Developing metrics and instruments to evaluate citizen science impacts on the environment and society

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1 Executive summary

The MICS project develops approaches and tools to evaluate citizen-science impacts. These tools can help to plan and implement projects in ways that lead to deeper impacts in the domains of **science, governance, the economy, society and the environment**. This deliverable identifies existing state-of-the-art research projects about nature-based solutions and **analyse the impacts in the aforementioned domains related to the inclusion of citizen science**. Reference projects are identified, and how they can be strengthened by citizen science is discussed. The findings on methods to include citizen science and the impacts this can cause are explored.

2 Introduction

The MICS project aims to develop a conceptual framework that hosts metrics, tools and methods to measure the impact of citizen science. This framework will be validated in specific societal and environmental settings in a priority research area of environmental science: nature-based solutions.

2.1 Nature-based solutions

Nature-based solutions (NBSs) are defined by the International Union for Conservation of Nature (IUCN) as "actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits". NBSs build on and support other closely related concepts, such as the ecosystem approach, *ecosystem services* (ESs), ecosystem-based adaptation/mitigation, and green and blue infrastructure. They all recognise the importance of nature and require a systemic approach to environmental change based on an understanding of the structure and functioning of ecosystems, including human actions and their consequences.

In framing NBSs and considering their applications, it is useful to think of them as an umbrella concept that covers a whole range of ecosystem-related approaches all of which address societal challenges. These approaches can be placed into five main categories, as shown in the following Table 1 [https://www.iucn.org/commissions/commission-ecosystem-management/our-work/nature-based-solutions].

Table 1. Main categories of NBS approaches

Category of NBS approaches	Examples
Ecosystem-restoration approaches	• Ecological restoration • Ecological engineering • Forest-landscape restoration
Issue-specific ecosystem-related approaches	• Ecosystem-based adaptation • Ecosystem-based mitigation • Climate-adaptation services • Ecosystem-based disaster risk reduction

Infrastructure-related approaches	• Natural infrastructure • Green infrastructure
Ecosystem-based management approaches	• Integrated coastal-zone management • Integrated water-resources management
Ecosystem-protection approaches	• Area-based conservation approaches, including protected-area management

NBSs, however, with respect to related concepts, have a distinctive set of premises:

1. Some societal challenges stem from human activities that have failed to recognise ecological limitations.
2. Sustainable alternatives to those activities can be found by looking to nature for design and process knowledge.

They therefore involve the innovative application of knowledge about nature, and they maintain and enhance natural capital. They are positive responses to societal challenges, and can have the potential to simultaneously meet environmental, social and economic objectives. Figure 1 shows examples of the EU research and innovation agenda on nature-based solutions.

NBSs are increasingly becoming part of policy and planning strategies, but multiple knowledge gaps have hindered their implementation and acceptance: natural systems behave differently depending on ecosystem type, climate, location, condition and management, and therefore generalised assumptions about the functioning and impact of NBSs can be made only with caution. This has led to a wide variation in their success and application. The effectiveness of NBSs depends to a large degree upon the perceptions regarding nature and upon the needs of stakeholders, such as citizens/public, user groups, conservation bodies, landowners, farmers, land managers, policy makers and practitioners.

Figure 1. Example of EU research and innovation agenda on nature-based solutions (source: European Commission, 2015).

A list of principles has been developed for NBSs by IUCN [https://www.iucn.org/commissions/commission-ecosystem-management/our-work/nature-based-solutions]. To define them, several existing frameworks were analysed (e.g. ecosystem approach and its principles, ecosystem-services approach, the original list of principles for NBSs in the 2013-

2016 IUCN Programme). This **set of NBS principles**, to be considered in conjunction with the NBS definition, is helpful in providing a full understanding of NBSs, and is as follows.

Nature-based solutions:

- embrace nature conservation norms (and principles);
- can be implemented alone or in an integrated manner with other solutions to societal challenges (e.g. technological and engineering solutions);
- are determined by site-specific natural and cultural contexts that include traditional, local and scientific knowledge;
- produce societal benefits in a fair and equitable way, in a manner that promotes transparency and broad participation;
- maintain biological and cultural diversity and the ability of ecosystems to evolve over time;
- are applied at a landscape scale;
- recognise and address the **trade-offs** between the production of a few immediate economic benefits for development, and future options for the production of the full range of ecosystems services; and
- are an integral part of the overall design of policies, and measures or actions, to address a specific challenge.

2.2 Purpose and scope of this report

This report on "*the state of the art and major knowledge gaps in NBSs with respect to the potential for strengthening by inclusion of citizen science*" is a deliverable of Task 5.4 and is basis of further activities in WP5.

Recommendations for the future of more locally embedded and more efficient NBSs through citizen science will be drafted in WP5. This will strengthen the impact and potential of citizen science. The sustainability-based approach that lies at the root of NBS science will be reinforced through tools that identify, foster and evaluate local involvement. These will strengthen transdisciplinary research in designing and implementing NBSs and will build on more comprehensive local knowledge. The intersection of stakeholders' perspectives in relation with ongoing developments in NBSs will result in a more sustainable and grounded application of NBSs.

The aim of this document is to provide a review on the state-of-the art of NBS projects that are or may be strengthened by citizen science, creating impact in different domains. Special attention is given to the projects that already include a citizen-science element.

First, the analysis of the impact of NBS projects involving citizen science is presented (section 3); then, selected state-of-the-art projects are reviewed (section 4).

3 General impact of NBS projects involving citizen science

One of the main aims of the MICS project is to develop metrics and instruments to measure costs and benefits of citizen science in relation to NBSs, in the domains of society, governance, the economy, science and the environment. Table 2 describes an initial list of impacts of NBS projects involving citizen science, which was derived from a workshop held by the MICS project at the 2019 River Restoration conference in Liverpool [https://www.therrc.co.uk/rrc-annual-conference-2019]. The workshop involved thirty-three participants working for different types of organisations, including the UK Environment Agency, Lincolnshire River Trust, the University of Leeds, Thames21, the UK National Trust, the Zoological Society of London, and Canal & River Trust [https://canalrivertrust.org.uk]. The session, organised on monitoring impact of citizen science, provided a preliminary list of possible impacts of NBS projects involving citizen science (Table 2). More information on the results of the workshop will be available in the reporting about milestone MS4, "*Report on workshop with practitioners and researchers from NBSs and other areas to validate the workflow for impact evaluation*".

Table 2. Preliminary list of impacts of NBS projects involving citizen science

Governance	
1.	Change in legislation
2.	Change in policy
3.	Change in public engagement in local environmental policy-making
4.	Change in public engagement in local policy-making
5.	Change in public engagement in policy-making
6.	Change in public engagement
7.	Changes in public opinion
8.	Changes in inclusion
9.	Changes in democracy
10.	Changes in citizen empowerment
11.	Changes in messaging fed back into governance policy, local councillors and forums
12.	Changes in the strength of voice of community to demand environmental improvement in locations where they engage via citizen science
13.	Changes in the strength of voice of community to demand improvement in locations where they engage via citizen science
14.	Changes in stakeholders' ability to lobby
Economy	
15.	Changes in cost of monitoring
16.	Changes in business awareness
17.	Changes in job support
18.	Changes in job creation
19.	Changes in building work experience

20.	**Changes** in **references** for people starting their work careers
21.	Changes in contribution to the open-data economy
22.	Changes in funding of NBS projects
23.	Changes in investments in NBSs
24.	Changes in small business involvement
25.	Changes in big business involvement
26.	Changes in the value of ecosystem services
27.	Changes in the supply chain
Society	
28.	Changes in capacity building at community level
29.	Changes in public opinion and behaviour
30.	Changes in building understanding
31.	Changes in building knowledge
32.	Changes in behaviour
33.	Changes in trust among local communities and organisations, NGOs, and government
34.	Changes in knowledge among local communities and organisations, NGOs, and government
35.	Changes in community confidence to engage
36.	Changes in long-term public engagement with stakeholders
37.	Changes in public engagement with stakeholders
38.	Changes in long-term relationships building with stakeholders
39.	Changes in relationships building with stakeholders
40.	Changes in social inclusion
41.	Changes in health
42.	Changes in well being
43.	Changes in social capital
44.	Changes in sense of ownership
45.	Changes in the engagement of multiple stakeholders
Science	
46.	Changes in the production of scientific NBS evidence
47.	Changes in science's legitimacy
48.	Changes in guiding references for scientific endeavours in the field of NBS research
49.	Changes in scientific knowledge (e.g., publications)
50.	Changes in innovations around concerns shared by some disciplines employing citizen science approaches
51.	Changes in practices around concerns shared by some disciplines employing citizen science approaches
Environment	

Mainly dependant on the NBS-project objectives, but some illustrative examples include:
52. Changes in water pollution
53. Changes in agricultural land management
54. Changes in the health of coasts
55. Changes in the health of rivers
56. Changes in the health of lakes
57. Changes in the sustainability of places to live
58. Changes in the sustainability of places to work
59. Changes in ecosystems
60. Changes in the restoration of ecosystems
61. Changes in the achievement of sustainable development goals
62. Changes in biodiversity
63. Changes in loss of biodiversity
64. Changes in ecological degradation (including pollution)
65. Changes in landscape destruction

4 State of the art of NBS projects

Based on the screening carried out for deliverable D2.1, the projects that focused on nature-based solutions were selected for this report. The first group of projects described already include a citizen-science component; the second group of projects do not include this component in their description, and ways in which citizen science can contribute to the project impacts are discussed. The project descriptions are extracted from the CORDIS website [https://cordis.europa.eu/projects/en] and from the project websites (see Annex1. Links to projects' websites).

