural and semi-natural habitats for the species movement) and what are considered barriers (i.e. physical obstacles to species movement). The land uses that are considered as landscape and barrier are shown in Table 1:

Table 1. Definition of land uses and other features as habitat or barriers for the calculation of landscape fragmentation	
Land uses (Baseline)	Classification

Artificial (Urban, industry and infrastructures)	Barrier
Agriculture (crops, pastures, arable land)	Barrier if it is not included as High Natural Value Farmlands[1] Habitat if it has HNV
Forests	Habitat
Transitional woodland-shrub	Habitat
Abandoned farmland	Barrier if it is not included as High Natural Value Farmlands[1] Habitat if it has HNV
Abandoned artificial	Barrier
New energy crops	Barrier[2]
Natural land	Habitat
Other nature	Habitat
Wetlands	Habitat
Water bodies	Habitat
Urban green leisure	Habitat[3]
Roads (TeleAtlas)	
Motorways	Barrier
National roads	Barrier

[1]As suggested in EEA - European Environmental Agency and FOEN - Swiss Federal Office for the Environment (2011)

[2] Immerzeel, D.J., Verweij, P.A., van der Hilst, F. & Faaij, A.P.C. (2014) Biodiversity impacts of bioenergy crop production: a state-of-the-art review. GCB Bioenergy, 6, 183-209.

[3] Since this land use may contribute to favour landscape connectivity (EEA - European Environmental Agency, 2012)

Only main roads were included as barriers, assuming to be 100 m wide, since this is the minimum information unit (pixel resolution). See also ‘Uncertainties’ section. Although motorways and national roads do not always reach 100 m wide, their impact on both sides of the road could easily have a significant impact on this distance (Saunders *et al*., 2002). In this context, regional and local roads were not included as barriers for two main reasons. First, since the pixel resolution of the source data (LUISA scenarios) was 100 m, including elements that might have a barrier effect at smaller spatial resolution would result in a mistreatment of the source data and an overestimation of the landscape fragmentation. Secondly, the role of secondary roads as barriers in the landscape appears not to be so important since they show permeability for the movement of many species (Forman *et al.*, 2003).

References used:

EEA - European Environmental Agency & FOEN - Swiss Federal Office for the Environment (2011) Landscape fragmentation in Europe. In. European Environmental Agency. , Luxembourg.

Jaeger, J. (2000) Landscape division, splitting index, and effective mesh size: new measures of landscape fragmentation. *Landscape Ecology*, 15, 115-130.

Moser, B., Jaeger, J.G., Tappeiner, U., Tasser, E. & Eiselt, B. (2007) Modification of the effective mesh size for measuring landscape fragmentation to solve the boundary problem. *Landscape Ecology*, 22, 447-459.

Saunders S.C., Mislivets M.R., Chen J. & Cleland D.T. (2002) Effects of roads on landscape structure within nested ecological units of the Northern Great Lakes Region, USA. Biological Conservation, 103, 209-225.

7. Data specifications — data references; external data references; data sources in latest figures

- LUISA scenarios: year 2010, 2020 and 2050
- High Natural Value farmland (Paracchini *et al.*, 2008)
- Roads: Tele Atlas
- EU-28 administrative regions: NUTS0

8. Uncertainties — methodology uncertainty; data set uncertainty; rationale uncertainty

Methodological uncertainty:

With the method here presented to assess landscape fragmentation it is important to consider some methodological limitations for a correct interpretation. The method used assumes all barriers to have the same role limiting the species movement. It is based on a binary classification of 'habitat' and 'non-habitat'. However, this is an oversimplification of the complex patterns of species movement though the landscape. For instance, for a given species the barrier effect might be larger in urban areas than in intensive agricultural areas, or in high traffic density roads as opposed to national roads less frequented. In addition, this indicator addresses the fragmentation of the landscape as a whole, looking at the spatial structure of the habitat patches, without focusing in a specific group of habitats or species (e.g. forest habitats and species). Landscape fragmentation will have a different impact on the biodiversity depending on their ecological requirements (type of habitats used) and dispersal distances of the species considered. Finally, the impact and relevance of the landscape fragmentation will depend on the ecological importance of the area affected. Landscape fragmentation should be of especial concern in key habitats for the maintenance of biodiversity and ecosystems.

Dataset uncertainty:

The main uncertainty from this indicator arises from the spatial resolution of the source data (100 m^2). Therefore, landscape fragmentation taking place at smaller spatial scale cannot be measured with the available data at European level. The role of agricultural intensification as a landscape barrier presents also some limitations given the available data. The High Natural Value Farmlands used to split the agricultural uses as habitat or non-habitat is static. Therefore, temporal changes of this factor cannot be integrated.

