Rating Energy Sustainability of Urban Communities

A comparison of four sustainability assessment tools for urban areas

MSc Thesis Sustainable Development – Energy and Resources

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"A map of the world that does not include Utopia is not worth even glancing at, for it leaves out the one country at which Humanity is always landing.

And when Humanity lands there, it looks out, and, seeing a better country, sets sail.

Progress is the realisation of Utopias."

Oscar Wilde

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Abstract

With more than half of the world's population now living in urban settlements, and the cities being bigger than ever imagined, sustainable urban development is one of the critical issues for the 21st century. The goal of sustainability has been embraced by many urban communities who have been committed to reducing their greenhouse gas emissions and the impact of their cities, districts, and neighbourhoods on the climate. Indisputably, one of the fundamental sustainability parameters that all urban communities wish to consider is energy sustainability. How can we assess the sustainability levels of an urban area though? And how can we monitor the transitional progress towards a clean energy future?

A growing awareness of this necessity has recently led to the development of assessment tools for sustainable urban communities, one of the main features of which is to grade the energy sustainability levels achieved in urban areas. Owing to the fact that these tools have been launched recently, the number of scientific articles or studies analyzing them is limited. Therefore, in order to enhance the currently dearth of research in this field, this present study is focused on the analysis and comparison of four assessment tools for sustainable urban communities: BREEAM Communities, BREEAM Gebiedsontwikkeling, GPR Stedenbouw, and LEED for Neighbourhood Development. The main goal of the comparison was to examine how the four tools assess energy sustainability in the urban environment, to evaluate their strengths and weaknesses, and to draw up conclusions for an improved tool.

To this end, the tools were, firstly, tested against theory and secondly, against a "real-world" case study area. For the theoretical comparison, an up to date literature review of current urban sustainability assessments led to the creation of a generic list of energy indicators for urban sustainable development. Based on this list, the tools were examined for the energy indicators they included and the compatibility they showed with the generic list. For the comparison against the "real-world" case study, the tools were applied in the Lijnbaan area, the central quarter of the city of Rotterdam, and conclusions were drawn in terms of their functionality.

The results of the comparison of the tools with the generic list of energy indicators showed significant incompatibility. GPR Stedenbouw was the tool with the biggest overlap with the generic list; however, the tool still lacks several quantitative energy indicators measuring important themes of energy sustainability. Moreover, the comparison revealed that the tools focus on measuring the relative improvement of the energy performance of the urban area and its progress during time, but not the actual energy consumption of the area and the related CO_2 emissions. Consequently, an area that has achieved a high rating does not necessarily have lower energy consumption than an area with lower rating- such an oversight can lead to misleading results. Furthermore, the comparison showed that the methodology of most tools (except for BREEAM Gebiedsontwikkeling) gives more emphasis to certified buildings than to other themes of energy sustainability, such as energy efficiency of the area and renewable energy production. Therefore, the tools tend to consider urban areas as a sum of individual buildings, and thus, their methodologies overlook the important synergies that are necessary for designing sustainable urban areas.

In addition, the application of the assessment tools in the Lijnbaan area revealed the complexity of the assessment process and the extensive amount of data that was required and often difficult to cover. In general, Lijnbaan scored very low in the energy themes of the tools, which can be explained by the fact that, within the studied period, there were no determined goals for improvement of the energy performance of this area. Besides, the prerequisite criteria for BREEAM and LEED certified buildings within the area, included in the respective tools, could not be fulfilled by Lijnbaan. As a result, the area failed to achieve any score, a fact that proves the limitations of the prerequisite criteria for certified buildings, which these tools included.

Contents

1. Introduction to Sustainable Urban Development

1.1 The necessity for sustainable urban development

Humans have always affected the environment from which they draw their sustenance. Hunting and the use of fire by our ancestors had a strong impact on other living creatures and their habitats. Farmers throughout history have significantly modified the landscapes in which they work and inhabit. However, urban society, with its fossil-fuel powered industrial, farming and transport systems, has had unparalleled impacts on nature. Humanity's power to affect the global environment has reached a critical stage. Now, more than ever before, we need to reverse the collision course between humans and nature on which we now find ourselves; this is above all a major challenge for city dwellers (Girardet, 2008).

In the last years, an extraordinary change has occurred on the face of the Earth: cities are becoming humanity´s primary habitat. In 1900, 15 per cent of a global population of 1.5 billion people lived in cities (Girardet, 2008). By the middle of 2009, the number of people in urban areas (3.42 billion) surpassed the number living in rural areas and since then the world has become more urban than rural (United Nations, 2010).

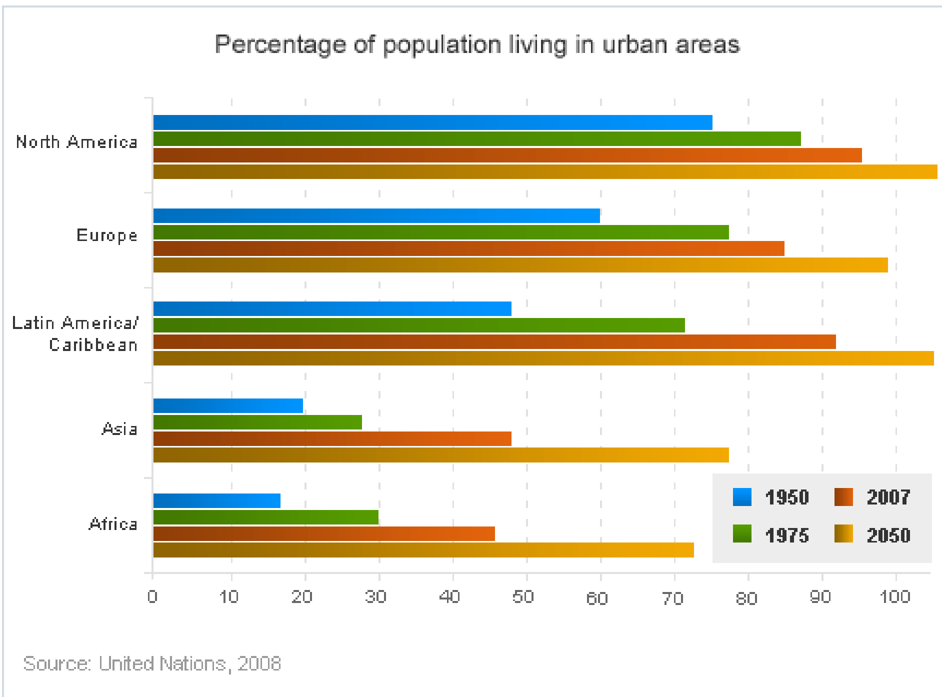


Figure 1: Percentage of population living in urban areas (Reproduced from United Nations, 2008)

All-out urbanization is fundamentally changing the conditions of humanity and tour relationship to the Earth. We humans have been undergoing an amazing transformation: from living in a world of farms, villages and small towns, we are changing ourselves into an urban species (Girardet, 2008). From being dependent primarily on nature´s local annual harvest, more and more of us are drawing on global food and timber supplies. From a reliance on purely local energy sources, we have switched to tapping into stores of non-renewable energy resources from all over the world. From leading locally self-sufficient lives, more and more of us are becoming citizens of a human- centred planet (Girardet, 2008).

Nevertheless, the implications of urban growth in terms both of the global use of resources and of human living conditions are numerous and complex. To make current urban lifestyle possible, cities are sucking in resources from all over the world. They consume energy in a very different way from those in the past. Most of the world´s energy is consumed in cities and for their benefit: either by cities themselves or by the farming, industrial production, and transport systems that supply them. All their internal activities-local transport, electricity supply, home living, services provision, and manufacturing- crucially depend on fossil fuels.

For example, as it transpires from Herbert Girardet's extensive study (from 1992) of London´s metabolism, 7 million Londoners used around 20 million tonnes of petrol or its equivalent annually, or two supertankers a week, and discharged some 60 million tonnes of carbon dioxide into the atmosphere (Girardet, 2006). However, at least the same amount of fuel again is required to bring in goods and products from outside, with more and more being flown in from halfway around the world (Girardet, 1999).

Despite all these numbers, we might rarely happen to reflect upon the environmental impacts of our daily energy use since it´s all so easily available on the press of a switch. However, most of the increase of carbon dioxide and other greenhouse gases is attributable to combustion in the world´s cities.

Overall, cities, are the major contributors to climate change and, and if current trends remain unchecked, will also be its principle victims. There are by now numerous warnings about the fact that humanity cannot afford to burn the Earth´s remaining underground reserves of fossil fuel, something that requires a dramatic rethink about the energy systems that currently support our cities but also the general organization and planning of urban areas towards sustainable forms.

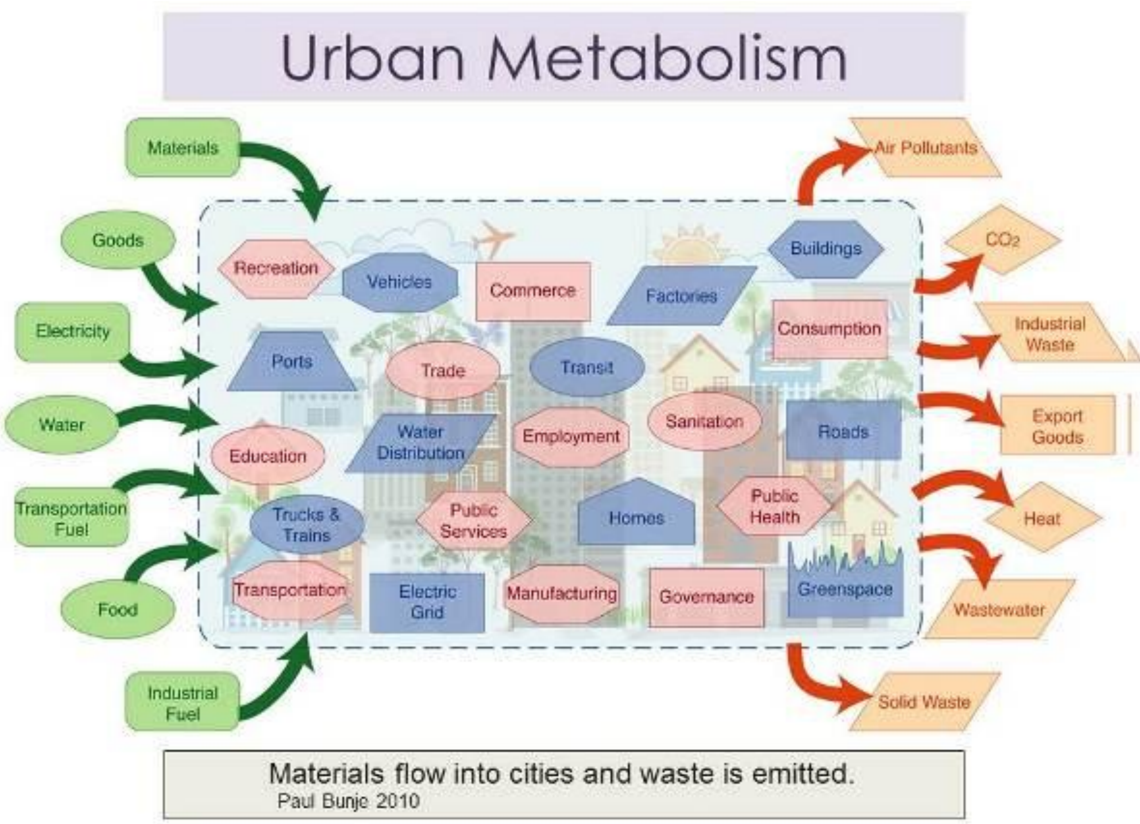


Figure 2: Urban metabolism diagram showing the materials flows and waste emitted. The diagram was created within the scope of a project focused on the energy metabolism of Californian communities (UCLA, 2011)

1.2 Notions and dimensions of urban sustainability

It is difficult to give one definition to sustainable urban development since sustainability is fundamentally a complex and multilateral issue. There are, in fact, many terms used today in discussing efforts to reduce environmental impacts and to live more lightly on urban land. Green urbanism, Urban Sustainable Development, Eco-cities, Green Cities, and Sustainable Cities are few of them.

An attempt at a definition of a sustainable city, based on the Brundtland´s Commission definition for sustainable development, is given by Girardet in his book "Cities, People, Planet":

A ´sustainable city´ enables all its citizens to meet their own needs and to enhance their well-being, without degrading the natural world or the lives of other people, now or in the future (Girardet, 2008).

The main question remaining is what specific measures need to be taken to create sustainable urban habitats, and how environmental and social concerns can be brought together into one convincing win-win scenario. The world community has vigorously addressed these issues since the early 1990s, starting with Agenda 21, the primary outcome of the 1992 Rio Earth Summit. According to Agenda 21, "by 1996, most local authorities in each country should have undertaken a consultative process with their population and achieved a consensus on a local Agenda 21 for their communities." This mandate for "local Agenda 21" planning has stimulated a large number of local planning initiatives and in fact has built the foundation for sustainable urban development (Wheeler et al, 2009).

The Aalborg Charter, which was produced by the cities and towns of Europe in 1994, states:

We understand that our present urban lifestyle, in particular our patterns of division of labour and functions, land-use, transport, industrial production, agriculture, consumption, and leisure activities, and hence our standard of living, make us essentially responsible for many environmental problems humankind is facing. This is particularly relevant as 80 percent of Europe´s population live in urban areas (Aalborg Charter, 1994).

In addition, it continues by stating the notion and principles for sustainable urban development as approved by the participatory European cities and towns:

We, cities & towns, understand that the idea of sustainable development helps us to base our standard of living on the carrying capacity of nature. We seek to achieve social justice, sustainable economies, and environmental sustainability. Social justice will necessarily have to be based on economic sustainability and equity, which require environmental sustainability. Environmental sustainability means maintaining the natural capital. It demands from us that the rate at which we consume renewable material, water and energy resources does not exceed the rate at which the natural systems can replenish them, and that the rate at which we consume non-renewable resources does not exceed the rate at which sustainable renewable resources are replaced. Environmental sustainability also means that the rate of emitted pollutants does not exceed the capacity of the air, water, and soil to absorb and process them. Furthermore, environmental sustainability entails the maintenance of biodiversity; human health; as well as air, water, and soil qualities at standards sufficient to sustain human life and wellbeing, as well as animal and plant life, for all time (Aalborg Charter, 1994).

In the Local Government Declaration to the 2002 UN Johannesburg Earth Summit, representatives from cities around the world expressed similar ideas:

With half of the world´s population now living in urban settlements, and with the world´s population due to grow to 8 billion by 2025…sustainable urban management and development is one of the critical issues for the 21st century. National states cannot, on their own, centrally manage and control the complex, fast-moving cities and towns of today and tomorrow-only strong decentralized local government, in touch with and involving their citizens, and working in partnership with national governments, are in a position to do so (United Nations, 2002 cited in Girardet, 2008).