The following projects have included a citizen-science component in their description.

4.1 CLEVER Cities

This is an H2020-funded project that applies a city centric approach, starting by key urban regeneration challenges and employing strong local partner clusters, to foster sustainable and socially inclusive urban regeneration. The project will co-create, implement, and manage locally tailored NBSs to deliver tangible social, environmental and economic improvements for urban regeneration. The involved partners are committed to make the interventions in front-*runner cities* (FR) cases for successful NBS and prepare robust replication roadmaps in *fellow cities* (FE) that also have NBS experience and expertise to offer. The long-term sustainability of actions is ensured in FR and FE by initiating urban innovation partnerships that will use SMART city principles to engage residents, establish new governance procedures, generate innovative financing and investment strategies.

This project will involve local monitoring teams that will use a variety of tools, such as sensors and citizen science, to keep track of the changes in the area. Also, the project uses nature-

based interventions to make cities more inclusive, and local citizens are the ultimate experts of their neighbourhoods, so their integration is essential to ensure real transformative action takes place in the cities through the collaborative development of solutions that respond to citizens' needs. Through **a network of local non-governmental organisations, research organisations, local city-governments and SMEs**, residents' neighbourhood associations and budding local entrepreneurs will be empowered to make the nature-based interventions their own: whether they be community gardens, green roofs or improved storm water drainage. With citizens playing such an essential role in this development, it is more likely they will identify with the changes taking place, feel a sense of ownership and make use of the renewed urban spaces.

Of special interest for MICS are CLEVER Cities' deliverable 1.1.4 on key concepts and associated indicators to measure NBS impact on urban regeneration:

[http://clevercities.eu/fileadmin/user_upload/Resources/D1.1_Theme_4_impact_indicators_ECOLOGIC_12.2018.pdf]

and CLEVER Cities' deliverable 4.1 on the monitoring and evaluation framework:

[http://clevercities.eu/fileadmin/user_upload/Resources/181130_D.4.1_Monitoring_Framework_TEC.docx.pdf].

Examples of impact indicators can be found in Table 3 - Table 6. This information was extracted from CLEVER Cities' deliverable on impact indicators.

Table 3. First and second priority indicators for human health and well-being (extracted from CLEVER Cities' deliverable on impact indicators)

	Code	Indicator	Scale(s)	Unit of measurement	Potential data sources	References
GROUP 1	Hd1	Overall mortality	City	annual mortality rate per 100 000 population	health statistics from death certificates, published by statistical offices	UnaLab ECLIPSE, TAPAS Health2020, SDG3
	Hd2	Change in lifespan	City	life expectancy at birth	official statistics of the cities	UnaLab ECLIPSE
	Hd3	Cardiovascular disease (CVD)	City	annual mortality rate – total CVD annual morbidity rate – total CVD per 100 000 population	health statistics from hospitals/doctors, published by statistical offices	URBAN, GreenUP UnaLab, EKLIPSE PASTA (39), SDG3, PHENOTYPE
	Hd4	Obesity	City	Proportion (%) of obese people – BMI over 30kg/m2	health statistics from hospitals/doctors, published by statistical offices	UNaLab, EKLIPSE PASTA, PHENOTYPE
	Hd5	Diabetes Type 2	City	mortality rate attributed to diabetes type 2	health statistics from hospitals/doctors, published by statistical offices	SDG3 T.3.4.1 (40)
	Hd5	Chronic respiratory diseases	City	mortality rate attributed to chronic respiratory disease	health statistics from hospitals/doctors, published by statistical offices	Health2020, SDG3
	Hd6	Allergies (pollen)	City	Proportion (%) of people suffering from allergies per 100,000 inhabitants, by age/sex	health statistics from hospitals/doctors, published by statistical offices	URBAN GreenUP UNaLab EKLIPSE (41)
	Hd7	Depression	City	major depressive disorder mortality rates from suicide and intentional self-harm per 100 000 population	health statistics from hospitals/doctors, published by statistical offices	Health2020, SDG3
	Hd8	Traffic injuries	City/ neighbour-hood	Motor vehicle accidents	official statistics from departments for transport	Health2020, SDG3

	Hd9	Weather-related mortality	City	mortality rate - heat-related causes (summer, age 65-75)	mortality statistics from death certificates published by statistical offices	UNaLab, (42)
GROUP 2	H1	Self-reported general health status	Regional to site	Proportion (%) of people feeling 1. 'good' and 'very good' in the past 12 months 2. 'bad' and 'very bad' in the past 12 months	Census data and dedicated study/survey, questionnaires3	GREEN-LULUS PHENOTYPE UNaLab BlueHealth (43,44) IWUN (45), (46)
	H2	Overall life satisfaction/ well-being	City / neighbour-hood /site	Percentage of people reporting overall life satisfaction ratings, on a scale from 0 to 10, by socio-economic class	Existing survey data or dedicated study based on qualitative interviews or questionnaire survey	(46)
	H3	Self-reported mental health status	City / neighbour-hood /site	Percentage of people reporting mental well-being on the scale from 0 to 5	existing survey data or dedicated study with interviews or questionnaire survey	WHO 5 Well-being Index, GREEN-LULUS UNaLab EKLIPSE (47) PHENOTYPE
	H4	Medication use	City / neighbour-hood /site	Percentage of people reporting medication use (hypertension, diabetes, pollen allergies, sedatives…)	Dedicated study questionnaire survey or data from health insurance	NAKO, (48)
	H5	Satisfaction with community/neigh-bourhood/NBS	Neighbour-hood / site	Percentage of people fairly or very satisfied with community/neighbourhood/NBS with places they like and places they avoid	Dedicated study - questionnaire survey and PPGIS (place-based survey – mapping places)	(46)
	H6	Number / share of people being physically active	City / neighbour-hood /site	Proportion (%) of people being physically active (min. 150 minutes per week)	Dedicated study with wearable sensors and app, qualitative interviews or questionnaire	UNaLab EKLIPSE + WHO recommend-dation

				survey (or existing scientific studies)	
H7	Walking and cycling in and around areas of interventions	Site	Proportion (%) of people using NBS for walking, cycling outdoor activities (gardening)	Dedicated study with on-site counting, smartphone app, qualitative interviews or questionnaire survey	URBAN GreenUP
H8	Share of people using green space (formally or informally)	Site	Proportion (%) of people using green by: age; gender; ethnic or cultural group; socio-economic status	Dedicated study questionnaire survey; SOPARC: System for Observing Play and Recreation in Communities	(20)
H9	Frequency of green space use	Site	Proportion (%) of people visiting green space: 1. three or more times a week 2. less than once a month	Dedicated study questionnaire survey	(46)

Table 4. First and second priority indicators for sustainable economic prosperity (extracted from CLEVER Cities' deliverable on impact indicators)

	Code	Indicator	Scale(s)	Unit of measurement	Potential data sources	References
FIRST PRIORITY	P1	Net outcomes into employment	City	Number of (un)employed people	Public employment agency	URBAN GreenUP KPIs (8)
	P2	Green jobs related to NBS (gardening, maintenance)	Regional to site	Number of employees or full-time equivalent jobs	Public employment agency, public administration in charge of green spaces, if site specific: survey or qualitative interviews	URBAN GreenUP KPIs / EKLIPSE framework (61)
	P3	Investment	Neighbour-hood to site	Amount of inward investment in property and business in project area	city administration data, business reports, data provided by real estate companies/ agents	(59)

	P4	Local tax revenue	City to Neighbour-hood	Increase in Council Tax/Business Rate revenue in project area	Tax revenues published by statistical offices	(59)
	P5	Commercial and domestic property prices	Regional to site	Property prices/ rent prices, characteristics of the neighbourhood/ community, environmental characteristics	(open source) geographical data, data provided by real estate agents/ companies, city administration (the latter also for socio-economic data)	Urban GreenUP KPIs/ EKLIPSE framework (8,59,62–64)
SECOND PRIORITY	P6	Number of jobs	Neighbour-hood to site	full-time equivalent jobs in project area	Public employment agency, if site specific: survey or qualitative interviews	(59)
	P7	Local employment	Neighbour-hood to site	Number of jobs taken by residents in project area	Public employment agency	(59)
	P8	Number of businesses and their business rates	City to site	Revenue from businesses in the NBS intervention areas, number of new shops/businesses opening in the environment of the NBS	Data from Opening Licences Department, companies business reports, economic data published by statistical offices , if site specific: Qualitative interviews or survey	URBAN GreenUP KPIs/ EKLIPSE framework (59)

P9	(Storm)water management costs	Neighbour-hood to city	Expenses for stormwater treatment facilities and erosion control measures, expenses of property owners to protect their property, predictions of flooding occurrences and their levels, potential impacts on property, infrastructure	Meteorological service, public administration/ public utilities, insurance companies	NAIAD (65)
P10	Energy costs for heating/cooling	Site	temperature differences (interior/exterior) or incoming and reflected radiation data, electricity prices	Dedicated study with technical measurement equipment needed for temperature differences, radiation data, Stock market for electricity	URBAN GreenUP KPIs (53,66)
P11	Numbers of visitors from outside town/city to intervention area	City to Site	Number of visitors pre and post NBS intervention	Tourism data published by statistical offices, survey (if site specific)	(59)

Table 5. First and second priority indicators for social cohesion and environmental justice (extracted from CLEVER Cities' deliverable on impact indicators)

