CITYkeys

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Smart City KPIs and related methodology

DRAFT for feedback

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Deliverable administration					
No & name	**D1.3 Smart city (project) KPIs and related methodology – for feedback**				
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Description of the related task and the deliverable in the DoW	This task will define the final choice for cross-sectoral KPI's, their definition and description, and their hierarchy in the assessment methodology (need to have/nice to have, for whom, how are individual projects interrelated , what are the consequences at the policy level). This task will therefore link back to tasks 1.1 and 1.2 and link forward to WP2. Based on the inventory of existing KPIs in Task 1.2, this task develops new/missing KPIs for the smart city framework that are needed by the cities (as defined in the Task 1.1) and/or are otherwise important for the project's overall objectives. These KPIs can also include indicators that have been already identified but are currently lacking sufficient scientific underpinning and/or broad consensus, and/or for which reliable assessment methods are still missing (e.g. the data collection for this indicator proves to be difficult). The KPIs will need to be cross-sectoral and fit into a holistic/integral framework which covers all dimensions of the project (People, Planet, Prosperity, Governance, Propagation). Each KPI will be defined and described. Data requirements and assessment method will be further addressed in T2.1 For each KPI a first evaluation is made about whether the indicator is applicable and relevant in all or only limited number of areas and contexts in Europe. The suggested new KPIs will then be discussed with a broader group of stakeholders as part of T4.1. along the lines of the indicator being Specific, Measureable, Acceptable, Realistic and Time-bound, in order to come to a final decision in T1.3 on which new KPI's will be used throughout the rest of the project. This deliverable will present a overview of the KPI's and all relevant information needed to integrate them in a framework, with a rough conceptual first draft of the assessment methodology. This deliverable will describe the identified new KPIs that are either needed to better respond to cities' or other relevant stakeholders' needs (as defined in Task 1.1) or otherwise to achieve the project's overall objectives but do not yet exist (based on T1.2) or common understanding and/or for which reliable assessment methods are still missing. The description of the KPIs includes definition, ontology, general description, data requirements, assessment method as well as a first evaluation of its applicability in different contexts.				
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1. PUBLISHABLE EXECUTIVE SUMMARY

This report describes the selection of indicators for assessing Smart City projects and the corresponding indicators on city level. Starting from the definition of a Smart City and Smart City Projects, impact indicators have been selected that can function as Key Performance Indicators for tracking the progress towards city and project objectives.

With a starting point in the Smart City definition, and taking into account the wishes of cities and citizens with regard to smart city projects and indicators, the indicators are arranged in an extended triple bottom line sustainability framework, including the themes people, planet, prosperity, governance and propagation. Under the main themes subthemes conforming with major policy ambitions have been identified.

Under these subthemes in total 108 project indicators and 78 city indicators have been selected. Not all indicators are equally suited for evaluating all types of smart city projects. Although there is a considerable body of common indicators, for specific sector projects a relevant subset of these may be used (i.e. some indicators are specifically suited for transport projects, other for building related projects, etc.).

The selection was based on an inventory of 43 existing indicator frameworks for (sustainable) cities and projects. The majority of the indicators in the CITYkeys selection have been derived from existing indicator frameworks. New indicators have been suggested to fill gaps in existing frameworks, mostly related to specific characteristics of smart city projects.

The current report is a 'halfway' result of task 1.3 in CITYkeys. At the end of 2015 it will be completed in deliverable 1.4 with the description of the data sources and indicator calculation procedures. Future discussions on these might bring further changes to the selection and definition of the indicators. Also the testing of the indicators in 2016 is expected to lead to refinements in this report.

2. INTRODUCTION

CITYkeys aims to speed up the transition to low carbon, resource-efficient cities by facilitating and enabling stakeholders in smart city projects and cities to learn from each other, create trust in solutions, and monitor progress, by means of a common performance measurement framework.

The ultimate goal is to support the wide-scale deployment of smart city solutions and services in order to create impact on major societal challenges related to the cities' fast growth and the Union's 20/20/20 energy and climate targets.

Cities will benefit from the CITYkeys results as these support their strategic planning and allow to measure their progress towards smart city goals. In addition, benefits are created from the enhanced collaboration within and between cities, providing the possibility to compare solutions and find best practices. Solution providers will benefit from better insight into business opportunities for their products and services, and into the possibilities for replication in a different city or context. Industrial stakeholders will benefit from the recommendations for new business, e.g. based on open data. These should bring environmental benefits as reduction of CO2 emissions, increased energy efficiency, increased share of renewables, as well as improving the quality of life through a better mobility, better communication between local authorities and their citizens, empowerment of citizens (i.e. smart citizens).

For the development of the performance measurement framework, CITYkeys is building on existing smart city and sustainable city indicator systems. The bases of the Citkeys indicator framework are the traditional sustainability impact categories **People, Prosperity and Planet**, but the performance measurement framework includes specific smart city KPIs that go beyond the traditional categories in showing not only the impact but also indices of the success factors for smart city endeavours and the suitability for dissemination to other cities and circumstances.

This task included:

- Harvesting the indicators from existing frameworks and structuring them according to the themes and subthemes of People, Planet, Prosperity, Governance and Propagation;
- Further defining, describing and making a selection of existing cross-sectoral indicators to the holistic/integral CITYkeys framework though an intensive dialogue involving both RTOs and cities involved in CITYkeys, as well as the SCC1 Lighthouse projects. In accordance with the aims of CITYkeys special attention was paid to the way in which smart city project performance could be linked to smart city goals on city level. Indicators were scored on several criteria to determine their relevance and feasibility;
- Drafting and discussing new indicators where needed.

The transparent and flexible CITYkeys performance measurement framework will be able to handle different sizes of cities in different smart city development stages and thereby support different development strategies of smart cities and –initiatives over a wide range of characteristics.

A draft list of the CITYkeys indicators is presented in this report. A final overview of the KPIs and all relevant information needed to integrate them in a framework will be included in D1.4, with a rough conceptual first draft of the assessment methodology. Changes are also to be expected after next stages of determining data collection procedures and testing.

2.1 Contribtions of partners

This report has been compiled by TNO, on the basis of an intensive cooperative indicator selection exercise by TNO, VTT and AIT. Following on the inventory of existing frameworks and indicator sets in task 1.2, all the project partners have evaluated the existing indicators and designed a selection fit for assessing smart city projects with the connected indicators on the city scale.

This reports was not possible without the advice and consultation in meetings and teleconferences, including commenting on indicators proposals, from:

- City of Vienna
- City of Tampere
- City of Zaragoza
- City of Zagreb
- City of Rotterdam
- Lighthouse project Remourban
- Lighthouse project Triangulum

2.2 Baseline

In recent years, several indicator frameworks for the performance measurement of urban systems have been developed within the European Framework programs FP6, FP7, and H2020, as well as part of other European initiatives, such as the Covenant of Mayors, the Reference Framework for Sustainable Cities, or the Green Digital Charter ((Neumann et al, 2015). However, many of these initiatives are either focused on performance on the city level (i.e. measuring a state, but not the performance of projects that influence this state) or on a specific sector (e.g. ICT, transport, energy). There is no European Framework so far, that fully addresses the topic of smart cities and smart city projects, as described in the Strategic Implementation Plan (EIP, 2013) and the Operational Implementation Plan on Smart Cities and Communities.(EIP,n.d.)

The aim of CITYkeys therefore is to develop an integrated indicator framework: a cross-sectoral, extended triple bottom line approach. Within this, T1.3 looks for the potential contributions that other European projects can make to an integrated performance measurement framework in two ways:

1. Building on existing knowledge captured in existing indicator frameworks;
2. Exchange of knowledge and experiences with stakeholders involved such as cities and lighthouse projects.

2.3 Relations to other activities

T1.3 relates to other tasks of WP1 on the input side and to WP2 on the output side:

- T1.3 takes into account the results of the survey on cities carried out in T1.1 “Requirements of cities / citizens”. See section 3.2.1
- T1.3 builds on the existing indicator frameworks mapped in T1.2, as well as the gap analysis. The selection of these indicators will be based on the definitions of a Smart City and of Smart City Projects developed in T1.2. See Section 3.2.2
- T1.3 serves as input for T2.1 and further WP2, in which the indicators from T1.3 will be further operationalised (data collection and calculation) and tested.

3. CITYKEYS

3.1 Background

The ultimate goal of CITYkeys is to support the speeding up of wide-scale deployment of smart city solutions and services in order to create impact on major societal challenges around the cities fast growth and the Union's 20/20/20 energy and climate targets. Therefore, CITYkeys aims to facilitate and enable stakeholders in projects or cities to learn from each other, create trust in solutions, and monitor progress, by means of a common integrated performance measurement framework.

3.2 Outcomes T1.1 and T1.2

The selection of indicators for the evaluation framework is based on the outcome of T1.1 and T1.2, especially the results regarding the needs of cities and citizens, the CITYkeys working definitions and the structure of the evaluation framework.

3.2.1 Needs of cities and citizens

Cities

Cities confirmed that the topic of "smart city" is high on their agenda as they expect a lot of benefits from becoming smart: efficiency, sustainability, participation of society and better quality of life. In describing what a smart city looks like, they agree that a "smart city" uses a lot of technology, combines energy, mobility and infrastructure, increases performance and efficiency, increases the participation of citizens, enables innovation and improves the social and economic fabric of the city.

