iSCAPE

Report on iSCAPE socio-economic impact assessment methodology

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Short Description	*This deliverable presents the methodology for the assessment of the socio-economic impacts of the iSCAPE project. The methodology has identifies a selection of quali-quantitative approaches able to map, describe and - to a certain extent - quantify the impact generated by the project. It builds on literature review of studies and researches and from a consultation process with the partners managing the interventions in the cities and the Living Labs. The methodological framework is designed as modular in order to adapt to the specificities of each of the project pilot.*		
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List of abbreviations

Acronym / Term	Definition
DoA	iSCAPE Description of Action
PM	Particulate Matter
VOCs	Volatile Organic Compound
CO2	Carbon Dioxide
SO2	Sulphur Dioxide
VSL	Value of Life
GDP	Gross Domestic Product
ES	Ecosystem Services
CTM	Chemical Transport Model
VSLY	Value of statistical life per year
PCS	Passive Control System
PCE	Perceived Citizens' Effectiveness
WTP	Willingness to Pay

1 Executive Summary

This deliverable presents the methodology for the assessment of the socio-economic impacts of the iSCAPE project, which aims to develop an integrated strategy for air pollution control in European cities, grounded on evidence-based analysis. The project will pursue its goal by leveraging passive control systems, behavioural change and developing policy recommendations. Moreover, it will make these solutions accessible to local communities through the Living Lab approach, involving a selection of stakeholders from the civil society and from the institutions in awareness and dissemination activities. The expected result is the increased visibility of the air pollution challenge and the valorisation of solution available at infrastructural and behavioural level. The focus of the assessment is therefore on the one hand the impact (or the potential impact) of the intervention studied and implemented by the project, and on the other hand the impact of the Living Lab activities and of the involvement of communities and institutions.

The methodology has been developed during the first year of the project and it has identified a selection of quali-quantitative approaches able to map, describe and quantify (when useful) the impact generated by the project. The methodological framework described in this deliverable includes the following well-know and tested approaches: Impact Pathway Approach, Hedonic pricing Approach, Life satisfaction approach, Unit-cost modelling and meta-analysis and Quality of Life approach. The selection of these methods came from a process of literature review of studies and researches that dealt with the same topic already, and from a consultation process with the partners managing the interventions in the cities and the Living Labs.
Not all these methods/approaches will be used for analysing all the project outputs, and especially all the pilot actions – which constitute the main focus of the impact assessment. The methodological framework, in fact, is designed as modular in order to adapt to the specificities of each of the project pilot and best describe its socio-economic benefits.

This document must be considered a work in progress: before the project assessment, that will take place during the last year, it could be updated according to the progress and adjustment of the project activities.

2 Introduction

The socio-economic assessment methodology described in this document is part of the wider goal of developing an approach to evaluate the impact of the iSCAPE outputs and pilots, which include also the analysis of the environmental impacts, developed within other tasks (5.1 and 5.2). The methodology will map and quantify, as much as possible, economic and social impact of the iSCAPE project focusing mainly – but not exclusively – on the results of the six foreseen pilots set up to involve and empower local stakeholders and the general public. Here below the list of the pilots with a synthetic description[1]:

- Bologna (Italy): Bologna is developing two pilots. The first one will deal with the role of trees as a Passive Control System to improve the air quality inside the urban environment, relying on two field in situ measuring campaign during winter and summer. Results will be shared with local authorities to introduce new interventions, and citizens will be involved and informed about the experiments. In the Lazaretto (a Bologna's neighbourhood), a second intervention will allow to assess the impacts of the use of photocatalytic coatings on a campus building. The test will be conducted estimating pollutants concentrations pre and post application of coats. Each phase of the project will be shared with students and campus employees.
- Bottrop (Germany): in Bottrop, the potted "Wandering Trees" pilot will make trees traveling around the city, temporarily greening inner-city streets and allowing to study the impacts on air quality and on the local community. The implementation of the living lab will bring a broad involvement of local stakeholders and of the general public.
- Dublin (Ireland): by conducting a long-term study, Dublin living lab will provide evidence on the effectiveness of low boundary walls (LBW). The deployment of a sensor network will allow to assess impact of an already existing LBW. Moreover, city stakeholders and citizens will assist in aesthetic and functional design of a new LBW trough participatory events and playful approaches, for example, using large Lego-like bricks.
- Guildford (United Kingdom): iSCAPE results in Guildford are envisioned as a portable, insightful, and user-interactive platform for raising citizens' awareness about air pollution issues in their neighbourhood and the use of green infrastructural interventions (such as such as trees and hedges) to combat pollution exposure, thereby improving community's health and well-being.
- Hasselt (Belgium): the intervention will trigger and analyse behavioural changes by providing a dedicated app to a population sample for observing their travel patterns. Intervention will be in the form of customised information to participants in relation to their exposure to pollutants, contribution in CO_2 emissions and physical activity level, aiming to influence more sustainable lifestyles.
- Vantaa (Finland): the pilot will focus on the influence of green roofs and parks on air quality and human well being and it will establish a platform for stakeholder like city authorities and inhabitants to combine their common effort for better city planning.

[1] For more detailed descriptions of the pilots please refer to D2.2

To develop the methodology for the impact assessment of the pilots and the participatory activities foreseen in the six cities, this deliverable built on three sources, as illustrated in figure 1: first an in-depth literature review dedicated to the iSCAPE interventions and their expected impacts; then a review of already existing methodologies dealing with the same objectives and of their possible adaptation to the iSCAPE scenarios. The third source is represented by the iSCAPE partners and their feedback.

The first two steps generated a draft framework of the socio-economic impact assessment methodology, including a selection of relevant areas of impact, variables and indicators and methods of evaluation. The framework was summarised in a presentation and discussed during individual webinars with each project partner engaged in the pilots. This consultation phase allowed validating and verifying the consistency of the methodology with the planned activities, refining and finalising the approach. Moreover, the discussion with the partners provided an overview of the typology of data available for each city, further narrowing the focus of the analysis.

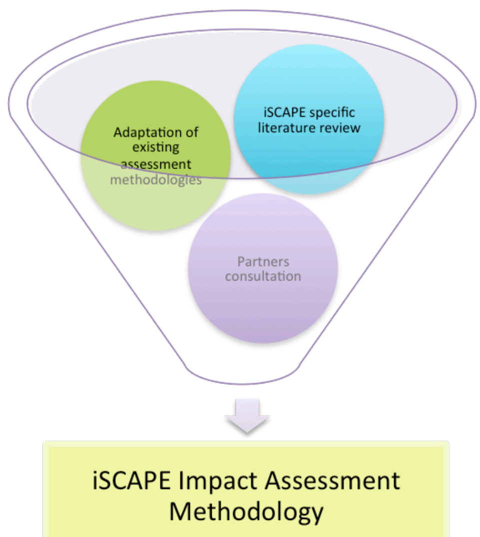

Figure 1 - Development of the impact assessment methodology

This process allows a wide exploitation of the already available research in the same field of investigation, guaranteeing at the same time the development of a tailor made framework already aligned with partners' plans and expectations.

The following paragraphs will explain the value and the objectives of an impact assessment and will provide an overview of this document.

2.1 Why a socio-economic impact assessment methodology for iSCAPE

The iSCAPE project aims to have a concrete impact on research, intervention and policies dealing with urban air pollution. Moreover, through the Living Lab approach, it is expected to reach the wider public and to raise awareness among the citizens, providing them knowledge and tools to proactively contribute to the solutions. From this perspective, the assessment of the socio-economic impacts of the project is a key tool to identify and value its results and its contribution in terms of advancements of academic studies concerning the air quality issue and its solutions. The assessment allows also the identification of real or expected impacts at social and economic level of the urban intervention under investigation and of the activities developed for citizens and other stakeholders.

The guide to impact assessment developed by the EC INFOREGIO Unit (European Commission, 2012b: 119) defines impact as,

> "a consequence affecting direct beneficiaries following the end of their participation in an intervention or after the completion of public facilities, or else an indirect consequence affecting other beneficiaries who may be winners or losers. Certain impacts (specific impacts) can be observed among direct beneficiaries after a few months and others only in the longer term (e.g. the monitoring of assisted firms). In the field of development support, these longer-term impacts are usually referred to as sustainable results. Some impacts appear indirectly (e.g. turnover generated for the suppliers of assisted firms). Others can be observed at the macro-economic or macro-social level (e.g. improvement of the image of the assisted region); these are global impacts. Evaluation is frequently used to examine one or more intermediate impacts, between specific and global impacts. Impacts may be positive or negative, expected or unexpected".

Running an impact assessment means answering the question "what is the difference the project makes?". For the iSCAPE project, more specifically the environmental impact will be evaluated in task 5.2 while the socio-economic impact will be covered by task 5.3. The methodology here described refers only to the latter.

It is important to highlight that an impact assessment can have different scope and the results could be useful for different audiences. The figure that follows maps the main goal of an impact assessment and the related methodological approaches.

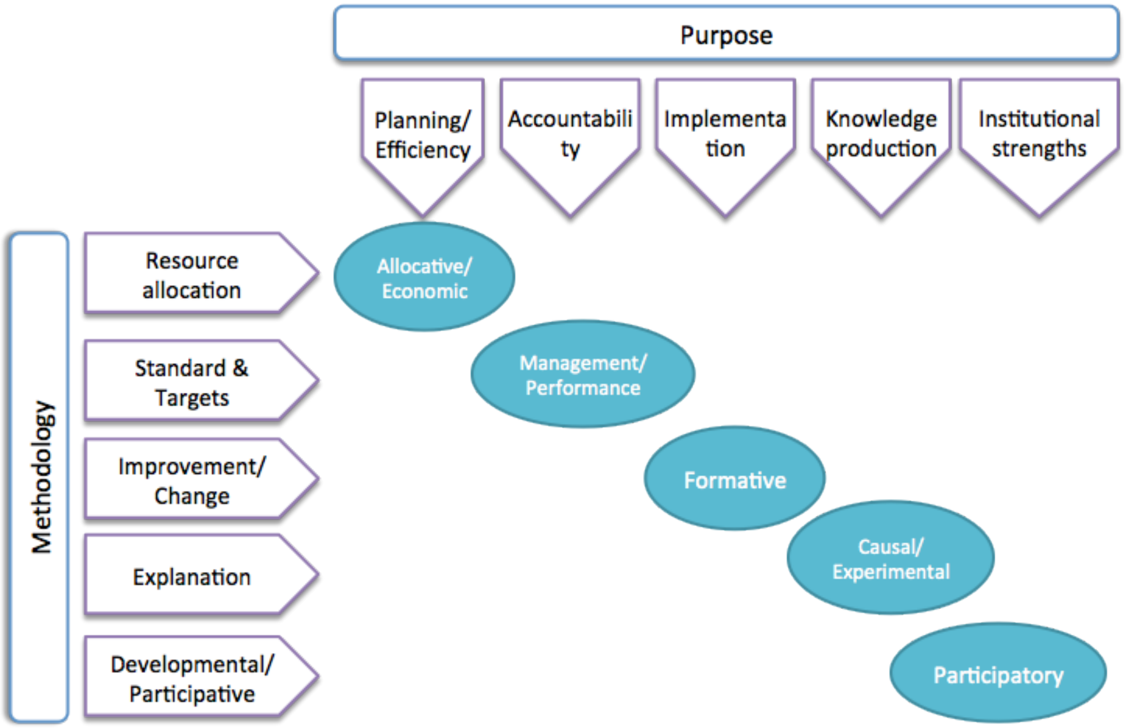

Figure 2 – Purposes and methodologies of impact assessment (Evalsed: the resource for the evaluation of socio-economic development. Regional Policy - Inforegio)

In the case of the iSCAPE project, the assessment will meet two goals: on one side, it will be a useful internal management tool, facilitating the coordination, aligning the expectations providing valuable lessons to the partners. On the other side, it will provide social and economic results to policy makers and stakeholders in a concrete and comprehendible form, supporting future actions and policies accordingly. As a final remark, it is important to mention, impacts tend to be observable after the end of a project. For this reason, the impact assessment activities that will take place during the iSCAPE project life time will be only able to assess **expected** or **modelled** impacts

2.2 Structure of the document

This deliverable reports the results of the extensive literature review concerning the interventions involved in the project and the studies already developed to address similar projects. Based on this research, it illustrates the framework and the methods for the assessment the economic and the social impacts of all studies, interventions and activities undertaken during the project. The document is articulated as follows:

- Chapter 3 presents the literature review of the socio-economic impacts of the three solutions to the air pollution issue explored by iSCAPE: passive control systems, behavioural changes and policy interventions, with the aim to provide a comprehensive knowledge of the interventions, their application and their expected effects;

- Chapter 4 presents an overview of socio-economic impact assessment developed for initiatives and projects similar to iSCAPE, to understand the depth and the approach of previous investigations in the field therefore underlying the original contribution provided by the iSCAPE project;
- Chapter 5 illustrates in detail the assessment framework, identifying dimensions, indicators and methods of analysis for the economic and the social impacts, together with the data gathering and the data analysis process that will be developed as next steps.

3 Literature review on socio-economic impacts of passive control system interventions, behavioural change interventions and policy interventions.

This chapter describes and analyses the air quality control interventions in iSCAPE, that can be roughly categorized in three categories: 1) passive control systems, including both green and grey solutions, 2) interventions that aim to change the behaviour of citizens and 3) direct policy interventions.

The main goal of the interventions is to reduce the effects related to air pollutants, but many of the interventions also bring other benefits to the citizens. In this section, a literature review of the socioeconomic impacts of interventions is presented. The interventions in iSCAPE, illustrated in the Introduction, are summarised in table 3.1.

City	**Intervention**	**Green / Grey / Behavioural / Policy**
Bologna	Street canyon with / without trees	Green Policy
Vantaa	Green roofs	Green Policy
Hasselt	Behavioural change – warning systems	Behavioural
Dublin	Low boundary walls	Grey
Guildford / Vantaa (Metropolitan area of Helsinki)	Green infrastructure	Green
Bottrop	Walking trees	Green Policy
Lazaretto	Photocatalytic painting	Grey

Table 1: iSCAPE planned interventions in each city

3.1 Socio-economic impact of passive control systems.

Passive control systems are usually mentioned in the literature as ways to reduce the negative effects of air pollution in cities (e.g. Gallagher et al., 2012; McNabola, 2010). The aim of the passive control systems is to manipulate the pollutant dispersion patterns in cities in order to reduce exposure to air pollutants. It can happen e.g. with low boundary walls, trees or on-street parking which block part of the dispersion from roads to pedestrian lanes. Reduction of concentrations of PM2.5[2] and harmful Volatile Organic Compounds (VOCs) have been reported in the literature (e.g. McNabola 2010). Next to the dispersion, research has shown that trees and other types of green interventions induce deposition of air pollutants and reduce air pollutant concentration levels (e.g. Yang et al. 2008).
The impact assessment of iSCAPE aims to study the social and economic benefits of reducing exposure and air pollutant concentration levels. The main impacts are naturally related to health benefits, of which reduction of mortality due to air pollutants represent around 90% of the benefits (e.g. Heo et al. 2016). However, many of the interventions bring also other types of benefits as well as costs. Green infrastructure can for example help to mitigate the heat-island-effect in the cities, reduce storm-water runoff to the sewage system, reduce noise pollution, bring aesthetic benefits, change the citizens approach and behaviour towards the use of local spaces. However, opportunity costs include reduction in parking or building space and maintenance costs. In this section, literature review of the expected benefits and costs is conducted. Based on this, the appropriate methodology to study the benefits and costs of each intervention can be chosen.