	Code	Indicator	Scale(s)	Unit of measurement	Potential data sources	References
FIRST PRIORITY	SJ1	Availability of parks and/or ecosystem services with respect to specific individual or household socioeconomic profiles	Regional / city / neighbour-hood	Availability of (public) green space within 300m walking, segregated by household socioeconomic characteristics (e.g. income, degree of education, ethnic background/nationality, age)	Geospatial data, census data, surveys	EKLIPSE framework (69), RECREATE case study (77), (79)
	SJ2	Changes in tenancy turnover rate in the site area	Neighbour-hood	Number of tenancy changes in a given area within a given timeframe	Data from citizen address registration	GRABS project in RECREATE (77)
	SJ3	Population density	City / neighbourhood	Number of people per area (Population (N)/sq km)	Official statistics of the city	
	SJ4	Children from 0-18 yrs	City / neighbourhood	Proportion of children (0-18 yrs) in the overall population, in %	Official statistics of the city	
	SJ5	Adults from 18-64 yrs	City / neighbor-hood	Proportion of adults (18-65 yrs) population, in %	Official statistics of the city	
	SJ6	Adults from 65+ yrs	City / neighbor-hood	Proportion of elderly (65+ yrs) population, in %	Official statistics of the city	
	SJ7	Population with higher education level	City / neighbor-hood	Proportion of population with more than 13 years of education (Hochschulabschluss in Germany), in %	Official statistics of the city	
	SJ8	Long term unemployment	City / neighbor-hood	Proportion of economically active population (15-65yrs)	Employment agency or ministry of social affairs	

				unemployed over 12 months, in %		
	SJ9	Proportion of population receiving social benefits	City / neighbor-hood	Proportion of population that receive social benefits, in %	Employment agency or ministry of social affairs	
SECOND PRIORITY	SJ10	Level of political participation	City / neighbor-hood	Voter turnout rate, number of individuals and organisations participating in political organisations and actions, offline engagement actions, and/or online engagement (online consultation, social media, etc.)	Voting statistics, counting participants in events or online engagement, dedicated study (survey, Interviews, and Participant Observation)	EKLIPSE framework (69), URBAN GreenUP KPIs (82), see GREENSURGE methodologies (83)
	SJ11	Distance travelled to urban green space	Neighbour-hood / site	shortest network distance / perceived distance	dedicated study	
	SJ12	Access/barriers to green spaces	Neighbour-hood / site	Proportion (%) of people perceiving 1. good access 2. barriers to green space/ NBS	dedicated study	

Table 6. First and second priority indicators for citizen security (extracted from CLEVER Cities' deliverable on impact indicators)

	Code	Indicator	Scale(s)	Unit of measurement	Potential data sources	References
FIRST PRIORITY	CS1	Crime in the immediate vicinity of a green area	Neighbour-hood	Number and types of crime committed in the demonstration area per inhabitant OR user	Crime statistics (segregated by type and time of day)	New indicator, assessment method derived from EKLIPSE framework, UNaLab, and STAR Communities (93); see (94) for detailed typology of crimes
SECOND PRIORITY	CS2	Level of devices contributing to the safety of users in the neighbourhood (e.g. lighting of public space areas, access control, presence of technical or specialized staff, etc.)	Site	Percentage of area covered by devices contributing to safety OR Number of devices contributing to the safety of users in the neighbourhood	Survey of buildings/ built environment	EKLIPSE framework
	CS3	Perception of safety	City /neighbour-hood / site	Residents' and area users' perceptions of safety	Interviews and/or surveys with local communities and users	NATURVATION (91), assessment method from EKLIPSE framework; SDG 16: 16.1.4

Code	Indicator	Scale(s)	Unit of measurement	Potential data sources	References
P12	Business returns	Neighbour-hood, Site	Business returns of companies near NBS intervention	Dedicated study based on companies business reports	URBAN GreenUP KPIs
P13	Gross value added	Regional to city	Regional/city-level data on national accounts	Economic data published by statistical offices	URBAN Green UP KPIs/ EKLIPSE framework (8)
P14	Earnings of people that enhanced their skills in the design and implementation of NBS	Regional to city	Earnings of people designing and implementing NBS pre- and post-intervention	Qualitative interviews or social survey	EKLIPSE framework (8)
P15	Fuel costs in NBS intervention area	Neighbour-hood, Site	Average fuel consumption per vehicle, Number of people using bicycle instead of car because of new NBS	Onsite counting or survey for bicycle use, data of automobile companies or independent studies on actual fuel consumption	URBAN GreenUP KPIs
P16	Visitor spend	City	Aggregate amount spend by visitors pre and post NBS intervention	Tourism data published by statistical offices	(59)
SJ4	Level of participation in the development and delivery of GI interventions	City, neighbour-hood, site	Number of individuals and organisations participating in meetings, offline engagement actions, and/or online engagement (online consultation, social media, etc.)	Counting participants in meetings or online engagement, survey, Interviews, and Participant Observation	EKLIPSE framework (69), GREENup KPIs (82), see also GREENSURGE methodologies (83)
SJ5	Changes in participation in organised associations	Regional, urban, neighbour-hood, site	Number of organised associations OR	Surveys, local statistics on registered organisations (if	EKLIPSE framework (69)

			Percentage of population with membership in organised association	available and at appropriate scale)	
SJ6	Change in accessible green public space	City, neighbour-hood, site	Change in absolute amount OR share (%) of green space accessible to elderly, young, and people with disabilities (i.e. lacking barriers, with adequate safety features)	Dedicated qualitative survey of green space	Urban GreenUP KPIs (82)
SJ7	Attachment to place	Neighbour-hood	Self-reported measures of attachment to place	Survey	(84) in EKLIPSE framework
SJ8	Level of empathy and positive emotions towards social environment	Neighbour-hood	Self-reported measures of empathy and emotions	Survey	(84) in EKLIPSE framework
SJ9	Level of family and social ties	microscale (neighbour-hood, site)	Self-reported measures of family and social ties	Surveys	(84) in EKLIPSE framework

4.2 EKLIPSE

The aim of the EKLIPSE H2020 project is to establish an innovative, light, self-sustainable EU support mechanism for evidence-based policy on biodiversity and ecosystems services open to all relevant knowledge holders and users, and to hand over this mechanism to the wider knowledge community by the end of the project. The mechanism will build on existing science-policy-society interfaces and be further refined via iterative evaluation and learning throughout the project. The mechanism will provide trustworthy evidence for policy and society upon request and will make the knowledge community more able to provide synthesized and timely evidence by providing a platform for mutual learning and engagement. EKLIPSE will directly support the further development of a "Network of Networks" of potential contributors to the EU mechanism's activities and ensure the involvement of relevant stakeholders in the following key areas:

1. jointly developing and setting up a business plan for the mechanism after the end of the project;
2. conducting joint evidence assessments using established and innovative methods to support policy and societal needs;
3. jointly identifying research needs and emerging issues, actively building the Network of Networks; and
4. encouraging societal engagement. (This will be supported by an interim governance structure, a strong communication component, including a Science-Policy-Society Forum, and an independent formative evaluation to ensure learning.)

For instance, EKLIPSE will foster social debate and citizen engagement with biodiversity and ecosystem services related policy and research. This is done through:

1. the development of a Science-Policy Society Forum to enable the open exchange of ideas, information and research findings and to mobilize all relevant stakeholders to find sustainable solutions;

2. ensuring the adequate information and engagement with all relevant project activities and mechanisms by, for example, the organization of science cafés in various regions in Europe by societies, including civil society and businesses.

A publication framed within the EKLIPSE project named *"a framework for assessing and implementing the co-benefits of nature-based solutions in urban areas"* (Raymond et al., 2017) identified a few indicators for assessing impacts of NBS, which could be adapted to the MICS project. Table 7 shows examples of different types of indicators for assessing the impacts of NBS.

Table 7. Examples of different types of indicators for assessing the impacts of NBS (extracted from Raymond et al., 2017)

Indicator	**Type of indicator**	**Unit of measurement**
Net carbon sequestration by urban forests (including GHG emissions from maintenance activities)	Environmental (Chemical)	T C per ha/year
Economic benefit of reduction of stormwater to be treated in public sewerage system	Economic (Monetary)	Cost of sewerage treatment by volume (€/m^2)
Area remaining for erosion protection	Environmental (Physical)	Km^2 or m^2
Species richness of indigenous vegetation	Environmental (Physical)	A count, magnitude or intensity score of indigenous species per unit area.
Annual amount of pollutants captured by vegetation	Environmental (Chemical)	T pollutant per ha/year
Index of ecological connectivity	Environmental (Physical)	Probability that two dispersers randomly located in a landscape can reach each other
Quality of the participatory or governance processes	Social (Process)	% of people living within a given distance from accessible, public green space.
Accessibility to public green space	Social (justice)	% of people living within a given distance from accessible, public green space
Level of involvement in frequent physical activity in urban green spaces	Social (physiological)	Number and % of people being physically active (min. 30 3 times per week) in urban green spaces

Net additional jobs in the green sector enable by NBS project	Economic (productivity)	New jobs/specific green sector/year

4.3 Nature4Cities

Based on a detailed mapping of urban challenges and relevant NBSs, this Horizon 2020 project aims to develop **interactive modules** to engage urban stakeholders in a collective-learning process about re-naturing cities, develop and circulate new business, financial and governance models for NBS projects, as well as provide tools for the impact's assessment, valorisation and follow-up of NBS projects. The different modules are:

- a database of generic NBS and associated environmental, economic and social performances;
- an observatory of NBS projects best practices / case studies;
- a set of innovative business, financial and governance models for the deployment of NBS in a range of different contexts, together with a tool to help urban stakeholders identify eligible models regarding their NBS project contexts;
- an **NBS project impact assessment toolbox** providing capabilities for environmental, economic and social impacts evaluation at different stages in the project development cycle from opportunity/feasibility studies to design steps and project follow-up. (This toolbox will build on a range of tools, from generic indicator-based assessment for early project stages, down to detailed modelling of NBS behaviours.)