In both planning and implementing smart city solutions, performance measurement is one key component. Nevertheless, and although they would like to do so, cities haven't yet widely adopted or implemented such performance measurement systems and CITYkeys could become a "facilitator" in this direction.

The areas where cities mostly need indicators to measure their smart city performance include: energy, GHG emissions, transportation, digital infrastructure and e-services, resource management, citizens' participation, competitiveness, economy, environment, quality of life and research and knowledge creation. On the smart city project level, the areas where cities mostly need indicators to measure performance include: GHG emissions, energy, transportation, digital infrastructure and e-services, environment, quality of life, research and knowledge creation, resource management, innovation, urban planning and social inclusion.

Citizens and stakeholders

Citizens and stakeholders follow adequately what their cities plan and implement and are definitely looking for more results, both in terms of quality and quantity. They define a "smart city" and its objectives in terms similar to the ones used by the cities' experts; nevertheless they put more emphasis in three objectives that are directly important to them:

- Improvement of quality of life;
- Better services from the city to the citizens;
- Creation of an innovative, competent and with high skilled jobs city.

The responses of citizens on their needs on the smart city level were very diverse, see Deliverable 1.1. of this project (Kontianaikois and Katalin De Cunto, 2015) . On the smart city project level, the most important project results included: creation of innovation and knowledge, better public transportation, protection of the environment, better education and skills building, cleaner energy, digital infrastructure and e-services, better city governance, creation of local enterprises, improvement of housing conditions, new jobs, and protection of natural resources.

The outputs of CITYkeys need to take into account the priorities of all city stakeholders and replying citizens and stakeholders gave two different sets of answers when asked what makes a "smart city project" useful. Useful *for the citizens* means a better environment and quality of life and in practice means better and more efficient services, tackling the social and economic challenges and a focus on innovation and jobs creation. Useful *for the cities* means tackling social issues at the same time as making the city more efficient and sustainable, more competitive and financially robust.

3.2.2 CITYkeys working definitions

In Deliverable 1.2 of this project (Neumann et al, 2015) the definition of a Smart City and a Smart City Project as used in CITYkeys are introduced.

A **Smart City** is a city that

- is improving the quality of life of its inhabitants [people]
- is significantly reducing its resource consumption [planet]
- is building an innovation-driven and green economy [prosperity]
- and is fostering a well-developed local democracy [governance]

A **Smart City Project** is a project that

- Has a significant impact in helping a city to become a smart city
- Is an integrated project combining multiple sectors

A Smart City project can be executed on the scale of:

- a single building, for instance improving the energy performance of a theatre, or
- a neighbourhood, for instance improving the waste collection, to the scale of
- the city or even the region, think of an improvement in the public transport system.

There is thus a wide range of possible projects that need to be covered by the evaluation framework.

3.3 CITYkeys Evaluation Framework

The CITYkeys assessment method and the indicators are to be used to evaluate the success of Smart City projects and the possibility to replicate the (successful) projects in other contexts. As follows from the smart city definition, success is determined by the transition across the entire ecological footprint of urban areas, simultaneously promoting economic prosperity, social aims and resilience to climate change and other external disturbances. Over the past decennia, the concept of sustainability - split up in the triple bottom line of social sustainability (People), environmental sustainability (Planet) and economic sustainability (Prosperity) - has become generally accepted in the development of indicator systems for national and regional urban development (SCOPE, 2007). The 3 Ps (people, planet, prosperity) have also gained considerable ground in company reporting (Kok, 2004).

The extent to which Smart City projects are able to have an effect on social, ecological and economic indicators forms the core of the evaluation. However, this is not enough to determine the success of a Smart City Project. Success is also determined by *How* projects have been - or will be - realised in various contexts. The **Governance** of developing and implementing urban Smart City projects is a determining factor for high scores in People, Planet & Prosperity indicators (Fortune and White, 2006). Therefore we need to include a number of indicators to evaluate the importance of the city context (external factors) and quality of the development and implementation process (internal factors).

Finally, the ability of individual Smart City projects to be copied in other cities and contexts determines its ultimate effect in achieving European goals with regard to energy and CO_2 emissions. Under the **Propagation** category, Smart City projects are evaluated to determine their potential for up-scaling and the possibilities for application in other contexts.

A subdivision of the evaluation framework in impact categories allows for more flexibility than a subdivision in driving forces, actors or sectors. In addition, as smart city projects in various sectors all contribute to the same impacts there will be fewer double indicators (such as 'energy savings' or 'emission of carbon dioxide'). Indicators that are relevant for a specific sector can easily be in- or excluded depending on the type of project to be evaluated without disturbing the logic of the assessment.

Each of the major themes (people, planet, prosperity, governance and propagation) encompasses several specific policy goals. In many cases these are not all mentioned in a smart city strategy, but may be scattered over various policy documents in a city. For the design of the citykeys indicator framework we have arranged these policy goals under the major theme headings. For instance, under the theme People, subthemes conforming with policy ambitions are created (see Fig.1): increasing diversity and improving social cohesion, increasing safety, guaranteeing good education for every citizen, etc..

The reasons for doing so, are:

- to underline the relation between policy ambitions and the key indicators that are to be used to measure progress towards these ambitions
- to provide the basis for comparing the indicators with each other, whereby users or user groups may attach weightings to policy goals (and thereby to the indicators belonging to a subtheme).
- to ease communication on the outcome of the indicators in terms that are familiar with the decision makers.

The following paragraphs provide succinct definitions of the themes and subthemes.

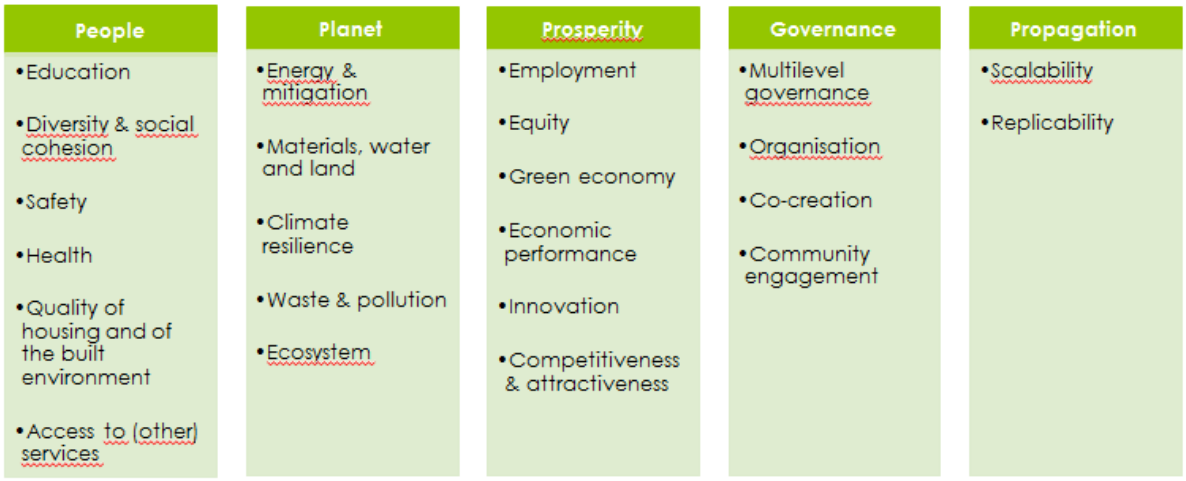

Figure 1: The CITYkeys indicator framework

3.3.1.1 People

Definition of People: The People side of sustainability refers to the long term attractiveness of cities for a range of inhabitants and users: if that is forgotten urban decay may lead to large deprived areas and ghettos. Aspects include quality of living for everyone, especially for the most vulnerable citizens, education, health care, community feeling, etc.

Subtheme definitions

- Diversity and social cohesion; promoting diversity, community engagement and social cohesion to increase the sense of community.
- Education: improving accessibility and quality of education for everyone
- Safety: lowering the rate of crime and accidents
- Health: improving the quality and accessibility of the public health system for everyone and encouraging a healthy lifestyle
- Quality of housing and the built environment: encourage mixed-income areas, ensure high quality and quantity of public spaces and recreational areas, and improve the affordability and accessibility to good housing for everyone.
- Access to (other) services: providing better access for everyone to amenities and affordable services in physical and virtual space

3.3.1.2 Planet

Definition of Planet: The ”Planet” aspect of sustainability in the first place refers to contributing to a ‘cleaner’ city with a higher resource efficiency and biodiversity and being better adapted to impacts of future climate change such as (in Europe) increased flooding risk, more frequent heat waves and droughts. Included in this theme are thus less consumption of fossil fuels and more generation and use of renewable energy, lower waste generation and less air pollution. As our planet extends beyond the city boundary, impacts through urban consumption in other parts of the world, are explicitly included.

Subtheme definitions

- Energy and mitigation: Reduce energy consumption, use waste energy and produce renewable energy
- Materials, water and land: Creating a society that treats its resources (materials, water, food and land) more efficiently and sustainably, among others by decreasing consumption and increasing recycling and renewable production (thereby considering 'spill-overs' to other resources).
- Climate resilience: Adapting to climate change by increasing the resilience of vulnerable areas/elements.
- Pollution and waste: Decreasing the emissions to the environment (in the city or elsewhere) (e.g. waste, noise and pollution to air, water and soil).
- Ecosystem: stimulating biodiversity and nature conservation

3.3.1.3 Prosperity

Definition of Prosperity: Contributing to a prosperous and equal society and supporting affordable, green and smart solutions. On the project level Prosperity stands for economic viability and the value of a Smart City project for a neighbourhood, for its users and its stakeholders, and even its indirect economic effect on other entities. Economic or financial indicators often need to be accompanied with an in-depth description of the business case, as single indicators are insufficient to evaluate e.g. the distribution of costs and investments.