9. Responsibility and ownership (indicator manager; ownership)

IES- Sustainability Assessment Unit (H-08)

10. Further work (short-term work; long-term work)

Short-term: measure landscape fragmentation arising from only sprawl of artificial uses (urban and industry related uses) and measure landscape fragmentation at NUTS2, NUTS3 and Large Urban Zones (LUZ)

Urban population exposure to air pollution by particulate matter

1. Identification (title; code) and classification (DPSIR; typology)

- Eurostat: Eurobase > Tables on EU policy> Europe 2020 Indicators > Resource efficiency > Thematic indicators > Nature and ecosystems > Safeguarding clean air > Urban population exposure to air pollution by particulate matter in µg/m3 (tsdph370)
- EEA (related indicator): Air Pollution: Exceedance of air quality limit values in urban areas

DPSIR typology: descriptive indicator of State

2. Rationale — justification for indicator selection;

The high density of population and economic activities in urban areas results in increased emissions of air pollutants and consequently ambient concentrations and population exposure. PM10 exposure is the main contributor to health problems due to air pollution. The Urban population exposure to air pollution by particulate matter indicator is part of the RE indicators, since it provides useful information on concentrations of PM10 in urban areas, which urban areas are the most affected by population, and what are the future tendencies related to the implementation of resource efficiency policies.

References used:

AirBase - The European air quality database provided by European Environment Agency (EEA). http://acm.eionet.europa.eu/databases/airbase/index_html

Breiman, Leo (2001). "Random Forests". Machine Learning 45 (1): 5–32. doi:10.1023/A:1010933404324.

European Commission (a) (2011). COM (2011) 571 - Roadmap to a Resource Efficient Europe, European Commission, Documentation and data. Retrieved from: [http://ec.europa.eu/environment/resource_efficiency/pdf/com2011_571.pdf] (accessed 30.07.2014).

EEA: Air quality in Europe – 2012 report, Report No. 4/2012, European Environment Agency, Copenhagen, DK, 2012.

EU: Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe (Offic J EU, L 152, 11 June 2008, 1–44), 2008.

European Commission / Eurostat (2013) Europop2010 (Eurostat Population Projections 2010-based). Last update 06.03.12, Extracted 10.01.13 Retrieved from: [http://epp.eurostat.ec.europa.eu/tgm/table.do?tab=table&init=1&language=en&pcode=tps00002&plugin=1]

Lavalle, C.; Barbosa,A.; Mubareka S.; Jacobs C.; Baranzelli C.; Pernina C. (2013) Land Use Related Indicators for Resource Efficiency - Part I Land Take Assessment. An analytical framework for assessment of the land milestone proposed in the road map for resource efficiency. Luxemboug, Publications Office of the European Union. .[http://bookshop.europa.eu/pt/land-use-related-indicators-for-resource-efficiency-pbLBNA26083/]

3. Indicator definition — definition; units;

The Urban population exposure to air pollution by particulate matter indicator shows the population weighted annual mean concentration of PM10 in urban areas, expressed in µg/m3. The indicator presents data for the year 2010, and the net changes in a short term period (2010 -2020) and in a long term period (2010 – 2050), for all EU 28 Member States.

4. Policy context and targets — context description; targets; related policy documents;

The EU Air Quality Directive (2008/50/EC) have set forth legally binding limit values for ground-level concentrations of PM10, for daily and annual exposure: the short-term limit establishes a limit value on daily mean concentrations of 50 µg/m3 not to exceeded more than 35 times per year. This Directive declared that this limit value should have been met by January 1st, 2005. The World Health Organisation (WHO) set the Air Quality Guideline level for annual mean concentrations of PM10 at 20 µg/m^3, much more restrictive than the limits imposed by European legislation.

5. Policy questions — key policy questions; specific policy questions (optional)

The Urban population exposure to air pollution by particulate matter indicator aims to answer the following specific policy questions:

- What progress is being made in reducing concentrations of air pollutants in urban areas to below the limit values defined in air quality legislation?

6. Methodology (indicator calculation; gap filling; references)

Concentrations of PM10 were calculated using Land Use Regression (LUR) Models. The LUR model was built using PM10 concentration for 2010 from the monitoring sites included in the AirBase database (dependent variable) and several parameters (independent variables) defined within a Geographic Information System (GIS). Some of these variables reflect sources or sinks for air pollution such as the road network, different types of land use and population density. Furthermore, factors such as elevation, topographical exposure, distance to sea, annual mean temperature and annual mean wind speed also influence the spatial concentration of pollutants and were included for the modelling. The Land Use Regression model was developed using Random Forest regression techniques (Breiman, 2001) and the results of concentration levels were presented in GIS maps. Population weighted concentrations were calculated for every pixel multiplying values of annual mean concentrations, by the percentage of population allocated to each pixel. The percentage of urban population allocated to each pixel is calculated by dividing the population projections per pixel from Eurostat, by the sum of the population within the cities, considering only the core of the cities.