3.1.1 Green interventions and the socioeconomic benefits of ecosystem services

Cities and urban systems are dependent on ecosystems existing both beyond and within the city limits. Bolund and Hunhammar (1999) identified seven types of different urban ecosystems: street trees, lawns/parks, urban forests, cultivated land, wetlands, lakes/sea and streams. Alternative classifications are available but usually almost identical. These ecosystems provide benefits to the citizens – benefits can be classified by different services provided by the ecosystems. These services are called ecosystem services (ES). As the competition of space in urban areas is increasing, new solutions have emerged and green roofs and green walls should be added to the list. Within urban areas, the primary issue from the perspective of human well-being is whether the urban settlements can provide a healthy and satisfying living environment for residents. Living ecosystems are recognized as a key to wellbeing as ES are increasingly acknowledged to increase the quality of life for urbanites e.g. by improving air quality, reducing noise and providing recreational services (e.g. Niemelä et al.,2010). At least, the following ES can be attributed to urban green: storm-water management, control of air pollution, control of noise pollution, aesthetics, psychological benefits, heat-island effect reduction and resulting

[2] Particulate Matters 2.5: for a more extensive explanation please see Chapter 4.

reduction in cooling energy demand, urban habitat, waste treatment, pollination, pest regulation, recreation, social cohesion, agriculture and timber. (e.g. Gomez-Baggethun et al., 2013). For a given ecosystem, the economic value of each ES can usually be estimated.
Another approach for the value of a given ecosystem service is to study the total value that people attach to all the ES provided. In this case, the benefits are not categorized based on ES but rather the value of total package is being analysed. This approach is usually the basis for the hedonic pricing method, in which the prices in the real estate markets can be used to analyse the willingness to pay in a proximity of a given ecosystem; or contingent valuation, in which people are asked to state their willingness to pay for a given ecosystem.
Next, we take a more elaborate look at the socio-economic benefits of the interventions in iSCAPE: trees, green roofs, and green infrastructure in general.

Green roofs

Green roofs are roofs that are partially or (almost) completely covered by vegetation as a result of planned action rather than neglect. Green roofs are an increasing feature of cities' urban planning tool set. The socioeconomic benefits and costs have been studied in several cities and countries, e.g. New York (Rosenzweig et al. 2006, Bianchini & Hewage, 2012) and Belgium (Claus and Rousseau, 2012). Green roofs provide at least the following ES:

- Membrane longevity: The historic experience built up with green roofs points at approximately doubling the lifespan of the roofing membrane. This amounts to an additional 20 years lifetime compared to a conventional roof. (e.g. Porche and Köhler, 2003). This benefit is dependent on the saved (future) cost of the conventional roof repair 20 years from now. In monetary terms, this protection of the roof ES is the largest benefit of a green roof, estimated saving in Helsinki was around 25€/m^2. (Nurmi et al. 2016)
- Energy cost savings: The green roofs can potentially reduce both cooling and heating energy use. However, depending on the climate, the green roofs can be optimized in a way that it mainly reduces cooling energy in hot climates and heating energy in cold climates (Roche & Berardi, 2014). The heating energy reduction is a result of the insulative properties of the vegetation. This effect is highly dependent on the building envelope characteristics on which the green roofs are placed. Generally, in non-insulated buildings, the impact of green roofs is much higher than in insulated ones: the better the insulation of the roof, the lower the contribution of green roofs. In cold, heating dominated climates, the insulation properties of the roof carry the highest significance as the heating load benefits from a low U value (U is the coefficient of thermal transmittance). In Helsinki, Nurmi et al. (2016) showed that there is around 3€/m^2 for every 0.01 decrease in thermal transmittance coefficient. In contrast in Madrid, the benefit is only around 0.25€/m^2 for every 0.01 decrease in thermal transmittance coefficient. As this benefit approaches 0 in warm climates, the green roof should be optimized to reduce cooling energy in the summer time. Roche and Berardi (2014) compared different types of green roofs in three different climate conditions for a one-story office building, and recorded annual cooling load reductions between 17% and 22% for optimal green roof designs in different climates. Saiz et al. (2006) showed similar kind of results for a green roof in Madrid. Additionally, it was shown that green roofs cool down the five highest floors, but the cooling effect is close to zero from 6th highest floor downwards.

Nurmi et al. (2016) showed that this benefit can be 24€-30€/m^2 in a climate comparable to Madrid. In Helsinki, Finland, the benefit was only 2€ for a residential building and at maximum around 10€/m^2 for an office building.

- Noise insulation: Lightweight vegetated roofs may increase transmission loss up to 10 dB at low frequency and up to 20 dB at mid-range frequencies (Connelly & Hodgson, 2013). Large amounts of green roofs in downtown areas may also affect the soundscape of the inner city, generally in the sense of attenuating mechanical noises (Irvine et al., 2009; Renterghem, Hornikx, Forssen & Botteldooren, 2013). Noise insulation for the roof is needed especially below flight routes, and green roof can act as a substitute for an additional roof layer. Economic benefits are comparable to membrane longevity benefit – around 20€/m^2, but only apply below flight routes
- Storm-water management: Green roofs can reduce the demand on sewer system capacity by delaying water flows and by reducing total runoff by retaining part of the rainfall and releasing it back to the atmosphere. Results from Berlin suggest that a lightweight low-growth green roof on 10% of building stock would result in a reduction of 2.7% in runoff for the region and 54% for each building (Mentens et al. 2006). Rosenzweig et al. (2006) showed that a similar green roof infrastructure in New York could produce a 2% reduction in total runoff. The extent of economic benefits is affected by complicated relationships between rainfall patterns (e.g. return periods of extreme rainfall events) and city specific storm-water and sewage system infrastructure. An important factor is the current state of the sewage system: if the system is not even capable to deal with the current rainfall, expensive modifications might be needed in the future due to climate change affecting the number of extreme rainfall events positively (IPCC, 2014). Particularly in these cases, the economic benefit of green roofs can be large. In Helsinki, a total benefit of 3.9€-9.4€/m^2 was found, but all the factors that affect the benefit positively are on a relatively low level in Helsinki (Nurmi et al. 2016).
- Air quality improvements: Tan and Sia (2005) found that levels of fine particles (PM) and sulphur dioxide (SO_2) decreased by 6% and 37% in the immediate air-space after a green roof was installed. Currie and Bass (2005) estimated that 109 ha of green roofs in Toronto could remove about 8 tons of unspecified air pollutants per year. Peck (2003) estimated that current roof greening in Toronto (cover over 6.5 million) results in a 5-10% reduction in nitrogen dioxide (NO_2), and in a reduction of 30 tons of PM_x. Yang et al. (2008) showed that a total of 1675 kg of air pollutants was removed by 19.8 ha of green roofs in one year in Chicago with the following distribution: 52% of ozone (0_3), 27% of NO_2, 14% of PM_{10} and 7% of SO_2. The annual total removal per ha of green roof was then 85kg, of which 44kg of 0_3, 23kg of NO_2, 12kg of PM_{10} and 6kg of SO_2. Yang et al. (2008) reported that their estimate was 18% higher compared to an estimate from Toronto (Currie and Bass, 2005).
- These reductions in air pollutants can converted into economic health benefits by air quality models that simulate the effects on the air pollutant concentration in a city, and then response-functions and economic estimates of mortality and morbidity are used to calculate the economic benefit. If unit costs for different emissions are already known for the area, the cost reduction can be estimated by multiplying the reduction of air pollutants by the unit cost of emission. In this case, the reduction is in a way modelled as a negative emission stack. This approach was used in Nurmi et al. (2016) where it was found that over 95% of

the benefits are in the form of reduction of PM2.5 and 90% of these benefits are based on reduction of early mortality due to PM2.5.

- Heat island effect: In urban environments, vegetation has largely been replaced by impervious and often dark surfaces. These conditions contribute to an urban heat island effects, wherein urban regions are significantly warmer than the surrounding suburban and rural areas, especially at the night-time. One of the benefits of green roofs is the possibility to mitigate the urban heat island effect (Berardi et al. 2014). A study by Santamouris (2012) reviewed urban heat island mitigation techniques, and remarked that large-scale application of green roofs could reduce the ambient temperature from 0.3-3 °C. By only considering the price of saved cooling energy, Bianchini and Hewage (2012) considered that extensive green roofs could results in a benefit of 1.2\$-3\$/m^2 and Rosenzweig et al. (2006) that the energy savings for cooling could be in the region of 0.7%-10%.
- Scenic benefits: White and Gatersleben (2011) compared the aesthetic quality of different roof types and found that people prefer view to a green roof compared to conventional roofs. Fernandez-Canero et al. (2013) argue that green roofs with similar appearances to conventional green areas are most valued by citizens. Jungels et al. (2013) showed that positive preferences towards green roofs increased as the green roofs became more familiar. Lee et al. (2014) confirm that green roofs carry aesthetic quality over concrete surfaces, aesthetic quality is however strongly dependent on the green roof characteristics, such as choice of vegetation and diversity. Scenic benefits have a potential to be a significant factor in green roof CBA; the increase in the property values in the buildings within 30m of a green roof were assessed to be between 0-1.2% with hedonic pricing method. Helsinki is a green city compared to many other cities, the benefits are likely to be higher in many other cities with less natural green cover. (Nurmi et al. 2016).

All in all, the literature shows that the private benefits (membrane longevity, energy cost savings, noise insulation) are not usually high enough to cover the expensive installation of a green roof, the social benefits (private benefits + storm-water management, scenic benefits, air quality improvements, heat island effect mitigation) usually surpass the costs. The factors that have a positive effect on the social benefits are: 1) cost of the reference roof so that higher reference roof price increases the benefits, 2) temperature profile of the location so that higher temperatures increase the benefits, 3) energy price so that higher energy price increases the benefits, 4) the average annual precipitation and frequency of extreme rainfall, 5) backlog of the current sewer system and 6) concentration of particulate matter and exposed population.

Urban Street Trees

Both the trees in the street canyon and the walking trees as iSCAPE-interventions can be best described as urban street trees rather than urban forest. Street trees offer many ES that the citizens can be benefit from. The ES of street trees include at least the following: air quality improvement, noise reduction, aesthetic and psychological benefits, storm-water management, sun/heat/rain protection, reduction of urban heat island effect and resulting reduction of cooling energy need. Economic value for these benefits have been calculated (e.g. Soares et al. 2011) and even software tools have been created for this purpose (e.g. STRATUM by USDA Forest Service). Other benefits have also been mentioned in the literature including increased safety of motorized and pedestrian traffic, increased feel of security, increased business and longer pavement life due to shading. (e.g. Burden, 2008). In iSCAPE, the focus is on the air quality improvements and changes in the exposure to air pollutants, but literature is reviewed for other benefits as well. The choice of tree species is not trivial either as the expected increase in dry-spells and heavy rain events must be taken into consideration when choosing the right tree species for a given location (Brune, 2016).

- Air-quality effects: Sometimes direct estimates of the effects of street trees on morbidity rates are estimated. Lovasi et al. (2008) found a lower prevalence of asthma levels in areas with more street trees: a decrease of 29% in the asthma levels was found when the tree cover was increased by 1 standard deviation (343 trees in $km^{2)}$). In Netherlands, Maas et al. (2009) found that the prevalence of 15 out of 24 disease clusters was lower in areas with more green cover. Donovan et al. (2013) found out that a decrease in green cover increased prevalence of cardiovascular and lower-respiratory-tract illness. However, by directly looking at the illness statistics and tree cover it is not clear which are the effects that cause the decrease in morbidity rates and it is hard to control all other factors that make up a good living area. Consequently, for the air-quality effects, the analysis usually follows a path of first estimating the reduction of pollutants and exposure, and then translating these changes into health effects. Usually micro-scale models are used to evaluate the effects of the trees on air quality in different parts of the street (e.g. road traffic lanes, pedestrian lanes) and are then integrated with larger-scale city level models. Also, physical models are available, as well as a range of monitoring techniques. (Vardoulakis, 2014). There is mixed evidence of the efficiency of trees to improve air quality in street canyons. While some studies indicate large potential for trees for dry deposition of air pollutants (McPherson et al. 1994; Tallis et al. 2011), more detailed dispersion models have shown that sometimes trees can affect the air quality in a negative way by disturbing the flow of air pollutants further from the streets. (Vos et al. 2013) outweighing the benefits of deposition. Vos et al. (2013) found that only high impermeable screens lead pollutant reductions at the pedestrian lane. More common options appear to have an opposite effect. As the evidence is contradicting the epidemiological studies, more research is needed and the iSCAPE intervention research is of high relevance for the urban designers.
- Storm-water management: Trees reduce runoff by: interception of precipitation; increase of rainwater infiltration into the open soil under the canopy; increasing the water storage capacity of soil, reducing the impacts of raindrops and decreasing soil erosion and pollutant wash-off (Tyrväinen et al. 1999). The reduction decreases the burden of sewage system and reduces the capital expenditure. The exact amount is dependent on the tree type and the soil, the precipitation pattern (including return periods etc.) and type and conditions of the sewage system (Soares et al. 2011).
- Aesthetic benefits: The aesthetic benefits of tree cover have been estimated with either hedonic pricing method or with contingent valuation method. Usually studies estimate the value of proximity to urban green, but some studies have estimated the value of individual trees (Donovan and Butry, 2009a), which is more relevant in relation to iSCAPE interventions. Anderson and Cornell (1988) found that a front-yard tree in front of a

residential house in Athens, Georgia increased the sales prices by around 400 dollars or 3.5-4.5%. However, this study was not directly related to trees in street canyons. Donovan and Butry (2009a) estimated the value of street trees by studying the housing prices in Portland, Oregon. They found that tree cover and crown area (estimating the "volume" of trees) within 30.5m from a house increased the housing prices by 3% at their mean values. In average, a house had 0.558 street trees in front of it and 84m^2 of crown area. They also estimated the aesthetic value of a single-tree: the value was estimated at 19,958 dollars or 9% of a mean house price.