Box I: ***The multiple goals of sustainable development as applied to cities***

Meeting the needs of the present…

- ***Economic needs*** - includes access to an adequate livelihood or productive assets; also economic security when unemployed, ill, disabled or otherwise unable to secure a livelihood.
- ***Social, cultural, environmental and health needs*** – includes a shelter which is healthy, safe, affordable and secure, within a neighbourhood with provision for piped water, sanitation, drainage, transport, health care, education and child development. Also a home, workplace and living environment protected from environmental hazards, including chemical pollution. Also important are needs related to people´s choice and control – including homes and neighbourhoods which they value and where their social and cultural priorities are met. Shelters and services must meet the specific needs of children and of adults responsible for most child-caring (usually women). Achieving this implies a more equitable distribution of income between nations and, in most, within nations.
- ***Political needs*** – includes freedom to participate in national and local politics and in decisions regarding management and development of one´s home and neighbourhood, within a broader framework, which ensures respect for civil and political rights and the implementation of environmental legislation.

…without compromising the ability of future generations to meet their own needs

- ***Minimizing use or waste of non-renewable resources***- includes minimizing the consumption of fossil fuels in housing, commerce, industry, and transport plus substituting renewable sources where feasible. Also, minimizing waste of scarce mineral resources (reduce use, reuse, recycle, reclaim). There are also cultural, historical and natural assets within cities that are irreplaceable and this non- renewable- for instance, historic districts and parks and natural landscapes which provide space for play, recreation and access to nature.
- ***Sustainable use of finite renewable resources*** – cities drawing on freshwater resources at levels which can be sustained (with recycling and reuse promoted). Keeping to a sustainable ecological footprint in terms of land area on which city- based producers and consumers draw for agricultural and forest products and biomass fuels.
- ***Biodegradable waste not overtaxing capacities of renewable sinks*** (eg. capacity of a river to break down biodegradable wastes without ecological degradation)
- ***Non-biodegradable wastes/emissions not overtaxing (finite) capacity of local and global sinks to absorb or dilute them without adverse effects*** (eg. Persistent pesticides; greenhouse gases and stratospheric ozone-depleting chemicals)

Source: Developed from Mitlin, Diana and David Satterthwaite, Cities and Sustainable Development, the background paper to Global Forum ´94, Manchester City Council and IIED, June 1994, as cited in Satterthwaite, 1999

1.3 The important role of cities in global sustainability

The majority of the sustainability challenges, as explained above, are most urgently experienced in the urban environment. Hence, cities are expected to play a key role in the battle for sustainable development and consequently in the quest for a sustainable society (Beatley, 2000). The director general of the 1992 Rio Earth summit, Maurice Strong, sums these issues up well: ` The battle to ensure that our planet remains a hospitable and sustainable home for the human species will be won or lost in the major urban areas´ (cited in Girardet, 2008).

There are several reasons for explaining the important role of cities in the fight for sustainable development. The first is their total size and the extraordinary concentration of resources and activities. Although average world figures conceal large differences across countries and regions that should be considered with caution, cities host more than 50% of the inhabitants of the planet but consume around 75% of its resources and produce roughly 75% of the overall greenhouse gas emissions (Mega, 2010).

In fact, cities are responsible for the bulk of national output, innovation, and employment, and they constitute the key gateways of transnational capital flows and global supply chains (OECD, 2006 cited in Mega, 2010). Therefore, problems related to energy and food security, climate change, water management, congestion, air pollution, cultural segregation or social tensions, all tend to come together and intertwine in cities (Kamal-Chaoui et al., 2009).

On the other hand, it is the same nature and characteristics of cities that offer good opportunities for addressing the sustainability challenges. In fact, compared with the average world citizen, each urban dweller consumes fewer resources and is responsible for lower levels of emissions than the rest of the inhabitants of the planet (Mega, 2010). High densities of cities mean much lower costs per household and per enterprise for the provision of piped, treated water supplies, the collection, and disposal of household and human wastes as well as for the energy distribution systems (Mega, 2010).

Furthermore, the concentration of production and consumption that take place in cities provides a greater range and possibility for efficient use of resources- through the recovery of materials from waste streams and its reuse or recycling. Actually, cities can make material or waste exchanges possible between industries. The collection of recyclable or reusable wastes from homes and businesses is generally cheaper, per person served (UNCHS, 1996).

Another advantage of the concentration of production and residential areas in cities is the considerable potential for reducing energy use. The energy demand for heating, for instance, can be eliminated by using waste process heat from industry or thermal power stations to provide space heating for homes and commercial buildings with Combined Heat and Power systems. Besides, certain forms of high-density housing, such as terraces and apartment blocks, considerably reduce heat loss from each housing unit, when compared to detached housing. Additionally, cities, due to their size, permit more centralized and large-scale energy production at a lower cost owing to the economy of scales, while their high density allows more efficient energy distribution systems (Mega, 2010).

Moreover, cities represent a much greater potential for limiting the use of motor vehicles, and subsequently, reducing the fossil fuels they use and the air pollution and high levels of resource consumption that their use implies. In fact, cities facilitated the use of low mobility modes such as walking or bicycling or public transport systems.

In addition, cultural reasons give also a big advantage to cities to address sustainability challenges. Cities have the capacity to engender new values, create new concepts, and introduce structures and patterns, which are quickly disseminated to the rest of the world. They are centres of creativity and innovation. The social economy[1] within each locality creates a dense fabric of relationships that allow local citizens to work together in identifying and acting on local problems or in taking local initiatives (Korten, 1995).

[1] Social Economy is a term, given to a great variety of initiatives and actions that are organized and controlled locally and that are not-profit oriented (Korten, 1995).

Because of such powerful urban cultural, economic, and political influences, cities are the ideal geopolitical medium for sustainability related projects and awareness campaigns (Mega, 2010).

Finally yet importantly, there are also fundamental political reasons that give cities a key role in the battle for sustainability. Cities have always promoted local democracy and this is a major precondition for advancing towards sustainable development. A great number of examples and initiatives already existing around the world, show that cities are already adapting to change and will lead and drive the transition to sustainable development.

Realizing the advantages of cities for the achievement of sustainable development goals is necessary. Stressing the potential of cities is important in that so many general works on sustainable development see cities as `the problem´ and choose not to consider how urban development can be made compatible with sustainable development goals, despite the increasing concentration of the world´s production and population in urban areas (Satherthwaite, 1999).

1.4 Energy transition: a key issue for urban sustainability

Demand for energy defines modern cities more than any other factor. As mentioned earlier, more than 70% of the total energy consumption in the built environment is used for heating and cooling buildings, for lighting, for electric and electronic appliances and for transport (Buttera, 2008). Thus, more than two thirds of total energy consumption is needed for urban metabolism.

Yet, most city people have a limited understanding of the origin of their energy supplies. In the past, our ancestors had the daily task of assuring firewood supplies, but now, we get electric or gas appliances with the simply flick of a switch. We are hardly aware of the power station, refinery, or gas field that our homes are plugged into. Few of us reflect on the environmental impacts of our daily energy use, unless we choke on exhaust fumes on a busy local street. However, we rarely confront the fact that there is a global price to pay: most of the increase in carbon dioxide in the atmosphere and global warming effect are attributable to combustion within, or on behalf of, our cities.

A critical issue thus for the future is whether urban systems that have been created by the use of fossil fuels could run on more sustainable energy technologies instead. Besides, it is crucial to find ways to reduce urban energy demand, by changing current energy consumption patterns and focusing on low-energy urban design and the reuse of waste energy.

Therefore, to design a renewable city means, firstly, that we must minimize energy demand, secondly, maximize the efficiency of energy supply and thirdly, maximize the share of renewable energy sources.

Certainly, to fulfil these aims involves a great list of combined ideas and actions, some of which are:

- **Optimize the energy efficiency of the urban structure and improve the urban microclimate**,

by optimizing the shape, orientation and distances between buildings, in order to obtain maximum solar radiation and wind protection in winter and minimum solar radiation combined with openness to ventilation in summer. These techniques, also known as passive solar design, along with integration of green areas and reflective surfaces help to fight heat island effect and consequently reduce the demands for cooling.

- **Reduce the energy demand of buildings,**

by using passive solar architecture and highly insulated envelopes, which can reduce heat losses, enhance natural ventilation, and consequently, reduce energy demand for heating and cooling. The envelope plays a crucial role on the energy efficiency of buildings. The skin of the buildings should allow fresh unconditioned air into the building when possible, optimize daylight to reduce artificial lighting, and minimize heat gains and losses.

- **Promote and adopt low energy consumption patterns,**

by monitoring and displaying energy use on building and city level and communicating the environmental and economical benefits of energy saving.

- **Maximize the efficiency of energy supply**,

by using Cogeneration Heat and Power systems, heat pumps, and district systems for heating and cooling. CHP or co-generation plants are the most efficient energy supply systems, as their waste heat can be used for heating neighbor buildings. The same waste heat can also be used for cooling by means of devices such as the absorption chiller, which uses low temperature heat to produce chilled water. Heat pumps are also very efficient ways to produce heat with exergy content. They are devices that pump heat flow from a lower to a higher temperature. When used for heating, they pump heat from the outdoor *to* the indoor environment, heating it; when used for cooling (refrigerators, air conditioners), they pump heat from the indoor to the outdoor environment. If aquifers are available, they can be used as a heat source in winter and heat sink in summer, improving the heat pump performance (Buttera, 2008).

- **Increase the share of renewable energy sources,**

by installing different renewable energy technologies depending on local characteristics and potential. Many technologies are available and applications are already in use in the urban environment:

a. Biomass

Biomass is frequently used for heating, especially in Scandinavian cities or cities that are close to forest areas, which can provide waste wood. Wood biomass can be used for supplying CHP power plants directly (as pellets or wood-chips) or after gasification (to biofuels). There is an assortment of biomass CHP plants all over Europe ranging from the 37MWe CHP plant of the Swedish town Växjo, supplying 35% of the electricity, and 95% of the heat needed (Energie-Cites, Biomass CHP Växjo) to the 1.1 MWe CHP plant in the alpine town of Tirano, supplying heat and electricity to 6,900 inhabitants (Buttera, 2008). Generally, wood biomass is chipped and burnt in boilers to produce steam, which supplies one or more turbines coupled with generators.

Besides, the popularity of biofuels is growing mainly in the automotive industry as a substitute for, or as an integration of, gasoline or diesel oil. (Buttera, 2008).

b. Solar Energy

Urban areas can take advantage in different ways of solar energy. First, passive solar architecture principles, when applied properly in the design of the area, can increase solar gains and decrease energy demand. Second, another consequence of an appropriate urban design is that most buildings are aligned along the east/west axis, making it easy to install solar collectors in their flat or south facing roofs and achieving maximum efficiency.

One of the most immediate and cost-effective uses of solar energy is for hot water production. Solar thermal systems are already compulsory for hot water production in countries like Spain, Israel, and Italy (Buttera, 2008).

Solar thermal systems can also be integrated in the district heating network, as in the community of Ballerup, in Denmark, where 50% of the energy consumption for hot water and heating of 100 apartments is provided by roof mounted solar collectors connected to a gas fired CHP plant (Energie-Cités& Solar District Heating Ballerup). The heat produced by these systems is combined with the district heating network, which provides the remaining 50% (Buttera, 2008).

Solar thermal district heating with seasonal storage is another way of using solar energy. An example of implementation of this technology is the city of Friedrichshafen, in the south of Germany, where excess heat in summer is stored in a large and well-insulated underground water tank and used during winter (Energie-Cites& Solar District Heating Friedrichshafen, 2002).

Apart from water heating, solar energy can be used for electricity generation with the use of photovoltaic panels. Photovoltaic systems, in the urban environment, are best used when integrated in the buildings' envelopes or on south-oriented flat or slopped roofs. Photovoltaic systems have already been installed in many cities in Europe, becoming one of the main elements of the energy system of fossil free cities. Even cities in Northern Europe, - like Malmö in Sweden – rely on solar energy for a considerable share of their electricity production, with the goal of becoming solar cities (SECURE, n.d.a). As it is claimed on the relevant report of Malmo, "*If we (Malmö) can generate solar energy, anyone can do it.*"

c. Wind Energy

Wind power is more frequent in coastal urban areas, where offshore wind parks are connected to the city's energy system, providing electricity. Offshore wind farms have become attractive options, due to technological improvements and the lowering of costs of large scale wind turbines; besides being capable of harvesting higher speed winds, these plants have the advantage of reducing the problem of visual impact, which often prevents or slows down the development of wind power (Buttera, 2008). For example, the world's third-largest, sea-based wind energy park stands on the water outside Malmö,. It is Sweden's largest investment in wind energy to date. The park consists of 48 wind generators producing 0.33 TWh of electricity per year. That equals electricity for 60,000 homes in the area of Malmö (Climate Malmö, 2009). Wind parks can also be found on hills around urban areas, but there are restrictions related to environmental protection of the natural landscape.

However, a new focus in urban sustainability is urban wind energy – smaller wind turbines with either horizontal or vertical axis that can be placed within the built environment. Although their cost-effectiveness is lower than that of large wind turbines, they are a valuable option for urban areas aiming to become fossil fuel-free (Buttera, 2008). Urban turbines could contribute considerably to the energy balance of an urban area, since a large number could be installed on roofs, incorporated into the urban landscape.

d. Geothermal Energy

Geothermal energy has been increasingly used for district heating. The geothermal water coming from the ground acts as a heat source directly heating the network fluid through a heat exchanger.

In countries like Iceland, geothermal energy plays a crucial role in the energy economy. The dominant use is for space heating where almost 90% of the houses are heated with geothermal water (Gunnlaugsson, Gislason, Ivarsson and Kjaran, 2000). In Reykjavik exists the world's largest heating utility, which serves almost 99% of the population (Buttera, 2008)

The city of Lund, in Sweden, is another example of use of geothermal energy for district heating. Due to the presence of the hot water in the ground below Lund, two geothermal plants with a maximum heat output of respectively 20 and 27 MW were commissioned in 1985 and 1986. The principle was to pump the 21 °C hot underground water from a 800 metre deep well. The water for district heating, heated by the heat pump, is at 77 °C and is used for the heat demand in the city. In ideal working conditions, this heat pump has an overall coefficient of performance (COP) of approximately 3.3, meaning that an input of 1 kWh electricity gives an output of 3.3 kWh heat. This is quite high and is a result of using the hot water from the underground. Normal heat pumps installed for example, in dwellings, work with a COP of around 2.7 (Energie- Cites, Geothermal Energy, Lund, 2002)

e. *Mini-hydropower*

Several derelict small hydro power stations can be found, especially in Europe. Most of them were built in the first half of the twentieth century and abandoned in the second half because they were not cost effective (Buttera, 2008). Many of these mini-hydro power plants are now being restored and put into operation, and new sites are also being explored and exploited (Buttera, 2008). Hannover is a city that has modernized old small hydro power plants and has also built a new hydroelectric power station. The new hydropower station was intended to work as an example of a technical structure that has a minimal impact on nature even in a countryside conservation and recreation area. The specific hydro power plant includes a fish ladder, which will permit the various species of fish that exist - or could exist - in the river to climb up and thus pass the weir (Energie-Cites, Mini Hydro Power, Hannover, 2002).