Subtheme definitions

- Employment: Improving local employment opportunities
- Equity: decreasing poverty and income inequality
- Green economy: improving the circular and sharing economy and sustainable/local consumption and production.
- Economic performance: increasing GDP and project performance (*internal performance)*
- Competitiveness and attractiveness: Improving the appeal of the city for residents and businesses.
- Innovation: facilitates innovation and creativity (through e.g. open data, knowledge sharing and cyber resilience).

3.3.1.4 Governance

Definition of Governance: Contributes to a successful process of project implementation as well as to a city with an efficient administration and a well-developed local democracy, thereby engaging citizens proactively in innovative ways.

Subtheme definitions

- Multilevel governance: Increasing support for SC initiatives by providing SC policies and budget at different government levels.
- Organisation: Facilitate the implementation of (integrated) SC policies by improving the organisation of the project/city with regards to;

- The composition, structure and quality of the project team/city administration;
- The quality of the implementation process;
- Sound leadership by the project leader(s) and city politicians;
- Transparency of the organisation.

- Co-creation: enhancing the active involvement of end-users, the community and professional stakeholders in city developments.
- Community engagement: increasing citizen participation in politics.

3.3.1.5 Propagation

Definition of Propagation: Improving the replicability and scalability of smart city project solutions at wider city scale.

Subtheme definitions

- Scalability: Increasing the potential for scaling up successful SC solutions (considering both geographic scale and thematic integration potential) to achieve wider impact in the city. Propagation (both transfer to other locations and countries, and up-scaling from small single projects) depends in the first place on inherent characteristics of the (innovative) Smart City Project.
- Replicability: Increasing the potential for replicating successful SC solutions in other cities.

3.4 Indicators at city and project level

The CITYkeys evaluation framework will support Smart Cities in strengthening their strategic planning and measure their progress. An important feature of this framework is that it not only focuses on the city as well as the project level, but most importantly, it will establish a link between the two. The CITYkeys evaluation framework will:

1. Evaluate the impact of a Smart City project comparing before and after situations or comparing expected impact with a reference situation.
2. Show the progress of the city as a whole towards smart city goals, comparing the year under study with a reference year.
3. Assess how the project has contributed to the objectives at city level.

For the design of the indicator lists, we have started with creating a list of indicators that are useful and feasible to evaluate smart city projects (using the principles described in the next Section). With this list as a starting point we have scanned existing urban indicator sets for corresponding indicators for evaluating city policies. In a few cases it appeared possible to find a corresponding indicator, in which the impact of smart city projects can be immediately expressed (in other words: if one would add the results of all smart city projects in a city, this could immediately be translated in (or related to) the score of the city indicator). For instance, the reduction of CO_2 emissions by a smart city project can be related to the city indicator 'yearly CO_2 emission' In the majority of the cases it is not possible to add project indicator scores quantitatively, but an indicator on the city level can be found that expresses the same intentions, but using a metrics that cannot be applied on the project level. Appendix 3 contains the overview of the link between the Citykeys project and city indicators.

3.5 Target groups for the indicator system

Indicators serve decision making. Indicator outcomes, be it individual indicators or assessments based on multiple indicators should reach the relevant decision makers. The various parts of the Citykeys indicators are aimed at decision makers on various levels.

The indicators on project level have two target groups:

- those decision makers managing smart city projects, who can use the indicators to learn about the relative success of smart city projects (how are they have been performing, what have been factors determining performance) in order to improve in the next projects, and
- decision makers in the city council, who need an insight in how the various projects they have decided upon, have been performing (also to be able to take better decision next time).

The project indicators can also be used in the design phase of a project: to give an impression on the expected performance based on design specifications, vis-à-vis already realized projects.

Because the European Commission is financing the, so called, lighthouse projects they are (temporarily) in a similar position as a city council, needing insight in the performance of their investments.

The smart city indicators equally have two target groups:

- decision makers in the city council who need to follow to impacts of their smart city strategy over time essentially answering the questions has the city become smarter and what has been the final result, and
- national governments and European bodies, to follow if their smart city policies have resulted in more attention for the overall aims (of reducing energy use and greenhouse gas emissions, increasing citizens participation, etc).

It is clear that for users of the city indicators progress over time is important. The city indicators thus should be easily included in the city's programme for gathering regular statistics.

4. INDICATORS

4.1 Types of indicators

For evaluating Smart City Projects we are interested in the degree to which these projects contribute to reaching city targets with regard to smart sustainable development. That means that the focus is on impact indicators (see box 1).

Impact indicators are applicable to all kinds of projects in all contexts: For instance, an indicator in the framework could be 'the reduction in greenhouse gas emissions', whether by e.g. introducing electric vehicles or by insulating dwellings. The number of electric vehicles introduced or houses insulated, is then less relevant, making the indicator framework suitable for evaluation of many types of projects in different contexts.

Impact indicators also leave room for the cities to find their own solutions to achieve a certain performance, instead of prescribing the way they should reach that or the measures that have to be taken/implemented. The latter ones have the risk to lower the possibility for innovative solutions to achieve the same goal, and might be outdated within a few years.

By focusing the indicators on impacts instead of sectors, also cross-sectoral solutions can be easily evaluated. The indicator framework will not implicitly put a focus on isolated, sector specific solutions. The occurrence of double indicators is minimised (for instance the multiple inclusion of an indicator on e.g. final energy use by each sector).

Box 1: Typology of indicators, according to stage in the process[1]

Input indicators

These indicators refer to the resources needed for the implementation of an activity or intervention, measuring the quantity, quality, and timeliness of resources. Policies, human resources, materials, financial resources are examples of input indicators.

Process indicators

Process indicators refer to indicators to measure whether planned activities took place. Examples include holding of meetings, conduct of training courses, distribution of smart meters.

Output indicators

Output indicators add more details in relation to the product ("output") of the activity, e.g. the number of smart meters distributed, the area of roof that has been isolated, the number of electric busses in the system.

Outcome indicators

Measuring the intermediate results generated by project outputs. Outcome indicators refer more specifically to the objectives of an intervention, that is its 'results', its outcome. These indicators refer to the reason why it was decided to conduct certain interventions in the first place. They are the result of both the "quantity" ("how many") and quality ("how well") of the activities implemented. Often they are 'coverage indicators' measuring the extent to which the target population has been reached by the project.

[1] Based on UNICEF Monitoring and Evaluation Training Resources.

Example: the outcome of an thermal isolation programme could be the number of well-isolated dwellings as percentage of the total number of dwellings covered by the programme.

Impact indicators

Measuring the quality and quantity of long-term results generated by programme outputs (e.g. measurable change in quality of life, reduced energy use, reduced air pollutant emissions and (even a more distant impact) improved air quality).

Usually it is easier to define and measure simple output indicators, as impact indicators can be complex, costly, and more difficult to measure. However, output indicators constitute a nearly endless collection of measures describing all kinds of project outputs. Impact indicators are fewer in number as they relate to a more limited collection of policy goals.

A disadvantage of impact indicators is that impacts are only apparent after the project has been implemented and is in full use, which might take a few years. In addition numerous contextual factors can influence the final impact reached. Nevertheless the impact is the only measure that counts for reaching policy goals.

The CITYkeys evaluations will be based on either the projected impacts for planned smart city projects, or on monitoring results for completed projects. Methodologies for calculating the impact compared to a reference situation without the project have been developed and tested for other assessment systems (Eurbanlab, 2014; ITU L1440, ITU L.1430).

In an assessment of a specific project, the project description will contain the information on the characteristics of the project, accompanied by a description of input variables (investment, operating costs, efforts to plan, design and realise the project) and of outputs (e.g. number of buildings retrofitted, number of smart meters installed, number of apps linked to smart meters, capacity battery storage units, number of electric vehicles (buses, taxis, scooters, vehicles operated by the city administration, etc), number of charging stations, number of smart street lights, number of bus stops with real time departure information, etc., etc., depending on the precise nature of the project), since that type of output/outcome information is often needed to calculate impact results (i.e. no information is lost).

4.2 Key Performance Indicators

The origin of Key Performance Indicators (KPI's) is in business administration. Key Performance Indicators provide businesses with a tool for measurement (DEFRA, 2006). They are quantifiable metrics that reflect the performance of a business in the context of achieving its wider goals and objectives. KPIs help businesses to implement strategies by linking various levels of an organisation or a project with clearly defined targets and benchmarks. Gradually the use of the term Key Performance Indicators has extended beyond business and industry to government administrations.

The difference between all kinds of other indicators or progress measures is that Key Performance Indicators are directly related to an organization's strategy and are critical for its successful execution of its strategy[2]. KPI's are always tied to a goal, a target or an objective.

In essence two questions are leading for the definition of KPI's in organisations[3] and also for smart city project implementation:

[2] Kellen, V. (2003), Business Performance Measurement: At the Crossroads of Strategy, Decision-Making, Learning and Information Visualization, Chicago.