7. Data specifications — data references; external data references; data sources in latest figures

- Refined CORINE land cover 2006 (Batista e Silva *et al.*, 2012), base year for the Baseline Scenario.
- Baseline Scenario projected land use maps from LUISA (urban fabric and industrial/commercial land uses classes)
- EUROPOP2010, population projections from Eurostat.
- EU-28 administrative regions: EuroBoundaryMap v81
- AirBase database (v7)

8. Uncertainties — methodology uncertainty; data set uncertainty; rationale uncertainty

The indicator is thought to be representative of the total urban population in Europe as a whole, but only the urban population in the Urban Audit cities collection is covered. So, population living in smaller towns and villages are not included.

The main uncertainty from this indicator arises from the use of regression models to assess mean annual concentrations. Uncertainty was expressed in relative terms by relating the RMSE to the mean PM10 concentration value for all the monitoring stations. The result value is 18%, that fulfils the data quality objectives for models as set in the Annex I of the Air Quality.

In relation to data set uncertainty, the air quality data is officially submitted by the national authorities. It is expected that data has been validated by the national data supplier and it should be in compliance with the data quality objectives as describe in the Air Quality Directives (EU, 2004, 2008). There are different methods in use for the routine monitoring of pollutants. Station characteristics and representativeness are in some cases insufficiently documented.

Regarding to climatic data used as input parameters, the resolution of original data is 0.25x0.25o, and from this original resolution, data were resampled to 100m resolution as used in the LUR model.

9. Responsibility and ownership (indicator manager; ownership)

Joint research Center, Institute for Environment and Sustainability, Sustainability Assessment Unit (H08)

10. Further work (short-term work; long-term work)

Short-term: built-up by NUTS2, NUTS3 , LAU 1 and 2, Large Urban Zones (LUZ) and other relevant classification groups such as:

- Urban – rural topology (NUTS3 3 category levels);

Urban population exposed to PM10 concentrations exceeding the daily limit value on more than 35 days in a year

1. Identification (title; code) and classification (DPSIR; typology)

- EUROSTAT: Eurobase > Tables on EU policy> Europe 2020 Indicators > Resource efficiency > Thematic indicators > Nature and ecosystems > Safeguarding clean air > Urban population exposure to air pollution by particulate matter in µg/m3 (tsdph370)
- EEA (related indicator): Air Pollution: Exceedance of air quality limit values in urban areas

DPSIR typology: descriptive indicator of State

2. Rationale — justification for indicator selection;

The high density of population and economic activities in urban areas result in increased emissions of air pollutants and consequently ambient concentrations and population exposure. PM10 exposure is the first responsible on health problems due to air pollution and consequently has been regulated and daily and mean annual limit values have been imposed.

The EU urban population exposed to PM10 concentrations exceeding the daily limit value on more than 35 days in a year indicator takes part of the RE indicators. This indicator provides useful information on the percentage of European urban population exposed to pollutant concentrations above the regulated thresholds, which urban areas are the most affected by population, and what are the future tendencies related to the implementation of resource efficiency policies.

List of reference used in this work:

AirBase - The European air quality database provided by European Environment Agency (EEA). http://acm.eionet.europa.eu/databases/airbase/index_html

Breiman, Leo (2001). "Random Forests". Machine Learning 45 (1): 5–32. doi:10.1023/A:1010933404324.

European Commission (a) (2011). COM (2011) 571 - Roadmap to a Resource Efficient Europe, European Commission, Documentation and data. Retrieved from: [http://ec.europa.eu/environment/resource_efficiency/pdf/com2011_571.pdf] (accessed 30.07.2014).

EEA: Air quality in Europe – 2012 report, Report No. 4/2012, European Environment Agency, Copenhagen, DK, 2012.

EU: Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe (Offic J EU, L 152, 11 June 2008, 1–44), 2008.

European Commission / Eurostat (2013) Europop2010 (Eurostat Population Projections 2010-based). Last update 06.03.12, Extracted 10.01.13 Retrieved from: [http://epp.eurostat.ec.europa.eu/tgm/table.do?tab=table&init=1&language=en&pcode=tps00002&plugin=1]

Kiesewetter G. , Borken-Kleefeld J., Schöpp, W., Heyes C., Thunis P., Bessagnet B., Terrenoire E., and Amann M., 2104: Modelling street level PM10 concentrations across Europe: source apportionment and possible futures Atmos. Chem. Phys. Discuss., 14, 18315–18354, 2014.