- **Reduce the volume of disposable waste generated, and use the energy content of waste**

Recycling wastewater and solid wastes have become some of the primary sources of energy of contemporary energy efficient cities.

Solid waste incineration, after selection and pre-treatment, supplying a CHP plant can give a significant contribution to the city's energy balance (Buttera, 2008).

Instead of being incinerated, waste can also be gasified, producing syngas. Such gas can be used either to supply a CHP unit or to be distributed for cooking use. A very good example of water and solid waste energy content reuse in implemented in Hammarby Sjöstad, a district of Stockholm in Sweden. About 1,000 flats in Hammarby Sjöstad are equipped with biogas stoves that utilize biogas extracted from wastewater generated in the community. Biogas also provides fuel for buses that serve the area. Collection of solid waste in the neighbourhood happens through an innovative vacuum-based underground collection system that allows efficient separation of organic, recyclables, and other wastes. Combustible waste is burned and returned to the neighbourhood in the form of electricity and hot water; the latter delivered through a district heating grid (Hammarby Sjöstad, 2007).

- **Reduce the need of transport within the urban environment and maximize green transportation**

Transport is a major factor contributing to energy consumption. Present urban mobility based on private cars is incompatible with sustainable development. Radical changes should take place within the urban planning to reduce the need to travel but also towards more sustainable transport modes. On the one hand, urban planning should be based on mixed use areas that combine residential with commercial, social and work places and recreation facilities to reduce the need for everyday mobility and commuting. On the other hand, sustainable urban mobility should promote more sustainable transport modes like public transport, walking and cycling but also new forms of vehicle use and/ or ownership (e.g. car-sharing, car pooling).

According to the local climate and resources, by combining in an appropriate way the above-mentioned goals, it is possible to design the energy system of an urban area with the aim of achieving zero CO_2 emissions. The energy system must be conceived at the beginning according to a new energy paradigm. This implies not only that the architectural design process for the individual buildings has to change, but also – and mainly- that the planning rules of the community have to change: no longer should there be a linear, fossil fuel- based, energy economy, but instead a circular, renewable sources- based, energy economy.

1.5 Exemplary cases of energy sustainability on neighbourhood, district, or city scale

This section includes inspiring recent examples of urban sustainability practices that combine the aforementioned goals and aim to achieve a climate neutral urban environment. The list is not exhaustive, to be sure, but these examples have been an inspiration for the development of the present study.

I. Beddington Zero Energy Development, London

Beddington Zero Energy Development (or BEDZED for short) is a new ecological housing project in the Hackbridge neighbourhood in south London. Designed by Bill Dunster Architects, it is billed as the first carbon-neutral development in the UK. Only energy from renewable sources is used within the district, and the district produces as much energy from renewables as it uses. There are 82 mixed tenure residential homes in BedZED, incorporating innovative approaches to energy conservation and sustainability. Among the houses are commercial buildings, an exhibition centre, a children's nursery and a show flat so that visitors can see what it is like to live at BedZED (Wheeler et al., 2009). The scheme helps people to live more sustainably, perhaps even within their share of the earth's renewable resources, without sacrificing a modern, urban and mobile lifestyle.

Energy principles:

- **Zero-Energy** – The project is designed to use only energy from renewable sources on site. There are 777 m^2 of solar panels to provide enough electricity to recharge a fleet of electric car-sharing cars (BedZED, 2009). Tree waste fuels the development's cogeneration plant to provide district heating and electricity. The wood both for construction and to burn as fuel comes from sustainable local forests (Wheeler et al., 2009).
- **Energy Efficiency** - A unique system of natural ventilation with heat recovery is provided through a visually distinctive set of wind cowls that rotate into the wind, capturing fresh air but also extracting heat from outgoing air
- **Passive Design** –Houses are oriented with living space to the south to take advantage of the solar gain and most units are provided with rooftop sky gardens.
- **High insulation** – The buildings are well insulated, and constructed from thermally massive materials that store heat during warm conditions and release heat at cooler times. Double or triple glazing is used to prevent any heat losses.

Figure 3: (Left) Beddington Zero Energy Development, Hackbridge, London. (Right) Detail of wind cowls providing passive ventilation with heat recovery (Sources: Sustainable Cities, CABE)

II. Hammarby Sjöstad, an eco-cycle model, Stockholm, Sweden

Few cities have done as much to put the idea of a sustainable circular energy metabolism into practice as Swedish cities and the new ecological district Hammarby Sjöstad is the leading case.

Hammarby Sjöstad provides an extremely powerful example of how this metabolic flows view can manifest in a new approach to urban design and energy systems in a new dense urban neighbourhood. From the beginning of the planning of this new district, an effort was made to think holistically and to understand the inputs, outputs, and resources that would be required.

Energy principles:

- **Energy from waste -** About 1,000 flats in Hammarby Sjöstad are equipped with biogas stoves that utilize biogas extracted from wastewater generated in the community. Biogas also provides fuel for buses that serve the area. Collection of solid waste in the neighbourhood happens through an innovative vacuum-based underground collection system that allows efficient separation of organic, recyclables, and other wastes. Combustible waste is burned and returned to the neighbourhood in the form of electricity and hot water, the latter delivered through a district heating grid. Furthermore, from the cooled and treated wastewater that leaves the Hammarby plant's heat pumps, heat is exchanged into cooling in the water that circulates in the district cooling network in Hammarby Sjöstad. Cooling is, in other words, purely and simply a waste product from the production of district heating (GlashusEtt, 2007).

- **Solar Energy -** 390m² of south-facing solar panels have been installed on the roof of a block. These panels capture the warm rays of the sun and use them to heat the buildings hot water supply. The solar panels shown in the picture below produce half of the energy required to meet the building's annual hot water requirement. Solar cells are also installed on buildings, contributing to the building's energy supply (GlashusEtt, 2007).
- **Reduce Energy Demand** - Many other important features at Hammarby reduce energy demand and carbon emissions. The most important perhaps is the close proximity to central Stockholm and the installation (from the beginning) of a high-frequency light rail system (the Tvarbanan) and an extensive pedestrian and bicycle network. There are also thirty car-sharing cars distributed throughout the neighbourhood. These transportation alternatives make it truly possible to live without a private automobile (Wheeler et al, 2009).

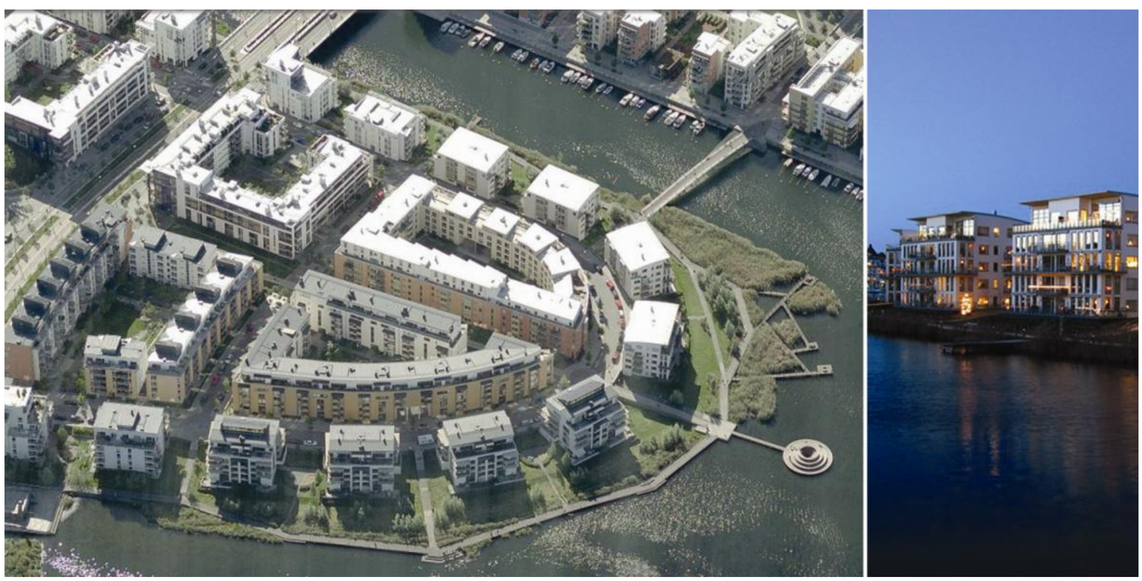


Figure 4: Hammarby Sjöstad, a unique environmental district in Stockholm*(Sources: Skyscraper City, Envac)*

III. Kronsberg Ecological District, Hannover, Germany

This model ecological housing district is Hannover's newest growth area. Designed and built as a model development for the 2000 World Expo, it incorporated almost all the available knowledge of ecological optimization and urban sustainability of that time. The sustainability dimensions begin with its basic form: relatively high-density, multi-family housing, situated along a new line of the city's tram system and with a car-minimal grid street pattern. The entire district is a traffic-calmed (30 km restricted) zone, with extensive bike lanes and onsite car sharing providing additional alternatives to the automobile (Wheeler et al, 2009).

In devising the energy concept for Kronsberg, the aim was to develop generally applicable energy efficiency measures that would be acceptable to developers and residents.

Energy principles:

- **Sustainable Generation** – In total, 104 apartments are heated with thermal solar collector panels, which also replace conventional insulation on the south-facing roofs of the housing blocks. Solar energy in summer is piped to an extremely well insulated cistern, and thus solar heating is possible from spring through to December. This covers around 40% of the total heating demand, the rest being supplied by the district heating network (Buttera, 2008). Three wind turbines were also built, including one large 1.8 MW turbine, and all are but a few hundred meters away from the housing. A centralized solar hot water heating system is used to serve one portion of the district (and store hot water in a partially underground tank, which doubles a children's play area. The overall result is that emissions are 85-95% lower than they would have been adopting current building and management standards (Buttera, 2008).
- **Reduce Heat Demand** – Minimization of heating energy demand in buildings was obtained by obliging all clients and construction companies, through the land sale contracts or urban construction contracts, to carry out construction work according to precise standards, such as:
    a. Heating energy index of 50 kWh/(m^2a) as a target value
    b. The calculation method for the heating energy index defined
    c. Monitoring by qualified engineers
    d. Penalty payments of 5 € /m^2 for exceeding the limit value
    e. Provision of subsidies by the local authority (Buttera, 2008)
- **Passive Design** – A special project for 32 family Passive Houses (heating energy consumption 15kWh/ m^2a) was developed.
- **Energy Efficient Appliances** – The tenants were offered energy-saving light bulbs and grants for the purchase of electricity saving appliances (washing machines and dishwashers, refrigerators and freezers).
- **Energy conservation strategies** – Advice was given in person or by telephone on electricity saving habits.

Figure 5: (Above) Kronsberg Ecological District in Hannover, Germany, (Below) Passive houses with green roofs and solar pv panels. ***(Source:Econode)***

IV. Vauban Solar District, Freiburg, Germany

Freiburg can call itself with some justification one of the birth places of sustainable urbanism. In the south of Freiburg, on a former area of a French barrack site, one of the biggest European solar districts was developed from the end of the last century, in order to host more than 5000 inhabitants and 600 jobs. The main objective of the project was to implement a city district in a co-operative and participatory way with special ecological, economic, social, and cultural prerequisites (Vauban district, 2012).

The planning for the district started in 1993 and the implementation phase started in 1997. Right from the beginning all issues (mobility, energy, housing, social aspects etc.) were discussed in working groups which were open to residents. Raising public awareness was regarded as key component when planning an environment-oriented district, as people have to be convinced that such action not only serves their interests from an ecological point of view but also helps to save money in the long term. Furthermore, change in people's belief system would bring about an acceptance of other policies (e.g. car sharing, public transport) which are not directly related to the process of building a new house (Energie-Cites - Freiburg, 2008).

An outstanding characteristic of the Vauban project is co-operative local planning, and this should set an example for other cities. Issues such as raising awareness and integration of residents' individual interests have been put into practice in an exemplary manner. The Vauban project shows how important is to achieve a high level of motivation among residents, local politicians, and persons in charge of implementation.

Energy principles:

- **Compulsory improved low energy standard** - All new buildings were built with energy use maximum 65 kWh/m^2a, while at the same time the average energy standard in Germany for newly built houses was about 100 kWh/m^2a (Vauban district, 2012).
- **Passive houses -** 92 units were built to passive house standard (15 kWh/m^2a),
- **Energy-plus houses** - 10 units of improved passive houses, so called "energy-plus houses" (houses which – on average - produce more energy than they need) were built up to December 2000 by an investor (Vauban district, 2012).
- **District heating grid and co-generation plant** - In 2002, a highly efficient co-generation plant (CHP) operating on wood-chips (80% wood chips, 20% gas) was implemented and connected to the district's heating grid (Vauban district, 2012).
- **Active use of solar energy** - Vauban is one of the biggest EU solar districts including more than 2500 m^2 of photovoltaic panels and 500 m^2 of solar panels (Vauban district, 2012)

Figure 6: One of the biggest EU Solar Districts - Vauban, Freiburg, Germany, *(Source: GreenCity Freiburg)*

V. Växjo Fossil Fuel Free City, Sweden

In 2000, Växjo won the International environmental award for excellent atmospheric protection and in 2007 it was awarded the Sustainable Energy Europe Award by the European Commission. In 1996 the city politicians decided unanimously that Växjo should become a fossil fuel-free city by 2030. So far, the emissions have been reduced at around 60% per inhabitant, compared with 1993 (Växjo Kommun, 2010). To this end, the city strives to use energy only from renewable sources, to use energy efficiently while cutting down the energy use per capita, and to go over to a fossil fuel free transport system.

Energy principles:

- **Renewable Energy** - In 2005, 51% of the energy consumption of Växjo was based on renewable energy sources. Most of the renewable energy consumption originates from the heating sector, where 88% of the consumption is based on renewable sources. In the transport sector, there are still things to be done, but as ethanol blended into the petrol, 2% of the energy in the transport was based on renewable sources. The remainder of renewable energy originates from non-locally produced energy, based on hydropower and wind power (Växjo Kommun, 2010).
- **Energy Efficiency -** 400 energy efficient apartments were built, some of which have energy efficient wooden construction while some others are passive houses. Furthermore, individual electricity metering systems are installed in apartments. On the display, those living in the

apartment can read their consumption of energy and get suggestions how to reduce it. Moreover, street lighting has been replaced with energy efficient lighting (Växjo Kommun, 2010).