The project delivered a report dedicated to "Citizen and stakeholder engagement strategies and tools for NBS implementation (D5.2)". The aim of the deliverable is to develop strategies towards inclusive planning and implementation processes of NBS. Mechanisms that foster participation and allow for the proper engagement of and communication with various stakeholders, including citizens, within different contexts. The report highlights the importance of stakeholder and citizen participation early in the process of planning and implementation of NBS. The benefit of participation works at three levels:

1. Participation results in substantive benefits, since local knowledge can help inform and improve the design and planning of NBS. Local residents can provide valuable knowledge as users of a specific place where the NBS intervention is planned, e.g. how they value the place or how they use it, contributing to a better understanding of how an NBS can be best adapted to the local situations.
2. Participation can add value to instrumental benefits such as social acceptance of the NBS project, increase the support and maybe foster the sharing of responsibilities concerning the implementation and maintenance of the NBS. Empowered local residents can generate change and initiate action (Scholten et al., 2015) while early engagement with local residents, answering questions and addressing concerns are critical to the successful implementation of a project.

3. Participation can have normative benefits, which concern the legitimacy of the planned project. The respect of democratic values and creation of a fair procedure for citizen and stakeholders to participate contributes to more socially fair outcomes.

4.4 NATURVATION

To unlock the potential of nature-based solutions for sustainable urban development (e.g. the potential to enhance biodiversity and improve environmental quality while contributing to economic regeneration and social well-being), NATURVATION will complete the following objectives to take a transdisciplinary, internationally comparative approach to:

1. advance assessment approaches to capture the multiple impacts and values of NBS to deliver a robust evidence base for decision-making;
2. enable innovation to identify the most promising governance, business/finance and participation models and how to overcome the systemic conditions that currently limit their use to support systemic integration;
3. generate momentum to realise the potential of NBS through co-design, co-development and co-implementation of new partnerships, knowledge, recommendations, processes and tools required to build capacity, enable replication and foster cultural change.

The transdisciplinary approach working with 'urban-regional innovation partnerships' in six different cities and a Task Force of highly respected international organisations working in this arena integrates science, social science and humanities and practical expertise and experience to achieve a step-change in the use of NBS for urban sustainability.

The NATURVATION project aims to engage through public through the development a Massive Open Online Course (MOOC) on NBSs in an urban world. The MOOC will develop an online learning community and contain a collection of inspiring and educational films about the opportunities, challenges and future of NBSs. The course combines both technical knowledge and the social sciences to better understand NBSs in a holistic perspective. The course brings together a collection of diverse films and key short readings on NBSs, as well as, interactive forums and practical assignments to create an online learning community. This initiative will build capacity among communities, increasing the community knowledge and confidence to engage and become more empowered.

The project delivered a report dedicated to "Social and cultural values and impacts of nature-based solutions and natural areas (D1.3, Part IV)" (Da Rocha et al., 2017), where they carried out a literature review on the social and cultural values and impacts of NBSs. The aim was to analyse and integrate the existing knowledge regarding the social and cultural values and benefits of NBS in the urban environment. In this report, the authors mention a result of particular interest for the MICS project: the examples of **social and cultural impacts identified in the literature reviewed per domain of NBSs** (shown in Table 8).

Table 8. Examples of cultural and social impacts identified in the reviewed literature (extracted from D1.3 "Social and cultural values and impacts of nature-based solutions and natural areas" (Da Rocha et al., 2017).

Type of cultural benefits	**Examples of benefits**
Aesthetic improvement	Enhanced beauty Improved aesthetic quality of the landscape
Spiritual connection	Provide sense of calm Benefits on affect and cognition Pleasure of experiencing nature Inspiration for art or culture Support exploration of religious feelings
Preservation of cultural heritage	Impact on cultural-historical values Safeguarding or restoring cultural heritage
Recreation opportunities	Provide opportunities for relaxation Enjoying nature Encourages physical exercise Opportunity for outdoor activities
Type of social benefits	**Examples of benefits**
Well-being enhancement	Improve physical and mental health Increase physical activity Relieves stress
Opportunities for social interaction	Encourage child's play Improved sense of community Meeting place for residents Participation and integration in decision-making processes Transparency Gender equity Feeling of collective activity
Enhancement of equality	Empower disadvantaged groups Reduce social isolation
Growth of employment	Employment opportunities in recreation, nature protection and nature tourism
Education development	Provide formal education opportunities Provide informal learning opportunities about nature Raise awareness on nature conservation
Safety advancement	Increased perception of safety Increased coping capacities/resilience with climate change

4.5 OPERAs – Operational potential of ecosystem research applications

The project aimed to improve understanding of how ES/NC contribute to human well-being in different social-ecological systems in inland and coastal zones, in rural and urban areas, related to different ecosystems including forests and fresh water resources. The OPERAs research established whether, how and under what conditions the ES/NC concepts can move beyond the academic domain towards practical implementation in support of sustainable ecosystem management. OPERAs used a systematic review of existing ES/NC practice to identify knowledge gaps and requirements for new policy options and instruments. New insights, and improved or novel tools and instruments, were tested in practice in exemplar case studies in a range of socio-ecological systems across locales, sectors, scales and time. Throughout this iterative process, available resources and tools were collected in a 'Resource Hub', a web-based portal that was co-developed by scientists and practitioners representing different interests and perspectives on the development, communication and implementation of the ES/NC concepts. The Resource Hub provided the main interface between OPERAs and a *community of excellence* (CoE) for continued practice that benefits from OPERAs outcomes.

The OPERAs project addresses the importance of public engagement for the conservation of ecosystems with the publication of a policy brief on how to engage citizens through applying the ecosystem service approach. This document states the following key messages:

1. Citizen/community engagement is important for conserving local ecosystems.
2. Decision-makers need to understand the ecosystem services that people value,
3. understanding demand can help inform conservation goals and actions ('capacity effect').
4. Understanding demand can also influence decisions and reduce conflict ('constraint effect').
5. Involving citizens in the decision-making process not only ensures their voices are heard, but gives policymakers the tools to communicate with them through an increased knowledge of the values that citizens derive from the ecosystem.

The document also describes an eight-step framework for eliciting citizens' demand for ecosystem services that has been developed based on experience from seven exemplar case studies in the OPERAs project and presents a range of instruments for decision-makers to elicit the values people place on ecosystem.

4.6 ProGIreg - Nature for urban regeneration with and for citizens

In the Horizon 2020 funded proGIreg project, three front-runner cities, Dortmund (DE), Turin (IT) and Zagreb (HR), will create Living Labs in urban areas that face the challenge of post-industrial regeneration. These areas suffer from social and economic disadvantages, inequality and related crime and security problems. They lack quality greenspaces, and have a negative impact on human health and wellbeing. Going beyond the current state-of-the-art with Green Infrastructure as a one-off state intervention, the proGIreg Living Labs will develop NBS that are citizen owned and co-developed by state, market and civil society stakeholders.

Innovation will take place on the technical level through the NBS deployments, on the social level through co-designing, co-creating and co-implementing NBS with local communities and on the economic level through combining NBS with market-ready business models.

The project involves the local involvement of citizens as they are considered to know best what is needed in their neighbourhood and it leads to more acceptance and a better connectivity with their neighbourhood. The project invites local residents and people interested in the development of an area to become involved in the co-creation process. These activities give voice to the community, build trust and knowledge between community and state, market and civil society stakeholders.

Scientific assessment and monitoring results from the Living Labs will be made available on the EU NBS platforms OPPLA and THINKNATURE will contribute to the European reference framework for NBS. Global impact will be achieved by a training programme for cooperative planning, implementation and management of NBS. It will be provided by partners from the cities, SMEs and universities involved. Training events will be organised in cooperation with the partner ICLEI. *Massive open online courses* (MOOCs) will be distributed via the EdX platform.

The proGIreg deliverable on "D4.3. Protocols of measurements" (Baldacchini, 2019), published on the project website, provides a series of indicators to assess the benefits produced by the implemented NBSs in four different domains. Tables Table 9-12 show a shortened list of indicators obtained based on the proGIreg methodology. A short explanation is provided along with the unit and type of data or data source from which indicators are derived. The full list can be found in Annex 2. List of indicators for to assess the benefits produced by the implemented NBS in four different domains).