- Are we doing the right things? Or how effective is the organization, whereby the indicator reflects the degree to which smart city projects conform to the requirements or expectations;
- Are we doing things right? Or, how efficient is the organization, whereby the indicator reflects the degree to which smart city projects deliver the expected impact at minimum resource costs.

As KPI's focus on these 'key' measures that are important for understanding the impacts of smart city projects, they prevent lengthy reports on many less relevant aspects.

4.3 Criteria for selecting indicators

In general, indicators (and even more so KPI's) should express as precisely as possible to what extent an aim, a goal or a standard has been reached or even surpassed. Data that are not linked to standards or specific goals of projects can be used as quantitative background information (e.g. the size of the project in million Euro), but are not suited for evaluative purposes. Often, however, various indicators are available to assess the progression towards a certain goal. Scanning the existing indicators sets for CITYkeys resulted in longlists of potential indicators per subtheme. To evaluate these criteria and make a shortlist of indicators for discussion with partners, a set of critera was used, based on the criteria used by the CIVITAS framework[4]:

1. RELEVANCE; Each indicator should have a significant importance for the evaluation process. That means that the indicators should have a strong link to the subthemes of the framework.
   Further the indicators should be selected and defined in such a way that the implementation of the smart city project will provide a clear signal in the change of the indicator value. Indicators that are influenced by other factors than the implementation of the evaluated project are not suited. Indicators that provide an ambiguous signal (if there is doubt on the interpretation of e.g. an increase in the indicator value) are equally not suited.

2. COMPLETENESS; The set of indicators should consider all aspects of the implementation of smart city projects. KPI's can be selected according to the People, Planet, Prosperity and Governance themes (and for project indicators also from the Propagation theme), which framework is fairly comprehensive in describing public policy goals.

3. AVAILABILITY; Data for the indicators should be easily available. As the inventory for gathering the data for the indicators should be kept limited in time and effort, the indicators should be based on data that either:
   - are available from the project leader or others involved in the innovation case that is being evaluated,
   - or can easily be compiled from public sources,
   - or can easily be gathered from interviews, maps, or terrain observations.

[3] Artley W. and Stroh, S. (2001), The Performance-Based Management Handbook, Vol. 2: Establishing an Integrated Performance Measurement System, Westwood Village: Performance-Based Management Special Interest Group.

[4] Rooijen, T. van, Nesterova, N. (2013). Applied framework for evaluation in CIVITAS PLUS II. CIVITAS WIKI, Deliverable 4.10

Indicators that require, for instance, interviews of users or dwellers are not suited as the large amounts of data needed are too expensive to gather. The same holds for indicators that require extensive recalculations and additional data, such as footprint indicators, and some financial indicators. The current selection contains, however, a few footprint type indicators that might be expected to become common in the near future (e.g. reduction in indirect CO2 emissions).

4. MEASURABILITY; The identified indicators should be capable of being measured, preferably as objectively as possible. For the majority of indicators in the People, Governance and Propagation themes, quantitative measurability is limited. Social sciences provide approaches to deal with qualitative information in a semi-quantitative way (Abeyasekera, 2005).

5. RELIABILITY; The definitions of the indicators should be clear and not open for different interpretations. This holds for the definition itself and for the calculation methods behind the indicator.

6. FAMILIARITY; The indicators should be easy to understand by the users. For a large number of indicators we have relied on indicators from existing indicator sets, that generally comply with this requirement. For new indicators a definition has been developed that has a meaning in the context of existing policy goals.

7. NON-REDUNDANCY; Indicators within a system/framework should not measure the same aspect of a subtheme.

8. INDEPENDENCE; Small changes in the measurements of an indicator should not impact preferences assigned to other indicators in the evaluation. In general we have kept to this principle, but given the political attention for both improving energy efficiency and reducing carbon dioxide emissions, we have included both indicators. As the current energy system is still largely based on fossil fuels, there is a direct relation between a reduction in the use of energy and the reduction of the emission of carbon dioxide. This will lead to a certain extent to double counting the impact.

The longlist of project indicators derived from existing frameworks and respective scores on these criteria can be obtained from the authors.

5. CITYKEYS INDICATORS FOR SMART CITY PROJECTS

A long- and shortlist of project indicators has been debated with all partners over various teleconferences and meetings to finally arrive at the list discussed in next paragraphs. The tables of indicators include the title, the unit, a short description, the source framework(s) and the type of indicator.

The title of the project indicator is phrased as 'improving' something, whether increasing something you want to stimulate, or decreasing something less favourable, comparing the before (or business-as-usual) and after (or expected results) situation.

Important in the choice for the unit of the indicator is the comparability of indicators across a variety of projects differing in type, size, etc. Absolute values, like kg CO2 emitted, are therefore not suitable. Consequently, most project indicators are defined as '% change' or use a Likert scale[5], for instance, % reduction in CO2-emissions.

The short description explains the indicator into more detail. Many indicators are aggregated indicators, inherently combining various elements. The description will provide some examples of elements that can be taken into account at the evaluation phase.

As far as possible, existing indicators of already developed frameworks have been used for the CITYkeys framework. For these indicators, the original frameworks are mentioned in the description as the 'source framework'. In addition, new indicators have been developed by the consortium members when they felt this was necessary for performing a complete evaluation of Smart City projects. The indicator titles of these indicators are marked in red. Paragraph 5.6 will analyse this difference between already available indicators and newly developed ones for CITYkeys objectives.

Finally, the type of indicator is mentioned in the table. An explanation of these types is given in section 4.1.

In total, 108 project indicators have been defined so far. However, this list is not final yet and changes can be made after from the test phase. More elaborate descriptions of the project indicators can be found in Appendix 1.

[5] A Likert scale is a five (or seven) point scale which is used to allow the individual to express how much they agree or disagree with a particular statement. In the CITYkeys evaluation Likert scales are used to express the analyst or independent expert estimate on the indicator.

5.1 People

5.1.1 Health

Indicator title	Indicator unit	Definition	Source	Type of indicator
Improved access to basis health care services	Likert	The extent to which the project has increased accessibility to basic health care; e.g. with regards to physical distance (<500m), 24hrs availability, e-health services, overcoming literacy and language barriers.	Rotterdam SCP; SCI	Outcome
Encouraging a healthy lifestyle	Likert	The extent to which the project encourages a healthy lifestyle; e.g. with regards to biking facilities (bicycle network close by) walking opportunities (network of pedestrian walkways covering the entire area, crossing arrangements); public sports facilities etc.		Process
Waiting time	%	Percentage reduction in waiting time due to the project (as an indicator for the quality of the service)		

5.1.2 Safety

Indicator title	Indicator unit	Definition	Source	Type of indicator
Reduction of traffic accidents	%	Reduction in number of traffic accidents (accidents, fatalities and casualties) due to the project	Civitas; 2DECIDE	Outcome
Reduction in violence	%	Reduction in number of violence, annoyances and crimes due to the project	Rotterdam SCP; Smart City Wheel; European Smart Cities v1.0 (2007); SCI	Outcome

5.1.3 Access to (other) services

Indicator title	Indicator unit	Definition	Source	Type of indicator
Improved access to public transport	Likert scale	Improved accessibility to public transit expressed in # of stops within 500m	Eurbanlab; Rotterdam SCP; Covenant of mayors; OECD; LEED; DGNB	Outcome
Improved quality of public transport	Likert scale	The extent to which the users' perception of the overall quality of the service provided is improved		outcome
Improved access to vehicle sharing	Likert scale	Improved accessibility to vehicle sharing options expressed in # of possibilities within 500m	LEED; DGNB	outcome
Extending the bike route network	%	Increase of the length of cycling roads	FIN Indicators; Transform; OECD; UNECE; Covenant of Mayors; European Green Capital Award study	output
Improved access to bike sharing	Likert scale	Improved accessibility to bicycle sharing options expressed in # of possibilities within 500m	DGNB (LEED and Transform indicator?)	outcome
Improved access to public amenities	Likert scale	The extent to whic important public amenities (such as green public spaces, community centres, theatres or libraries) are available within 500m	Smart City Profiles; RFSC; FIN indicators; Eurbanlab; 2000Watt; SCI; Rotterdam SCP; Eco-Districts	outcome
Improved access to commercial amenities	Likert scale	The extent to which important commercial amenities (such as grocery stores, restaurants, bars, shops etc.) are available within 500m	Eurbanlab, OECD; Rotterdam SCP	outcome
Improved access to online services	Likert scale	The extent to which access to online services was improved.	Triple Helix Model, Smart City Wheel	outcome

5.1.4 Education

Indicator title	Indicator unit	Definition	Source	Type of indicator
Improved access to educational resources	Likert	The extent to which the project improved accessibility to educational resources, related to # of people/households affected and taking into account the ease of use, either physically or digitally.	ITU	outcome
Increased environmental/sustainability education	Likert	The extent to which the project has used opportunities for increasing environmental awareness and educating about sustainability and the environment		output
Improved digital literacy	Likert	The extent to which the project has improved digital literacy		outcome

5.1.5 Diversity and social cohesion

Indicator title	Indicator unit	Definition	Source	Type of indicator
People reached	%	Percentage of people in the target group that have been reached and/or are activated by the project		output
Increased consciousness of citizenship and social coherence	Likert	The extent to which the project has contributed in increasing consciousness of citizenship	ITU	impact
Increased participation of vulnerable groups	Likert	The extent to which project has led to an increased participation of vulnerable groups in society		impact