- Heat-island reduction and energy: Trees can cool down buildings during summer by shading the buildings and mitigate urban heat island effect, cool down the cities in general and consequently reduce the cooling energy use. Akbari et al. (1992) quantified the reduction of cooling costs in Sacramento, California, and found a reduction of 26%-47% of cooling costs for 16 trees planted around the two test houses. McPherson et al. (2005) found cooling energy cost reductions between 10-50% if trees were optimally planted around the building. Donovan & Butry (2009) estimated that a tree could reduce a building cooling energy by 82kWh per year, so that the annual benefit would translate into a benefit of 15.5 dollars. They point out that this is very close to the estimates of McPherson et al. (2005) and a reduction between 10-50% in the annual cooling energy costs if multiple trees are planted on west side of the building.

Green infrastructure

In contrast to individual interventions, such as trees and green roofs, green infrastructure is a more comprehensive concept and in iSCAPE it typically includes also parks, open fields, and urban forests. The concept aims to highlight a more systematic view of urban green and its functions (Renaud et al. 2009) and is a way to understand the total effects of related interventions. Along these lines, it is more common to estimate the total value of main categories of green infrastructure than to break the benefits of a singular ecosystem into isolated ecosystem services (ES) at a time. Support for this "bundling" of ES into main green infrastructure categories has emerged in the literature, with studies reporting that markets and individuals (or households) incorporate urban green in their economic behaviour via compound categories and received benefits (Czembrowski and Kronemberg 2016). The most common valuation techniques are the hedonic pricing and contingent valuation methods. The hedonic method is typically seen as the method able to capture spatially variable benefits and interventions, since it is tightly connected to the location equilibria of households and firms, reflecting the compensation and overall utility they receive from different locations and the implied location-sensitive risks and amenities.

The meta-analysis of Brander and Koetse (2011) compared and synthesized the results of various earlier contingent and hedonic valuations of open green spaces and found that the value increases when population density increases (connected by the authors to scarcity and crowdedness), the value does not vary significantly with income, although regional differences in preferences are a serious limitation in transferability of results, and that urban parks have higher value than other green types. The study concluded that, although contingent and hedonic valuations provide similar results, attention is needed to understand what kinds of economic benefits are captured by each method.

The meta-analysis of Perino et al. (2014) found that the marginal value of urban green space is decreasing in distance, income and population, and increasing in the size of green space. The authors also provided a simulation analysis of future urban growth and the implied changes in the amount of green infrastructure in various UK cities, and concluded that changes in the provision of urban green spaces can create, or destroy, billions of pounds' worth of benefits to residents. Methodologically, they described a spatially-referenced benefit-transfer methodology for transferring similar results to other urban regions and demonstrated the use of distributional weights and of GIS data.

The hedonic analysis of Siriwardena et al. (2016) found a non-linear relationship between the economic benefits of property-level tree cover and regional-level tree cover and showed that property-level tree cover of about 30% and county-level tree cover of about 38% maximize the implicit price of tree cover in property values in US locations. Moreover, they were able to conclude that, compared to the current % of tree cover in the US, the findings indicate an under-investment, which is interesting to combine with knowledge from iSCAPE's air quality experts. They offered detailed specifications on the influence of various tree-specific parameters (e.g. age of trees) on the economic benefits.

Finally, the hedonic analysis of Votsis (2017) studied the price/m^2 effects of apartments' distance to different types of urban green in Helsinki (park, forest, open field), finding that the economic impacts of different green interventions vary across different areas and densities of a city. The effect of green space is positive at 1-4% of average price per square meter. Urban forests have the highest value, followed by parks and open fields. The results appear to favour the preservation of tree-covered spaces in all parts of the city, but parks are beneficial for dense areas only, whereas open fields in suburban areas only. The study confirms that the value of green interventions is in principle positive, but conditional on the type or combination of types of green and the location at which it is placed. It shows that environmental and economic objectives of green interventions can be synchronized if certain spatial planning principles are followed. It also shows that understanding the economic impacts of green interventions requires the study of a city's agglomeration dynamics and relation between land use and residential/firm location theory.

Additional indirect, cross-sectoral benefits, as well as costs, beyond those measured by the hedonic price equilibrium or contingent valuation are generated by green infrastructure and related interventions. These benefits and costs are typically hard to measure without large-scale equilibrium or microsimulation frameworks, and some of them are described in Section 3.3 (Policy interventions) below.

3.1.2 Grey interventions and the socio-economic benefits

Low boundary walls

Air quality benefits: Low boundary wall in street canyons can be used to reduce personal exposure to air pollutants on the footpaths. The wall acts as a baffle to modify the air flow pattern. The results from Gallagher et al. (2012) indicate that reductions in concentration are highest in windward of the footpath ranging from 26%-50%. On leeward footpath, the results were mixed. McNabola et al. (2008) found reductions of 40% for perpendicular wind directions and up to 70% parallel wind directions. The costs of these low boundary walls include the installation costs and the required space, that is then not usable e.g. for trees or parkin space. To quantify the benefits in either terms of health or money, more information is needed about the number of daily users of the footpath and the average amount of time spent in the footpath. Epidemiological studies can then be used to predict the change in mortality and morbidity.

Photocatalytic paint

Air quality effects: Kolarik and Toftum (2012) evaluated the impact of a photocatalytic paint on indoor air pollutant levels. The study showed that activation of photocatalytic paint by illumination did not have positive effect on the perceived air quality. Lavfs et al. (2010) studied the photocatalytic reactions of nitrogen oxides for a commercially available photocatalytic Ti02 doped façade paint. They showed that photocatalytic paint can be an effective sink of NO and NO_2. Also, they simulated the impact in a street canyon, and estimated that a reduction of 5% could be achieved for NOx. The positive effect can however be compromised if harmful VOCs are being emitted from the painted surfaces, as indicated by Auvinen and Wirtanen (2008). The paint must thus be carefully selected and further developed to reduce the formation of harmful VOCs.

3.2 Socio-economic impact of behavioural interventions

As described in iSCAPE D1.3, environmental awareness and related pro-environmental behaviours are highly influenced by the group of belonging, which often has a key role in pushing people in changing their behaviour, when rational motivation such as health effects or economic incentives are often not enough to influence individual behaviour. This makes the iSCAPE Living Lab approach a key asset to maximise the impacts of the pilots.

In iSCAPE, awareness raising and provision of air-quality information among citizens has at least three objectives:

1) To alert people of poor air quality so that they can reduce their exposure
2) To ensure that people have all the information possible to make informed decisions
3) To encourage people to reduce their personal emissions

Based on evidence, it seems – at least on a short perspective - much easier to reach objectives 1) and 2) and to change behaviour in a way that people can mitigate their own exposure rather than reduce the overall emission rates (Bickerstaff and Walker, 1999). ISCAPE-interventions are also more about objectives 1 and 2 than 3.

Warning systems

Research related to the impacts of air quality information dissemination and warning systems has been done for several decades as the problem of educating people how to best avoid exposure and how to reduce emissions is hardly a new one. In 1998 in UK Bickerstaff and Walker studied the public response to the air quality information. The air-quality information was available on hourly basis from multiple sources, including internet. Also, an air quality forecast was available and it was updated 2 times each day. The research revealed that most people had never received air quality information, and only around 20% of the people understood the health impacts related to poor air quality. However, a bit contradictory, 70% of the respondents stated that they had at least sometimes tried to avoid exposure to air pollutants, closing the windows and reducing outdoors activity being the most used options. It seems that these responses were related more to self-perceived air quality than based on air quality information. Only 10% of the respondents claimed that they had on a longer time scale tried to reduce their own emission, e.g. by choosing not to use their own car.

Johnson (2003) evaluated how changes in communicating Air pollution index (PSI) in Philadelphia, affected the way individuals receive or use air quality information. Here as well, it was concluded that neither the old nor the new format did particularly well at increasing knowledge of air pollution or resulting in a response to reduce exposure. The information was not found well trusted (only 59% found that the air quality information can be trusted) and a high number of respondents (34%) did not agree that breathing polluted air (above the risk limits) has a negative impact on health. Around 50% of the respondents said that they could reduce their outdoor activities based on the information. However, adding health concerns and risk group definitions to the information were positive ways to improve the information. Research by Bush et al. (2001) also showed that disseminating basic level air quality information for the public is not enough. Public consultation and participation is necessary in order to be able to make air quality information more meaningful with respect to how they relate to health and the corresponding actions that should be taken. The information needs to be targeted at the risk groups to have a higher response level. Here, current information technology offers high potential, as iSCAPE-interventions will show.

No study directly estimates the economic value of air quality information. Based on the literature, it has very high potential, but how the information is disseminated to the public, how it is perceived by the public, and how it provokes responses, all lead to information decay. Only a fraction of the benefits is actually achieved. In iSCAPE, we will use information service chain – analysis to analyse the current economic benefits of air quality information and how much value can be created with new information and dissemination systems. This analysis has been used earlier to estimate the economic value of weather warnings, e.g. by Nurmi et al. (2013) and by Pilli-Sihvola et al. (2016). We will also monitor the behavioural interventions gathering data directly from the participants to the pilots to assess the project impact at behavioural and awareness level before and after the involvement in the activities.

Valuing air quality information and changes in behaviour – Information Service Chain Analysis

Even though air quality information is constantly available and disseminated to the public, the majority of the citizens does not listen, understand or trust air quality information or even if they do, they don't change their behaviour accordingly. The majority of the potential value of air quality information is consequently not realized. The hypothetical maximum benefit potential of air quality information can be estimated by e.g. agent based simulation models and pollution response-functions, so that only a fraction of the health costs remains. However, the actual value of the information stems from the use of the information and the extent to which the end users are able to interpret and use the information. (Pilli-Sihvola et al. 2016).
A tool to estimate the current level of benefit realization and the potential for innovation, used previously in the relation of weather services (Nurmi et al. 2013), is an Information Service Chain Analysis model (ISCA). It can be used in a semi-quantitative way indicating orders of magnitude of improving potential per step. The six steps of the ISCA assess the extent to which:

1. Information is accurate (accuracy)
2. Information contains appropriate data for the end-user (appropriateness)
3. The user has (timely) access to the information (access)
4. The end user adequately understands the information (understanding)
5. The end user responds to the information (responsiveness)
6. Reponses actually help to avoid the damage (response effectiveness)

The original model Weather Service Chain Analysis (WSCA) also had a seventh step indicating how other people benefit from the responses, but in relation to air quality information, the benefits are mainly health benefits for the agent taking the action. Based on literature review, the main hurdles for the benefit realization are related to steps 4, 5 and 6. In iSCAPE, we will analyse how the iSCAPE-interventions can improve these steps, and quantify the potential benefit of the interventions.

3.3 Socio-economic impact of policy intervention

Policy interventions that improve air quality via passive control systems or behavioural changes can have many definitions (depending, for instance, on sector or government level), can be classified in numerous ways, and can range from local-scale singular interventions to city-wide comprehensive multi-objective strategies or even regional and national strategies. In this section, we focus on the socioeconomic effects - or "generalized" effects, since a total enumeration is an ambiguous issue, especially when considering long-term and indirect channels -of green infrastructural interventions, whereas more precise social or economic effects were discussed in earlier sections.

The socio-economic impacts of green interventions that are targeted specifically to air quality are generally understood through studying the cross-sectoral impacts of green strategies themselves on the urban microeconomic equilibrium, which in turn can be placed under the umbrella term of "green" or "sustainable" growth. From this perspective, Hallegatte et al.

(2011) describe that the toolbox of policy instruments aimed at achieving green growth can be a combination of price-based policies—which is the most widely discussed instrument—norms and regulation, public production and direct investment, information creation and dissemination, education and moral suasion, or industrial and innovation policies.

Although there can be alternative points of view, the main objective in green growth or sustainable urban development is achieving synergies between different environmental and socio-economic objectives and between different sectors, the generation of co-benefits across sectors and objectives from a given intervention, and eventually maintaining or boosting urban economic growth by the extensive utilization of green practices (de Serres et al., 2010; Hallegatte et al., 2011). This is often described as transitioning to a sustainable urban equilibrium and a major question surrounding the implementation of air quality interventions should concern the trade-offs and/or costs-benefits of transitioning to that equilibrium (Verhoef and Nijkamp, 2002; Rode, 2013).

An OECD study by de Serres et al. (2010) found that green growth policies can lead to a significant reallocation of resources within and across broad economic sectors, whereas a World Bank study by Hallegatte et al. (2011) substantiated the above line of thought by showing how re-allocations of resources, reduced environmental externalities, and increased efficiency due to sustainable innovations push the production possibility frontier outwards. Vandermeulen et al. (2011) point out that the total economic effects of green interventions can be measured by combining a cost-benefit analysis at the local scale and multiplier analysis at the regional scale. They identify the following economic impacts for green infrastructure projects:

- Project investment costs
- Regional investment benefits
- Regional excess burden
- Project maintenance costs
- Regional labour benefits
- Regional costs of land use change
- Avoided costs by non-motorized means of transport
- Project recreation benefits
- Regional recreation benefits
- Health effects by non-motorized means of transport
- Environmental effects

Health and environmental effects have been discussed in the preceding sections and the respective methodology is explained in Section 5. The above list contains other effects that are not explicitly named. For instance, in cities with limited supply of land and unmet demand for housing and/or office floor-space, opportunity costs will become important and, although not explicitly listed, these are included in regional costs of land use change.

When discussing policies that will eventually affect spatial behaviour and the use of land or allocation of resources in space, it is also important to keep in mind that land is a limited resource and cities are spatially optimized systems. More specifically, from a spatial planning, intervention implementation, and urban economic development planning viewpoint, urban economic theory describes that urban land use and morphology, transport infrastructure and mobility patterns, environmental amenities and risks, and residential and firm location patterns are elements of a spatial equilibrium and are engaged in a recursive feedback structure in the partial (individual) equilibria of the markets which they affect (Wegener, 1994; Brueckner et al., 1999; Brueckner, 2011). From this follows that when (a) extensive land use changes occur in an urban area (following, for instance, extensive green infrastructural projects), or (b) a location demonstrates high levels of environmental amenities (for instance, parks, coastal features, or a sustainable/green public image), then the property and transport markets will tend to move to new equilibria mainly due to:

- Price and demand changes in the residential property market
- Price and demand changes in the transport sector

If the above changes are extensive, they will tend to influence:

- Land use composition at local and citywide scales
- Supply of transport and changes in the spatial distribution of accessibility
- Labour market aspects, such as firm location and employment supply

Note that not all of the aforementioned changes occur when a green intervention happens, and it requires extensive and high-impact changes to observe shifts in the urban spatial equilibrium.

4 Literature review on socio-economic impacts methodology tested in initiatives similar to iSCAPE

Before further illustrating the methodology developed for the social and economic impact assessment of the iSCAPE activities, this chapter provides an overview of already existing studies and discussions to measure and assess the social and economic impacts of similar projects and research. This literature review has a double aim: on one hand, it will support the development of the iSCAPE metrics identifying effective and already available frameworks. On the other hand, it will allow defining the current state of the art of this field of studies, therefore highlighting the contribution provided by this report.