- **Sustainable Heating -** In Växjo, the heating is mainly based on wood products. In 1997, a new 100MW power and heating plant was built for the production of electricity and heating based on wood chips. Other biofuel based small-scale district heating plants have been built. Furthermore, municipal subsidies are given to private persons for solar panels for heating or for conversion from oil heating to biomass heating. In addition, most single-family houses have been connected to the district heating. Moreover, absorption cooling, based on the biomass heating plant, has been introduced in the hospital and university of Växjo (Växjo Kommun, 2010).

Figure 7: (Left) Växjo-Sweden, the greenest city in Europe. (Right) Picture promoting fossil fuel free Växjo. (*Source: Växjo Kommun*)

1.6 The scope of the present study

From all the aforementioned, it becomes clear that more and more cities or urban districts and neighbourhoods are realizing their crucial role in sustainability agenda and embarking on the journey to become "greener", "carbon neutral", "zero CO_2", or "fossil fuel-free". These goals, undoubtedly, cannot be achieved unless there is a shift from fossil power and other forms of unsustainable energy generation, to a renewable and sustainable power base. How can we measure, though, this shift and progress of the cities and urban areas towards sustainability?

This necessity seems to have been acknowledged, since a lot of attention has been given recently to developing assessment frameworks and tools for urban communities. Such tools aim to work as an interface between architects/ urban planners, and decision makers by setting a framework that incorporates in the planning process specific targets related to sustainability. On the one hand, planning authorities and communities can benefit from them by having assistance for decision-making, while architects and urban planners may use the tools to improve the sustainability of their projects.

Owing to the fact that all these tools have been launched recently, the number of scientific articles or studies analyzing them is limited. To this end, the present research study focuses on enhancing the currently limited research on urban sustainability assessment systems by analyzing and comparing the methodologies of existing tools.

As a result, four tools were chosen for the analysis: BREEAM Communities, BREEAM-NL Gebiedsontwikkeling, GPR Stedenbouw, and LEED for Neighbourhood Development. BREEAM Communities and LEED ND are the most accepted and prevailing methods in the industry for international sustainability assessments of urban scale developments, while BREEAM-NL Gebiedsontwikkeling and GPR Stedenbouw are two Dutch tools, finalized within 2011.

The main goal of the present study was to examine how the four assessment tools for urban communities assess energy sustainability, and subsequently to evaluate their strengths and weaknesses, and thus draw up suggestions for an improved tool. The specific goal is summarized in the following research question:

- *R.Q: "How is energy sustainability assessed by the four assessment tools for urban communities?"*

The following sub-questions were also examined in the present study:

- *Sub-Q1: "Which factors of energy sustainability are considered by the four tools and which energy indicators are used in order to measure these factors?"*

- *Sub-Q2: "Which features of the methods of the tools are brought out after their practical implementation on the same case study areas?"*

- *Sub-Q3: "Which recommendations can be given for the improvement of the tools and their methods?"*

The methodology used for the comparison of the tools comprised of two different parts. Firstly, the tools were compared and checked, based on findings coming from a review of up-to-date literature. Secondly, the tools were compared based on a "real world" case study and their practicality was checked and analyzed.

More specifically, a state-of-the-art literature review was done to bring insights into the current urban sustainability assessments (official lists of indicators of urban sustainability and international city rankings) and the way they incorporate energy sustainability themes. The objective was to identify which energy issues (for example energy efficiency, renewable energy, urban heat island, energy on buildings etc.) are included in assessments for urban sustainability and which indicators the literature uses to assess them.

The preferred energy indicators from literature and additional energy indicators devised by the author were added to create a generic list of energy indicators for urban sustainable development. Based on this list, the selected four tools were examined for the energy indicators they included and the compatibility they showed with the generic list. In that way, the first conclusions were drawn on the methodologies of the tools.

Secondly, the tools were checked against "reality". The four tools were applied to an existing area, which was used as a case study. Thus, it was explored how the inputs for the different indicators were generated in practice and conclusions were drawn on the functionality of the tools.

Ultimately, the outcomes from the comparison of the tools were summarized and suggestions for an improved tool were given.

2. Literature Review of Energy Indicators for Sustainable Urban Development

2.1 Measuring urban sustainability

One of the main questions facing those interested in bringing about more sustainable communities and cities is: how do we recognize progress towards sustainability? Some method for measuring the direction of current trends and success or failure of initiatives is crucial. As more and more cities adopt sustainability as a goal and aim to radically change current ways of cities´ development, it becomes an urgency to determine whether the actions taken are indeed leading the communities to become more sustainable. Formulating clearly articulated methods for measuring and reporting on urban sustainability is a prerequisite in any attempt for sustainable urban development.

Urban sustainability reports include a range of information about environmental, economic, and social conditions and policies in the local community, and use that information to make judgments about whether the community is making progress towards sustainability.

In order to measure and evaluate the progress, indicators are used while reporting on urban sustainability. In general, indicators are parameters or values that provide information about a phenomenon (Guy and Kibert, 1998). Most of indicators are, in fact, simplifications of complex phenomena and provide only an indication of conditions or problems (Whorton and Morgan, 1975; Clarke and Wilson, 1994). The purpose is to show how well a system is working. If there is a problem, an indicator can help to determine what direction should be taken to address the issue.

In general, indicators may help politicians and citizens to define individual or collective targets, linking them to clear goals and reaching them with concrete projects (OECD, 1998). Especially for sustainability issues, indicators may carry out a fundamental role as an interface between science, politics, and society: measuring sustainable development allows the entrance of social and environmental themes in the political and economical discussion (Morrison-Saunders, Pope and Annandale, 2003). In brief, if chosen properly, indicators can contribute to sustainability debates through two major roles: reducing the amount of data required to describe a situation fully and facilitating communication with diverse audiences (Keirstead, 2007).

- Effective indicators are **relevant**; they show you something about the system that you need to know
- Effective indicators are **easy to understand**, even by people who are not experts.
- Effective indicators are **reliable**; you can trust the information that the indicator is providing.
- Lastly, effective indicators are based on **accessible data**; the information is available or can be gathered while there is still time to act.

Box II: Characteristics of effective indicators (Sustainable Measures, 2010)

As far as urban sustainability is concerned, indicators should be used with the aim to reveal in what fields a city is doing better than in others and according to its specific goals. They should contribute to making the city more visible and transparent, aid in comparison, evaluation and prediction, help construct and harmonize data banks, provide decision-making with relevant information, stimulate communication, and promote citizen empowerment and participation (Mega, 2005). Urban sustainability indicators are useful to different communities for different reasons. For a healthy, vibrant community, indicators help monitor that health so that negative trends are caught and dealt with before they become a problem. For communities with economic, social, or environmental problems, indicators can point the way to a better future. For all communities, indicators can generate discussion among people with different backgrounds and viewpoints, and, in the process, help create a share vision of what the community should be.

However, the right selection of indicators in order to measure urban sustainable development is a highly complicated task. Firstly, the problem relies on the complexity of the concept of sustainable development since it involves and balances three different goals: the utility for economic development, the equity for social development and the ecological integrity for environmental development. Hence, sustainability requires multidimensional indicators that show the links among a community´s economy, environment, and society. Secondly, the selection of right indicators for sustainable urban development becomes a problem since there is no single "best" definition of urban sustainability (Maclaren, 1996); different communities are likely to develop slightly, or even significantly different conceptualizations of urban sustainability, depending on their current economic, environmental, and social circumstances and on community value judgments. Consequently, a set of indicators designed to measure progress towards achievement of one community´s sustainability goals may not necessarily be appropriate for measuring progress in another community.

Nevertheless, despite the complexities, urban sustainability indicators, and subsequently urban sustainability reporting help communities get a clear picture of the problems they are facing and set tangible targets in their pursuit of sustainable development.

2.2 In search of energy indicators for sustainable urban development

In a world threatened by climate change and fuel shortages, a significant improvement in the energy efficiency of cities is a crucial first step towards a sustainable future. The expertise already exists to bring urban energy use down by a tremendous percentage, without affecting the quality of living. However, in order to facilitate the transition of cities and communities, clear goals and targets need to be set and the progress towards them needs to be measured. In order to evaluate the contribution of local initiatives towards more sustainable energy future and monitor energy improvements on the urban scale, energy indicators should be used. Ideally, energy indicators particularly for urban sustainable development should document and give an overview of how energy, people, and materials flow through a city or an urban area while monitoring the process of efficiency improvement of cities/urban areas (Mega, 2005).

Energy indicators for urban sustainability, in contrast to the general energy indicators for sustainable development, are focused especially on the particular characteristics and demands of the local community. For that reason, there is no single and definitive set of energy indicators for sustainable urban development in the current literature. Instead, various sets of indicators, outcomes of local initiatives towards urban sustainability, give an overview of the diverse energy issues, but also the common goals between different communities in their pursuit for a sustainable energy future.

Taking everything into account, this specific chapter of the present study has been focused on collecting different energy themes and indicators that have been developed by local initiatives, or promoted by official bodies, or used in international city assessments and rankings. These energy themes and indicators have been further used to create the generic list of energy indicators for urban sustainable development, as it is explained in chapter 3.

The following have been chosen as important sources of indicators:

- The European common indicators for urban sustainability by European commission,
- The "Sustainability tools and targets for the urban thematic strategy" (STATUS) tool, outcome of a partnership project between ICLEI organization (Local governments for sustainability) and international research institutes and universities
- Eight of the most popular and thorough international city assessments and rankings assessing and comparing cities in terms of sustainability or quality of living

Each of the sources is further analyzed in the following paragraphs.

Due to time restriction, the study has been focused only on energy sustainability of the urban <u>built</u> environment, which includes a general overview of the energy performance of the whole city/area as a system, as well as the performance of buildings. Energy savings related to sustainable transport or energy production from waste have not been included in the scope of the present study. The potential savings resulting from changes in transport and from exploitation of urban waste are huge. However, the interventions and improvements that can be done on the urban transport systems and the different ways to deal with urban waste are numerous and demand a whole new profound study. Hence, no energy indicators related to sustainable transport or waste have been included in the present essay and the following sources of indicators have been researched only for energy indicators related to the urban built environment.

2.2.1 The European common indicators initiative for urban sustainability

Following the guidelines of 1994 Aalborg Charter, the European Union focused on developing a set of common indicators for urban sustainability. The European Common Indicators initiative was started off in May 1999 with the setting up of a working group on sustainable indicators (on the initiative of, and under the supervision of, the Expert Group on the Urban Environment and led by the French Environmental Ministry) (Ambiente Italia, 2003). Their task was to develop common (harmonized) indicators towards sustainability, in close collaboration with a wide group of local authorities.

Since the beginning, the aim of the initiative had been to develop and test indicators reflecting local actions towards sustainability in as integrated a way as possible. The outcome was a proposal, suggesting a set of ten indicators on a limited number of themes, in order to allow the strengthening of some core methodologies through effective implementation (Ambiente Italia, 2003). Towns and cities, however, could adapt or add to the ten indicators to suit local circumstances (UN, 1996).

1. Citizen satisfaction with the local community
2. Local contribution to global climatic change
3. Local mobility and passenger transportation
4. Availability of local public open areas and services
5. Quality of local ambient air
6. Children's journeys to and from school
7. Sustainable management of the local authority and local business
8. Noise pollution
9. Sustainable land use
10. Products promoting sustainability

As it can be remarked, there is no specific indicator directly related to energy issues. However, energy use is included as a parameter to the “Local contribution to global climatic change”. The indicator measures the annual CO_2 equivalent emissions per capita, differentiated by sector: residential, industry, tertiary and transport and energy sector, aiming to highlight not only the emissions´ quantities but also the relevant sources of CO_2 emissions (Ambiente Italia, 2003). Indisputably, the indicators referring to local mobility, public open areas, and the quality of air are also interrelated to energy consumption: transport and mobility indicators include fuel use; public green areas contribute to passive energy savings while the quality of local ambient air is also affected by emissions from energy use.

Extract from the Aalborg Charter:

Instruments and tools for urban management towards sustainability

….We know that we must base our policy-making and controlling efforts, in particular our environmental monitoring, auditing, impact assessment, accounting, balancing and reporting systems, on different types of indicators, including those of urban environmental quality, urban flows, urban patterns, and, most importantly, indicators of an urban systems sustainability.

Signed by 1860 EU local authorities (last updating: April 2003)

Box III: Extract from Aalborg Charter (Aalborg Charter, 1994)

2.2.2 The ICLEI's STATUS tool for assessing local government's progress for sustainable development

The ICLEI is an association of over 1220 local government members who are committed to sustainable development. For this reason, it was chosen as an important and appropriate source of indicators for urban sustainability.

ICLEI was founded in 1990 as the "International Council for Local Environmental Initiatives". It provides technical consulting, training and information services to build capacity, share knowledge, and support local government in the implementation of sustainable development at the local level (ICLEI, 2012).

The outcome of the partnership between ICLEI Europe and various universities, research institutes and other bodies[2] was the development of the STATUS tool that assesses sustainability on the urban level, with focus on Europe. STATUS tool (Sustainability Tools and Targets for the Urban Thematic Strategy) gives local governments the opportunity to self-assess their own progress with sustainable development, through inputting their own target values against a package of local sustainability indicators. These indicators have been selected from a number of European and national data sources, and have been specifically adapted to be relevant at the local level (STATUS, 2012). The indicators are also designed to be usable by local authorities at different stages of sustainability implementation. For each indicator presented in the tool, there is a set unit of measurement, and an indicative target. Every local authority can set its own target values related specifically to its local context and can enter relevant baseline data against these.

The tool covers 10 themes and includes 64 indicators that assess different issues of sustainability. For each indicator, the tool provides a definition, a method (i.e. measuring units), the relevance of the indicator with current policies, regulations and targets set by EU and in general existing targets for the specific topic. The list of the ten themes can be seen in the list below:

1. Governance
2. Local Management
3. Natural Environment

[2] University of Northumbria (UK), ABO Akademi University (FI), Trinity College (IR), VTT Technical Research Centre of Finland (FI), Ambiente Italia Srl Istituto di Recerche (IT), Union of the Baltic Cities, Commission on Environment, Secreteriat (FI)

4. Sustainable Consumption
5. Planning and Design
6. Sustainable Transport
7. Health
8. Vibrant and Sustainable Local Economy
9. Social Equity and Justice
10. Global responsibility

The analytical list of all themes and indicators used in STATUS tool can be found in the appendix I.

The indicators related to energy are included in the theme of "Global Responsibility" with the subthemes of "Greenhouse gas emissions" and "Renewable Energy", as it can be seen from the table below.