5.1.6 Quality of housing and the built environment

Indicator title	Indicator unit	Definition	Source	Type of indicator
Social housing	Likert scale	Change in the percentage of social dwellings as share of total housing stock in the project	Eurbanlab	outcome
Connection to the existing cultural heritage	Likert scale	The extent to which making a connection to the existing cultural heritage was considered in the design of the project	Eurbanlab; LEED; DGNB	input
Design for a sense of place	Likert scale	The extent to which the project included details in the design that make a place distinctive, fostering a sense of authentic human attachment and create a feeling of belonging.	Eurbanlab	input
Ensuring the Comfort & Image of Public Spaces	Y/N	Does the project have suitable management arrangements (systems, activities, plans) in place to ensure that the quality & image of public spaces is retained after project completion. This also includes a maintenance friendly design.	Eurbanlab; DGNB: ISO 37151	process
Increased use of groundfloors	Likert scale	The extent to which the project has contributed to the expansion of ground floor usage.		outcome
Increased access to urban public space	Likert scale	The extent to which the project has increased the amount and accessibility of an urban public open space	OECD; Rotterdam SCP	outcome
Increased access to green or recreational space	Likert scale	The extent to which the project has increased the amount and accessibility of an urban public green and /or recreational space	LEED; DGNB; Smart City Wheel; Triple Helix Model; ISO 37151	outcome

5.2 Planet

5.2.1 Energy & mitigation

Indicator title	Indicator unit	Definition	Source	Type of indicator
Reduction in annual final energy consumption by buildings	% reduction	Change in annual final energy consumption of buildings (kWh/m2/yr) for all forms of energy (heat and water heating, cooling, lighting, cooking, ventilation and other ancillary services, electrical appliances) due to the project.	Eurbanlab; Concerto; CIVIS, DGNB	impact
Reduction in annual final energy consumption by transport	% reduction	Change in annual final energy consumption of transport of all types (GJ/year) due to the project.	2 Decide	impact
Reduction in annual final energy consumption by street lighting	% reduction	Change in annual final energy consumption of street lighting (kWh/ yr) due to project.	Urbgrade	impact
Reduction in annual final energy consumption by ICT	% reduction	Change in annual final energy consumption of ICT of all types (kWh/year) due to the project		impact
Reduction in annual final energy consumption by public buildings	% reduction	Change in annual final energy consumption of public buildings (kWh/m2/year) for all usages (heat and water heating, cooling, lighting, cooking, ventilation and other ancillary services, electrical appliances) due to the project.	Eurbanlab; Concerto; CIVIS, DGNB	impact
Embodied energy of materials - quantitative	% reduction	The total embodied energy saved by the project expressed as percentage of total embodied energy of all materials used	Eurbanlab	outcome
Embodied energy of materials - qualitative	Likert scale	The extent to which measures have been taken to reduce the embodied energy of materials used in the project.	Eurbanlab	process

Increase in local renewable energy production	%	Percentage increase in the share of renewable energy produced at the project site as % of total energy consumption on-site. In case biomass is used to generate energy on-site, the transport distance is limited to 100 km.	Eurbanlab; Eco-Districts, Concerto; LEED: CIVIS; IDEAS	impact
Carbon dioxide emission reduction	%	Reduction (%) in direct (operational) CO2 emissions achieved by the project.	Eurbanlab;CIVIS; Concerto; 2 Decide; DGNB	impact
Reduction in lifecycle CO2 emissions	%	Reduction in lifecycle CO2 emissions achieved by the project.	CIVIS; DGNB	impact
Maximum Hourly Deficit	MHDx	The maximum yearly value of how much the hourly local demand overrides the local renewable supply during one single hour (by energy type)	IDEAS	outcome

5.2.2 Materials, water and land

Indicator title	Indicator unit	Definition	Source	Type of indicator
Increased efficiency of resources consumption	% reduction	%-reduction in material consumption due to the project (compared to business as usual) as share of total material consumption by the project	Eurbanlab; ISO 37151; DGNB	impact
Share of recycled input materials	%	Share of recycled and re-used materials expressed as % of total metric tonnes of materials used	Eurbanlab; LEED	input
Share of renewable materials	%	Share of renewable (also rapidly renewable) materials expressed as % of total metric tonnes of materials used	Eurbanlab	impact
Share of materials recyclable	%	Share of materials used by the project that can be recycled after the life time expressed as % of total metric tonnes of materials used	Eurbanlab	impact
Life time extension	Likert	The extent to which measures for extending the lifetime of the assets have been taken		process

Reduction in water consumption	%	Reduction in public water supply consumption (by households, industry and other) brought about by the project expressed as % of total volume of water consumed		impact
Increase in water re-used onsite	%	% of the average annual rainwater and/or wastewater generated by the project (excluding any existing buildings) retained onsite and reused to replace potable water	LEED; OECD	outcome
Self-sufficiency - Water	%	Increased share of local water resources (extracted within a 100 km radius of the project) used as a % of the volume of total water consumption.	City Protocol	impact
Increase compactness	%	The increase in compactness caused by the project calculated as increase in population living in densely populated "compact" areas	FIN Indicators	impact
Self-sufficiency - Food	%	Increase in the share of local food production (within a 100km radius) due to the project as a percentage of the tonnes of total food demand		impact

5.2.3 Climate resilience

Indicator title	Indicator unit	Definition	Source	Type of indicator
Climate resilient neighbourhood	Likert scale	The extent to which adaptation options on neighbourhood scale have been included in the design of the project	Eurbanlab	process

5.2.4 Pollution & waste

Indicator title	Indicator unit	Definition	Source	Type of indicator
Decreased emissions of Nitrogen oxides (NOx)	% reduction	% reduction in NOx emissions achieved by the project	Eurbanlab; Civitas; 2Decide	outcome
Decreased emissions of Particulate matter (PM10)	% reduction	% reduction in PM10 emissions achieved by the project	Eurbanlab; Civitas	outcome
Decreased emissions of Volatile Organic Compounds (VOC)	% reduction	% reduction in VOC emissions achieved by the project		outcome
Decreased emissions of Sulphur dioxide (SO2)	% reduction	% reduction in SO2 emissions achieved by the project		outcome
Decreased emissions of Carbon monoxide (CO)	% reduction	% reduction in CO emissions achieved by the project	Civitas	outcome
Reduced exposure to air pollution	%	Change in number of hours/days per year of net exceedances of limit values for PM10, PM2.5, O3, NO2 and SO2 at the project site.	OECD; 2Decide; RFSC; FIN Indicators; Rotterdam SCP;	impact
Reduced exposure to noise pollution	%	Reduction of people affected by nois pollution	ISO 37120; FIN Indicators; Rotterdam SCP; OECD; ClimateCon; European Green Capital Award study; DGNB	impact
Reduction in the amount of solid waste collected	% reduction	The reduction in the amount of waste collected due to the project as percentage of the total amount of waste collected	Siemens Green City Index; Smart City Profiles; Rotterdam SCP; Transform; Desire; OECD; ClimateCon; SCI; European Green Capital Award study; City Protocol	output

5.2.5 Ecosystem

Indicator title	Indicator unit	Definition	Source	Type of indicator
Increase in green and blue space	%	%-increase of green and blue spaces (m2) compared to the existing green and blue spaces (m2)		outcome
Increased ecosystem quality and biodiversity	Likert	The extent to which ecosystem quality and biodiversity aspects have been taken into account		process

5.3 Prosperity

5.3.1 Employment

Indicator title	Indicator unit	Definition	Source	Type of indicator
Increased use of Local workforce	%	Percentage of total project costs spent on local suppliers, contractors and service providers	Eurbanlab	output
Proximity to jobs	%	Increase of job opportunities within 800 meters of the geographic centre of the project.	LEED	outcome

5.3.2 Equity

Indicator title	Indicator unit	Definition	Source	Type of indicator
Fuel poverty	%	Change in % of (gross) household income spent on energy bills	Eurbanlab	outcome
Costs of housing	%	Change in the percentage of gross household income spent on housing. The housing costs include all fixed expenditures on housing (such as rents and hereditary tenure OR mortgage payments), and excludes expenditures for services or utilities.	Eurbanlab; LEED	outcome

5.3.3 Green economy

Indicator title	Indicator unit	Definition	Source	Type of indicator
Certified companies	%	Share of suppliers/subcontractors used in the project which have some kind of green/social certification going beyond minimal ISO		output
Green/social procurement	Likert scale	The extent to which additional requirements for environmental and social performance were considered during the procurement process (next to price)		process
External costs	Likert scale	The extent to which external life cycle costs (social & environment; here/elsewhere; now/later) were considered throughout the project OR Have you communicated external costs?		process
Green jobs	%	Green jobs (created by the project)		output

5.3.4 Economic performance

Indicator title	Indicator unit	Definition	Source	Type of indicator
Financial benefit for the end-user	€(/household/yr)	Quantitative effects (direct costs and revenues) and qualitative effects(indirect costs and revenues) Total cost savings end users: the financial benefit for users of the project/innovation through reduction in energy/water use or the generation of renewable energy on site	DGNB; Eurbanlab	output
Net Present Value (NPV)	euro/m2	A positive NPV indicates that the inflows outweigh the initial investment, rendering the project feasible at the target discount rate and investment period.	Urbgrade; Eurbanlab; Concerto; 2DECIDE	output