The review is based on papers analysing the impacts of air pollution on cities and communities from the social and economic point of view. Most of the researches focus on some specific pollutants and on a selection of countries, working on identifying the most appropriate dimensions to analyse the monetary and non-monetary impacts of the air pollutions flows. The analysis and the conclusions presented by the academic literature can be gathered in four main streams of analysis: the quality of life approach; the selection of the air pollution indicators; the data availability; and the hedonic pricing methodology.

Some of these topics will be addressed in detail in the following chapters, nonetheless it is relevant to introduce them here in the wider context of the path leading to the development of the appropriate methodology.

Quality of life approach

Many studies dealing with air pollution impacts on societies build on the quality of life approach, often also referred to as life satisfaction approach or, from a narrower perspective, happiness approach. Different wordings to refer to the general concept of assessing subjective well-being (Moro, 2008) considering values and assets which deeply affect people and societies without reflecting monetary or even tangible wealth (Bullock, 2008). This approach is described and analysed in chapter 5.3. For this review, it is useful to keep in mind two premises about it: first, the main purpose of using the quality of life approach is not to compare levels of well-being in an absolute sense but rather to seek to identify its determinants and to measure (often with tailored surveys to a sample of local population) their value with respect to one another and with respect to other available assets (Welsh, 2003). Moreover, after years of investigating this field of studies, measures of life satisfaction are generally found to have a high scientific standard in terms of internal consistency, reliability and validity, and a high degree of stability over time (Diener et al. 1999).

A list of indicators affecting life satisfaction emerges from the literature review (Brereton 2007, Ferreira 2013, Leuchinger 2009, Streimikiene 2015, Martuzzi 2012, McLeod 1999): age, disability status, marital and partnership status, gender, labour force status, occupational position, type of employment contract, noise, air pollution, climate, crime rate, smell, water pollution, population density, voter turnout at the last elections, traffic congestion, average commuting time, proximity to major roads, railways and airports, educational attainment, marital status income, household tenure, health. Air pollution studies have already proved how some of those indicators such as noise, poverty, violence, defined as stressors, are often spatially correlated with indicators marking the citizens' environmental exposure (Clougherty, 2009). With the aim of assessing how air pollution impacts on people's quality of life, most papers make use of a selection of dimensions according to the object of their research and evaluating how they change in relation to air pollution indicators fluctuation.

Since air pollution is the core topic of the studies considered for this review, some of them dedicate a specific attention to the integration of the environmental dimension into the quality of life assessment. The environmental dimension is one of the major influences on quality of life and one of the factors used to investigate subjective well-being. On top of the indicators listed before (noise, climate, quality of natural assets such as water), Streimikiene suggests applying the following groups of indicators: environmental quality, environmentally responsible behaviour and consumption of environmental services. These groups are related because responsible behaviour has a positive impact on environmental quality and leads to more sustainable consumption of services provided by the environment (Streimikiene, 2015).

Moreover, by using Geographical Information Systems (GIS) further research employed data disaggregated at the individual and local level to show that, while socio-economic and socio-demographic characteristics are important, consideration of amenities such as climate, environmental and urban conditions is critical when analysing subjective well-being. Location-specific factors are shown to have a direct impact on life satisfaction (Brereton, 2007). Therefore, the spatial variables and the distance play a key role in determining the impacts of environmental factors on happiness and life satisfaction. The following quote highlights the importance of translating this acquired knowledge into appropriate policy measures:

"The findings show that climate has a significant influence on well-being, (…) Access to major transport routes and proximity to coast and to waste facilities all influence well-being. However, the manner in which they enter the happiness equation differs depending on the amenity in question. (…) These results may have potentially important implications for the setting of public policy, such as the location of waste facilities, the routing of major roads, location of airports etc., so as to have as minimal negative impact as possible on well-being." (Brereton, 2007)

One last observation emerging from the analysis of the literature concerning air pollution and quality of life is the prominent role played by the health indicator. It is a recurring indicator in many of the papers for different reasons: the availability of measurable data about health in cities and regions; the immediate and intuitive fallout of health issues on a society well-being; and the possibility to translate what is in principle a non-economic and intangible asset of a community (the average conditions of health) into monetary and economic values, estimating the costs and the savings of the increasing or decreasing of specific diseases for the society. It will also play a critical role within the iSCAPE methodology.

Air pollution indicators

As anticipated, many researches aim to uncover the relation between some of the indicators presented in the previous paragraph, and some indicators marking the status of the air quality. To give a complete overview of the materials provided by the literature and to facilitate the understanding of our own methodology, which will make use of some of these indicators, here below a short description of the three main ones, which appear, together or separately, in most of the papers:

- PM10 (Particulate matter 10): defined by the European Environmental Agency as "an air pollutant consisting of small particles with an aerodynamic diameter less than or equal to a nominal 10 micrometer (about 1/7 the diameter of a single human hair). Their small size allows them to make their way to the air passages deep within the lungs where they may be deposited and result in adverse health effects. PM10 also causes visibility reduction."[3] PM includes particles directly emitted into the air such as diesel soot, agricultural and road dust, and emissions from mechanical scrapings. PM is also produced through photochemical reactions involving pollutants that are a by-product of fuel combustion from motor vehicles, power plants and industrial boilers. Traffic is one of the main source of PM10, therefore traffic policy measures have a great potential in terms of health benefits, including also noise and psychosocial effects (Martuzzi, 2002).
- SO2 (Sulphur dioxide): it is "emitted when fuels containing sulphur are combusted. It is a pollutant which contributes to acid deposition which in turn can lead to potential changes occurring in soil and water quality. The subsequent impacts of acid deposition can be significant, including adverse effects on aquatic ecosystems in rivers and lakes and damage to forests, crops and other vegetation. SO2 emissions also contribute as a secondary particulate pollutant to formation of particulate matter in the atmosphere, an important air pollutant in terms of its adverse impact on human health."[4]. Already available datasets and some of the papers quoted in this chapter already prove the robust negative impact of SO2 concentrations on self- reported life satisfaction (Ferreira 2013, Leuchinger 2009).
- CO2 (Carbon dioxide): Carbon dioxide enters the atmosphere through burning fossil fuels (coal, natural gas, and oil), solid waste, trees and wood products, and also as a result of certain chemical reactions (e.g., manufacture of cement). Carbon dioxide is removed from the atmosphere (or "sequestered") when it is absorbed by plants as part of the biological carbon cycle[5]. CO2 emissions have constantly grown with improvements in living standards, and the use of more efficient cars can help to reduce greenhouse gas (GHG) emissions in the transport sector. (Streimikiene, 2015)

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[3] https://www.eea.europa.eu/themes/air/air-quality/resources/glossary/pm10
[4] https://www.eea.europa.eu/data-and-maps/indicators/eea-32-sulphur-dioxide-so2-emissions-1/assessment-1
[5] https://www.epa.gov/ghgemissions/overview-greenhouse-gases

Data availability

With respect to both the indicators listed in the Quality of Life paragraph and the ones listed for air pollution measurement, it is important to underline that data availability stands out as a common issue for many of the studies taken into account. Eurostat is the main data source for most of them, and whenever possible authors integrated its datasets with on-the-field surveys, in particular for the data gathering of quality of life indicators. It still stands out that often the selection of countries or regions for the analysis, and occasionally the selection of the indicators are guided by the availability of relevant data. As summarised by Ferreira:

There are a number of papers analysing the relationship between air pollution and subjective well-being. A common challenge to these papers is that to obtain high quality data on air pollution with detailed spatial disaggregation and link these to a specific individual is almost an impossible task. Unlike for other individual characteristics that might influence people's subjective well-being, information on environmental characteristics is typically not collected in the survey instrument and thus cannot be matched with respondents at the household level. (Ferreira, 2013)

The iSCAPE project is going to face the same problem and, while implementing the impact assessment, it is likely that some data-wise selection will be needed.

Hedonic pricing approach

The effects of air pollutants on cities and communities tend to become tangible on physical assets like trees or buildings, framing a two-sided relation where on one hand such assets can support the containment of air pollution (as illustrated in the previous chapter), while on the other hand the air quality can affect the value and the conditions of local amenities and buildings. In particular, sulphur dioxide "*has been found in hedonic pricing studies to have a significant impact on housing prices.*" (Welsh 2003).

Similarly to the quality of life approach, the hedonic pricing approach is discussed in detail in chapter 5.2. It is the approach most frequently used by studies concerning air pollution impacts, in order to assess the market effects of the improvement or the deterioration of air quality on house pricing. Together with the monetarisation of the health impacts, to date the hedonic pricing approach stands out as of one of the more reliable methods to integrate the economic dimension into the overall assessment. Accompanied by other models, necessary to make the framework flexible and tailored on the iSCAPE goals, the hedonic pricing approach will represent one of the cornerstones of the economic impact assessment.

This approach and the life satisfaction one result by previous research complementary and their joint application is therefore recommended:

Traditionally, the benefits of clean air have been assessed with the hedonic method (…). Research suggests that hedonic estimates indeed substantially underestimate the benefits of clean air. (…)The life satisfaction approach captures the residual effect of air pollution for which people are not already compensated in the housing market. (Leuchinger, 2009)

The literature review presented in this chapter shows the opportunities and the obstacles on the way the development and implementation of the iSCAPE impact assessment. Previous studies provide a sound basis in terms of approaches and metrics to identify and evaluate the project of impacts. The quality of life approach offers a wide range of dimensions and indicators that can be adapted to the project interventions through analysis and consultations. The hedonic pricing approach is similarly already tested as the appropriate process to translate air pollutions impact into economic ones. Moreover, the two approaches provide complementary set of results that will allow framing a comprehensive assessment.
At the same time, many researches have been hinder in their completeness and accurateness by the lack of comparable, recent and available data. On the light of the diversity of iSCAPE interventions and data needed, coordination among partners to guarantee the necessary data flow will be a key element to deliver the final assessment. The methodology presented in the following chapters have been nonetheless framed keeping in mind this potential obstacle, and developed in a flexible a modular way to avoid that some missing data could affect the whole evaluation.

5 iSCAPE socio-economic impact assessment methodology

5.1 The overall framework

In developing the following methodology, the main challenge lays in the alignment between the quantitative and qualitative analyses, more specifically the impact that can be expressed in monetary terms and those that cannot. Moreover, the methodology aims to assess a **research** project, maintaining consistency with the EC concept of project assessment, while the project is running. For these reasons the methodological framework that follows can be considered as a first version of an elaboration that will be updated throughout the project, in order to be able to describe in an effective and reliable way the impacts of all activates and results achieved by the project. Depending on the project progress, the assessment report could be preceded by some amendments to the methodology illustrated in the following paragraphs.

The framing of the methodology starts with the identification of the project outputs under assessment. For the iSCAPE project we can identify three overarching outputs:

- Modification in the concentration and distribution of a set of defined air pollutant achieved by mean of different instruments/processes (passive control systems, behavioural change interventions and policy interventions).
- Engagement of citizens and local stakeholders in pilot actions following a LL approach.
- Scientific papers, book and other scientific productions.

In order to map and describe the impacts of the above-mentioned different outputs, in different local contexts and through different specific activities, a single methodology would not be sufficient. For this reason, iSCAPE builds on the experience of the SEQUOIA project and of those projects that followed it, defining an *ad hoc* methodology (Passani and others, 2014) based on the combined use of different techniques in order to overcome the limits of each single method (i.e. collection of statistics, case studies, peer review, cost-benefit analysis, multi-criteria analysis (MCA), input-output models, etc.) and in order to gather quantitative and qualitative data within the same analytical framework.

More specifically, the SEQUOIA methodology is structured in four main steps:

1. Mapping the areas of impact
2. Baseline identification
3. *Ex post* scenario description
4. Final assessment analysis

In this document, the areas of impact mapped are described in the social impact section (paragraph 5.3.1) and are based on the behind GDP approach. The baseline identification will be investigated in Task 5.2 for both the environmental and socio-economic dimensions and all the three are going to be equally relevant for the impact assessment activities.

The *ex ante* and *ex post* scenarios detailed information will be gathered to quantify two kinds of impacts: economic impacts and social impacts. The division between economic impacts and social impacts is intended only for methodological purposes. In fact, the two impacts are analysed through different methodologies (see chapters 5.2 and 5.3), the main difference being that the former uses monetized variables, while the latter uses non-monetized variables. This does not wish to create a dichotomy between them, as the two assessments are fully complementary, as already mentioned in chapter 4. Moreover, the economic impact will mainly focus on the first output while the social impact will focus on the second and third impacts, for a specific reason: the reduction of pollutants promoted by the iSCAPE interventions will have a direct impact on health in terms of reduction of death and of medical costs for pollution-related diseases. These can be expressed in monetary terms using the methodologies described in chapter 3. The improvement of air quality impacts on other social aspects is less direct and is very much dependent by the perception citizens have of air quality and its eventual improvement. For this reason, the social impacts will be mainly observed looking at the changes introduced by the engagement activities and the Living Lab activities, which will promote a better understanding and a more grounded perception of the phenomenon.

The economic impact assessment will mainly focus on the marketable impacts on health and house pricing, relying depending on the pilot on one of four different methods: the impact pathway approach, the hedonic pricing approach, the life satisfaction approach and the unit-cost modelling and meta-analysis, all described in detail in the following chapter.

The **social impact assessment** is inspired by the fundamentals of Multi-Criteria Analysis (MCA) (Köksalan et al. 2011; Dodgson et al. 2009), according to which each of the various impacts should be expressed in its most suitable metric, by using appropriate indicators. This is justified by the fact that most of the social impacts generated by iSCAPE pilots (e.g. the impacts on citizens' awareness on environmental issues, change on their behaviours, scientific production, etc.) cannot be expressed or transformed into monetary terms. Therefore, the result of social impact assessment will be a multi-criteria/multi-dimensional description of the non-monetary impacts of each project assessed, using a set of appropriate qualitative-quantitative indicators.

The Sequoia approach envisaged a final step in which the economic and impact assessment results were synthetized in a single index. At the present stage of the iSCAPE project and considering the lessons learned in other impact assessment exercises applied to EC research projects (see Bellini et al, 2015), it is not recommended to plan such a synthetic index, even if the possibility to do so is not excluded at the time of writing. This is because the iSCAPE pilots are quite different in terms of their focus, of the specific activities that will be carried out and of the number and typology of citizens that will be engaged. Resulting in the fact that, for the social impact assessment, a qualitative, descriptive approach is more indicated. This will make it more difficult to translate the results of the social impact assessment in numerical terms, a necessary step to generate a single, synthetic indicator together with the results of the economic impact assessment.