10. Global Responsibility	**Greenhouse gas emissions**	Total CO2 equivalent emissions per capita	Tones/cap/year
		Total electricity consumption per capita	kWh/cap/year
	Renewable Energy	Share of energy consumption produced by renewable sources	% of energy produced by renewables out of all energy produced by the whole
		Capacity installed for renewable energy production	kW/capita

The themes of "Sustainable Transport" and "Sustainable Consumption" are also strongly interrelated to energy consumption, but a further analysis of these topics is out of the scope of this study.

2.2.3 City assessments and rankings

City assessments and city rankings assess, compare, and reward cities for their environmental performance or general quality of living. The city awards and rankings generally aim to provide an incentive for cities to inspire each other and share best practices, while facilitating commitment to ambitious goals for environmental improvement and sustainable development. Table 1 presents an overview of some of the most popular city assessments for sustainability issues or general quality of living standards, which were used as sources for energy indicators for urban sustainability. Some of them assess only European cities, while others refer to US or Canadian cities, and only one ("Quality of living-global city rankings") has a global approach. However, not all assessments have focus on sustainability and not all of them make a specific mention to energy issues; some of the assessments have been focused more on social issues, while others rank the cities based on real estate criteria.

Table 1: Overview of city rankings used in the process of collecting energy indicators for urban sustainable development

Name	**European Green Capital Award**	**European Green City Index**	**Smart Cities**	**Smarter Cities**	**Sustainable Cities Index**	**Sustainable Cities Report**	**SustainLane**	**Quality of living Global city rankings**
Developed by	European Commission	Siemens-Economist Intelligence Unit	TU Wien, University of Ljubljana & OTB Delft	Natural Resources Defense Council	Forum for the Future	Corporate Knights	SustainLane	Mercer
Publica-tion year	2011	2009	2007	2011	2010	2011	2008	2011
Ranks	European cities	30 leading European Cities	70 European medium size cities (50.000-100.000 citizens)	US cities	20 biggest cities in UK	Canadian cities	50 most populous US cities	Global
Comments	For cities that want to improve both the living environment and address global environmen-tal problems	Focused on energy and green issues. Independe-ntly researched-not based on voluntary submission from city govern-ments	Broad approach-74 indicators	Focus on Energy-the other issues still remain to be developed	Only for UK	Only for Canada	No methodology and list of indicators available on the internet	Not specific for sustainabili-ty issues-more from the real estate perspective

A brief presentation of each assessment is given above while the extensive lists of themes and indicators used in each one are included in the Appendix I.

2.2.3.1 European Green Capital Award

The European Green Capital Award (EGCA) is the result of a European Commission initiative inspired by 15 European cities and the association of Estonian cities in May 2006 in Tallinn. The aim of the award is to promote sustainability and the sharing of best practices between cities from European Union, with a number of inhabitants more than 200,000.

The title rewards a number of different elements of environmental achievements in a city, based on the following three aspects:

i. *The greenest city:* The award rewards the 'greenest' city in Europe based on the city's environmental condition as defined by the performance levels relative to each of the proposed indicators. The city with the highest urban environment quality in Europe will be rewarded.

ii. *Implementation of efficient and innovative measures and future commitment:* The award rewards the city that has implemented the most innovative and efficient environmental measures and has shown that it is committed to do the same in the future.

iii. *Communication and networking:* The award rewards a city, which can act as a role model and inspire other cities to boost their efforts towards a greener urban environment by sharing experiences and promoting best practice among European cities and beyond (European Commission, 2012).

Evaluation of the cities for 2012 and 2013 was based upon 12 themes/indicators, very similar to the ones developed within the European common indicators initiative:

1. Local contribution to global climate change
2. Local transport
3. Green urban areas incorporating sustainable land use
4. Nature and biodiversity
5. Quality of local ambient air
6. Noise pollution
7. Waste production and management
8. Water consumption
9. Waste water treatment
10. Eco innovation and sustainable employment
11. Environmental management of the local authority
12. Energy performance

There is no specific indicator for energy issues; however, energy sustainability is included in the theme of "Local contribution to climate change," as well as in "Local transport", "Quality of local ambient air", and "Waste production and management" (energy recovery). An overview of energy indicators used in the EGCA can be seen in the table below.

1	**Local contribution to Global Climate Change**	Total CO2 equivalent per capita, including emissions resulting from use of electricity
		CO2 per capita resulting from use of natural gas
		CO2 per capita resulting from transport
		Grams of CO2 per kWh used
2	**Energy performance**	Energy consumption & performance of municipal buildings per square meter
		The development and goals for renewable energy share of all energy (heat and electricity)
		The strategy of renewable vs non-renewable mix as well as the renewable energy mix (different renewable energy sources) dynamics for the coming two decades
		Integration and performance of renewable energy technology in municipal buildings and homes
		Development of compatible and integrated district systems and the facilitation of more sophisticated city-wide control

2.2.3.2 European Green City Index

The Green City Indices are research projects assessing and comparing cities in terms of their environmental performance. They have been conducted by the Economist Intelligence Unit and have been sponsored by Siemens. Firstly, the index for European Cities was developed while later green city indices for Latin America, Asia, US & Canada, Germany and Africa (expected) followed as well (Siemens, 2009). For the present study, the European Green City Index was chosen as a representative example of this category of indices.

The European Green City Index measures and rates the current environmental performance of major European cities, as well as their commitment to reducing their future environmental impact by way of ongoing initiatives and objectives. The goal of the index is to allow key stakeholder groups — such as city administrators, policymakers, infrastructure providers, environmental non-governmental organisations (NGOs), urban sustainability experts, and citizens — to compare their city's performance against others overall, and within each category. The index also allows for comparisons across cities clustered by a certain criteria, such as geographic region or income group (Siemens, 2009).

The European Green City Index differs from other studies in the fact that it is independently researched, rather than being reliant on voluntary submissions from city governments. The assessments were based, wherever possible, on publicly available data from official sources, such as national statistical offices, or local city authorities.

The European Green City Index scores cities across 9 categories:

1. CO_2 Emissions
2. Energy
3. Buildings
4. Transport
5. Water
6. Waste
7. Land Use
8. Air quality
9. Environmental governance

These categories include 30 indicators. The extensive list of all indicators used in the European Green City Index is presented in the Appendix I.

Energy issues are included in the theme of "CO_2 emissions", "Energy" and "Buildings" and the relevant indicators are presented in the table below.

1	**CO2**	CO2 emissions
		CO2 intensity
		CO2 reduction strategy
2	**Energy**	Energy consumption
		Energy intensity
		Renewable energy consumption
		Clean and efficient energy policies
3	**Buildings**	Energy consumption of residential buildings
		Energy-efficient buildings standards
		Energy-efficient buildings initiatives

2.2.3.3 Smart Cities

"Smart cities" is a ranking for medium-sized European cities. It is the outcome of project collaboration between the Centre of regional science of Vienna University of Technology, the department of Geography of University of Ljubljana and the Research Institute of Housing, Urban and Mobility Studies of Delft University of Technology (Smart Cities, 2007). The ranking aims to reveal the challenges of medium-sized cities, in contrast to the usual rankings that focus on the "global" metropolises. Medium-sized cities, which have to cope with competition of the larger metropolises on corresponding issues, appear to be less well equipped in terms of critical mass, resources, and organizing capacity. "Smart Cities" ranking aims to identify the strengths of medium-sized cities in Europe and illustrate their respective differences and comparative (dis-)advantages towards each other (Centre of Regional Science Vienna UT, 2007).

The evaluation of the cities is based on 6 main themes:

1. Smart Economy (Competitiveness)
2. Smart People (Social and Human Capital)
3. Smart Governance (Participation)
4. Smart Mobility (Transport and ICT)
5. Smart Environment (Natural resources)
6. Smart Living (Quality of life)

Energy issues and indicators appear in the theme of "Smart environment" as it can be seen in the table below.

5	**Smart environment**	Sustainable resource management	Use of electricity per GDP

The extensive list of the 6 themes and 74 indicators is presented in Appendix I.

2.2.3.4 Smarter Cities

"Smarter Cities" is a project of the Natural Resources Defence Council of United States of America. A primary goal of the Smarter Cities project is to identify leader cities, those cities that for a specific sustainability factor are putting in place best practices, testing innovative new programs, passing model legislation, etc (Smarter Cities, n.d). To this end, starting in August 2010, a series of research projects have been carried out, each one to probe one of the following sustainability factors:

1. Air Quality
2. Energy Production and Conservation
3. Environmental Standards and Participation
4. Green Building
5. Green Space
6. Innovation
7. Recycling
8. Standard of Living
9. Transportation
10. Water Quality and Conservation

The research projects include surveys that municipalities need to fill in, in an attempt to evaluate cities across the country. The first survey started in 2010, focused on Municipal Energy, and was sent to 655 US cities with a population greater than 50,000. The survey aims to rank cities on their use of energy from renewable sources and on their progress in improving energy efficiency.

Energy issues and indicators appear in the themes of "Energy Production and Conservation" and "Green Building" and they are presented in the table below.

2	**Energy Production and Conservation**	US DOE Green Power Network and Survey: Top three fuels used for power generation (6 points)
		Survey: Energy conservation incentives offered (2 points), green power offered by utility (2 points)
4	**Green Building**	USGBC LEED Project Directory: Number of total LEED-certified buildings (4 points) and any number of LEED-platinum buildings (1 point)
		EPA Energy Star: Any number of Energy Star-rated buildings (2 points)
		Survey: Use of an alternative green building certification system (1point); sprawl reduction strategies (2 points)

The extensive list of themes and indicators used in the surveys are included in the Appendix I.

2.2.3.5 Sustainable Cities Index

The Sustainable Cities Index is a project developed by the Forum of the Future, a leading non-governmental organization in the UK. It tracks progress on sustainability in Britain´s 20 largest cities, highlighting their environmental performance, quality of life and their readiness for the challenges of the future. The index is intended to highlight and reward cities' achievements, encourage healthy competition, and give citizens the tools to hold their leaders to account (the Forum of the Future, 2012). The Sustainable Cities Index is independently researched. Hence, it is not dependent on voluntary submissions of local governments.

The index measures cities on 13 indicators in three broad baskets:

1. Environmental impact – the city's impact in terms of resource use and pollution;
2. Quality of life – what the city is like for people to live in;

3. Future-proofing – how well the city is preparing for a sustainable future.

A small number of indicators have been deliberately chosen in an attempt to give an insight into the cities´ sustainability, rather than as an exhaustive representation. Energy indicators appear only in the "environmental impact basket" and they are presented in the table below.

1	**Environmental impact basket**	Ecological footprint – the impact of services, food, housing, transport and consumables on the environment (2004 estimates).

The extensive list of indicators used in the Sustainable Cities Index can be found in Appendix I.

2.2.3.6 Sustainable Cities Report

The Sustainable Cities Report is a ranking methodology for Canadian cities, developed by Corporate Knights, an independent Canadian based media company with an explicit focus on corporate responsibility. The most populous centres in each province and territory and the ten most populous cities in the country are selected for inclusion. Cities are then grouped into three groups based on population: Big Cities have over 700,000; Medium Cities have over 250,000; and Small Cities have between 10,000 and 250,000 (Corporate Knights, 2011).

The ranking scores cities based on 28 indicators across 5 categories:

1. Ecological integrity
2. Economic Security
3. Governance and Empowerment
4. Infrastructure and Built environment
5. Social Well-Being

Data collection for each indicator makes use of a variety of sources, including Statistics Canada and Environment Canada, and a detailed survey designed by Corporate Knights (Corporate Knights, 2011).

Energy issues appear in the categories of "Ecological Integrity", "Governance and Empowerment", and "Infrastructure and Built Environment" and they are further presented in the table below.

1	**Ecological Integrity**	Current GHG reduction levels
		Total environmental footprint
3	**Governance and Empowerment**	GHG emissions target
4	**Infrastructure and Built Environment**	Community/Business Solar/Geothermal/retrofit programs
		Developer Incentives for Green buildings (geothermal/solar/green roof/grey water/bike parking)

The extensive list of themes and indicators, used in Sustainable Cities Report by Corporate Knights, is presented in Appendix I.

2.2.3.7 Sustainlane

SustainLane US City Rankings is a proprietary, peer-reviewed, national survey that ranks the 50 most populous US cities in terms of their sustainability practices. The ranking aims to explain how people's quality of life, and city economic and management preparedness are likely to fare in the face of an uncertain future (SustainLane, 2012). It has been developed by SustainLane.com, an online community connecting local people interested in living healthy on a green planet.

The overall rankings were determined by averaging 16 individual category rankings:

1. Air Quality
2. City Commuting
3. City Innovation
4. Energy & Climate Change
5. Green Building
6. Green Economy
7. Housing Affordability
8. Knowledge & Communications
9. Local Food & Agriculture
10. Metro Street Congestion
11. Metro Transit Ridership
12. Natural Disaster Risk
13. Planning & Land Use
14. Top Water Quality
15. Waste Management
16. Water Supply

All data and information, used for the 2008 US SustainLane city ranking, were drawn from surveys and interviews from and from publicly available sources published in the period between 2002-2008 (SustainLane, 2012).

Energy indicators appear in the categories of "City Innovation", "Energy and Climate Change", "Green Building" and "Green Economy" and they are presented in the table below.

6	**Green (LEED) Building**	Number of US Green Building Council's Leadership in Energy and Environmental Design (LEED) certified and registered buildings (number of LEED buildings per 100,000 people)
11	**Green Economy**	Green, or LEED (Leadership in Energy and Environment) buildings per capita
		Presence of a city or public-private incubator for clean technology industries, including renewable energy, advanced transportation, advanced water treatment, alternative fuels, green building, and energy efficiency
12	**Energy and Climate Change Policy**	City greenhouse gas tracking and carbon emission inventories
		Carbon emission reduction goals
		Overall renewable energy use
		Percentage for each city's alternative fueled vehicles as part of the total vehicle fleet was credited to cities with such fleets of greater than 12 percent of total fleet
		Additional credit was given to cities that had formally signed onto the US Mayor's Climate Protection Agreement begun by Seattle Mayor Greg Nickels, had instituted significant, wide-ranging mitigation or adaptation programs, or had mounted significant city-wide planning efforts as of December 2007
13	**City Innovation**	City commercial green building incentives
		City residential green building incentives

The full list of themes and indicators, used in SustainLane US city ranking in 2008, is presented in Appendix I.

2.2.3.8 Quality of living

Quality of Living is a global city ranking survey developed by Mercer, a consultancy for Human Resources with global work (Mercer, 2011). The ranking measures cities upon 10 categories:

1. Political and Social Environment
2. Medical and Health Considerations
3. Public Services and Transport
4. Consumer Goods
5. Economic Environment
6. Schools and Education
7. Recreation
8. Housing
9. Socio-Cultural Environment
10. Natural Environment

The methodology and information about data collection for the ranking survey are not publicly available. The Quality of living report of 2011 is available for sale online.