Table 9. Indicators for socio-cultural inclusiveness

Indicator	Explanation	Units	Data
Total population	Total number of persons living in the specific area. Indicator should be collected for both the city and LL district level	Number	BASE
Population density	Number of persons per square km of land area. Indicator should be collected for both the city and LL district level	n/(m*m)	BASE
Population growth rate	Average annual rate of change of population size (%). Indicator should be collected for both the city and LL district level	%	BASE
Migration rate	Net number of migrants per 1,000 population. Indicator should be collected for both the city and the LL district scale	%	BASE
Material deprivation rate	Material deprivation rates gauge the proportion of people whose living conditions are severely affected by a lack of resources	%	BASE
Work intensity	% employed out of total economically active population (15-64 years of age, according to the definition of the International Labour Organisation)	%	BASE

Table 10. Indicators for human health and well-being

Indicator	Explanation	Units	Data
Use of green and blue spaces	Time spent in natural environments[13]	Hours/ week	GQ
Visual exposure to green space	The amount of green space in the view from windows at home and the frequency of looking at the view	Number	GQ

Satisfaction with green and blue spaces	Satisfaction (scale 1 to 5) with the green/blue spaces in the neighborhood[13]	Number	GQ
Perceived general health	Self-perceived general health[14]	Number	GQ
Somatization	Somatization (scale 0 to 3) and category (low, moderately high, very high) [15]	Number	GQ
Self-reported mental health and well-being	Mental health and well-being (scale 1 to 6) [14]	Number	GQ
Perceived stress	Perceived Stress Scale (scale 0 to 4) [16]	Number	GQ
Self-reported anxiety	Anxiety (scale 0 to 3) and category (mild, moderate, severe)[17]	Number	GQ
Self-reported depression	Number of participants reporting depression	Number	GQ
Current asthma and/or allergies	Number of participants with asthma or allergy attacks/episode	Number	GQ

Table 11. Indicators for ecological and environmental benefit assessment

Indicator	Explanation	Units	Data
Reduction of air pollutants	Potential estimation of pollutant abatment[2,22]	%	BASE
Greenness	Spatial map indicating the presence of green areas for each pixel[23]	Normalized index (10 m pixel)	GIS
Carbon uptake	The estimation of the carbon sequestered by the NBS[2,22]	t C ha^{-1} $year^{-1}$	D
Reduction of energy demands	The energy not consumed for heating and cooling buildings can be accounted with an estimation of reduction of CO_2 emissions[2,22]	t C $year^{-1}$	D
NO_2 Removed	Changes on NO_2 concentration within the NBS with respect to control point[2,22]	%	E
O_3 Removed	Changes on O_3 concentration within the NBS with respect to control point[2,22,24]	%	E
Air temperature modification	Changes on day and night average, minimum and maximum temperatures within the NBS with respect to control point[2]	ΔC° / day	F
PM removed	Estimation of PM removed by the green surfaces of the NBS[2,25]	g m^{-2}	G

Table 12. Indicators for economics and labour market

Indicator	Explanation	Units	Data
GDP per capita	GDP (at PPS- Purchasing Power Standards), Euro Gross domestic product (GDP) is a measure for the economic activity. It is defined as the value of all goods and services produced less the value of any goods or services used in their creation. The volume index of GDP per capita in Purchasing Power Standards (PPS) is expressed in relation to the European Union (EU28) average set to equal 100. If the index of a country is higher than 100, this country's level of GDP per head is higher than the EU average and vice versa. Basic figures are expressed in PPS, i.e. a common currency that eliminates the differences in price levels between countries allowing meaningful volume comparisons of GDP between countries.[27]	Number	BASE
Businesses in the area - Industrial	Number of companies of industrial sectors registered in the area per 1,000 inhabitants Industrial sectors are those with codes B-D-F of NACE Rev2 classification (Eurostat)	Number	BASE
Businesses in the area - Commercial	Number of companies in the service sector registered in the area per 1,000 inhabitants Service sectors are those covered by the EU Service Directive (0123/2006)[28]	Number	BASE
Public jobs	Total number of jobs in public sector	Number	BASE
Private jobs	Total number of jobs in private sector	Number	BASE
Public green jobs	Total number of public green jobs Green jobs are those within the environmental economy. These encompass two broad groups of activities and/or products: 'environmental protection' — all activities related to preventing, reducing and eliminating pollution and any other degradation of the environment; 'resource management' — preserving and maintaining the stock of natural resources and hence safeguarding against depletion.[29]	Number	BASE
Private green jobs	Total number of private green jobs	Number	BASE

4.7 URBAN GreenUP

URBAN GreenUP [https://www.urbangreenup.eu/] is a project funded under the European Union's Horizon 2020 programme. Its objective is the development, application and replication of Renaturing Urban Plans in a number of European and non-European partner cities with the aim to improve air quality and water management, as well as to increase the sustainability of our cities through innovative NBSs. This project aims to develop a methodology:

1. to support the co-development of Renaturing Urban Plans focused on climate change mitigation and adaptation and efficient water management; and
2. to assist in the implementation of NBSs in an effective way. (NBS classification and parametrization will be addressed and some resources to support decision-making will be established as part of the project activities.)

A large scale and fully replicable demonstration action of NBS accompanied by innovative business models will provide evidences about the benefits of NBS contributing to the creation of new market opportunities for European companies, and fostering citizen insight and awareness about environmental problems.

This project aims to understand the "value" people place on local environments, specifically the quality or functionality of nature. The project's report on city diagnosis and monitoring procedures (D5.3) describes a number of *key performance indicators* (KPIs) used to assess the renaturing city methodology and the baselines being developed. Of particular interest to the MICS project, are the following KPIs in relation to NBSs in urban areas described in D5.3 (see Table 13).

Table 13. Core KPIs for the URBAN GreenUP project (extracted from URBAN Green UP (2018), D5.3 City Diagnosis and Monitoring Procedures)

Type of indicator	**KPI definition**
Environmental, Chemical	Tonnes of carbon removed or stored per unit area per unit time
	Total amount of carbon stored in vegetation
Environmental, Physical	Decrease in mean or peak daytime local temperatures
	Heatwave risks
	Use of Star tools to calculate projected maximum surface temperature reduction
Physical indicators	Run-off coefficient in relation to precipitation quantities
	Absorption capacity of green surfaces, bioretention structures and single trees
	Temperature reduction in urban areas
	Areas (ha) and population (inhabitants) exposed to flooding
Chemical indicators (water quality)	Drinking water provision
	Water for irrigations purposes
Environmental (biological)	Production of food
	Increased connectivity to existing GI
	Pollinator species increase
Environmental (chemical)	Annual mean levels of fine particulate matter in cities concentration recorded ug/m3
	Trends in emissions NO_X, SO_X
Economic indicators	Monetary values: value of air pollution reduction; total monetary value of urban forests including air quality, run-off mitigation, energy savings, and increase in property values. use of GI Val to calculate the value of air quality improvements
Economic	Volume of water removed from water treatment system
	Volume of water slowed down entering sewer system
Economic	Number of jobs created; gross value added
Social indicators (benefits)	Accessibility (measured as distance or time) of urban green spaces for population

	Weighted recreation opportunities provided by Urban Green Infrastructure
Health indicators related to ecosystem service provision	Increase in walking and cycling in and around areas of interventions

4.8 EdiCitNet - Integrating Edible City Solutions for social resilient and sustainably productive cities

The systemic use of urban landscapes for food production is a major step towards more sustainable, liveable and healthier cities. A multitude of initiatives, however fragmented, are prospering, forming a global movement of Edible Cities. Their products, activities and services – the *Edible City Solutions* (ECS) - empower local communities to overcome social problems by their inclusive and participatory dynamics and to create new green businesses and jobs, and thereby generating local economic growth and fostering social cohesion. EdiCitNet will leverage the substantial benefits of ECS at local level and catalyse their replication by launching a fully open and participatory network of cities, empowering their inhabitants, by a common methodology:

- to systematically explore the wealth and diversity of existing ECS;
- to adapt, plan and implement successfully proven ECS in their specific urban context.

To make this happen, EdiCitNet will close knowledge gaps in the effective implementation of ECS and their transformation into sustainable, innovative business models. This new insight will feed into openly shared and globally accessible knowledge base and methodology to enable sustainable and evidence-based integration of ECS into the long-term urban planning of cities covering a large spectrum of urban, climatic, social, environmental and cultural contexts.

A recent paper introducing the conceptual framework of ECS states that NBSs have not been able to actively involve citizens and to address successfully food security, poverty alleviation, and inequality in urban areas (Säumel et al., 2019). The Edible City approach promises a strategic step towards the development of sustainable, liveable, and healthy cities - especially through more participation. The authors provide an analysis of strengths, weaknesses, opportunities, and threats (SWOT) to explore the capacity of ECS to enhance multifunctionality of urban landscapes with special focus on social cohesion and quality of life. Based on this, they identify and discuss strategies for fostering socially relevant implementations for the case study cities and beyond.

Due to the urban component of this project, citizen participation and inclusion is essential to reach the objectives of the project. In the meantime, the results of the project will have a substantial economic impact, as they will incorporate sustainable, innovative business models.

4.9 GrowGreen - a partnership for greener cities to increase liveability, sustainability and business opportunities

The project aims to create climate and water resilient, healthy and liveable cities by investing in NBSs. Making nature part of the urban living environment improves quality of life for all citizens and will help business to prosper. High quality green spaces and waterways provide innovative and inspiring solutions to major urban challenges, such as flooding, heat stress, drought, poor air quality and unemployment and will help biodiversity to flourish. The GrowGreen partnership will give space to nature in urban planning and development by joining forces with cities and experts in Europe and around the world, to implement solutions that deliver social, environmental and economic benefits. The effective use of green will contribute to health, reduce climate impacts, and create an attractive environment for citizens, visitors and investment.

At the core of this project is value creation by city governments by promoting NBSs involving citizens, business and public-private partnerships in neighbourhoods and throughout cities. GrowGreen will promote learning, sharing and replicating the NBSs and strategies developed in its partner cities and will join forces with other relevant networks, projects and initiatives to create a global movement for a sustainable urban future. This project will affect the relationships between citizens, business and other stakeholders as citizens will help businesses thrive in the urban environments created.