5.2 Economic impact assessment

The economic modelling approach starts from the choice whether we are interested in valuing the economic effects of increase or decrease of emissions, or are we looking at the value of changes in air-quality directly. Also, the choice of impacts that are included in the analysis affect the choice of the modelling approach: e.g. health impacts are usually modelled with an Impact Pathway Approach, while if we want to also include market effects such as labour productivity, macroeconomic models are needed. The impacts are often classified as either market impacts, such as costs of providing health care services, or non-market impacts such as loss of utility due to illness or in the worst case of increased mortality. In figure 3, the typology of costs is depicted (OECD, 2016):

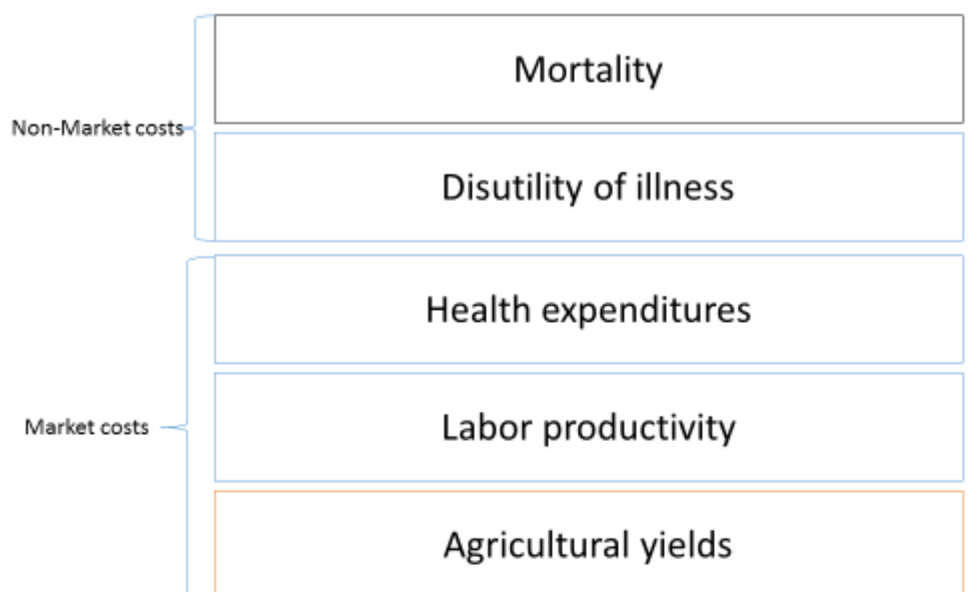

Figure 3 - Typology of costs of air pollution (OECD, 2016)

In this section, we go through different valuation methods, explain what effects can be captured with each method, and evaluate how they should be used in the context of iSCAPE-interventions.

Impact Pathway Approach

In figure 4, the basic logic of Impact Pathway is depicted. The phase diagram in this figure follows the logic that we "follow" the initial emission through changes in the emission concentrations in the city all the way to the monetized health impacts.

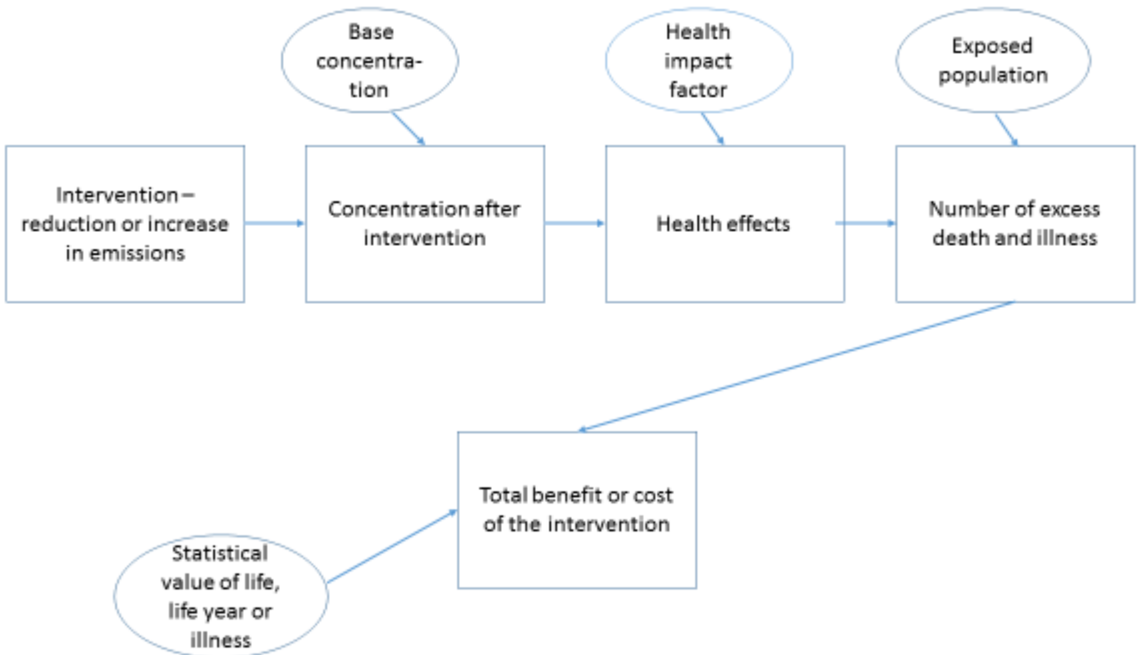

Figure 4 – Impact Pathways logical chain

Examples of the use of the Impact Pathway Approach are numerous and include both national and regional assessments in Europe (e.g. Holland et al. 2011) in North-America (e.g. Heo et al. 2016; Fann et al. 2009) and on a national level for example in the UK (Defra 2015). The approach was developed in the 1990s in an EU-project called eXterne.
The model in figure 4 is a one-way model in that way that the causal link between different nodes only goes one way. This results in a very useful property of conditional independence between a node and all its parents except its direct parent. For those pollutants that can be modelled this way, e.g. PM2.5, it allows researchers of different expertise to model only one link at a time and the experts of the next link can continue the process. Next, we present the required modelling and information for each consecutive node.

Emission modelling – concentration before and after the intervention

The first step in the Impact Pathway model is to estimate how the intervention or change in emission scenarios will affect the air quality in the surrounding regions. This also requires the knowledge of the base emissions and base concentrations. Thus, air quality modelling is the first phase of the process. Such air quality models include chemical transport models (CTM) which are state-of-the-art with high time and spatial output resolution, dispersion models which translate the emission from a source to receptor areas but neglect much of the meteorological and atmospheric phenomena, and reduced models that are CTM models with limited spatial and temporal resolution but require less computational resources (Heo et al. 2016).

Health response

After we have estimated the change in the concentration levels due to the intervention, we need to know how these concentration level changes are translated into health impacts. The health impact factor knowledge is taken from epidemical studies that have studied the association between concentration rates and the mortality and morbidity rates, and response-functions are estimated based on that association. The current state-of-the-art response-functions are from a WHO-project HRAPIE, that used meta-analysis techniques to include all current knowledge. Those response functions tell the relative increase in mortality or morbidity rates. In table 2, we give as an example of the response-functions for long-term PM2.5 caused mortality and morbidity.

PM, long-term exposure							
Pollutant metric	**Health outcome**	**Group**	**RR (95% CI) per 10 μg/m³**	**Range of concentration**	**Source of background health data**	**Source of CRF**	**Comments**
$PM_{2.5}$, annual mean	Mortality, all-cause (natural), age 30+ years	A*	1.062 (1.040–1.083)	All	European mortality database (MDB) (WHO, 2013c), rates for deaths from all natural causes (International Classification of Diseases, tenth revision (ICD-10) chapters I–XVIII, codes A–R) in each of the 53 countries of the WHO European Region, latest available data	Meta-analysis of 13 cohort studies with results: Hoek et al. (2013)	
$PM_{2.5}$, annual mean	Mortality, cerebrovascular disease (includes stroke), ischaemic heart disease, chronic obstructive pulmonary disease (COPD) and trachea, bronchus and lung cancer, age 30+ years	A	Global Burden of Disease (GBD) 2010 study (IHME, 2013), supra-linear exponential decay saturation model (age-specific), linearized by the $PM_{2.5}$ expected in 2020 under the current legislation scenario	All	European detailed mortality database (WHO, 2013d), ICD-10 codes cerebrovascular: I60–I63, I65–I67, I69.0–I69.3; ischaemic heart disease: I20–I25; COPD: J40–J44, J47; trachea, bronchus and lung cancer: C33–C34, D02.1–D02.2, D38.1	CRFs used in the GBD 2010 study	An alternative to all-cause mortality Both age-specific and all-age estimates to be calculated to assess the potential effect of age stratification

Table 2 –Response-functions for long-term PM2.5

Table 3 is interpreted as follows: the expected increase in mortality is 6.2% per year with every $10\mu g/m^3$ concentration increase in the annual mean. The 95% confidence interval is between 4% and 8.3% interval. The group "A*" indicates strong reliability of the analysis. Note that numerical estimates for the concentration-chronic illness does not exists. For health care expenditure and labour productivity, some numerical values exist, but usually with low reliability.

PM, short-term exposure (continued)							
Pollutant metric	Health outcome	Group	RR (95% CI) per 10 μg/m^3	Range of concentration	Source of background health data	Source of CRF	Comments
$PM_{2.5}$, daily mean	Hospital admissions, respiratory diseases, all ages	A*	1.0190 (0.9982–1.0402)	All	European hospital morbidity database (WHO, 2013f), ICD-9 codes 460-519; ICD-10 codes J00–J99	APED meta-analysis of three single-city studies	
$PM_{2.5}$, two-week average, converted to $PM_{2.5}$, annual average	Restricted activity days (RADs), all ages	B**	1.047 (1.042–1.053)	All	19 RADs per person per year: baseline rate from the Ostro and Rothschild (1989) study	Study of 12 000 adults followed for six years in 49 metropolitan areas of the United States (Ostro, 1987)	One 1987 study from the United States; no data of background rate in Europe
$PM_{2.5}$, two-week average, converted to $PM_{2.5}$, annual average	Work days lost, working-age population (age 20–65 years)	B*	1.046 (1.039–1.053)	All	European Health for All database (WHO, 2013e)	Study of 12 000 adults followed for six years in 49 metropolitan areas of the United States (Ostro, 1987)	High variability of background rates based on reported sick absenteeism in Europe, reflecting intercountry differences in definition

Table 3 - Response-functions for short-term PM2.5

Exposed population and number of expected deaths and illness

After we have knowledge of the concentration level and the response to the concentration, we can multiply the expected changes with the population information. As the response-functions generally forecast the same rate of change for the mortality for all demographic groups, the total population data and mortality rates is enough if we use the statistical value of life to quantify the results. If we use the value of statistical life years, we also need mortality and population data for different age groups.

The changes in the exposure can be modelled by either modifying the response-functions (so that a 2% decrease in exposure could result in a 2% decrease in air-pollution caused mortality) or by manipulating the data of the exposed population.

Economic valuation of small changes in risks related to mortality and illness

As a next step, as we have estimated the number of excess/avoided mortality, morbidity and other end-points in a given area, we need to decide which unit costs to apply for each end-point.

The most important end-point is the excess mortality. The excess mortality can be valued either by counting the number of excess/avoided premature deaths, or by counting the life years that have been lost/saved. The value per statistical life year (VOLY) is essentially an approach for adjusting VSL estimates to reflect differences in remaining life expectancy and involves calculating the value of each year of life extension. This adjustment is needed if the affected population is of very different age than the VSL from the original study. VSL (value of statistical life) is by definition the monetary value that people attach to small changes in the risk of death. This value can be estimated e.g. from a wage-mortality risk labour market equation, where the rate that people are willing to take a riskier job and the premium demanded for the increase, is the monetary value of the change (e.g. Viscusi & Masterman, 2017). If the increase is e.g. 0.01, the statistical value of life is the demanded premium multiplied by 100. So as in this example the VSL reflects the value of life for work-age population, and if the air pollution mainly affects elderly, this adjustment is needed. As the degree of life extension is usually closely related to the age of the affected individuals, VSLY (Value of statistical life per year) is often interpreted as an approach for adjusting VSL to reflect age differences (Robinson, 2008). However, in the US (e.g. executive order 12866) the approach to use VOLY instead of VSL has been politically disputed as it gives different values for the life of different age groups. In iSCAPE, we use VSL as our base case, but we with sensitivity analysis, we also show how the results would change, if the remaining life years are adjusted.

In a meta-analysis of 68 papers Viscusi and Masterman (2017) found that the average VSL is 12 million dollars and median 9.7 million dollars (2015 dollars). They recommend using U.S. publication bias corrected value of 9.7 million dollars and adjusting to local income with income elasticity, found typically in the range of 0.6-1. Recommended values for European countries tend to be lower: WHO (2012) recommend using EU average value of 2.487 million euros and 3.371 million euros for EU27 countries. OECD (2012) recommends similar (lower) values based on their own meta-analysis of valuation studies: For EU-27 a value between 1.8-5.4 million USD is recommended with the base value of 3.6 million USD (USD 2011).

Unit values to illness (valuated at small risks) and for hospital admissions are also found in the literature, for example OECD (2016).

On a European level, the values obtained by Holland (2012) in the EC4MACS-project, represent the most updated information. A wide range of values for different illnesses and for different countries are found in the report, these values will be applied in iSCAPE-project as well. However, we will use the same values for same losses across different countries, as opposed to many other studies. This is to be sure, that we give the preferences of each individual in each country within the study the same weight, this approach is often referred as distributional weighting: giving the same value for the same loss is an approach commonly used in climate change economics. (Azar, 1998; Johansson-Stenman, 2000).

Uncertainties in the analysis

For most part of the analysis, the uncertainty can be quantified, as both the estimated value and the confidence interval are reported. For example, in the case of excess mortality, the estimated increase for an increase of concentration of PM2.5 by $10\mu g/m^3$ is 6.25% and the 95% confidence interval is 4%-8.3%. We will assume that each source of uncertainty is independent of each other, e.g. the uncertainty in the response functions is independent of the uncertainty in establishing economic values for life. If one intervention has uncertainty only from one source and an uncertainty from another source, these uncertainties have no covariance. This way, a simple portfolio analysis methodology can be applied for each city.

Reduced form impact models

Sometimes we can estimate, observe or assume the resulting change in the concentration level (or with the linear response-function a change in the total exposure of the population). For example, in iSCAPE the low-cost sensor development might provide enough information so that concentration maps can be adjusted for the iSCAPE-interventions. In that case, a reduced form of the impact pathway analysis can be used. This is depicted in figure 4. The rest of the analysis follows the aforementioned logic. This approach has been used both on city-level (e.g. Kan and Chen, 2004) on a national level (e.g. Roayl College of Physicians, 2016) and on a continental (OECD, 2015) and global level (OECD, 2016).