Profitability ratio	ratio	The relation between the net present value of an investment and the cost of the investment.	Urbgrade	output
Internal rate of return (IRR)	%	The IRR of an investment is the discount rate at which the net present value of costs (negative cash flows) of the investment equals the net present value of the benefits (positive cash flows) of the investment. It is expressed as the net present value (NPV) equal to zero.	Urbgrade; 2DECIDE	output
(dynamic/static) Payback Period	# yrs	The Payback period of an investment is the number of years at which the net present value of costs (negative cash flows) of the investment equals the net present value of the benefits (positive cash flows) of the investment. It is expressed as the net present value (NPV) equal to zero.	Urbgrade, Eurbanlab; Concerto	output
Total cost vs. subsidies	%	The percentage of total required subsidies as share of total investment for development	Eurbanlab	output

5.3.5 Innovation

Indicator title	Indicator unit	Definition	Source	Type of indicator
Financial benefit for the end-user	€(/household/yr)	The financial benefit for users of the project/innovation through reduction in energy/water use or the generation of renewable energy on site	DGNB; Eurbanlab	output
Involvement of extraordinary professionals	Likert	The extent to which the project involved professionals normally not encountered in these type of projects, e.g. representatives of the creative industry, professionals from other discplines	Smart City Wheel	process

Innovation ecosystem	Likert scale	To what extent is the project part of or stimulates an innovative environment, based on e.g. the use of open data and being part of innovation platform or living lab.		process
Quality of open data	Likert scale	Increase in the quality of the open data produced by the project		output
New startups	#	number of start-ups related to the project	Smart City Wheel	output
Interoperability	Likert scale	The extent to which the project has increased a community infrastructure that provides services to and accept services from other community infrastructures and to use the services so exchanged to enable them to operate effectively together. For example possibilities to exchange information between related but different services (?).	ISO 37151	process

5.3.6 Attractiveness & competitiveness

Indicator title	Indicator unit	Definition	Source	Type of indicator
Decreased delay by traffic congestion	h/veh-km	Average delay per vehicle kilometre (congestion)	2DECIDE	outcome

5.4 Governance

5.4.1 Organisation

Indicator title	Indicator unit	Definition	Source	Type of indicator
Leadership	Likert scale	The extent to which the leadership of the project is successful in creating support for the project	Eurbanlab	process
Balanced project team	Likert scale	The extent to which the project team included all relevant experts and stakeholders (i.e. the client, architect, installer, construction company, sustainability advisor etc.)	Eurbanlab; DGNB	input
Prior collaboration between team members	Likert scale	The extent to which the project team had prior collaboration experiences before conducting the project in question	Eurbanlab	process
Involvement of the city administration	Likert scale	The extent to which the local authority is involved in the development of the project, other than financial, and how many departments are involved.		process
Clear division of responsibility	Likert scale	The extent to which the responsibility for achieving the sustainability goals & ambitions clearly been assigned to (a) specific actor(s) in the project	Eurbanlab; LEED	process
Continued monitoring and reporting	Likert scale	The extent to which continuous monitoring and reporting has been used to verify that the project was executed according to ambitions, rules & regulations	Eurbanlab	process
Market orientation	Likert scale	The extent to which the project was planned on the basis of a Market analysis (i.e. SWOT-Analysis, business model canvas etc.)	DGNB	process

5.4.2 Co-creation

Indicator title	Indicator unit	Definition	Source	Type of indicator
Professional stakeholder involvement	Likert scale	The extent to which professional stakeholders outside the project team have been involved in planning and execution	Eurbanlab; Green Digital Charter	process
Bottom-up or top-down initiative	Likert scale	The extent to which the project idea originated from the local community itself		process
Local community involvement in planning phase	Likert scale	The extent to which residents/users have been involved in the planning process	Eurbanlab; Green Digital Charter	process
Local community involvement in implementation phase	Likert scale	The extent to which residents/users have been involved in the implementation process		process

5.4.3 Community engagement

No indicators identified at project level.

5.4.4 Multi-level governance

Indicator title	Indicator unit	Definition	Source	Type of indicator
Smart city policy	Likert scale	The extent to which the project has benefitted from a governmental smart city policy	Eurbanlab	input
Municipal involvement - Financial support	Likert scale	The extent to which the local authority provides financial support for SC projects	DGNB	input

5.5 Propagation

5.5.1 Replicability & scalability

Indicator title	Indicator unit	Definition	Source	Type of indicator
Social compatibility of product/service	Likert scale	The extent to which the project's solution fits with people's 'frame of mind' and does not negatively challenge people's values or the ways we are used to do things.	Eurbanlab	process
Technical compatibility of product/service	Likert scale	The extent to which the innovation fits with the current practices and regulations, the administrative procedures, the routines and behaviours of its potential adopters and the corresponding existing technological standards/infrastructures.	Eurbanlab	process
Complexity for end users of the solution	Likert scale	The extent to which the solution is perceived as difficult to understand and use for potential end-stage adopters (i.e. during use phase)	Eurbanlab	outcome
Complexity for professional stakeholders	Likert scale	The extent to which the innovation is perceived as difficult to understand, implement and use for professional users of the solution (i.e. for installation, maintenance)	Eurbanlab	outcome
Trialability	Likert scale	The extent to which the solution can be experimented with on a limited basis in the local context before full implementation	Eurbanlab	process
Advantages for end users	Likert scale	The extent to which the project offers clear advantages for end users (cheaper, comfort etc.)	Eurbanlab; 2DECIDE; CIVITAS; ISO 37151; Civitas	outcome
Advantages for stakeholders	Likert scale	The extent to which the project offers clear advantages for stakeholders (ease of management, maintenance costs etc.)	Eurbanlab	outcome

Visibility of Results	Likert scale	The extent to which the results of the project are visible to external actors	Eurbanlab	output
Solution(s) to development issues	Likert scale	The extent to which the solution meets a general need in society, and more specifically, if to which the innovation offers a solution to problems which are common to European cities or whether it is a solution for a local problem.	Eurbanlab	impact
Market demand	Likert scale	The extent to which there is a general market demand for the innovation	Eurbanlab	impact

5.5.2 Factors of success

Indicator title	Indicator unit	Definition	Source	Type of indicator
Changing professional norms	Likert scale	The extent to which the project changes the professional 'state of the art', thereby inspiring a new or improved norm of what a good urban development should look like.	Eurbanlab	impact
Changing societal norms	Likert scale	The extent to which the project changes the norms and values on what a good urban development should look like of those directly and indirectly involved	Eurbanlab	outcome
Diffusion to other locations	Likert scale	The extent to which the project is copied in other cities and regions	Eurbanlab	impact
Diffusion to other actors	Likert scale	The extent to which the new technologies, principles and/ or practices in this project are copied by other commercial parties (e.g. developers or builders)	Eurbanlab	impact

Change in Rules & Regulations	Likert scale	The extent to which the project has contributed to, or inspired, changes in rules & regulations (at local -city planning, zoning- or national-, -spatial law, energy laws- level)	Eurbanlab	impact
Change in public procurement	Likert scale	The extent to which the project has inspired new forms of public procurement procedures	Eurbanlab	impact
New forms of financing	Likert scale	The extent to which the project has contributed to- or inspired- the development of new forms of financing	Eurbanlab	impact
Increased (Smart City) tourism	#	The number of smart city tourists attracted by the project		impact

5.6 Response to the gap analysis

In the discussions a number of new project indicators have been added to the selection of indicators from existing indicator frameworks:

People

1. Encouraging a healthy lifestyle
2. Waiting time
3. Improved quality of public transport
4. Increased environmental/sustainability education
5. Improved digital literacy
6. People reached
7. Increased participation of vulnerable groups
8. Increased use of groundfloors

Planet

1. Reduction in annual final energy consumption by ICT
2. Life time extension
3. Reduction in water consumption
4. Self-suffiency – Food
5. Decreased emission of VOC
6. Decreased emissions of Sulphur dioxide (SO2)
7. Increase in green and blue space
8. Increased ecosystem quality and biodiversity

Prosperity

1. Certified companies
2. Green/social procurement
3. External costs

4. Green jobs
5. Innovation ecosystem
6. Quality of open data

Governance

1. Structure of the city administration
2. Bottom-up or top-down initiative
3. Local community involvement in implementation phase

Propagation

1. Increased (Smart City) tourism

Many of the 'new' indicators are related to specific goals of smart city projects, such as 'people reached', 'quality of open data', 'local community involvement in implementation phase'. Others are simply additions to existing indicator sets such as 'VOC emissions'. Some of the 'new' indicators are reformulations or combinations of existing indicators, such as 'improved quality of public transport'.

6. CITYKEYS INDICATORS FOR SMART CITIES

Because a strong focus of the CITYkeys framework is on the relation between project and city indicators, the selection of project indicators as discussed in chapter 5 has formed the basis for defining city indicators. From the longlist of city indicators, derived from existing frameworks, an indicator was chosen, in consultation with all project partners,that has the closest resemblance with one of the selected project indicators. If several indicators were equally suitable, the preference went to an indicator that cities already use and/or are familiar with. In the next paragraphs, the tables of selected city indicators are shown, discussing the title, the unit, a short description, the source framework(s) and the type of indicator.

The title of the city indicator is phrased as evaluating a static situation. A static indicator, assessing the situation at a certain recurrence in time, will allow monitoring over various time periods.