Energy indicators are included in the “Natural Environment” Category and they are presented in the table below.

3	**Public Services & Transport**	Electricity
10	**Natural Environment**	Climate

The complete list of themes and the 39 indicators used in Quality of Living is included in the Appendix I.

2.2.4 An overview of energy indicators used in literature

As it can be remarked from the previous sections, despite their similarities, urban sustainability assessments and city rankings are very different in their approaches or methods. Since they are often targeted on different goals, the chosen themes and indicators used, differ significantly. Even for assessments that are focused on the same goals, like sustainability or environmental performance of cities, the variations of parameters and indicators are considerable. In reality, it is impossible to find in the literature one single "official" list of indicators assessing urban sustainability, a fact that is in accordance with the analysis of Maclaren (1996) about different conceptualizations of urban sustainability by the various local communities, as mentioned in section 2.1.

Likewise, energy issues are also assessed with a wide range of indicators, in the different urban assessments and city rankings. Some assessments devote a whole theme/category only on energy issues, while others include energy indicators either in the themes of environmental performance or other categories. However, despite the variations of indicators and themes, one may encounter common topics, related to energy sustainability, in all urban assessments. For instance, most urban assessments will include the themes of energy consumption or energy performance of the city or the area, the amount of GHG or CO_2 emissions, the energy performance of buildings, the penetration of renewable energy production in the total amount of energy consumed, and policies or strategies promoting energy efficiency.

The graphic lists below show the thematic clusters of energy indicators as encountered in all different assessments and rankings for urban sustainable development in the existing literature. Once more here, it needs to be stressed that the present study has been focused on energy sustainability only of the urban built environment. Hence, energy indicators related to sustainable transport or energy extraction from waste have not been included.

Emissions

- Local contribution to global climate *(ECII)*
- Total CO_2 emissions per capita [tonnes/cap/year] *(ICLEI), (EGCI)*
- CO_2 intensity-total CO_2 emissions per unit of GDP [grams /€GDP_{2000}] *(EGCI)*
- GHGs emissions inventory *(SLCR)*
- CO_2 emissions inventory *(SLCR)*
- Total CO_2 eq. per capita, icluding emissions resulting from use of electricity [tonnes/capita/year] *(EGCA)*
- CO_2 per capita resulting from use of natural gas [tonnes/cap/year] *(EGCA)*
- CO_2 per capita resulting from transport [tonnes/cap/year] *(EGCA)*
- Grams of CO_2 per kWh used [gr/kWh] *(EGCA)*
- Current GHG reduction levels *(SCR)*
- GHG emissions target *(SCR)*

Buildings

- Total final energy consumption in the residential sector, per square metre of residential floor space [GJ/m2/year] *(EGCI)*
- Energy consumption & performance of municipal buildings per square meter (Not given-GJ/m2/year) *(EGCA)*
- Number of total LEED-certified buildings (4 points) and any number of LEED-platinum buildings *(SrC)*
- Use of alternative green building certification system *(SrC)*
- Community/Business Solar/geothermal/retrofit programs *(SCR)*
- Developer Incentives for Greenbuildings (geothermal/solar/green roof/grey water/bike parking) *(SCR)*
- Number of LEED-certified buildings *(SCR)*

Energy consumption

- Total electricity consumption per capita [kWh/cap/year] *(ICLEI)*
- Total final energy consumption in Gigajoules per year [Gj/year] *(EGCI)*
- Total final energy consumption, in MJ per unit of real GDP, in Euros, base year 2000 [MJ/ GDP_{2000}] *(EGCI)*
- Use of electricity per GDP *(SC)*
- Ecological footprint – the impact of services, food, housing, transport and consumables on the environment *(SCI)*
- Total envrionmental footprint *(SCR)*

European Common Indicators Initiative: ECII

Status Tool, ICLEI: ICLEI

European Green City Index: EGCI

Sustainlane ranking: SLCR

European Green Capital Award: EGCA

Smart Cities: SC

Smarter Cities: SrC

Sustainable Cities Index: SCI

Sustainable Cities Report: SCR

Quality of Living:QOL

Figure 8: Overview of the energy indicators for urban sustainable development, as encountered in the literature, clustered in the main common themes

Policy-Qualitative

- The strategy of renewable vs non-renewable mix as well as the renewable energy mix (different renewable energy sources) dynamics for the coming two decades ***(EGCA)***
- CO2 Reduction strategy: An assessment of the ambitiousness of CO2 emissions reduction strategy ***(EGCI)***
- Clean and Efficient Energy Policies: An assessment of the extensiveness of policies promoting the use of clean and efficient energy ***(EGCI)***
- Energy-efficient buildings standards: An assessment of the extensiveness of cities' energy efficiency standards for buildings ***(EGCI)***
- Energy-efficient building initiatives: An assessment of the extensiveness of efforts to promote energy efficiency of buildings ***(EGCI)***
- GHG emissions target ***(SCR)***
- Additional credit was given to cities that had formally signed onto the US Mayor's Climate Protection Agreement begun by Seattle Mayor Greg Nickels, had instituted significant, wide-ranging mitigation or adaptation programs, or had mounted significant city-wide planning efforts as of December 2007 ***(SLCR)***
- Presence of a city or public-private incubator for clean technology industries including renewable energy, alternative fuels, green buidlings &energy efficiency ***(SLCR)***
- Energy conservation incentives offered ***(SrC)***
- Sprawl reduction strategies ***(SrC)***

Renewable energy

- Share of energy consumption produced by renewables [% of energy produced by renewables on the total energy produced by the whole population-residential, commercial, institutional, industrial] ***(ICLEI)***
- Capacity installed for renewable energy production [kW/inhabitant] ***(ICLEI)***
- Renewable Energy consumption- The percentage of total energy derived from renewable sources, as a share of the city's total energy consumption [%TJ] ***(EGCI)***
- Overall renewable energy use ***(SLCR)***
- Share of energy provided in the city that is sourced from renewable energy sources ***(EGCA)***
- Green power offered by utlity ***(SrC)***

European Common Indicators Initiative: ECII

Status Tool, ICLEI: ICLEI

European Green City Index: EGCI

Sustainlane ranking: SLCR

European Green Capital Award: EGCA

Smart Cities: SC

Smarter Cities: SrC

Sustainable Cities Index: SCI

Sustainable Cities Report: SCR

Quality of Living: QOL

Figure 9: Overview of the energy indicators for urban sustainable development, as encountered in the literature, clustered in the main common themes

As it can be seen from figures 8 and 9, the energy indicators, found in the literature, were clustered in five broad categories:

1. Emissions, including all indicators encountered that measure CO_2 equivalent or Greenhouse Gas Emissions (GHGs)
2. Energy consumption, including all indicators encountered in literature measuring the total energy consumption of the city per inhabitant, per year or per GDP
3. Buildings, including all indicators that measure the energy performance of buildings
4. Renewable energy, including all indicators encountered that measure the share of energy demand produced by renewable sources, or the capacity installed for renewable energy production
5. Qualitative-policies, including all qualitative indicators found in the urban assessments or indicators promoting policies, strategies and goals of the city/area for improving energy performance

To sum up the foregoing, it was observed that, despite the differences in methodologies, certain energy themes and indicators are repeated often in urban sustainability assessments.

Firstly, indicators related to emissions were found in almost all assessments; some were focused on Greenhouse Gas Emissions, while others were only measuring CO_2 emissions. Secondly, all assessments refer to the general energy performance of the city/area; the methodologies for measuring this performance vary a lot though. Some rankings include indicators measuring energy consumption per capita, others energy consumption per GDP, while others, instead of including specific indicators of energy use, measure the total environmental footprint. Thirdly, the assessments and rankings examined assess the buildings' energy performance by measuring the number of certified buildings and the respective ratings. The certificate mostly used in the assessments for U.S. cities is the LEED Green Building Rating System developed by U.S. Green Building Council. Lastly, most of the assessments measure the penetration of renewables in the energy sector of the area by measuring the share of total energy consumed within the area, which has been produced by renewable energy sources.

The specific themes and indicators have been considered in order to develop the generic list of energy indicators of urban sustainable development, as it is further explained in chapter 3.

3. Towards a Comprehensive List of Energy Indicators for Sustainable Urban Development

3.1 Creating a generic list of energy indicators for urban sustainable development

The present chapter is focused on presenting the methodology used for creating a generic list of preferred energy indicators for urban sustainable development. The various energy indicators for urban sustainable development, found in the literature and presented in chapter 2, were used to create a generic list of preferred themes and indicators for energy sustainability on the urban level. The generic list of indicators comprises of the preferable indicators from those found in the various official lists and city rankings, as well additional indicators devised by the author. The additional indicators were based on themes and goals considered important for energy sustainability on the urban level, which were not included in the existing lists found in the literature.

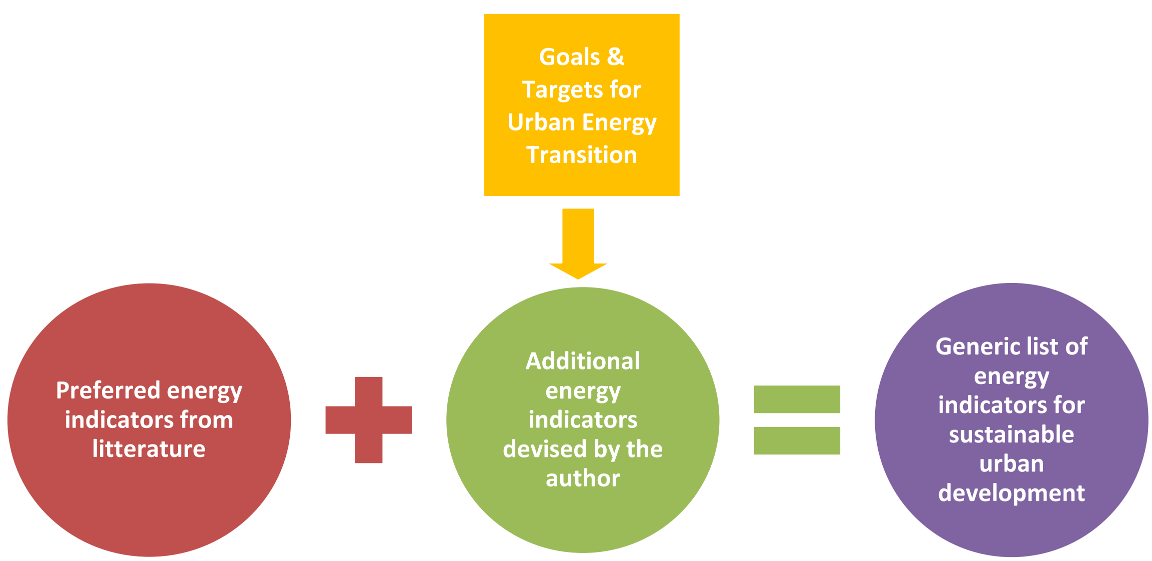
3.1.1 Methodology

In order to draw up a generic list of energy indicators for urban sustainable development, a three-stepped methodology was applied.

Firstly, a selection of the energy indicators- found in the literature and presented in Chapter 2 and Appendix I- was made. Those indicators and themes, which appeared most often in the lists in the literature, were chosen for inclusion in the generic list of energy indicators for urban sustainable development. The indicators, expressed in different metric systems of units, were transformed accordingly to the International System of units (SI).

Secondly, in order to come up with additional energy indicators, not included in the existing lists from the literature, it was essential to define a set of goals for achieving urban energy transition. Specific goals were needed in order to define the main necessary targets of action in order to achieve sustainable energy development in the urban environment.

Lastly, as soon as the specific targets were defined, indicators were devised to monitor the progress of urban areas towards these targets. These devised indicators, and the indicators selected from the literature review, comprised the generic list of energy indicators for urban sustainable development.



To define the targets for sustainable urban energy development, the ultimate goal was decided to be a climate neutral urban environment, i.e. renewable and sustainable power based urban communities, whether cities, towns, or villages. This can be best achieved through a hierarchy of actions that include, firstly, aggressive reduction of energy consumption, and secondly, conversion to totally renewable energy systems.

Hence, the main goals set for sustainable urban areas were:

1. Reduce energy demand
2. Use renewable energy

Nevertheless, before the transition to renewable power is complete, clean, and efficient use of fossil fuels, might be necessary as an intermediary step. Hence, a third step could be added for the transitional period:

3. Supply the remaining demand cleanly and efficiently

The specific three-stepped strategy is also known as Trias Energetica and it has been applied in different sustainable approaches to urban areas since the end of 1980s (Tillie et al, 2009).

For the present study, focus was given mostly to achieving the first two goals. Consequently, the indicators of the generic list refer to these goals.

3.1.2 Boundaries

The present study has been focused on sustainable energy in the urban environment and more specifically, on the creation of a generic list of energy indicators that would measure the progress towards a fossil fuel-free urban environment. That can be achieved with a great number of combined actions and interventions on: power generation systems, urban planning, buildings design and architecture, transport, waste management, citizens' consumption patterns, local policies, water management, and other areas where energy use is included.

However, due to time restriction the present study was focused on sustainable energy indicators only within the built environment. Transport and waste are also two key areas for the transition towards energy sustainability in the urban environment; transport, because it is one of the highest consuming sectors within the urban environment, and waste, because of the large potential of energy that can be extracted from it. Nevertheless, these two themes include many issues and the definition of the right energy indicators within these fields requires an additional extensive study. Therefore, the created list of generic energy indicators includes only energy indicators relevant to the urban built environment and not to transport or waste.

Furthermore, the proposed generic list of energy indicators only comprises of quantitative indicators. Qualitative indicators measuring policies and strategies leading to sustainable urban development were not included. The field of policies is highly important for urban energy transition and requires extensive study. Besides, it is mostly relevant at the city level , rather than at the neighbourhood or district level. Consequently, any qualitative indicators for energy policies and strategies were not included in the generic list of energy indicators.