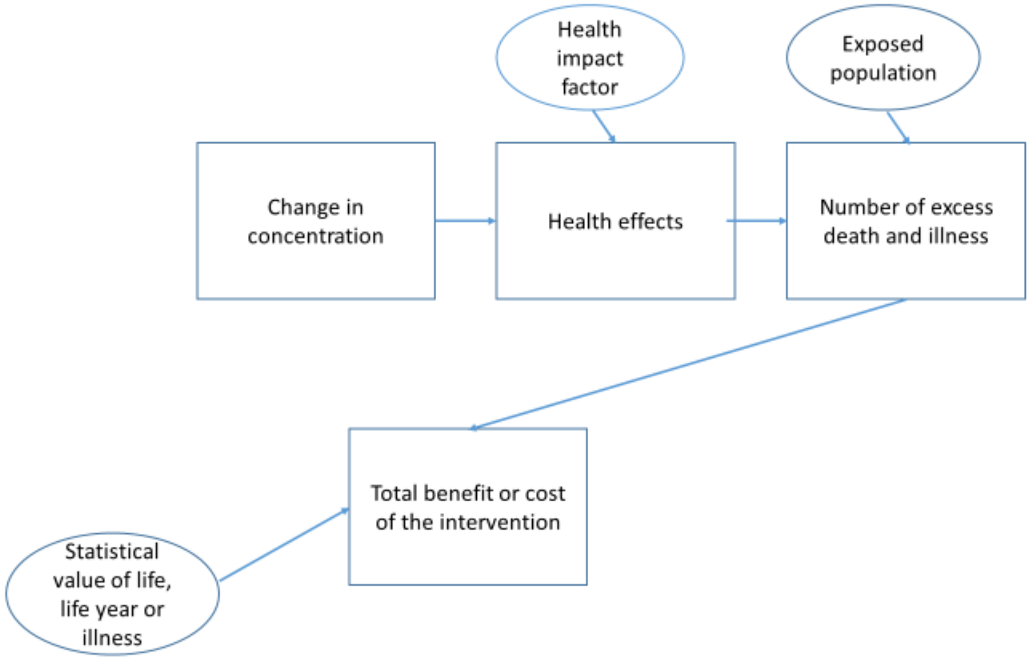

Figure 5 –Reduced form of impact pathways analysis

The impact model can further be narrowed down by combining health effects, number of excess death and illness and total benefit into a single box. This is done by a model that is specifically intended for these use: the response-functions, population data and the statistical values are either built in the model, or required as input data. These models include e.g. BeTa developed in Europe (Holland and Watkiss, 2002) or BenMAP developed in US (EPA, 2017).

Hedonic pricing approach

Hedonic analysis is often used to capture the market value of those attributes of the urban environment that are not traded explicitly in their own markets and are furthermore spatially heterogeneous. The functional relationship between the price of a differentiated commodity, such as housing, and the vector of its attributes can be interpreted as an equilibrium outcome from the market interactions between sellers and buyers (Rosen 1974; Kuminoff et al. 2010). Attributes of the natural environment enter the hedonic equilibrium as location-specific amenities. Moreover, when a property transaction is realized in the housing market, the match between the lower bound of the seller's asking price and the upper bound of the byer's offer bid reflects a price that compensates for locational advantages and disadvantages, relative to other locations of a particular urban area (DiPasquale and Wheaton 1996). In the long run, prices reflect the equilibrium between demand for hedonic attributes and supply of those attributes (Rosen 1974), and households will be fully compensated for locational disadvantages – at least in theory.

There is substantial discussion on what portion of the value of a non-market good is captured by hedonic analysis, which has implication for what is measured when air quality is used as a hedonic attribute. Although shadow prices are often seen as the willingness to pay for environmental goods, they primarily indicate the marginal loss or gain of an agent in the housing market when a marginal change happens in one of the hedonic attributes, provided that these are not substantial citywide changes (Tyrväinen 1997). It is therefore important to realize that the hedonic price reflects first and foremost the dynamics of a city's spatial equilibrium, and one should not use it uncritically as an indication of the total value of an environmental attribute. There are indications that the marginal values estimated by hedonic analysis underestimate the value of an environmental attribute since they do not reflect the full compensation of households for environmental amenities or disamenities (see Luechinger 2009), but it is also shown that the estimates do not differ substantially from those derived by contingent valuation (Brander and Koetse 2011). Moreover, Rosen's theory assumes perfect information, which implies fully transparent risks of natural hazards. This is usually not the case, which implies that risks are not fully reflected in the hedonic price equilibrium – seller and buyer curves do not meet precisely, translating to an excess surplus for the seller (see Pope 2008).

Air quality has been assessed with hedonic analysis and the lessons learned are mostly methodological. Anselin and Le Gallo (2006) confirm that bad air quality is reflected in house prices, but find that this happens only for air quality levels that stand out clearly from the average (i.e. highest category of bad air quality). They also report that air quality is best incorporated as a hedonic attribute through categorical variables derived from Kriging interpolation. The recommendation to use categorical variables appears to echo best practices and similar recommendations from physics-based or meteorology-based air quality research. Useful elements can be derived also from hedonic studies of interventions aimed to improve air quality. When it comes to land-based nature-based solutions (e.g. parks, urban forests), there are indications that one should include those interventions into the hedonic function, because consumers are not able to separate the individual services derived from those interventions (e.g. air quality reduction); they rather will bundle several services together into one land use category (Czembrowski and Kronenberg 2015).

With respect to air quality and it valuation through hedonic functions, the lesson from hedonic price theory and applied literature appears to be that, in many cases, air quality will not be identifiable as an individual attribute in the hedonic price equilibrium. Therefore, additional methods have to be used as complementary methods if the interest is on the total welfare effects of improving air quality, simply because the hedonic price equilibrium is a partial equilibrium and because it involves significant elements of bounded rationality and game behaviour. However, hedonic analysis should be employed as an indicator of the effects of urban planning interventions surrounding air quality improvements and understanding their relation to important aspects of urban dynamics, such as density, scarcity of resources, and urban growth and development (Brueckner et al. 1999; Votsis 2017).

Life satisfaction approach

Life satisfaction approach is a relatively novel approach to value air quality. With life satisfaction approach, the self-perceived quality of life is regressed to explanatory variables, including income and air quality variables. Using the coefficient of income and air quality variables, one can calculate the rate that an individual would be willing to trade income for better air quality. This is equivalent to Willingness-to-pay which is the measure of monetary welfare change. However, as people tend to pay less for housing with areas of bad air quality and is already compensated via lesser housing costs, the WTP must be corrected for those estimates (Luechinger, 2009). By looking at how people valuate changes in concentration levels of pollutants, one can directly valuate the value of a change in air quality without using statistical value of life or illness. Those market costs that are not incurred by the individual but are costs for the society, as majority of the health care costs, must be added to the total cost estimate. As we will see in chapter 5.3, this approach is key for the development of framework for the social impact assessment.

Unit-cost modelling and meta-analysis

Unit-cost modelling means that the expected reduction of emissions from a given source are multiplied by pre-existing estimates of the unit damages from that particular source. This is the most straightforward method with the least amount of resources needed to capture the air quality benefits. However, it solely relies on earlier estimates that are usually not estimated for that location or source that is in question. The assumptions in the model are buried very deep in the original studies where the estimates are taken. For these reasons, e.g. UK government only advices to use this approach for small-scale projects under 50 million pounds of total effect (HM Treasury green book, 2013).

This model can be improved dramatically by meta-analysis regression models (Stanley & Doucouliagos, 2012). With meta-analysis, the earlier literature estimates can be gathered systematically and the effect of different assumptions can be quantified. Moreover, the regional characteristics of emission sources, such as population nearby, can be included, and the effect of these regional characteristics can be included in the analysis. In iSCAPE, we have gathered all the available damage cost estimates. The literature review can be summarized with the following table, including all the studies taken into account:

Study	Air quality modelling	Area and resolution	Pollutants	Stack heights/Source types	VSL/VOLY info	Other impacts
Muller and Mendelsohn (2009 & 201)	Integrated assessment model: "Air Pollution Emission Experiments and Policy model (APEEP)" Run for increasing ton of each pollutant one source at a time	10,000 sources across United States, ground sources aggregated by county, point sources individually	PM10, PM2.5, NOx, SO2, VOC, NH3		2 million dollars, tailored to the age of the exposed population by calculating the present value of the remaining years – also give the damages based on uniform VSL values	Morbidity, decrea crop yields, redu timber, enhan depreciation of m made materi reduced visibility a recreation
Fann et al. (2009)	Response surface model, Based on air quality modelling using CMAQ version 4.4. with 36km horizontal domain.	Nine urban areas in the U.S: New York/Philadelphia (combined), Chicago, Atlanta, Dallas, San Joaquin, Salt Lake City, Phoenix, Seattle and Denver	Particles (PM2.5), NOx, SOx, NH3, VOC	Industrial point sources, Electrical generating units, area sources, mobile sources	6.2 million dollars	Morbidity
Heo et al. 2016	Reduced form models of CTMs, built from tagged CTM simulations and generalised via regressions, Estimating Air Quality Social Impacts Using, Regression (EASIUR), spatial resolution 36kmx36km	County-level estimates in U.S.	PM2.5, NOx, NH3, SO2,	Ground level, 150m, 300m	VSL 8.6 million dollars	
Buonocore et al. 2014	CMAQ 4.7, full model.	Lower Great Lakes region, Mid-Atlantic Region U.S.	PM2.5, NOx, SO2	Power-plants in the US, stack height 3	7.2 million dollars	
Levy et al. 2009	County-resolution source-receptor matrix	U.S.	PM2.5, NOx, SO2	407 coal-fired power plants in U.S, stack height 3	6 million dollars	
Holland et al. 2011	Dispersion modelling approach called EMEP	Europe	NH3, NOx, NMVOCs, PM2.5, PM10, SO2	Industrial facilities in Europe	VOLY (low estimate): 54000 € VSL (high estimate): 2,08 million euros	Morbidity, c damage,
Defra 2015		Britain	NOx, PM, more generally	Agriculture, Waste, Industry, Transport, Rural	VOLY: 35,000 pounds	

			SOx and NH3			
Schwermer et al. 2014	Cost-transfer from a study by Preiss et al. (2008)	Germany	PM2.5, PM10, NOx, SO2, NMVOC, NH3	Power generation, industry, small-scale combustion, transport	Same assumption as in Preiss et al. (2008)	
Preiss et al. 2008	Eulerian dispersion model, Tarrason 2008	Europe	NH3, NMVOC, NOx, PM10, PM2.5, SO2	County average external costs in Europe	40,000 in 2000, 47,344 in 2010, 26,038 in 2020; growth rate of 2% with income elasticity 0.85	Work loss da restricted activity da morbidity, cro materials a ecosystems
EPA, 2013	Benefit transfer of the values from UK, Defra, taking also into account the differences in VOLY	Australia	PM2.5	Not specified	VOLY: 288,991 Australian dollars	
Bickel et al. 2003	Gaussian dispersion model ROADPOL	Selected case-studies in Europe: inland waterway transport in Rhine area, road transport in Helsinki, Florence, Berlin and Florence	NOx, PM2.5, SO2, CO, Benzene, NMVOC	Road transport, inland waterway transport, rail transport	VOLY: 74 700€	Morbidity a restricted activity day
Walton et al. 2015	London Air Quality Modelling toolkit, a kernel modelling approach	London	PM2.5, NO2	Transport in London	VOLY: 36 379	NO2 is treated w HRAPIE concentrati response function, a provided sensitiv analysis results for l certain impacts ba on HRAPIE functions

Table 4 –Literature review for the economic impact assessment (unit-costs and meta-analysis)

The damage estimates from the literature sources have been collected for PM2.5, NOx, and NH3. In iSCAPE, we combine this data with geographical data describing the emission sources, including both geo-economical and geo-physical data. Both the modelling choices, types of sources and the spatial characteristics or emission sources (e.g. demographical information, meteorological conditions) will be coded as variables in the analysis and the extent of how variables affect the heterogeneity of damage estimates will be analysed with weighted-least-squares method. By this way the analysis will allow more sophisticated damage cost –method than using values from a single study from a different location.

Economic impacts and methodologies per city in iSCAPE

In this project, we apply combinations of the abovementioned methodologies for the assessment of economic impacts in the seven participating cities. In each city, the employed methodology is determined, firstly, by the kind of air quality intervention that is being tested—which determines the kind of economic impacts to be expected—and, secondly, by data availability. The following table provides an overview of interventions, economic impacts, and methods per city.

City	Intervention	Economic impacts	Methodology
Bologna	Street canyon with / without trees	**[1]** Change/difference in the concentration level of pollutants and resulting changes in mortality and morbidity rates **[2]** Aesthetic benefits **[3]** Psychological benefits	Reduced form impact model Benefit-transfer of other benefits based on literature review
Vantaa / Lazaretto	Green roofs	**[1]** Uptake of pollutants **[2]** Reduced energy use for cooling and heating **[3]** Aesthetic benefits **[4]** Storm-water management benefits **[5]** Heat Island effect **[6]** Noise insulation benefits **[7]** Membrane longevity **[8]** Reduction of heat-island effect	City-level meteorological models combined with avoided cost techniques, e.g. reduction in cooling degree days etc. Hedonic pricing to estimate the changes in thermal comfort index Earlier estimates by Nurmi et al. (2016) of green roof benefits Unit cost modelling with the help of meta-analysis
Hasselt	Behavioral change – warning systems	**[1]** Reduced exposure to air pollutants and resulting health benefits	Reduced form models with sensitivity analysis of changes in the exposed population / Also information uptake models (WSCA modified)

Dublin	Low boundary walls	**[1]** Reduced concentration levels on pedestrian walk lane, reduced exposure, and resulting health benefits **[2]** Costs: reduced space in the streets?	Reduced form models with sensitivity analysis of different assumptions of changes in the exposure of population
Guilford / Vantaa (Metropolitan area of Helsinki)	Green infrastructure	**[1]** Total effect measured via real estate prices, not including effects that are not within market prices **[2]** Green infrastructure benefits include aesthetic benefits, psychological benefits, recreational benefits etc. **[3]** Indirect effects inferred qualitatively from housing market adjustments	Hedonic pricing / Simulations of behavior in the housing market with changing green infrastructure parameters City-level meteorological models combined with avoided cost techniques, e.g. reduction in cooling degree days etc. Hedonic pricing to estimate the changes in thermal comfort index Questionnaire based surveys on individual values for different green spaces
Bottrop	Walking trees	**[1]** Air pollution removal **[2]** Aesthetic benefits	Contingent valuation Benefit transfer of earlier benefit estimates of urban trees Reduced form models related to air pollutants
Lazaretto	Photocatalytic wall	**[1]** Uptake of pollutants	Reduced form models

5.3 Social Impact assessment

In the light of what illustrated in chapters 3 and 4, the assessment of iSCAPE interventions' social dimension builds on the assumption that there is no pre-exiting methodology for the evaluation of the social impacts of the project pilots. Moreover, the interventions and the Living Lab activities of each pilot are highly different and they are going to produce different impacts. Accordingly, this part of the methodology should be able on the one hand to capture non-monetary impacts and on the other hand to be applicable in a modular way, allowing pilots to be evaluated about dimensions that are relevant to their goals. To fulfil these objectives and develop our assessment framework we focused on the quality of life approach, selecting a set of dimensions and indicators that will be assessed against data provided by different actors involved in the process.