Lavalle, C.; Barbosa,A.; Mubareka S.; Jacobs C.; Baranzelli C.; Pernina C. (2013) Land Use Related Indicators for

Resource Efficiency - Part I Land Take Assessment. An analytical framework for assessment of the land milestone proposed in the road map for resource efficiency. Luxemboug, Publications Office of the European Union. .[http://bookshop.europa.eu/pt/land-use-related-indicators-for-resource-efficiency-pbLBNA26083/]

3. Indicator definition — definition; units;

The EU urban population exposed to PM10 concentrations exceeding the daily limit value on more than 35 days in a year measures the percentage of population in urban areas exposed to PM10 concentrations exceeding the daily limit value (50 µg/m3) established by the Air Quality Directive (2008/50/EC) on more than 35 days in a calendar year.

The indicator presents data for the year 2010, and the net changes in a short term period (2010 -2020) and in a long term period (2010 – 2050), for all EU 28 Member States.

4. Policy context and targets — context description; targets; related policy documents;

The EU Air Quality Directive (2008/50/EC) have set forth legally binding limit values for ground-level concentrations of PM10, for daily and annual exposure: the short-term limit establishes a limit value on daily mean concentrations of 50 µg/m3 not to exceeded more than 35 times per year. This Directive declared that this limit value should have been met by January 1st ,2005.

The World Health Organisation (WHO) set the Air Quality Guideline level for annual mean concentrations of PM10 on 20 µg/m^3 much more restrictive than the limits imposed by European legislation.

5. Policy questions — key policy questions; specific policy questions (optional)

The Urban population exposure to air pollution by particulate matter indicator aims to answer the following specific policy questions:

- What progress is being made in reducing concentrations of air pollutants in urban areas to below the limit values defined in air quality legislation?
- What is the percentage of European urban population exposed to pollutant concentrations above the regulated thresholds?

6. Methodology — methodology for indicator calculation; methodology for gap filling; methodology references

Concentrations of PM10 were calculated using Land Use Regression (LUR) Models. The LUR model was built using PM10 concentration for 2010 from the monitoring sites included in the AirBase database (dependent variable) and several parameters (independent variables) defined within a Geographic Information System (GIS). Some of these variables reflect sources or sinks for air pollution such as the road network, different types of land use and population density. Furthermore, factors such as elevation, topographical exposure, distance to sea, annual mean temperature and annual mean wind speed also influence the spatial concentration of pollutants and were included for the modelling. Land Use Regression model was developed using Random Forest regression techniques (Breiman, 2001) and results of concentration were presented in GIS maps. Kiesewetter et al (2014) analyzed relations between annual mean level concentrations and the limit on daily exceedances, finding that there is a good correlation between the 36^{th} highest daily mean and annual mean. Specifically the daily limit value 50 µgm−3 is well represented by an annual mean limit of 30 µgm−3. This value was used within the map of annual mean concentrations, considering only the core of the cities, to specify areas over the limit.

7. Data specifications — data references; external data references; data sources in latest figures

- Refined CORINE land cover 2006 (Batista e Silva *et al.*, 2012), base year for the Baseline Scenario.
- Baseline Scenario projected land use maps from LUISA (urban fabric and industrial/commercial land uses

classes)

- EUROPOP2010, population projections from Eurostat.
- EU-28 administrative regions: EuroBoundaryMap v81
- AirBase database (v7)

8. Uncertainties — methodology uncertainty; data set uncertainty; rationale uncertainty

The indicator is thought to be representative of the total urban population in Europe as a whole, but only the urban population in the Urban Audit cities collection is covered. So, population living in smaller towns and villages are not included.

The main uncertainty from this indicator arises from the use of regression models to assess mean annual concentrations. Uncertainty was expressed in relative terms by relating the RMSE to the mean PM10 concentration value for all the monitoring stations. The result value is 18%, which fulfils the data quality objectives for models as set in the Annex I of the Air Quality.

In relation to data set uncertainty, the air quality data is officially submitted by the national authorities. It is expected that data has been validated by the national data supplier and it should be in compliance with the data quality objectives as describe in the Air Quality Directives (EU, 2004, 2008). There are different methods in use for the routine monitoring of pollutants. Station characteristics and representativeness are in some cases insufficiently documented.

Regarding to climatic data used as input parameters, the resolution of original data is 0.25x0.25o, and from this original resolution, data were resampled to 100m resolution as used in the LUR model.

9. Responsibility and ownership (indicator manager; ownership)

Joint research Center, Institute for Environment and Sustainability, Sustainability Assessment Unit (H08)

10. Further work (short-term work; long-term work)

Short-term: built-up by NUTS2, NUTS3 , LAU 1 and 2, Large Urban Zones (LUZ) and other relevant classification groups such as:

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