3.1.3 Goals for urban energy transition

The complete set of goals and targets, which was devised as a preliminary step to the creation of the generic list of energy indicators for urban sustainable development is presented in Box IV:

Box IV: The set of goals and targets devised for achieving sustainable energy development in the urban environment

Reduce Energy Demand (and subsequently CO_2 Emissions)

- ***With sustainable urban design***
  - *Optimize orientation to take advantage of passive solar design principles*
  - *Optimize orientation and solar exposure to maximize the use of renewable resources in the operation of buildings and complexes*
  - *Fight heat island effect and reduce energy demand for cooling*
  - *High density compact communities with functional mix (save energy by avoiding energy losses through transmission, facilitating communal and district heating and avoiding long distance transport)*
- ***With sustainable buildings***
  - *Bioclimatic design (glass architecture)*
  - *Passive solar techniques*
  - *Natural ventilation*
  - *High insulation*
  - *Green roofs*
  - *Shading*
- ***With reuse of waste energy***
- ***With sustainable consumption***
  - *Energy metering and monitoring at both city and building level*
  - *Highly-efficient appliances for houses*
  - *Highly-efficient lighting on the city scale*

Generate power sustainably

- ***With renewable energy resources***
  - *Solar energy*
  - *Wind energy*
  - *Geothermal energy*
  - *Biomass*
  - *Mini-hydropower*
- ***With highly efficient technologies***
  - *CHP*
  - *Heat pumps*
  - *Use of energy storage*

As it can be seen, the two main goals set for sustainable urban energy transition are: “reduce energy demand” and “generate power sustainably”.

For the reduction of energy demand, four different areas of action were chosen: interventions on urban scale, interventions on building scale, reuse and recycling of waste energy, and reducing the consumption.

The second goal, "generate power sustainably", includes the power generation of renewable energy resources and the use of highly efficient technologies that can be combined either with renewable energy sources or with fossil fuels.

3.2 The list of suggested energy indicators for urban sustainable development

A list of proposed energy indicators for urban sustainability was created based on the goals determined for urban energy transition, and taking into account the most common energy indicators found in the literature,. One or more indicators were coupled for each target.

The indicators were divided into two levels of importance: the key indicators and the secondary indicators. The key energy indicators are the most important indicators for giving an overview of the energy performance of an urban area, and evaluating the progress towards energy sustainability. These indicators should be included in every assessment for urban sustainable development. The secondary indicators are useful as explanatory indicators; they show why the outcome of the key indicators was favourable or unfavourable. Hence, they measure different characteristics and parameters of the area that affect the total energy performance. In total, the list comprises of 4 key indicators and 21 secondary indicators.

The generic list of indicators is presented in tables 2, 3, and 4. Table 2 includes the key indicators and tables 3 and 4 the secondary ones. The left columns of the tables include the goals determined for urban energy transition, while the right columns include the relevant indicators serving the specific goals.

Table 2: Generic list of key energy indicators for urban sustainable development

Key indicators				
Goals	**Sub-goals**	**No**	**Indicator**	**Unit**
Reduce Energy Demand and subsequently CO_2 emissions		K1	*Total final energy consumption per capita*	(MJ/cap/year)
		K2	*Total final electricity consumption per capita*	(kWh/cap/year)
		K3	*Total CO_2 eq. emissions per capita, including emissions resulting from use of electricity*	(tones CO_2/cap/year)
Generate Power Sustainably		K4	*Percentage of total energy consumption produced by renewable energy sources*	(%)

Table 3: Generic list of secondary energy indicators (part 1)

<table>
<tr><th colspan="5">Secondary Indicators (1)</th></tr>
<tr><th>Goals</th><th>Sub-goals</th><th>No</th><th>Indicator</th><th>Unit</th></tr>
<tr><td rowspan="4">Reduce energy demand with sustainable urban design</td><td>Optimize orientation to take advantage of passive solar design principles</td><td>S1</td><td>Percentage of floor area of buildings or blocks orientated to the south within 25 degrees (for northern hemisphere) or to the north (for southern hemisphere)</td><td>(%)</td></tr>
<tr><td>Optimize orientation and solar exposure to maximize the use of renewable resources in the operation of buildings and complexes</td><td>S2</td><td>Percentage of m^2 of roofs in the area that are flat or south-facing sloped</td><td>(%)</td></tr>
<tr><td>Promote mixed use compact city model</td><td>S3</td><td>Population and jobs per m^2</td><td>(inhabitants/m^2 & number of employed citizens/m^2)</td></tr>
<tr><td>Improve urban microclimate, fight heat island effect and reduce energy demand for cooling</td><td>S4</td><td>Percentage of Urban Tree Canopy Cover</td><td>(% of the m^2 of the area, which when seen from above, is occupied by tree crowns)</td></tr>
<tr><td rowspan="6">Reduce energy demand with sustainable buildings</td><td rowspan="6">• Reduce energy demand of buildings by bioclimatic design and passive solar techniques
•Reduce energy demand of buildings by applying natural ventilation
•Reduce energy demand of buildings with high insulation
•Reduce energy demand of buildings with green roofs and green façades</td><td>S5</td><td>Total energy consumption of buildings within a year per m^2 of floor area/division for space heating and cooling, water heating, ventilation and lighting</td><td>(GJ/m^2/year)</td></tr>
<tr><td>S6</td><td>Total electricity consumption of buildings within a year per m^2 of floor area/division for space heating and cooling, water heating, ventilation and lighting</td><td>(kWh/m^2/year)</td></tr>
<tr><td>S7</td><td>Total CO_2 eq. emissions within a year per m^2 floor area resulting from building sector/division for space heating and cooling, water heating, ventilation and lighting</td><td>(kg CO_2 eq/ m^2/year)</td></tr>
<tr><td>S8</td><td>Share of floor area of buildings ranked with the maximum score on the national building rating system</td><td>(%)</td></tr>
<tr><td>S9</td><td>Share of floor area of passive buildings in the area</td><td>(%)</td></tr>
<tr><td>S10</td><td>Share of floor area of zero-energy buildings in the area</td><td>(%)</td></tr>
</table>

Table 4: Generic list of secondary energy indicators for urban sustainable development (part 2)

Secondary Indicators (2)				
Goals	**Sub-goals**	**No**	**Indicator**	**Unit**
Reduce energy demand with reuse of waste energy	–	S11	*Net amount of waste heat generated that is imported/exported in/out of the area's boundaries*	(MJ/cap/year)
Reduce energy demand with sustainable consumption	***Energy metering and monitoring on city and building level***	*S12*	*Share of floor area of buildings with installed sub-metering energy systems*	*(%)*
	Highly – efficient lighting and infrastructure on the whole city scale	*S13*	*Share of energy efficient public lighting within the area*	*(%)*
Generate sustainably with renewable energy sources	***Generate sustainaibly using solar energy***	*S14*	*Percentage of total energy derived from solar power as a share of the area's total energy consumption*	*(%)*
	Generate sustainaibly using wind energy	*S15*	*Percentage of total energy derived from wind power as a share of the area's total energy consumption*	*(%)*
	Generate sustainably using geothermal energy	*S16*	*Percentage of total energy derived from geothermal power station as a share of the area´s total energy consumption*	*(%)*
	Generate sustainably using biomass	*S17*	*Percentage of total energy derived from biomass power stations as a share of the area´s total energy consumption*	*(%)*
	Generate sustainably using hydropower	*S18*	*Percentage of total energy derived from hydropower stations as a share of the area´s total energy consumption*	*(%)*
Generate sustainably with highly efficient technologies	***Generate sustainably with CHP***	*S19*	*Percentage of total energy consumed within a year that has been produced by combined heat and power plants*	*(%)*
	Promote district/ community heating	*S20*	*Percentage of total heat demand that has been covered by district/ community heating*	*(%)*
	Use of energy storage	*S21*	*Percentage of total energy consumed within a year that has been stored for a period before being consumed*	*(%)*

3.3 Complete description of each indicator

This section presents definitions and details about each of the energy indicators included in the generic list of energy indicators for urban sustainable development. The purpose of use of each indicator and the reasoning behind the selection are further explained.

Key Indicators

Indicator K1: Total final energy consumption per capita

Brief Definition	The sum of energy consumption in one year by the different end use sectors on a per capita basis
Unit	MJ / capita
Relevant Goal	Reduce energy demand and subsequently CO_2 emissions
Type	Key Indicator

Purpose: This indicator measures the level of energy use on a per capita basis and reflects the energy-use patterns and aggregate energy intensity of an urban area.

Data needed to compile the indicator: Energy commodity for use of energy (energy balance) and year population.

Relevance to sustainable urban development: This specific indicator is the most important for measuring and monitoring the energy use of an area. Energy consumption can be measured every year, specific reduction targets can be determined and the progress towards the goals can be monitored. The indicator is relevant to the general goal of reducing the total energy demand of an urban area, one of the three primary steps towards sustainable energy transition. Indicators measuring the energy use are included in most of the city assessments and rankings. However, energy use is not always measured on a per capita basis. Some assessments measure energy use per GDP and others measure energy consumption in kWh. For the specific list, the per capita indicator was selected since it gives a better insight of real energy consumption and because it facilitates the comparison of energy use levels between different cities. Moreover, all indicators were chosen to be in SI units.

Indicator K2: Total final electricity consumption per capita

Brief Definition	The amount of electricity consumed by citizens (residential, industrial and other sectors) in one year in the area, regardless of the reason for the usage
Unit	kWh/capita /year
Relevant Goal	Reduce energy demand and subsequently CO_2 emissions
Type	Key Indicator

Purpose: The indicator measures the level of electricity use on a per capita basis and reflects the electricity-use patterns of a city or an area.

Data needed to compile the indicator: Electricity data per year provided by the energy providers and year population. There might be certain difficulties, because, since the liberalization of energy markets in many countries, the providers might be reluctant to provide data related to electricity consumption, due to its commercially sensitive nature (STATUS, 2012).

Relevance to sustainable urban development: Electricity is a key requirement of modern societies and a prerequisite for standard quality of life. However, electricity use, when is based on use of fossil fuels, can become a major cause of air pollution and climate change. Measuring the demands of a society for electricity, a general overview of the consumption patterns is acquired and strategies for reducing irrational consumption can be determined. The indicator serves the general goal of reducing the total energy demand of the area by measuring and controlling the electricity demands of the area. This indicator, together with the first indicator, that measures total energy demand, can give a total overview of the whole energy system and consumption patterns.

Indicator K3: Total CO_2 eq. emissions per capita, including emissions resulting from use of electricity

Brief Definition	The amount of carbon dioxide equivalent emissions released into the atmosphere per capita, due to the energy consumed by all citizens in one year
Unit	Tones CO_2/capita/year
Relevant Goal	Reduce energy demand and subsequently CO_2 emissions
Type	Key Indicator

Purpose: The indicator measures the CO_2 equivalent emissions, a metric measure used to compare the emissions from various greenhouse gases based upon the global warming potential. Carbon dioxide equivalents are commonly expressed as 'million metric tonnes of carbon dioxide equivalents (MMTCDE). The carbon dioxide equivalent for a gas is derived by multiplying the tones of the gas consumed by the associated global warming potential weighting factor.

Data needed to compile the indicator: Electricity and fuel consumption and year population

Relevance to sustainable urban development: Over the past 100 years, global mean temperature has increased by 0.7 °C and in Europe by about 1.0 °C. Each decade over the past half century has been hotter than the last (Heinzerling, 2010). Temperatures are projected to increase further by 1.4 to 5.8°C by 2100, with larger increases in Eastern and Southern Europe. There is increasing evidence that most of this warming can be attributed to the emission of greenhouse gases and aerosols from human activities. Warming-up of the atmosphere is part of changes in climate and (extreme) weather conditions. If these changes persist, they will influence water availability, flood hazards, agricultural productivity, and natural areas. Reducing CO_2 emissions should be therefore one of the highest priorities for any local authority.

Indicator K4: Percentage of total energy consumption produced by renewable energy sources

Brief Definition	Percentage of energy consumed within the area within a year, which has been derived from renewable sources, such as sunlight, wind, biomass, geothermal heat, tides
Unit	%
Relevant Goal	Generate power sustainably
Type	Key Indicator

Purpose: The indicator measures the amount of energy consumed within the area, which has been derived from renewable energy sources. The ultimate goal for a fossil fuel free area is to reach to 100% of energy consumption covered by renewable(s).

Data needed to compile the indicator: The amount of energy consumed coming from renewable energy sources and the amount of total energy consumed within the area.

Relevance to sustainable urban development: Renewable energy derives from natural processes that are replenished constantly, and replaces conventional fuels in electricity generation, hot water/space heating and motor fuels. Renewable energy use has the advantage of not resulting in any CO_2 emissions (apart from the embodied ones during manufacturing and construction) and is the main way towards sustainable energy future. So far, the share of total energy consumption that has been produced globally by renewable energy sources is not enough to mitigate the problem of climate change. New but also existing urban areas need to move away from fossil power and other forms of unsustainable energy generation, to a renewable and sustainable power base. By measuring the share of renewable energy production, this indicator monitors the progress achieved so far towards a fossil fuel free urban environment. Another indicator often encountered for measuring renewable power generation is the one measuring the total capacity of renewable energy production installed within the area. However, this indicator does not facilitate the comparison between different urban areas. For this reason, the indicator measuring the share of total energy covered by renewable(s) was preferred.

Secondary Indicators

Indicator S1: Percentage of floor area of buildings or blocks orientated to the south within 25 degrees (for northern hemisphere) or to the north (for southern hemisphere)

Brief Definition	The share of floor area of buildings, existing in the area, which have an orientation to the south, meaning that their total parcel frontage is within 25 degrees of south (for areas in northern hemisphere). The opposite applies for areas in the southern hemisphere
Unit	%
Relevant Goal/Sub-goal	Reduce energy demand with sustainable urban design/Optimize orientation to take advantage of passive solar design principles
Type	Secondary Indicator

Purpose: This indicator measures the solar orientation intensity, the degree to which the aspect of the lot enables passive solar design to reduce heating, cooling, and lighting requirements throughout the year.

Data needed to compile the indicator: The floor area of buildings in m^2 whose total parcel frontage is within 25 degrees of south/or north and the total floor area of buildings. The floor area of a building is a real estate/ architecture term referring to the amount of area measured in m^2 (or square feet) taken up by a building or part of it. The ways of defining the "floor area" depend on what factors of the building should or should not be included, such as external walls, internal walls, corridors, lift shafts, stairs etc. For the generic list of energy indicators floor area refers to gross floor area, which is the total floor area contained within the building measured to the external face of the external walls.

Relevance to sustainable urban development: Southern orientation is one of the passive solar design techniques that take advantage of solar gains and in that way reduce the energy requirements of the building. Southern orientation of the parcel and the building enables even traditional designs to take advantage of sunlight. The maximum profit of solar gains is achieved when the longer axis of the building, also known as the ridgeline, is oriented east/west. By facing the ridgeline this direction, the longer dimension of the building faces the sunny south, for buildings in the northern hemisphere, or the opposite for buildings in the southern hemisphere. Although the optimum position for maximum solar benefits is true south, the orientation may vary within 25 degrees with minimal effect. Depending on the climate and the design, as much as 100% of a building's heating needs can be provided by the sun. Hence, the right orientation of buildings can contribute significantly to the reduction of total energy demand of the urban built environment. Controlling the buildings heights to prevent over-shadowing neighbouring buildings, is a strategy that can support the specific goal (The European Passive Solar Handbook, 1992).