Quality of Life approach

In recent years, a wide debate has spread about the best ways to measure well-being and progress in modern societies capturing dimensions beyond the existing economic indicators. The necessity to overcome the role of GDP (Gross Domestic Product) as a key indicator to evaluate the overall condition of a country or a community has raised an intense debate, stimulating fruitful reflections about what is perceived as healthy, desirable and relevant by citizens at large from a social and environmental perspective. Concepts such as well-being and quality of life came under the spotlights for describing the value that cannot be expressed directly in monetary term but still represent part of the wealth of a country or community. This debate has also confirmed the growing importance of the natural environment and of phenomena such as climate change within the public debate (Eurostat 2011[6]).

First attempts to expand this approach include the Genuine Progress Index (GPI)[7], developed across the ‘80s and the ‘90s with the specific aim to replace or integrate the GDP and currently used mostly in the US within the ecological economics field of studies. The final goal of the Index is to bring closer citizens and policy makers, based in the assumption that progress and sustainability are achievable only if governments base their decisions on indicators that really matters for people’s everyday life. The Index metric includes indicators as income distribution, housework, education, resources depletion, crime, pollution, leisure time, defensive expenditures, public infrastructure and dependence on foreign assets.
In the same years, the Center of Bhutan Studies developed the Gross National Happiness Index (GNH), to measure the collective happiness in a country in opposition to the GDP as a key indicator. The Index vision focuses on "sustainable and equitable socio-economic development; environmental conservation; preservation and promotion of culture; and good governance"[8] and it builds on nine topics: psychological well-being, health, time use, education, cultural diversity and resilience, good governance, community vitality, ecological diversity and resilience, and living standards. It is not by chance that a country like Bhutan become pioneer in this filed of study: in fact, the country have a very low GDP compared to other countries but the quality of life for its citizens can be higher than in many so-called developed countries.

Since then, several panels and initiatives at national and international level dealt with the problem of how to comprehensively capture progress and well-being in advanced evaluation metrics, leading to more technical but equally relevant debates about the availability of statistically relevant data for monitoring and evaluation, and eventually to support decision-making processes. The Stiglitz-Sen-Fitoussi Commission (SSFC) report[9] and the Communication of the European Commission on “GDP and Beyond”[10] challenged a range of international, national and regional metrics urging to improve current indicators for measuring progress, well-being and sustainable development. The key concept addressed and criticised by these analyses was the ability of an indicator such as the GDP to provide a correct perception of people and

[6] http://epp.eurostat.ec.europa.eu/portal/page/portal/pgp_ess/0_DOCS/estat/SpG_Final_report_Progress_wellbeing_and_sustainable_deve.pdf
[7] http://rprogress.org/sustainability_indicators/genuine_progress_indicator.htm
[8] http://www.grossnationalhappiness.com/
[9] http://ec.europa.eu/eurostat/documents/118025/118123/Fitoussi+Commission+report
[10] https://ec.europa.eu/eurostat/cros/system/files/06_GDP%20and%20beyond.pdf

environment conditions, therefore supporting the need for new data and methodologies. In 2011, The European Statistical System Committee (ESSC) presented a report, on Measuring Progress, Well-being and Sustainable Development prepared by the Sponsorship Group, co-chaired by Eurostat and INSEE (France). The report illustrated 50 actions to be adopted by the European Statistical System (ESS), to implement the results of the "beyond GDP" debate and to build new well-being indicators. According to the report, quality of life need a multidimensional measurement approach, economic indicators should take into account household perspectives and distributional aspects of income, and environmental sustainability should be included among the pillars of the evaluation of well-being. In the same year, the Organization for Economic Cooperation and Development (OECD) launched the Better Life Initiative[11] with the aim to identify the core aspects of life that matters when it comes to people's well-being. The initiative brought to the development of an index built on 11 key dimensions ranging from traditional measures such as income and jobs, health, education, to housing, personal safety, life satisfaction, environment, community and work-life balance. Moreover, each topic is built on one to four specific indicators (i.e. the Jobs topic is based on the employment rate, personal earnings, the long-term unemployment rate and job security) and the index allows comparing results for men and women, and seeing how much social and economic status affects results. The index fulfils the purpose of comparing well-being across countries and of supporting national institutions in orienting their agenda and their policy debates.

This perspective and the indexes developed over the years with the aim to evaluate non-economic and often qualitative dimensions of life and policies represented the basis to build the framework of the social impact assessment of iSCAPE. Based on the review of the aforementioned indexes and on the consultation with the partners, we identified a selection of dimensions and sub-dimensions able to capture the impacts of all the iSCAPE interventions and activities, and to complement the economic analysis described in the previous paragraphs.

The table that follows summarizes the main areas identified as relevant in the analysis of the quality of life by Eurostat, Istat (the Italian statistical office which is playing a leading role in this debate) and the OECD.

EUROSTAT	ISTAT	OECD
Productive or other main activity	Health	Housing
Material living conditions	Education and training	Income
Health	Employment and Work-Life balance	Jobs
Education	Economic wellbeing	Community
Leisure and social interaction	Social relations	Education
Economic and physical safety	Political life and institutions	Environment
Governance and basic rights	Safety	Civic engagement
Natural and living environment	Subjective wellbeing	Health
Overall experience of life	Landscape and cultural heritage	Life satisfaction

[11] http://www.oecdbetterlifeindex.org/#/23224325342

	Environment	Safety
	Research and innovation	Work-Life balance
	Quality of Services	

Table 5- Dimensions of quality of life: a comparison between Istat, Eurostat and EOCD approaches

As evident there are many similarities among the three frameworks, and we elected to take the Eurostat approach as the main point of reference because it represents the European standard to the quality of life research and because it assures homogeneity of data amongst the European countries. As described in the following lines, we will not be able to use the available data in a direct way but still, having country reports considering these dimensions can be of help in interpreting the assessment results.

Before describing the adaptation of the quality of life approach to the iSCAPE analysis, a final remark concerns the available datasets. It is important to notice, in fact, that the quality of life dimensions are populated with national statistical data coming from different, but official sources and with ad hoc surveys conducted by the national statistic offices of European countries on statistically representative samples. Therefore, all the data are at national (macro) level and only some of them are available at regional or city level. On the contrary iSCAPE interventions will be deployed at very local level and will engage citizens statistically not representative of the national, regional or urban population. Furthermore, the iSCAPE interventions will not have a direct impact on the entire urban population, as they will engage a restricted number of citizens and stakeholders. For this reason, it will be necessary to: a) adapt the Eurostat indicators and variables to the micro level in which the project is operating b) gather data directly from the engaged citizens and c) develop a model for generalising those data. The latter will be only feasible once the data have been gathered and on a case by case base, evaluating the feasibility to generalise the gathered data at city level looking at their quality, reliability and representativeness.

5.3.1 The overall social impact assessment framework

Drawing on the studies mentioned in the previous paragraph, we developed a framework consisting on a selection of 9 areas of impact, each one articulated in sub-dimensions tailored on the pilots and their expected outcomes.

As a first step, we selected those dimensions that could be impacted by the project interventions considering the iSCAPE activities. We ended up excluding three dimensions because not affected by the project, at all or in a meaningful and documentable measure:

- Economic and physical safety
- Governance and basic rights
- Overall experience of life

Health was then excluded because already covered by the economic impact assessment approach to which, as said, the social impact assessment is complementary (see par. 5.1).

The second step was to analyse the sub-dimensions and the related variables of each of the above-listed macro dimensions. Each macro dimension is composed of several sub-dimensions (see table 6 as an example) and related variables, not all relevant for the purpose of our assessment.

Productive or other main activity	Quantity of employment	Employment and unemployment
		Underemployment, quantity
		Underemployment, quality
	Quality of employment	Work/life balance
		Temporary work
		Assessment of quality of employment
	Other main activity	Inactive population
		Unpaid work

Table 6 - Sub-dimension related to Productive or other main activity

At the end of this process, we ended up with the following list of areas of impacts and sub-dimensions coming directly from the Eurostat approach to quality of life:

Productive or main activity	Quantity of employment
	Quality of employment: Work-life balance
Material living conditions	Income
Education	Competences and skills
	Opportunities for education
Leisure and social interaction	Quantity of leisure
	Quality of leisure
	Social interaction
	Social cohesion

	Social capital
	Community empowerment
Natural and living environment	Pollution
	Access to green and recreational spaces
	Landscape and built environment

Table 7 - iSCAPE areas of impact coming from Eurostat approach to quality of life

Those first five dimensions and their sub-dimensions have been then further integrated. Following a social innovation approach, for which the innovation produced by an intervention should be not only more efficient and effective than the previous ones, but also more equal and fair (Phills, Deiglmeier and Miller, 2008), we added the category of **Inclusiveness and equal opportunities** in order to understand if the iSCAPE interventions are able to engage different social groups and are sensible to topics such as social exclusion and discrimination. Environmental studies show that often quality of air is correlated to social status so that in the same city those belonging to lower social status are more exposed to pollution than those of higher social status (Szasz and Meuser, 1997; Bulle and Pellow, 2006). Also related to the literature of social innovation, but also driven by some of the pilot actions (see D2.2), we added the areas of impact on **Behaviours** to map the capability of iSCAPE to positive influence pro-environmental behaviours.

Then we added a category to assess the **Policy** results planned by the project, to be enable an overview of the outreach of this kind of activities. Finally, considering the very nature of the iSCAPE project, i.e. a Horizon research project, a **Scientific Impact** area has been added. This will map the value generated by the project in terms of scientific production.

It has to be noticed that those categories have been applied to the iSCAPE methodology even if the variables selected for the assessment are sometimes slightly different from the official ones used by Eurostat. This adaptation has two goals: being able to capture the project activities and outputs with a tailor-made analysis; and being able to capture the micro-level of the changes produced by the project (while Eurostat variables often refer to a macro-level of analysis).

Social impact sub-dimensions, indicators and variables

The figure that follows visualise the selected areas of impacts and their sub-dimensions.

Figure 6 Social impacts: areas of impact and related sub-dimensions

As anticipated, not all 9 areas of impact are equally applicable and or relevant for all the iSCAPE pilots: therefore, we mapped the relevance of each impact area for each of the iSCAPE pilots. As the overall methodology, pilots' partners validated this mapping during our consultation process. The relevance level is rates as:

- ✓: low
- ✓✓ : medium
- ✓✓✓ : high

The table that follows visualises the 9 areas of impact and the related relevance for each of the iSCAPE pilot actions.

Pilots/LLs	Productive or main activity	Material and living conditions	Education	Leisure and social interactions	Natural and living environment	Behaviours	Policies	Scientific Impact	Equality
Dublin	-	-	✓✓✓	✓✓✓	-	tbd	✓✓	✓✓✓	✓✓
Guilford	✓	✓	✓✓	✓✓✓	✓✓✓	tbd	✓✓	✓✓✓	✓✓
Vantaa	-	-	✓✓✓	-	-	tbd	✓✓	✓✓✓	✓✓
Bottrop	✓	✓	✓✓✓	✓✓✓	✓✓	tbd	✓✓	✓✓✓	✓✓
Hasselt	✓	✓	✓✓✓	-	-	✓✓✓	✓✓	✓✓✓	✓✓
Lazaretto	✓	✓	✓✓	✓	✓✓✓	tbd	✓✓	✓✓✓	✓✓
Bologna	✓	✓	✓✓		✓✓✓	tbd	✓✓	✓✓✓	✓✓

Table 8 – "social" areas of impacts and relevance for each of the iSCAPE pilot actions.

This mapping will be used when interpreting the results of the assessment exercise to be sure to consider the uniqueness of each intervention and to assure that special attention is given to the areas of impact seen as most relevant in each pilot action. The paragraphs below describe in detail the nine dimensions and their indicators. The descriptions are based on the Eurostat definitions of quality of life indicators, and adapted to the context of the iSCAPE project.

Productive or main activity

This dimension refers to work in all its aspects, paid and unpaid, from a quantitative and from a qualitative perspective. It can cover aspects such as working hours, employment rate, safety and ethics of employment, work-life balance. With respect to iSCAPE, two indicators are going to be affected by the project activities (table 9), which are "quantity of employment" and "quality of employment as in work-life balance":

- Through the first one, we aim to assess if the business-oriented outputs and activities of the project (i.e. monitoring kits, photocatalytic paintings, building on green infrastructures, maintenance of new green infrastructures) are going to affect the commercial entities in the consortium and at the local level.
- The second one, mainly addressed to Living Lab participants involved in the behavioural studies or in the policy-oriented ones, will assess the impact of the behavioural or policy changes induces by the project on their commuting time. Change may be trigged by the use of new transport modalities or new transport paths.

Area of impact	Indicators	Variables
Productive or mail activity	Quantity of employment	N. of new jobs created by project results' exploitation
	Quality of employment: Work-life balance	Change in the average satisfaction with commuting time
		Changes in the work-life balance thanks to pilot activities/outputs

Table 9 –Social dimensions of impact – Product or mail activity

Material and living conditions

Material and living conditions focuses on the more material assets impacting on people quality of life, assets which relevance cannot be neglected also in a more qualitative and non-monetary evaluation. For Eurostat, this dimension deals with aspects such as income, household, consumption, poverty. Within the context of this methodology, Income (table 10) is the only indicator relevant to the end of the assessment of the project activities impacts:

- We aim to assess if local intervention or their simulation will produce an impact on the income of the commercial activities in the neighbourhood affected by the project.
- We also aim to assess if more sustainable lifestyles will lead to decreasing the costs at household level.
- And we will assess the foreseen increase in income for iSCAPE partners or stakeholders involved in the development of commercially exploitable outcomes.

Area of impact	Indicators	Variables
Material and living conditions	Income	Change in income for commercial activities in the areas interested in the pilot actions
		Change in household tenure (cost saving)
		Change in income for companies or other organisations exploiting the project technical outputs (green services providers)

Table 10 –Social dimensions of impact – Material and living conditions

Education

Education is nowadays recognised as a key aspect of societies well-being, since knowledge and skills account for an increased capacity of making context-wise choices, living a healthier life and also generating income (source needed). At a general level, this dimension can include the assessment of the education level, the typology of acquired skills and the availability of education opportunities. We expect iSCAPE to impact on two of the Eurostat indicators (table 11):

- the Opportunities for education: the Living Labs are going to organise a number of events and gatherings aiming to raise awareness and transmit knowledge about the air pollution issue.
- and the Competences and skills: on top of an increased awareness participants to the Living Labs will gain a specific set of skills necessary to join some of the activities (i.e. air quality monitoring through the monitoring kits).