4.10 PHUSICOS - Solutions to reduce risk in mountain landscapes

The overarching objective of PHUSICOS – 'According to nature' is to demonstrate that nature-based and nature-inspired solutions for reducing the impact of extreme weather events in rural mountain landscapes, are technically viable, socially acceptable, cost-effective and implementable at the regional scale.

The project aims to demonstrate that the benefits of NBSs are inclusive by increasing the ecological, social and economic resilience of local communities. Nature-based and nature-inspired solutions are more than green and blue infrastructure. These solutions also include sustainable management and responsible use of land, water and natural resources.

The project's work package on "learning arena innovation to encourage knowledge exchange" will facilitate closer collaboration between stakeholders. This collaboration will be achieved using learning arena innovation to encourage knowledge exchange through the identification of possible NBSs, co-development of scenarios and modelling their impacts at the demonstrator sites, as well as training programmes for key stakeholder groups: decision-makers, technical specialists including local contractors and citizens.

The co-development of the training programmes is expected to increase capacity building and support knowledge transfer to help participants that lack know-how with regard to the: 1) appropriateness of technical aspects, 2) viable land management options, and 3) collaboration between private-public actors to operate the NBS.

4.11 URBiNAT - Healthy corridors as drivers of social housing neighbourhoods for the co-creation of social, environmental and marketable NBS

This project focuses on the regeneration and integration of deprived social housing urban developments through an innovative and inclusive catalogue of NBSs, ensuring sustainability and mobilising forces for social cohesion. Interventions focus on the public space to co-create with citizens new urban, social and nature-based relations within and between different neighbourhoods. Taking the full physical, mental and social well-being of citizens as its main goal, URBiNAT aims to co-plan a healthy corridor as an innovative and flexible NBS, which itself integrates a large number of micro NBS emerging from community-driven design processes.

URBiNAT will engage citizens and stakeholders in a collaborative process with consortium partners to co-develop local diagnostics, the selection of NBS, the design of healthy corridors, as well as their implementation continuous monitoring. A set of participatory NBS will support these innovative processes of regenerating urban areas. This co-creation methodology will empower the citizens and contribute to the health and wellbeing of communities.

4.12 WaterCoG - Water Co-Governance for Sustainable Ecosystems

The focus of the Interreg Water Co-Governance for Sustainable Ecosystems project (WaterCoG) [https://northsearegion.eu/watercog/] is to understand how the implementation of EU directives can be achieved at a local level in the North Sea Region.

WaterCoG aims to demonstrate through the adoption of new participatory, ecosystem service based approaches that implementation and integration of different water management frameworks can be achieved at the same time as providing additional social, economic and environmental benefits not currently being realised. A strong transnational component will identify and incorporate common, transferable elements of different approaches into an up-scaling toolbox that will extend the impact of the project and build capacity for delivering improved sustainable management strategies for NSR ecosystems. The projects' output aims for a change in working practice that will improve the integration between top-down implementation of European and national directives and bottom-up, participatory developed solutions for improving the quality and sustainable management strategies of NSR ecosystems.

This project supports the general public to better understand wetlands and peatlands, by offering opportunities for amateur scientists to get involved in gathering data. This will improve understanding of the wetlands managed and provide educational opportunities for the public. For example, students are offered the opportunity to carry out hands on studies of the peat soils by carrying out peat surveys. The students to enter the data into a specially developed app, allowing the data to be easily recorded and used to support future peat

management solutions. The students are be taught about wetlands, their geology and ecology, and the importance of preserving them.

4.13 OpenNESS

OpenNESS aims to translate the concepts of *natural capital* (NC) and ESs into operational frameworks that provide tested, practical and tailored solutions for integrating ES into land, water and urban management and decision-making. It examines how the concepts link to, and support, wider EU economic, social and environmental policy initiatives and scrutinizes the potential and limitations of the concepts of ES and NC. OpenNESS works in close cooperation with decision makers and other stakeholders.

The specific aims of OpenNESS are:

1. To advance conceptual understanding of ES and NC and provide operational frameworks for application of the concepts in real-world management and decision-making situations.
2. To examine how existing and forthcoming EU regulatory frameworks can enhance or restore the benefits derived from ES and NC using multi-scale scenario approaches.
3. To develop and refine approaches for mapping and modelling the biophysical control of ES that can be used to assess the effectiveness of mechanisms, instruments and best management practices for sustaining ES delivery in the face of multiple uncertain drivers whilst conserving biodiversity.
4. To develop hybrid methodologies that address trade-offs synergies and conflicting interests and values in the use of ES through a combination of monetary, non-monetary and deliberative methods within multi-criteria and Bayesian approaches to decision support.
5. To apply the concepts and methods developed and refined in the project to concrete, place-based case studies in a range of social-ecological systems with stakeholders and analyse the implications of local, regional and EU level decisions on the ES flows and use in other parts of the world.
6. To translate the results into policy recommendations and integrate the outputs in a Menu of Multi-Scale Solutions and associated datasets that are available for ES users and managers as well as decision-makers
7. To disseminate the results and to promote and maintain science-policy dialogue on the use of the concepts of ES and NC in sustainable land, water and urban management.

A book chapter written by Priess and Kopperoinen (2017) and framed within the OpenNESS project, states that public participation can go beyond participatory monitoring of ecosystem services in a research project. For instance, groups of urban gardeners could map their ecosystem services use with the objective to identify their main interests or the diversity of their contributions to food production or their recreational activities using a mapping app for example as described by Fagerholm and Palomo (2017).

Any cultural ecosystem services activities are especially difficult to address via scientific mapping and modelling tools that do not involve the broader public, so there is large deficit of information about certain cultural ecosystem services such as gardening, outdoor activities, appreciation of cultural heritage or intellectual experiences, which are much harder to evaluate without asking or involving citizens. Thus, citizen-science projects have enormous potential in the context of cultural ESs to contribute to decision-making and management. In addition, citizens are increasingly contributing to public debates and decision-making, particularly with regard to the governance of regulatory or supply services, for example by discussing and defining environmental thresholds such as the use of water resources.

The OpenNESS project also published a synthesis paper on indicators for ecosystem services (Czúcz and Arany, 2016), where the authors explain the complexity of selecting indicators for ecosystem services as they require to integrate and balance general scientific and policy aspects. In this document the authors recommend to use of an ES cascade levels as a template for indicators (Figure 2). This technique could be useful in MICS to select indicators.

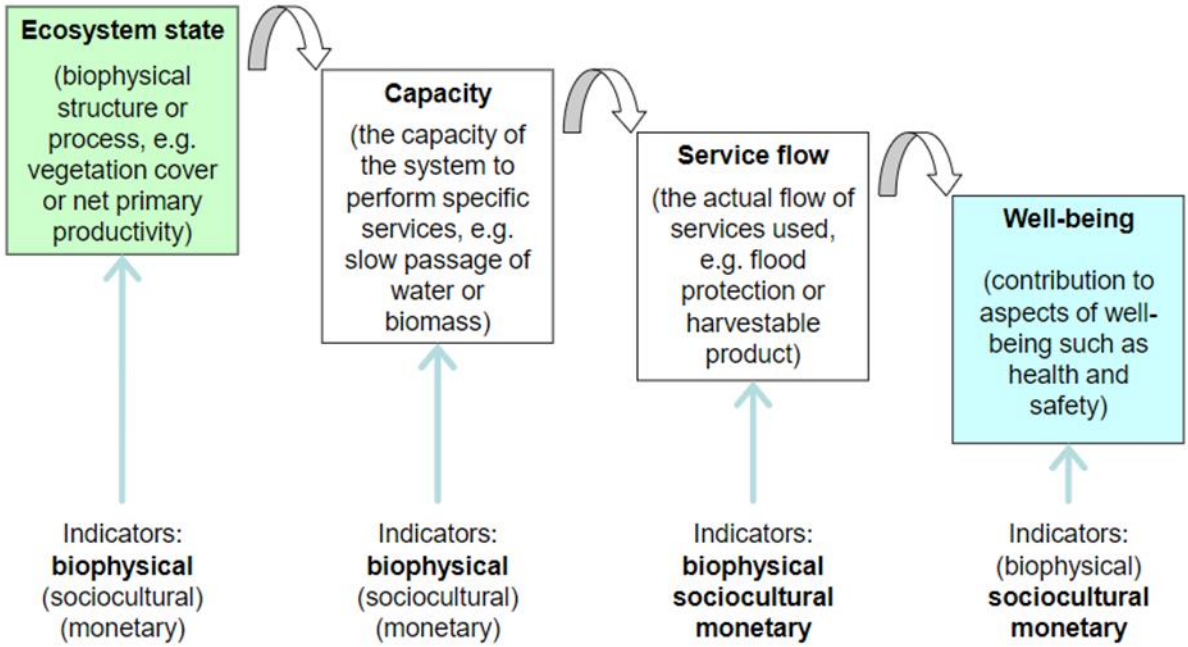

Figure 2. The ES cascade model as an indicator template (extracted from Czúcz & Arany, 2016)

The following projects do not have included a citizen-science component in their description, therefore plausible impacts of incorporating citizen science elements are discussed.