Important in the choice for the unit of the indicator is the comparability of indicators across a variety of cities differing in size, demography, dominant type of companies/sectors, etc. Here too, absolute values are not suitable. Consequently, most city indicators are defined as '%' or use a Likert scale, for instance, the share of population with good access to public transport expressed in percentage.

It should be noted that in the project indicator set several indicators have been defined as qualitative indicators expressing for instance the quality of public transport connections, while on the city level a more conventional quantitative indicator was selected (such as the share of population with a public transport stop within 500 m). The reason is that on the project level a simple quantitative indicator was judged as insufficient for expressing the impact of the project, while for the city indicator set the traditional quantitative indicator was judged more feasible.

The short description explains the indicator into more detail. More elaborate descriptions of the city indicators can be found in Appendix 2.

Also for city indicators, existing indicators of already developed frameworks have been used for the CITYkeys framework when available. For these indicators, the original frameworks are mentioned in the description as the 'source framework'. In addition, new indicators have been developed by the consortium members when they felt this was necessary for performing a complete evaluation of Smart Cities. The indicator titles of these indicators are marked in red. Paragraph 6.6 will analyse this difference between already available indicators and newly developed ones for CITYkeys objectives.

Finally, the type of indicator is mentioned in the table. An explanation of these types is given in section 4.1.1. Preferably, the city indicator type matches the type of the related project indicator.

In total, 78 city indicators have been defined so far. However, this list is not final yet and changes can be made after insights from the test phase.

6.1 People

6.1.1 Health

Indicator title	Indicator unit	Definition	Source
Access to basic health care services	%	Share of population with access to basic health care services < 500m	Rotterdam SCP; SCI
Encouraging a healthy lifestyle	Likert	The extent to which policy efforts and equivalent implementation of measures are undertaken to encourage a healthy lifestyle; e.g. with regards to biking facilities (bicycle network close by) walking opportunities (network of pedestrian walkways covering the entire area, crossing arrangements); presence of public sports facilities, availability and affordability of education on healthy lifestyle,support in work/life balance.	

6.1.2 Safety

Indicator title	Indicator unit	Definition	Source
Traffic accidents	# of accidents, fatalities and casualties/1000 inhabitants	The number of recorded transport injury accidents and the resulting number of fatalities and casualties caused by any means of transport. A recorded injury accident is any transport incident causing death or injury which is recorded by the police.	Civitas; Rotterdam SCP; European Green Capital Award study; 2Decide; CASBEE_City_2012; UNECE; ,GCIF; COMIND; URBES
Crime rate	#/100.000 inhabitants	# of violence, annoyances, crimes/100.000 inhabitants	Rotterdam SCP; Smart City Wheel; European Smart Cities v1.0 (2007); SCI; City Protocol; GCIF

6.1.3 Access to (other)services

Indicator title	Indicator unit	Definition	Source
Access to public transport	%	% of inhabitants with a public transport stop/transportation connection (train, tram, subway) within reasonable (500m) distance	Rotterdam SCP; Covenant of mayors; OECD; City Protocol; GCIF; 2000-Watt;
Access to vehicle sharing	%	Share of population with access to (e-)car sharing options within 500m, (including carsharing parking spaces, carsharing stations).	LEED; DGNB
Length of bike route network	km/inhabitant	The total length of bicycle paths divided to the length of streets (excluding motorways) in km/inhabitant	FIN Indicators; Transform; OECD; UNECE; Covenant of Mayors; European Green Capital Award study; City Protocol; URBES
Bicycle sharing solutions for city travel	#	Available bicycles to share per capita	UNECE
Acces to public amenities	%	Share of population with good access (within 500m) to basic public infrastructure, i.e. services/facilities provided by the town/city council for the general public to use, with or without charge (e.g. community centres, sports grounds, restrooms, drinking fountains).	Smart City Profiles; RFSC; FIN indicators; Eurbanlab; 2000Watt; SCI; Rotterdam SCP
Access to commercial amenities	%	Share of population wth good access to commercial amenities providing goods for daily use, taking into account number of amenities within reasonable (500m) distance	Eurbanlab ,OECD, Rotterdam SCP; City Protocol
Access to high speed internet	%	Percentage of households having access to high speed internet of above 30 Mbps. Ensure city connectivity and the provision of efficient infrastructures.	ISO 37120; RFSC; Rotterdam SCP; Transform; UNECE; ITU; Green Digital Charter; European Green Capital Award study; City Protocol; GCIF; ITU; URBES; Smart City Wheel; Triple Helix Model; European Smart Cities v1.0 (2007)

6.1.4 Education

Indicator title	Indicator unit	Definition	Source
Access to educational resources	Likert	The extent to which accessibility to educational resources has improved, related to # of people/households affected and taking into account the ease of use, either physically or digitally.	
Environmental education	%	The percentage of schools with environmental education programs	SCI
Digital literacy	#	Number of students reached	

6.1.5 Diversity and social cohesion

No indicators identified at city level.

6.1.6 Quality of housing and the built environment

Indicator title	Indicator unit	Definition	Source
Social housing	%	Percentage of social dwellings as share of total housing stock in the city	UNECE; City Protocol; Eurbanlab; SCI
Preservation and restoration of regional history	Likert	The extent to which making a connection to the existing cultural heritage was considered in the design of the project	Eurbanlab; CASBEE_Urban development_2014
Ground floor usage	%	Percentage of ground floor surface of buildings that is used for commercial or public purposes	
Access to urban public space	%	Percentage of population with access to urban public spaces within 500 meters	OECD; Rotterdam SCP
Access to green or recreational space	%	Percentage of population with access to public areas and/or green areas within 500 meters	UNECE; ClimateCon; OECD; SCI; European Green Capital Award study; City Protocol; GCIF; URBES; Rotterdam SCP

6.2 Planet

6.2.1 Energy & mitigation

Indicator title	Indicator unit	Definition	Source
Annual final energy consumption of buildings	MWh/cap/yr	Final energy consumption of buildings for all forms of energy (heat and water heating, cooling, lighting, cooking, ventilation and other ancillary services, electrical appliances) per city capita annually.	Eurbanlab; Transform
Final energy use for transport	GJ/cap/yr	Annual final energy consumption of transport of all types (GJ/year)	Eurbanlab
Final energy consumption by street lighting	kWh/cap/yr	Annual final energy consumption of street lighting (kWh/cap/yr) in city per capita.	
Final energy consumption by ICT	MWh/cap/yr	Annual final energy consumption of IT of all types (MWh/cap/year) in city	Green Digital Charter
Final energy consumption by public buildings	kWh/m2/year	Change in annual final energy consumption of public buildings (kWh/cap/year) for all usages (heat and water heating, cooling, lighting, cooking, ventilation and other ancillary services, electrical appliances) due to the project	City Protocol; ISO 37120; Covenant of mayors
Renewable energy produced within the city	%	This indicator is the percentage of total energy derived from renewable sources as a share of the city's total energy consumption	Eurbanlab; Transform; OECD; UNECE; READY
CO2 emissions	t CO2/cap/yr	The total amount of CO2 in tonnes (equivalent carbon dioxide units) generated over a calendar year by all activities within the city, excluding indirect emissions outside city boundaries (numerator), divided by the current city population.(denominator)	ISO 37120; Smart City Wheel; SCI; FIN indicators; DESIRE; RFSC; UNECE; European Green Capital Award study; City Protocol; GCIF

6.2.2 Materials, water and land

Indicator title	Indicator unit	Definition	Source
Resource efficiency	t/cap/year	Material consumption in metric tonnes per capita per year	
Water consumption	m3/cap/year	Total annual water released into the distribution network	Siemens Green City Index; FIN Indicators; European Green Capital Award study; UNECE; OECD; ClimateCon; Rotterdam SCP; City protocol; GCIF; COMIND
Grey water use	%	Percentage of houses equipped to reuse grey water	OECD
Water Exploitation Index(+)	%	Annual total water abstraction as a percentage of available long-term freshwater resources in the geographically relevant area (basin) from which the city gets its water	DESIRE
Water leakage/losses	% reduction	Reduction in water losses compared to previous measurement	Siemens Green City Index; UNECE; FIN Indicators; City Protocol; GCIF; URBES
Population density	%	Share of people living in densely populated neighbourhoods expressed as % of total population	FIN Indicators
Local food production	%	Share of local food production (within a 100km radius) as a percentage of the tonnes of total food demand	

6.2.3 Climate resilience

Indicator title	Indicator unit	Definition	Source
Climate resilient design	Likert scale	The extent to which adaptation measures have been implemented in the city	Eurbanlab

6.2.4 Pollution & waste

Indicator title	Indicator unit	Definition	Source
Nitrogen oxide emissions (Nox)	g/cap	Emission of NOx per capita	Siemens Green City Index; European Green Capital Award study
Particulate matter emissions (PM10)	g/cap	Emission of PM10 per capita	Siemens Green City Index; European Smart Cities v1.0 (2007); European Green Capital Award study; Civitas
Emissions of volatile organic compounds (VOC)	g/cap	Emission of VOC per capita	European Green Capital Award study
Sulphur dioxide emissions (SO2)	g/cap	Emission of SO2 per capita	Siemens Green City Index
Carbon oxide emission (CO)	g/cap	Emission of SO2 per capita	Civitas
Air quality		To be further elaborated	RFSC; FIN Indicators; Rotterdam SCP; OECD; COMIND
Noise pollution		To be further elaborated	ISO 37120; FIN Indicators; Rotterdam SCP; OECD; ClimateCon; European Green Capital Award study; City Protocol; URBES
Recycling rate	%	The share of the total municipal waste that is being recycled expressed in % of total municipal waste collected	Siemens Green City Index; Smart City Profiles; Rotterdam SCP; Desire; OECD; ClimateCon; CASBEE_City_2012; SCI; City Protocol; GCIF; 2000-Watt
Municipal solid waste	t/cap/yr	The amount of municipal solid waste generated per capita annually	Siemens Green City Index; Smart City Profiles; Rotterdam SCP; Transform; Desire; OECD; ClimateCon; SCI; European Green Capital Award study; City Protocol