Area of impact	**Indicators**	**Variables**
Education	Opportunities for education	N. of events providing knowledge opportunities organised
		Average number of participant for each event
	Competences and skills	New skills acquired by participants to the activities
	Awareness	Change in awareness on quality of air-related issues

Table 11 –Social dimensions of impact - Education

Leisure and Social Interaction

Social cohesion, social interaction and leisure activities are all key dimensions of a society well-being. By leisure activities we mean all those activities that community members undertake for their own desire, pleasure and possibly enrichment. The organisation of time in a society is a critical aspect when it comes to the extent to which its members are able to provide themselves with these kinds of activities. Social interactions, on the other side, are essential traits of all human life and their quality has a strong impact of the individual overall well-being: the extent of their personal and community network tend to affect not only their private life but also their job and health condition.

For iSCAPE we identified six indicators to assess the Living Lab impact in this dimension:

- the quantity of leisure, to assess the leisure events provided by the project;

- the quality of leisure, about the participants' perception of those events;
- the social interaction, to evaluate whether joining the project activities impacted on people's personal relationships;
- the social cohesion, to assess the impact on the community level of trust;
- the social capital, which will monitor if participating to the iSCAPE activities enlarged the social networks of the participants;
- and the community empowerment, to assess if the community strengthen itself by gathering in new organisation and informal groups.

Area of impact	**Indicators**	**Variables**
Leisure and social interaction	Quantity of leisure	N. of leisure event organised
		Average number of participant for each event
	Quality of leisure	Perceived quality of the leisure activities organised
	Social interaction	Feeling of loneliness
		Satisfaction with personal relationships
	Social cohesion	Rating of trust in others
	Social capital	N. of new social relations established
	Community empowerment	N. of new community initiatives organised by participants of iSCAPE LLs
		Description and number of new civic society organisations and/or informal groups created at local level

Table 12 –Social dimensions of impact – Leisure and social interaction

Natural and Living Environment

Although, as mentioned above, task 5.2 will deal in detail with the environmental impacts of the project outputs, the Natural and Living Environment is a highly relevant dimension for the social assessment of iSCAPE. It concerns all those aspects influencing the environment in which people live, such as pollution, local amenities, distribution of local buildings, landscape. For the assessment of this project, we identified three indicators that are likely to be affected by it:

- Air Pollution: this indicator will be calculated within task 5.2 of the project. For the purpose of the social assessment, we will use the data produced by that task to analyse the correlation between the change in air pollution indicators and the change in social impacts indicators.
- Access to green and recreational spaces: the indicator assesses the improvement to the green and recreational spaces available to citizens brought by the greening intervention in cities and neighbourhoods, which participants to the LL are expected to be able to evaluate.
- Landscape and built environment: the indicator assesses the usability of the architectural infrastructure and the access to the services in the area.

Area of impact	Indicators	Variables
Natural and living environment	Air Pollution	Reduction of pollutant as analysed in task 5.2
	Access to green and recreational spaces	Changes in average satisfaction with recreational and green areas
	Landscape and built environment	Changes in the average satisfaction with living environment

Table 13 –Social dimensions of impact – Natural and living environment

Behaviours

As illustrated, one of the interventions aims to specifically tackle the behavioural dimension of the air pollution issue, gathering data about citizens' transport habits and then providing them the information necessary to understand how a change in such habits would impact their contribution to air pollution and the damage they receive from it. Moreover, all Living Labs will organise awareness raising opportunities that can impact on participants' behaviours.
To assess the results of these activities we identified two indicators:

- In the impact on green behaviour we will evaluate changes in behaviours according to the activities deployed by the Living Lab, personalising the surveys and the specific questions for each city;

- In the Impact on Perceived citizens' effectiveness we assess the perceptions participants and stakeholders have of the improvements brought by the behavioural changes.

Area of impact	Indicators	Variables
Behaviours	Impact on green behaviours	To be developed case by case: i.e. impact on mobility-related behaviours, impact on electricity consumption, impact on green consumption, etc.…
		Impact on Perceived citizens' effectiveness (PCE)
	Impact on other behaviours	To be developed case by case

Table 14 –Social dimensions of impact – Behaviours

Policies

Most of the interventions and of the studies aims to produce policy recommendations and to see them embedded as much as possible in the local institutional context. For this reason in the final phases of the assessment we will investigate about:

- Quantity of policies delivered by the project;
- Quality of the policies, estimated by participants and stakeholders of the Living Labs;
- And Institutional change, to assess whether some of the temporary organisations generated during the development of iSCAPE managed to reach a sounder level of institutionalisation.

Area of impact	Indicators	Variables
Policies	Quantity of policies	N. of new policies proposal's developed
	Quality of policies	Average satisfaction for the new policy proposals developed
	Institutional change	iSCAPE living Lab level of institutionalisation

Table 15 –Social dimensions of impact – Policies

Scientific Impact

Since iSCAPE is a research project, all partners are expected to contribute to the production of rigorous and innovative scientific material to enrich the wider area of research dedicated to the air pollution. To assess the academic outcomes of the project the methodology will evaluate on one hand the scientific production, gathering information about papers and contents as presented in in table 16, and on the other hand the level of interdisciplinarity of scientific outputs.

Area of impact	Indicators	Variables
Scientific impact	Scientific production	Number of researchers in the project
		Number of peer reviewed articles with impact factor
		Number of peer reviewed articles without impact factor
		Number of non peer-reviewed articles
		Description of topics covered
		Number of patent and patent application developed by the project
	Level of interdisciplinarity	N. of disciplines and subdisciplines represented in deliverable and published articles

Table 16 –Social dimensions of impact – Scientific impact

Inclusiveness and equal opportunities

The last dimension of impact integrated in the ones of the Eurostat metric is Inclusiveness and equal opportunities, to assess how much the outcomes of the project produce a fair and equal development according to a social innovation approach. In the context of iSCAPE, we identified two relevant indicators:

- Inclusiveness, evaluating the inclusion of participants from different background and from disadvantaged social position (people with disabilities, elders, children, people coming from low-income families, unemployed, etc.) into the Living Labs activities;
- And gender balance, because as demonstrated by the literature, air pollution is a gender sensitive issue, which makes the ration between involved men and women a significant indicator.

Area of impact	Indicators	Variables
Inclusiveness and equal opportunities	Inclusiveness	N. of cultural background represented among LLs participants
		N. of participants belonging to categories at risk of social

		exclusion among LLs participants
	Gender balance	Ratio between men and women engaged in the LL activities

Table 17 –Social dimensions of impact Equality

5.4 Data gathering and data analysis process

During the last year of the project, the methodology described in this deliverable will be used to assess the socio-economic impact of the pilots and of the iSCAPE project overall. Data will be gathered from each city involved in the project. For the economic impact assessment, the results of the experiments run in the pilot by the scientific partners through sensors and simulations and the available local statistic will represent the core of the data flow elaborated to assess the potential economic impact. The social assessment, on the other side, will gather most of the data directly from the involved actors through surveys and focus groups.

Based on earlier sections, especially 3-3.3 and 5-5.2, the economic impact assessment framework can be depicted in figure 5. In table 18, we list the interventions, the expected economic impacts and the methodology we have chosen to apply in each case. Data needs are presented in the last column.

iSCAPE Suggested economic impacts and requested data per city and intervention

City	Data needs
Bologna	**[1]** Estimates of the changes in the concentration levels of pollutants following the intervention **[2]** Demographic information **[3]** Mortality rates **[4]** If available: Illness / hospital admission rates
Vantaa / Lazaretto	**[1]** Housing transaction data: --Per individual property; the data should contain the selling price, geographical coordinates (or street address) and structural attributes of the sold dwelling (age, size, condition, rooms, etc.). --Alternatively, per postcode or other sub-city zone with average selling price and as many zone descriptors as possible (accessibility, commuting, % green space, public services, etc.). **[2]** Meteorological / climate data
Hasselt	**[1]** Change in the exposure rates in relative terms (e.g. 10% less exposure for those who install the app) **[2]** Mortality rate data **[3]** If available: Illness / hospital admission data

Dublin	**[1]** Change in the exposure / concentration at street-level **[2]** Demographic information **[3]** Mortality rate data **[4]** If available: Illness / hospital admission data
Guilford / Vantaa (Metropolitan area of Helsinki)	**[1]** Housing transaction data: --Per individual property; the data should contain the selling price, geographical coordinates (or street address) and structural attributes of the sold dwelling (age, size, condition, rooms, etc.). --Alternatively, per postcode or other sub-city zone with average selling price and as many zone descriptors as possible (accessibility, commuting, % green space, public services, etc.). **[2]** Geographical information of the city, including green space, transport and other amenities **[3]** Meteorological information, e.g. thermal comfort before and after the intervention **[4]** Air pollutant concentration maps before and after given intervention **[5]** Survey results
Bottrop	**[1]** Survey data, including willingness to pay, income level of individuals etc. **[2]** Meta-analysis results to use unit-cost model
Lazaretto	**[1]** Uptake of pollutants / changes in the concentration levels **[2]** Demographic information **[3]** Mortality rates **[4]** If available: Illness / hospital admission data

Table 18 –Economic impacts and requested data per city and intervention

For the social impact assessment, the source of the data illustrated in the previous chapter is represented in table 19, that summarises the involvement of Living Labs, local actors and project partners in the process:

Variables	**For which Living Lab?**	**To whom at local level?**	**To whom in the consortium?**
Productive or main activity			
n. of new jobs created by pilot exploitation	all	local stakeholders	Pureti and exploitation leader
Average satisfaction with commuting time	Hasselt		
Changes in the work-life balance thanks to pilot outputs	Hasselt		
Material and living conditions			
change in income for commercial activates in the areas interested in the pilot action	all	commercial activities	
Change in household tenure (cost saving)	all	participants to the living labs activities	

Change in income for companies or other organisations exploiting the project technical outputs (green services providers)	all	participants to the living labs activities	
Education			
n. of events providing knowledge opportunities organised	all	none	responsible of the living labs
average number of participant for each event	all	none	responsible of the living labs
New skills acquired by participants to the activities	all	participants to the living labs activities	
Leisure and social interaction			
n. of leisure event organised	Dublin, Guildford, Bottrop		responsible of the living labs
average number of participant for each event	Dublin, Guildford, Bottrop		responsible of the living labs
Perceived quality of the leisure activities organised	Dublin, Guildford, Bottrop	participants to the living labs activities	
Feeling of loneliness	Dublin, Bottrop, Bologna	participants to the living labs activities	
Satisfaction with personal relationships	Dublin, Bottrop, Bologna	participants to the living labs activities	
rating of trust in others	Dublin, Bottrop, Bologna	participants to the living labs activities	
n. of new social relations established	Dublin, Bottrop, Bologna	participants to the living labs activities	
n. of new community initiatives organised	Dublin, Bottrop, Bologna	participants to the living labs activities	
Description and number of new civic society organisation and/or informal groups created at local level	Dublin, Bottrop, Bologna	participants to the living labs activities	
Natural and living environment			
Changes in average satisfaction with recreational and green areas	Guildford, Vantaa, Bottrop, Bologna	participants to the living labs activities	
Changes in the average satisfaction with living environment	Guildford, Vantaa, Bottrop, Bologna		
Behaviour			
Impact on green behaviour	Hasselt	participants to the living labs activities	
Impact on citizens perceived effectiveness	Hasselt	participants to the living labs activities	
Policies			
n. of new policies proposal developed	all	local stakeholder	responsible of the living labs
Average satisfaction for the new policy proposals developed	all	local stakeholder	responsible of the living labs
N. of institutions created	all	local stakeholder	responsible of the living labs
Inclusiveness and equal opportunities			
N. of cultural background	all	participants to the	

represented		living labs activities	
N. of participants belonging to categories at risk of social exclusion	all	participants to the living labs activities	
Scientific Impact			
Number of researchers in the project	none	none	all partners
Number of peer reviewed articles with impact factor	none	none	all partners
Number of peer reviewed articles without impact factor	none	none	all partners
Number of non peer-reviewed articles	none	none	all partners
Description of topics covered	none	none	all partners
Number of patent and patent application developed by the project	none	none	all partners
n. of disciplines and sub-disciplines represented in deliverable and published articles	none	none	none

Table 19 –Social dimensions of impact – Data source

The data are going to be gathered from all the actors involved into the Living Labs activities and in the deployment of the interventions: iSCAPE partners, LL responsible, citizens and other institutional stakeholders. In the surveys, all external actors will provide a first set of General Information necessary to categorise the participants to the impact assessment anonymised surveys:

- Demographic variables: they include age, gender, income, title of study, cultural background, family composition, occupation.
- Psychographic variables: soft variables investigating actors' attitudes, interests and behaviours. In the specific case of iSCAPE, this section of the survey has been developed in collaboration with the Hasselt University within the D4.1, and will deal with participants' opinion about environmental issues and their pro-environmental behaviours.
- Institutionalisation level: it allows understanding at which level the new Living Lab is going to be embedded into the local texture, and how much is organisation is going to be formalised.

The following sections will be articulated in modular and personalised sections depending on the Living Lab, the activities and the category of the respondents, investigating the appropriate dimensions of impact as indicated in table 19. Respondents will answer the same set of questions before and after the participation to the interventions and to the Living Lab complementary activities, to allow the assessment of the social impacts through the comparison of their answers before and after the project activities. In the before-activities surveys respondents will be asked to estimate the expected impacts of the three last dimensions, Policy, Inclusiveness and Equal opportunities and Scientific impact, and their answers will be compared with the after-activities surveys.

The timing of the surveys submission is planned for each Living Lab according to their scheduled activities, from June 2017 (Hasselt) until April 2019 (Dublin). As explained, they are going to receive a survey before the beginning of the activities and one after the end. Since the framing of the Living Lab activities is always in progress, with opportunities of meetings and discussion with citizens and other stakeholders arising while the project unfolds, we are constantly monitoring their implementation through a monthly updated shared file where Living Labs can record their progress and their next steps. This tool is proving very useful to ensure a full understanding of their results and their flow of activities, therefore allowing to regularly verify the consistency of the impact assessment methodology with their progress.

6 Conclusions

iSCAPE brings together different expertise and its workflow builds on a chain of several activities, many of which are complex and innovative. For this reason, the development of an appropriate methodological approach for the project tackled challenging areas of investigation, about which there is no acknowledged approach to assess the expected economic and social impacts. As already mentioned, the application of the methodology will require fine-tuning of some dimensions or methods according to the project results during the next year and a half, to verify to what extent other dimensions are going to be affected by the project impacts.

The major challenges in shaping the methodology have been represented by the identification of the appropriate metric and methods capable of capturing the project life cycle, and by the integration between the assessment of more quantifiable impacts and non-quantifiable ones and or the impacts that could be expressed in monetary terms and those that cannot, both necessary to evaluate the project developments and improvements in each city involved. With respect to the first point, the partners' involvement represented a crucial asset to the finalisation of this work so that this methodology could be considered as the result of a collaborative effort.

The socio-economic impact assessment exercise will run during the last year of the project. As explained the data gathering for some of the dimensions of impact is already ongoing and will continue during all Year2, to be finalised during the first half of Year3 and allow the data analysis before the end of iSCAPE.

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