4.14 REFORM - REstoring rivers FOR effective catchment Management

The overall aim of the REFORM project was to provide a framework for improving the success of hydromorphological restoration measures to reach, in a cost-effective manner, target ecological status or potential of rivers. Success is defined as being hydromorphologically sustainable, ecologically effective, and exploiting the full potential within the socio-economic setting. Cost-effective implies an optimisation of both ecosystem health and the goods and services that natural, modified and restored rivers, floodplains and connected groundwater provide. The restoration framework addresses the relevance of dynamic processes at various spatial and temporal scales, the need for setting end-points, analysis of risks and benefits, integration with other societal demands (e.g. flood protection and water supply), and resilience to climate change. The REFORM consortium developed protocols and procedures to monitor the biological response to hydromorphological change with greater precision, to support the design of programmes of restoration and mitigation measures for the WFD, in particular for the second round of RMBPs, and to integrate restoration better with socio-economic activities.

The inclusion of a citizen component in this project, such as the monitoring of the ecological status for example, can reduce the cost of data collection. In the meantime, with this type of initiatives, citizens would learn about river restoration issues, engage their local communities in identifying and delivering solutions and provide local knowledge.

4.15 NAIAD – Nature insurance value: assessment and demonstration.

The NAIAD H2020 project aims to operationalise the insurance value of ecosystems to reduce the human and economic cost of risks associated with water (floods and drought) by developing and testing - with key insurers and municipalities - the concepts, tools, applications and instruments (business models) necessary for its mainstreaming. Eight demonstration sites (DEMOs) throughout Europe will display and ensure the applicability and transferability of the developed tools and methods across all of Europe. The assumption is that Natural Assurance Schemes can reduce risk, especially to drought and flooding, and this risk reduction can be assessed and incorporated within insurance schemes.

Trans-disciplinarily and stakeholder engagement are at the core of NAIAD for two reasons: first, because the conceptual and assessment methodologies combine physical, social and cultural and economic aspects, integrated into tools and methods but second, and most importantly “road tested” and validated with the stakeholders and end users themselves at the DEMOs.

NAIAD will contribute to providing a robust framework for assessing insurance value for ecosystem services by:

(i) enabling full operationalisation through improved understanding of ecosystem functionality and its insurance value at a broad range of scales in both urban and rural context;
(ii) making explicit the links between ecosystem values and social risk perception; and
(iii) the application of developed methods and tools in water management by relevant stakeholders, especially businesses, public authorities and utilities.

The DEMO cases for this project require data to validate the models used to assess the tools; therefore, data gathered by citizens will be especially relevant for that purpose. For instance, volunteers can collect data on water quality in urban environments, used to model ecosystem services.

4.16 ARIES - ARtificial Intelligence for Ecosystem Services

This project was developed to seek a more complete scientific narrative for discourse about ecosystem services after the realization that overly simplified conceptual frameworks could lead to inaccurate policy decisions. ARIES strives to quantify the benefits that nature provides to society in a manner that accounts for dynamic complexity and its consequences, but keeps models clear enough to users to remain understandable, usable, and adaptable to conditions of varying data availability. Since the beginning of ARIES, we have concentrated our efforts on two main innovations:

An extension of ecosystem services science to renew its focus on beneficiaries and the spatial and temporal dynamics of flows.

The capability to automatically assemble the most appropriate models to a region of interest, based on a simple user query, using modular model components and data chosen according to context.

To be relevant to policy and decision making, scientific tools must consider the linkages between people and nature – termed "coupled human-natural systems." ARIES integrates scientific data and models that simulate and integrate environmental and socioeconomic systems, deepening our understanding of the natural world and of how the choices society makes can impact future economic prosperity and environmental sustainability.

The ARIES approach can be used to map and quantify ecosystem services, an activity that can be improved with citizen science. Just like in the Openness and MAES projects, groups of citizens could map their ecosystem services use with the objective to identify their main interests in an area, using an app for example. As mentioned in an article by Schröter et al. (2017), in the case of data driven and spatially explicit ecosystem services assessments or models, citizen science approaches can be an important complement to collect data to improve or validate ecosystem models. Together with new technological developments for sensors and mobile technologies that facilitate accurate and standardised data collection citizen science might evolve to a powerful tool for ecosystem assessments.

4.17 MAES - Mapping and Assessment of Ecosystems and their Services

MAES is a specific action of the European Commission aims to provide a knowledge base on ecosystems and their services in Europe. It underpins the achievement of all 6 targets of the biodiversity strategy and is also relevant to a number of other EU sectoral policies such as agriculture, maritime affairs and fisheries, and cohesion.

A coherent analytical framework as well as common typologies of ecosystems for mapping and a typology of ecosystem services for accounting have been to be applied by the EU and its Member States in order to ensure consistent approaches to map and assess the state of ecosystems and their services in their national territory.

As in the case of the OpenNESS and ARIES projects, ecosystem services mapping can be a way to have citizens involved in ecosystem services mapping. For instance, Priess and Kopperoinen (2017) identified several participatory mapping methods available for CS in the context of ES mapping and assessment, covering work with conventional paper maps or tables, or digital tools such as geo-graphic information systems (GIS) or smart-phone apps. The higher the level of involvement of citizens, the higher the level of knowledge is needed for citizens, for instance, knowledge about different ecosystem services, to handle spatial data in a geographic information system, to prepare paper or digital maps of the study area, or to evaluate information generated during the citizen science project.

4.18 ReNature

The aim of this project is to establish and implement a nature-based solutions research strategy for Malta with a vision to promote research and innovation and develop solutions in a pursuit of economic growth, whilst at the same time improving human well-being and tackling environmental challenges. The strategy will be complemented by a newly-developed research cluster to act on it, with a vision to stimulate both scientific excellence and innovation capacity towards achieving the goals of sustainable development.

In particular, challenges that can be addressed through nature-based solutions are those associated with the attainment of sustainable urbanisation through the design of cities that support communities, promote public health, cultural identity and social cohesion.

ReNature will establish twinning between the *Malta College of Arts, Science and Technology* (MCAST), and internationally leading research institutions from other member states to stimulate knowledge exchange between them and nurture a new generation of scientists and practitioners around an emerging nature-based solutions cluster for Malta.

The main objectives of the project are to:

- strengthen collaboration between MCAST, Maltese national authorities and ReNature partners through stimulating common research projects and information flow among the different players;

- develop evidence-base to inform practitioners and policy-makers alike on landscape and urban planning as key components of green infrastructure;
- extend the partnership by clustering with ongoing and future projects on nature-based solutions at European scale within, but not limited to, the Horizon 2020 framework;
- provide solutions and alternatives to national authorities, policy-makers and businesses on the implementation of nature-based solutions.

5 Final considerations

This deliverable is an initial step towards the creation of opportunities to improve NBSs science and to produce a set of policy recommendations for NBSs framed within WP5 (dissemination and outreach). A range of NBS projects have been identified and the impacts of those involving citizens science have been acknowledged. The selected projects range from urban regeneration to restoring rivers for effective catchment management. The variety of the projects chosen and their approach to their impact assessment provide good grounds to develop the MICS methodology to measure the impact of citizen science on NBSs.

6 List of abbreviations

CS	citizen science
D	deliverable
ES	ecosystem service
H2020	European Union's Horizon 2020 research and innovation programme
NBS	nature-based solution
NC	natural capital
WP	work package

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8 Annex1. Links to projects' websites

Project name	Website
CLEVER Cities	http://clevercities.eu/
EKLIPSE	http://www.eklipse-mechanism.eu/
Nature4cities	https://www.nature4cities.eu/
NATURVATION	https://naturvation.eu/
Operas	http://www.operas-project.eu
proGIreg	http://www.progireg.eu/
URBAN GreenUP	https://www.urbangreenup.eu/
EdiCitNet	https://cordis.europa.eu/project/rcn/216082/factsheet/de
GROWGREEN	http://growgreenproject.eu/
PHUSICOS	https://phusicos.eu/
URBiNAT	https://urbinat.eu/
WaterCoG	https://northsearegion.eu/watercog/
OpenNESS	http://www.openness-project.eu/
REFORM	https://reformrivers.eu/
NAIAD	http://naiad2020.eu/
ARIES	http://aries.integratedmodelling.org/
MAES	https://biodiversity.europa.eu/maes
ReNature	http://renature-project.eu/

9 Annex 2. List of indicators for to assess the benefits produced by the implemented NBS in four different domains (proGIreg project)

Indicators for socio-cultural inclusiveness

Indicator	Explanation	Units	Data
Total population	Total number of persons living in the specific area. Indicator should be collected for both the city and LL district level	Number	BASE
Population density	Number of persons per square km of land area. Indicator should be collected for both the city and LL district level	n/(m*m)	BASE
Population growth rate	Average annual rate of change of population size (%). Indicator should be collected for both the city and LL district level	%	BASE
Migration rate	Net number of migrants per 1,000 population. Indicator should be collected for both the city and the LL district scale	%	BASE
Material deprivation rate	Material deprivation rates gauge the proportion of people whose living conditions are severely affected by a lack of resources	%	BASE
Work intensity	% employed out of total economically active population (15-64 years of age, according to the definition of the International Labour Organisation)	%	BASE
Diversity statistics	% foreign born residents (if available, for both scales) or population by ethnicity	%	BASE
Educational attainment	Average level of education completed by the 18 years of age and older population	Number	BASE
Recreational or cultural facilities	Relevant for LL/regeneration level: Number and identification of recreational and/or cultural facilities	Number	BASE
Accessibility of public urban green spaces	% population having access to green space within a 15-minute walking distance or within	%	BASE