6.2.5 Ecosystem

Indicator title	Indicator unit	Definition	Source
Ratio of green and water spaces	%	Share of green and water surface area of total land area	CASBEE_City_2012
Total number of endemic species	#	# of endemic species present in the city	City Protocol

6.3 Prosperity

6.3.1 Employment

Indicator title	Indicator unit	Definition	Source
City's uneployment rate	%	Residents unemployed as a share of all economically active residents	ISO 37120, ClimateCon; SCI; European Green Capital Award study; City Protocol; UN HABITAT CPI; GCIF; Triple Helix Model; SCI; European Green Capital Award study; COMIND; RFSC; UNECE
Youth unemployment rate	%	Total number of unemployed youth (numerator) divided by the youth labour force (denominator)	ISO 37120; European Green Capital Award study; City Protocol

6.3.2 Equity

Indicator title	Indicator unit	Definition	Source
Fuel poverty	%	Percentage of city inhabitants in fuel poverty	Eurbanlab; Transform
Affordability of housing	%	% of population living in affordable housing	Eurbanlab; UNECE; SCI

6.3.3 Green economy

Indicator title	Indicator unit	Definition	Source
Certified companies	%	Share of companies with some kind of green/social certification going beyond minimal ISO, of total	
Environmental considerations in the city's public procurement	%	Annual procurement using environmental criterial	FIN Indicators
Green jobs	%	Share of jobs related to measuring, avoiding, reducing, limiting or removing environmental damages as well as the preservation of natural resources	…; Green Digital Charter; SCI; Transform

6.3.4 Economic performance

Indicator title	Indicator unit	Definition	Source
Gross Domestic Product	€/cap	Gross domestic product on the level of the city per capita	Triple Helix Model; Green Digital Charter; ClimateCon; City Protocol; UN Habitat CPI; GCIF; READY; UNECE
New business registered in reference year (net entry rate)	#	Number of new founded enterprises per year	Triple Helix Model; European Green Capital Award study; City Protocol
Median disposable Income	€/household	Median disposable annual household income	ClimateCon; European Green Capital Award study; GCIF; COMIND; Triple Helix Model

6.3.5 Innovation

Indicator title	Indicator unit	Definition	Source
Creative industry	%	Share of people working in creative industries	Triple Helix Model; European Green Capital Award study; Smart City Wheel
Open information facilities/innovation hubs in the city	#	# of open information facilities/innovation hubs in the city, whether private of public	
Quality of the datasets	#	High quality of open data are 'accurate, available, complete, conformant, consistent, credible, processable, relevant and timely'.	City Protocol
New startups	#	Number of new startups	Smart City Wheel
Research intensity	%	R&D expenditure as percentage of GDP	Triple Helix Model; ITU; UNECE; Smart City Wheel; European Smart Cities v1.0 (2007)
Open data	#	# of open datasets relevant to the city	

6.3.6 Attractiveness & competitiveness

Indicator title	Indicator unit	Definition	Source
Average delay per vehicle kilometre (congestion)	h/veh-km		IDEAS; European Green Capital Award study
Public transport use	#/cap/year	Annual number of public transport trips per capita	City Protocol; ISO 37120; GCIF
Rate of population change due to migration	%	Rate of population change due to migration = Number of social increase-decrease of population (Number of move-ins – Number of move-outs) / Total population	CASBEE_City_2012; European Green Capital Award study
Population Dependency Ratio	%	age-population ratio of those typically not in the labor force (the dependent part) and those typically in the labor force (the productive part). It is used to measure the pressure on productive population.	GCIF
International Events Hold	#/cap	Number of international congresses and fairs atendees.	Smart City Wheel
Tourism intensity	nights/cap	Number of tourist nights per year per capita within a defined destination. To take into account nights sharing accomodation,etc	UNECE; European Green Capital Award study; Triple Helix Model

6.4 Governance

6.4.1 Organisation

Indicator title	Indicator unit	Definition	Source
Balanced project teams	%	The percentage of smart city projects in which the project team included all relevant experts and stakeholders in the earliest stages of the project's design (i.e. the client, architect, installer, construction company, sustainability advisor etc.)	RFSC
Cross-departmental integration	Likert	The extent to which cross-departmental " Smart City" management is rolled out	Transform
Establishment within the administration	Likert	The extent to which the municipal efforts regarding smart city are reflected by a dedicated structure and staff resources	Smart City Profiles

Monitoring and evaluation	Likert	The extent to which the progress of policies/strategies/projects is evaluated and are adapted according to the findings	RFSC
Ease of access to information	%	The extent to which information is published in an easily accessible form	ITU

6.4.2 Co-creation

Indicator title	Indicator unit	Definition	Source
Citizen participation	Likert	The extent to which citizens are actively taking part in smart city projects	Transform
Open public participation	(Total amount of open public participation processes/City population)*1 000	The extent to which citizens participate in decision making	City Protocol

6.4.3 Community engagement

Indicator title	Indicator unit	Definition	Source
Voter participation	%	% of people that voted in the last municipal election as share of total population eligible to vote	ISO 37120; European Smart Cities v1.0 (2007); UNECE; European Green Capital Award study; City protocol; GCIF; COMIND

6.4.4 Multi-level governance

Indicator title	Indicator unit	Definition	Source
Smart city policy	Likert	The extent to which the city has a supportive smart city policy.	
Expenditures by the municipality for a transition towards a Smart City	€/capita	Expenditures by the municipality for a transition towards a Smart City	Smart City Profiles
Multilevel cooperation	Likert	The extent to which your city cooperates and /or coordinates with other municipalities and/or other levels of government	RFSC

6.5 Propagation

As the potential for dissemination of smart city projects to other contexts or other cities can only be assessed on the project level, this them is not included on the city level.

6.6 Response to the gap analysis

On the city level fewer new indicators have been added than on the project level. This is largely due to the fact that there were many more city level indicators readily available, and because of the difficulty of aggregating project level results to an indicator on city level (while for the assessment of projects the indicator was deemed necessary).

People

1. Encouraging a healthy lifestyle
2. Access to educational resources
3. Digital literacy
4. Ground floor usage

Planet

1. Final energy consumption by street lighting
2. Resource efficiency
3. Local food production

Prosperity

1. Certified companies
2. Open information/innovation hubs
3. Open data

Governance

1. Smart city policy

7. CONCLUSIONS

7.1 Summary of achievements

Based on the inventory of indicators from 43 existing indicator sets for evaluating project and urban sustainability a set of indicators for assessing the impacts of smart city projects has been designed for CITYkeys. The majority of indicators in the set are derived from existing urban indicator frameworks. Eleven indicators have been newly formulated to fit the aims of CITYkeys.

The indicator selection for evaluating smart city projects has been linked with corresponding indicators on city level. Of the around 80 project indicators, there are only 28 that can be quantitatively related (or aggregated) to a corresponding indicator on the city level. For 37 indicators on project level no corresponding city indicator could be found: all the propagation indicators belong to this category, because this theme is only relevant for projects. Also several other indicators are useful for measuring the success of a project, but are too specific to be used on the city level.

This means that the possibilities to aggregate quantitatively from project to city level are limited. The majority of these indicators concern energy use, emissions from CO2 and air pollutants, and waste generation, with some possibilities in the people and prosperity themes.

The resulting indicator selection responds to the wishes of cities and citizens for the coverage of their priorities and reflects city (sustainability) goals, and does not appear as a typical set on indicators on smartness of a city. Indicators that reflect the degree of smartness of a city (or a project) would be input and output indicators that are difficult to harmonise seen the diversity of smart city projects, and quickly outdated.

Due to the multitude of different smart city projects, the CITYkeys indicator set focuses on impact indicators[6], as these can be usedfor all types of interventions. Some output and outcome indicators are included where impacts are difficult to estimate or calculate at project level.

7.2 Relation to continued developments

The current report reflects the state of development of the CITYkeys indicators. In the period up to January 2016 for each indicator the data needs will be described in detail, which will form the basis for describing the indicator calculation procedures (in a guideline) and elaborating these in practical tools. A system architecture for linking project to city indicators will be proposed.

Another part of the development will be the implementation of the performance measurement system (primarily on the project level, but linking with the city level where possible) including a user interface. In this step issues around the weighing and aggregation of indicators will be investigated.

All this preparatory work leads to testing of the indicators in smart city projects or cases in the partner cities. The cooperation with the existing (and maybe upcoming) lighthouse projects will be continued.

[6] See Section 4.1 for definitions of types of indicators.

7.3 Other conclusions and lessons learned

The intensive consultation process with partner cities and Lighthouse projects has contributed to a reasonably complete and comprehensive set of indicators, without confusing details, and which is reasonably balanced with regard to the city's objectives, certainly on the project level.

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