Dwelling size	Availability of amenities[8]	Number	BASE
Public housing	Percentage of residents in public housing	%	BASE
Burden of housing costs	Average rent/m² in ppp; average rental burden[8]	%	BASE
Density of the built environment	Floor Area Ratio (Total floor area divided by total built surface area), or if unavailable, Building Coverage Ratio	%	BASE
Use of green and blue spaces	Change in time spent in natural environments (separate for parks/urban gardens, natural green spaces, agricultural fields, and blue spaces) in spring-summer and autumn-winter	Hours per week	GQ
Connectedness to nature	Sense of connectedness and oneness to nature[9]	Number (total scale score)	GQ
Self-perceived social support/cohesion	State of cohesiveness of society as a whole, measured in terms of individuals[10]	Number (total scale score)	GQ
Mindfulness	Ability of being conscious or aware of something within the environment[11]	Number (total scale score)	GQ
Perceived restorative quality of implemented NBS	Perception of restoration coming from an NBS[12]	Number (total scale score)	GQ
Greenness	Spatial map indicating the presence of green areas for each pixel	Normalized index (10 m pixel)	GIS
Walkability	GIS derived raster image, function of connectivity, accessibility and perceived pleasantness with values ranging from 0 to 1 where 1 indicates the most walkable area (e.g., a park with pedestrian lanes well connected to city hot spots like residential and working areas) and 0 indicates the least walkable area (e.g., a major urban road).	Normalized index (30-1000 m pixel)	GIS
Self-perceived increased restoration	Change in perception of restoration coming from an NBS	Number (total scale score)	A
Self-perceived increase of social interactions and cohesion	Self-perceived change in the quantity and quality of social contacts	Number (total scale score)	A

Indicators for human health and well-being

Indicator	Explanation	Units	Data
Use of green and blue spaces	Time spent in natural environments[13]	Hours/ week	GQ
Visual exposure to green space	The amount of green space in the view from windows at home and the frequency of looking at the view	Number	GQ
Satisfaction with green and blue spaces	Satisfaction (scale 1 to 5) with the green/blue spaces in the neighborhood[13]	Number	GQ
Perceived general health	Self-perceived general health[14]	Number	GQ
Somatization	Somatization (scale 0 to 3) and category (low, moderately high, very high) [15]	Number	GQ
Self-reported mental health and well-being	Mental health and well-being (scale 1 to 6) [14]	Number	GQ
Perceived stress	Perceived Stress Scale (scale 0 to 4) [16]	Number	GQ
Self-reported anxiety	Anxiety (scale 0 to 3) and category (mild, moderate, severe)[17]	Number	GQ
Self-reported depression	Number of participants reporting depression	Number	GQ
Current asthma and/or allergies	Number of participants with asthma or allergy attacks/episode	Number	GQ
Physical activity	Physical activity levels, calculated as the metabolic equivalent of task (MET) minutes per week[18]	MET minutes /week	GQ
Overweight and obesity	Body Mass Index (BMI)-based overweight or obesity	kg/m²	GQ

Visits to and time spent in NBS(s)	Hours/week spent in NBS site(s)[19]	Hours/week	GQ (post only)
Perceived improvement in neighbourhoods	Number of participants perceiving an improvement in the Living Lab neighbourhood	Number	GQ (post only)
Physical activity	Physical activity, calculated as the metabolic equivalent of task (MET) minutes per week, performed in the NBSs[18]	MET-min/week	A
Visits to and time spent in the NBS	Number of visits and hours/visit spent in the NBS[13]	Hours/week	A
Perceived increase in visits to the NBS	Number of participants to report increased visits to the NBS site	Number	A
Satisfaction with the NBS	Score of satisfaction with the NBS[13]	Number	A
Perceived restoration	Score of restorative quality of the NBS[12]	Number	A
Adverse impact NBS	Number of participants reporting an adverse event while in the NBS[20]	Number	A
Use of the NBS	Number of visitors of the NBS per week[21]	Number	B
Activity type within the NBS	Number of visitors by activity types per week[21]	Number	B
Activity level within the NBS	Energy expenditure in the NBS per week, calculated as the metabolic equivalent of task (MET) minutes per week[21]	MET-hour/week	B

Indicators for ecological and environmental benefit assessment

Indicator	Explanation	Units	Data
Reduction of air pollutants	Potential estimation of pollutant abatment[2,22]	%	BASE
Greenness	Spatial map indicating the presence of green areas for each pixel[23]	Normalized index (10 m pixel)	GIS
Carbon uptake	The estimation of the carbon sequestered by the NBS[2,22]	t C ha^{-1} $year^{-1}$	D
Reduction of energy demands	The energy not consumed for heating and cooling buildings can be accounted with an estimation of reduction of CO_2 emissions[2,22]	t C $year^{-1}$	D
NO_2 Removed	Changes on NO_2 concentration within the NBS with respect to control point[2,22]	%	E
O_3 Removed	Changes on O_3 concentration within the NBS with respect to control point[2,22,24]	%	E
Air temperature modification	Changes on day and night average, minimum and maximum temperatures within the NBS with respect to control point[2]	ΔC° / day	F
PM removed	Estimation of PM removed by the green surfaces of the NBS[2,25]	g m^{-2}	G
Equivalent used soil	Total natural soil saved by using the regeneration procedures	m^2	H
Global warming potential (GWP)	GWP will be expressed on an equivalency basis relative to CO_2	kg	H
Water dependency (WD)	It is the quantity of water needed per kg of food production	m^3/kg	H
Shannon Diversity Index	Measure of species diversity related to species richness[26]	Number	I
Shannon Evenness Index	Measure of species diversity related to species equality[26]	Number	I
Simpson Diversity Index	Measure of species diversity related to species dominance[26]	Number	I
Simpson Evenness Index	Measure of species diversity related to species richness[26]	Number	I

Indicators for economics and labour market

Indicator	Explanation	Units	Data
GDP per capita	GDP (at PPS- Purchasing Power Standards), Euro Gross domestic product (GDP) is a measure for the economic activity. It is defined as the value of all goods and services produced less the value of any goods or services used in their creation. The volume index of GDP per capita in Purchasing Power Standards (PPS) is expressed in relation to the European Union (EU28) average set to equal 100. If the index of a country is higher than 100, this country's level of GDP per head is higher than the EU average and vice versa. Basic figures are expressed in PPS, i.e. a common currency that eliminates the differences in price levels between countries allowing meaningful volume comparisons of GDP between countries.[27]	Number	BASE
Businesses in the area - Industrial	Number of companies of industrial sectors registered in the area per 1,000 inhabitants Industrial sectors are those with codes B-D-F of NACE Rev2 classification (Eurostat)	Number	BASE
Businesses in the area - Commercial	Number of companies in the service sector registered in the area per 1,000 inhabitants Service sectors are those covered by the EU Service Directive (0123/2006)[28]	Number	BASE
Public jobs	Total number of jobs in public sector	Number	BASE
Private jobs	Total number of jobs in private sector	Number	BASE
Public green jobs	Total number of public green jobs Green jobs are those within the environmental economy. These encompass two broad groups of activities and/or products: 'environmental protection' — all activities related to preventing, reducing and eliminating pollution and any other degradation of the environment; 'resource management' — preserving and maintaining the stock of natural resources and hence safeguarding against depletion.[29]	Number	BASE
Private green jobs	Total number of private green jobs	Number	BASE

Turnover in the green sector	Companies with activity in the environmental economy; turnover in EUR	EUR	BASE
Employment rate	The percentage of employed persons in relation to the comparable total population[21]	%	BASE
Unemployment rate	The number of people unemployed as a percentage of the labour force, according to the Eurostat/ILO definition[22]	%	BASE
Revenues by household	Average household disposable income **Household disposable income** is the total amount of money households have available for spending and saving after subtracting income taxes and pension contributions.[22]	EUR	BASE
Current property sale value for residential use	Property value, average, EUR/m², for single- and collective housing, sale price	EUR/m²	BASE
Current property rental value for residential use	Property value, average, EUR/m², for single- and collective housing, renting (monthly)	EUR/m²	BASE
Current property value for commercial/ industrial/ office use	Property value, average, EUR/m², sale price	EUR/m²	BASE
Current property rental value for commercial/ industrial/ office use	Property value, average, EUR/m², renting (monthly)	EUR/m²	BASE
Free services	Total number of free public services/amenities: • Parks/green spaces • Public libraries	Number	BASE

	• Public sports facilities (with free access) • Cultural/civic centres		
Number of tourist visits	Measured as total number of overnight stays in tourism accommodations per year	number	BASE
Number of temporary events	Number of trade fairs, congresses, symposiums, concerts, parades before NBS implementation	number	BASE
Number of foreign students	% of foreign students out of total number of students enrolled in higher education	%	BASE
Retail trade turnover	The Retail Trade Index is a business cycle indicator which shows the monthly activity of the retail sector in value and volume. It is a short-term indicator for final domestic demand.[34]	EUR	BASE
Local taxes	Average local taxes per capita	EUR	BASE
Green investment programmes/funds	Public investment programs, and investment funds	EUR	BASE
Percentage of green jobs	Number of jobs that belong to the categories considered to belong to the environmental economy by Eurostat	%	GQ
Monthly disposable income	Income available each month for spending and saving after discounting taxes and social security. In the case of self-employed respondents, average monthly disposable income also after discounting taxes and social security.	EUR	GQ
Percentage of people renting houses	% of respondents who declare to rent their home.	EUR	GQ