Indicator S2: Percentage of m^2 of roofs in the area that are flat or south-facing sloped

Brief Definition	The share of surface of roofs within the area, which are flat or south-facing sloped available for installation of renewable energy production technologies
Unit	%
Relevant Goal/Sub-goal	Reduce energy demand with sustainable urban design/Optimize orientation and solar exposure to maximize the use of renewable resources in the operation of buildings and complexes
Type	Secondary Indicator

Purpose: This indicator measures the number of buildings whose design facilitates the operation of renewable energy technologies.

Data needed to compile the indicator: The total surface of roofs, which are flat or sloped with south orientation, and the total surface of all roofs within the area

Relevance to sustainable urban development: The optimal orientation of buildings favours not only passive solar design techniques, but also the use of renewable energy sources. Ideal parts of buildings for renewable energy installations (such as solar PV panels or urban wind turbines) are usually roofs and south-facing slopes. The higher the number of buildings with optimal orientation and available roofs, the greater the potential for renewable energy production in the urban area; controlling the buildings' heights works as a supporting strategy next to optimal orientation. This indicator serves the goal of optimizing orientation and belongs to the category of sustainable design interventions for energy efficiency.

Indicator S3: Population and jobs per m^2

Brief Definition	The amount of people living and the amount of people working in the area
Unit	Population/m^2 and employed citizens per m^2
Relevant Goal/Sub-goal	Reduce energy demand with sustainable urban design/Promote mixed-use, compact city model
Type	Secondary Indicator

Purpose: This indicator comprises of two complementary indicators measuring the population and the employed citizens per m^2 in the area, as an indication of the density levels of the area and hence, the energy requirements.

Data needed to compile the indicator: The amount of residents of the area, the amount of people working within the area, and the total surface of the area in m^2.

Relevance to sustainable urban development: The density of cities is one of the primary goals of New Urbanism[3]. The placement of buildings and how compactly they are grouped can have a profound and direct impact on energy consumption and, thus, on CO_2 emissions. Compact building blocks prevent transmission losses from walls to the outer environment. Moreover, compact cities have the advantage to facilitate communal and district heating, which is far more energy efficient than individual heating systems. Moreover, mixed-use cities prevent long distance transport and subsequently, reduce the vast energy demand for transport. Besides, functional mix in cities distributes energy demand over a larger portion of the day, which eliminates high peaks of energy demand. However, higher density requires

[3] New Urbanism is an urban design movement, which arose in the US in the early 80's. It promotes mixed land uses, greater dependence on public transport, cycling and walking, decentralization of employment location and traditional neighborhood design (Calthorpe, 1993 & Katz, 1994)

careful design of high quality public space within the limited space available (Lehmann, 2008). These two indicators were chosen to promote the compact city model and its significant contribution to energy savings.

Indicator S4: Percentage of Urban Tree Canopy Cover

Brief Definition	The percentage of the area, which when seen from above, is occupied by tree crowns
Unit	%
Relevant Goal/Sub-goal	Reduce energy demand with sustainable urban design/Improve urban microclimate, fight heat island effect and reduce energy demand for cooling
Type	Secondary Indicator

Purpose: This indicator measures the amount of urban forest, as a factor that reduces heat island effect and thus, energy demand for cooling.

Data needed to compile the indicator: The proportion of the area that, when viewed from above, is occupied by tree crowns or the layer of leaves, branches, and stems of trees that cover the ground.

Relevance to sustainable urban development: Urban heat island effect is one of the problems facing modern urban areas and one of the reasons for an increased energy demand for cooling in cities. Urban heat island is a metropolitan area, which is significantly warmer than its surrounding rural areas. During the night, buildings block surface heat from radiating into the relatively cold night sky. Moreover, the lack of vegetation in urban areas does not allow the phenomenon of evapotranspiration to take place. Typically, electricity demand in cities increases by 2–4% for each 1°C increase in temperature. Hence, it is estimated that 5–10% of the current urban electricity demand is spent to cool buildings just to compensate for the increase of 0.5–3.0°C in urban temperatures (Akbari et al, 2001). Planting of urban trees is one inexpensive measure that can mitigate the heat island effect. There are many different methods and indices in the literature measuring the urban heat island effect, but no single one that is generally or officially approved. Hence, the indicator of "Urban tree canopy cover" was chosen as a general indication of the green within urban areas. This specific indicator offers a more complete image of the urban forest because it includes both public and privately owned trees. The bigger the urban tree canopy cover, the less the energy demands in urban areas.

Indicator S5: Total energy consumption of buildings within a year per m² of floor area/division for space heating and cooling, water heating, ventilation and lighting

Brief Definition	The amount of energy consumed by citizens (residential, industrial and other sectors) in one year in all buildings of the area, divided into the categories of: space heating and cooling, water heating, ventilation and lighting
Unit	$GJ/m^2/year$
Relevant Goal/Sub-goal	Reduce energy demand with sustainable buildings
Type	Secondary Indicator

Purpose: This indicator measures the total energy demand only at the level of the whole building, while giving information about the different categories for energy use, namely space heating and cooling, water heating, ventilation and lighting.

Data needed to compile the indicator: Yearly energy consumption for space heating and cooling, water heating, ventilation and lighting, for the whole building, and the total m^2 of buildings' floor area (for definition of the term "floor area" refer to indicator S1).

Relevance to sustainable urban development: Buildings currently account for 40% of energy use in most countries, putting them amongst the largest end-use sectors (IEA, 2010). The building sector has been identified as one of the most cost-effective sectors for reducing energy consumption, with estimated possible energy savings of 1509 million tonnes of oil equivalent (Mtoe) by 2050 (IEA, 2010). Moreover, by reducing overall energy demand, improving energy efficiency in buildings can significantly reduce carbon dioxide (CO_2) emissions from the building sector, translating to a possible reduction of 12.6 gigatones (Gt) of CO_2 emissions by 2050 (IEA, 2010). Therefore, measuring the energy patterns of building sector is of primary importance for achieving urban energy sustainability. The specific indicator is divided into four different categories of energy use at the building level in order to give a clear overview of energy consumption and facilitate decision making for strategies for improving urban energy systems.

Indicator S6: Total electricity consumption of buildings within a year per m² of floor area/division for space heating and cooling, water heating, ventilation and lighting

Brief Definition	The amount of electricity consumed by citizens (residential, industrial and other sectors) in one year in all buildings of the municipality, divided into different categories of electricity use for space heating and cooling, water heating, ventilation and lighting
Unit	kWh/m^2/year
Relevant Goal/Sub-goal	Reduce energy demand with sustainable buildings
Type	Secondary Indicator

Purpose: This indicator measures the electricity use per m^2 and reflects the electricity use patterns for every different energy service (space heating and cooling, water heating, ventilation and lighting).

Data needed to compile the indicator: Yearly electricity consumption for space heating and cooling, water heating, ventilation and lighting, at the building level, and the total m^2 of the buildings' floor area (for definition of the term "floor area" refer to indicator S1).

Relevance to sustainable urban development: This indicator gives complementary information about the energy use in the building sector. Knowing the energy and electricity consumption of buildings per year, any other fuel consumption can be calculated and thus the complete building sector's performance can be monitored.

Indicator S7: Total CO_2 eq. emissions within a year per m² floor area resulting from building sector/division for space heating and cooling, water heating, ventilation and lighting

Brief Definition	The amount of carbon dioxide equivalent emissions released into the atmosphere per m^2, due to the energy consumed by the building sector in one year
Unit	kg CO_2-eq/m^2/year
Relevant Goal/Sub-goal	Reduce energy demand with sustainable buildings
Type	Secondary Indicator

Purpose: This indicator measures the amount of CO_2 equivalent emissions released into the atmosphere due to energy consumed by the building sector.

Data needed to compile the indicator: Electricity and fuel use by the building sector on a yearly basis, CO_2 equivalent emissions factors, and the total m^2 of buildings' floor area (for a definition of the term "floor area" refer to indicator S1).

Relevance to sustainable urban development: This indicator focuses specifically on CO_2 emissions related to energy use only by the building sector, revealing how much the specific sector contributes to the total emissions of the whole city/area.

Indicator S8: Share of floor area of buildings ranked with the maximum score on the national building rating system

Brief Definition	The share of floor area of buildings in the urban area that have been ranked with the maximum score on the national building rating system
Unit	%
Relevant Goal/Sub-goal	Reduce energy demand with sustainable buildings
Type	Secondary Indicator

Purpose: This indicator measures the share of built surface that has been certified with the maximum score in the national building rating system. It is a complementary indicator of the energy performance of the building sector.

Data needed to compile the indicator: The total sum of m^2 floor area of buildings that have been certified with the maximum score in the national building system and the total m^2 of buildings floor area (for definition of the term "floor area" refer to indicator S1).

Relevance to sustainable urban development: In order to monitor and improve the energy performance of buildings, European countries have been obliged, since 2002, to develop national energy performance certificates based on general directives, and adapted to the national specific conditions and demands (BPIE, 2010). Building rating systems and certificates include indicators in different themes related to energy reduction at the building's level, such as bioclimatic design, passive solar techniques, insulation, materials etc. Based on these parameters a score system has been developed, showing the overall energy performance of the building. Scores are usually given with letters on a scale A to G, with A referring to the most energy efficient building and G to the least (IEA, 2010). Since national energy rating systems are compulsory and all new buildings must be ranked based on these systems, this indicator functions as a tool for comparison of building sectors between different areas/cities.

Indicator S9: Share of floor area of passive buildings in the area

Brief Definition	The share of floor area of buildings in the urban area that have been certified as passive houses
Unit	%
Relevant Goal/Sub-goal	Reduce energy demand with sustainable buildings
Type	Secondary Indicator

Purpose: This indicator measures the share of square footage of buildings in the area certified as passive houses, with annual heat requirement ≤ 15 kWh/m^2/year (for European constructions). Passive houses have a great potential to reduce energy consumption of buildings. Hence, by measuring the share of passive houses in the area, the specific indicator gives an additional indication of the general energy performance of the building sector of the area.

Data needed to compile the indicator: The total sum of m^2 floor area of buildings that have been certified as passive houses by the relevant authority and the total m^2 of buildings floor area (for a definition of the term “floor area” refer to indicator S1).

Relevance to sustainable urban development: A passive house is a building in which a comfortable interior climate can be maintained without active heating and cooling systems. The house heats and cools itself, hence "passive" (Passive House Institute, n.a.). Due to their low energy requirements, passive houses can contribute significantly to urban energy transition. When combined with renewable energy technologies, passive houses can become zero-energy buildings, a key element of fossil fuel free urban areas.

Indicator S10: **Share of floor area of zero-energy buildings in the area**

Brief Definition	The share of floor area of buildings in the area/city whose net energy consumption and CO_2 emissions annually is zero
Unit	%
Relevant Goal/Sub-goal	Reduce energy demand with sustainable buildings
Type	Secondary Indicator

Purpose: By measuring the share of floor area of buildings in the area with zero net energy consumption and zero CO_2 emissions, this specific indicator gives an additional indication of the general energy performance of the building sector of the area.

Data needed to compile the indicator: The total sum of m^2 floor area of buildings that have been certified as zero-energy buildings by a relevant authority, and the total m^2 of buildings’ floor area (for a definition of the term “floor area” refer to indicator S1).

Relevance to sustainable urban development: The requirements about the energy performance of new buildings are becoming higher and there are many ambitious developments in urban areas calling for zero net energy consumption for new buildings. This indicator, along with the one referring to passive houses, serves as a supplementary indication of the energy performance of the building sector in an urban area.

Indicator S11: Net amount of waste heat that is imported/exported in/out of the area's boundaries

Brief Definition	The amount of waste heat generated from processes taking place within the boundaries of the area that is exported for reuse outside the area’s boundaries, deducted from the amount of waste heat that is imported for reuse within the area’s boundaries
Unit	%
Relevant Goal/Sub-goal	Reduce energy demand with reuse of waste energy
Type	Secondary Indicator

Purpose: Reuse of waste heat is a way to reduce energy demand. Waste heat can be reused within the area's boundaries or can be exported to cover the heat demand of another area. This specific indicator measures the net amount of waste heat that is exchanged across the area's boundaries, as an indication of sustainable use of energy.

Data needed to compile the indicator: The amount of waste heat that is imported, the amount of waste heat that is exported and the precise boundaries of the area.

Relevance to sustainable urban development: Harnessing waste streams of heat is a way to reduce the primary energy demand. Heat can be a waste product from different processes, such as electricity generation or cooling processes. Instead of being released into the atmosphere, it could be reused to cover heat demand of other processes within the area or outside the area's borders, and subsequently reduce the total energy demand. This kind of process should be facilitated within the urban environment, and urban design can play a role in that by locating nearby facilities with complementary heat use patterns.

Indicator S12: Share of floor area of buildings with installed sub-metering energy systems

Brief Definition	The share of buildings in the area with installed sub-metering systems for monitoring energy use
Unit	%
Relevant Goal/Sub-goal	Reducing energy demand with sustainable consumption/ Energy metering and monitoring at both city and building level
Type	Secondary Indicator

Purpose: This indicator measures the share of floor area of buildings in the area, which have a metering system for monitoring energy use and consequently promoting rational energy use.

Data needed to compile the indicator: Floor area of buildings with energy metering systems and the total buildings floor area in the area (for definition of the term "floor area" refer to indicator S1).

Relevance to sustainable urban development: Monitoring energy use is one of the ways to observe demand patterns and peaks, and to control irrational consumption. Energy metering systems in buildings, measuring electricity consumption, can contribute to this. In fact, one of the most important factors for reducing energy demand is to change consumers' behaviour and current consumption patterns. Energy sub-metering systems can monitor the energy consumption of the different users in a building. Combined with display screens of the energy used and software for interactive monitoring of energy use, energy sub-metering systems can lead to conservation of energy and to reduction of total energy demand of buildings.

Indicator S13: Share of energy efficient public lighting within the area

Brief Definition	The share of public lighting which is provided by highly efficient fittings and appropriate control systems
Unit	%
Relevant Goal/Sub-goal	Reducing energy demand with sustainable consumption / Highly efficient lighting and infrastructure on the whole city scale
Type	Secondary Indicator

Purpose: This indicator measures the amount of public lighting that is provided with highly efficient systems and hence, the amount of energy savings gained on the specific sector of an area/city.

Data needed to compile the indicator: The amount of public lighting provided with energy efficient fittings and the total amount of public lighting.

Relevance to sustainable urban development: Providing street lighting is one of the most important and expensive responsibilities of a city (USAID, 2012): Lighting can account for 10-38% of the total energy bill in typical cities worldwide (NYCGP, 2009). Inefficient lighting wastes significant financial resources every year. Energy efficient technologies and design can cut street lighting costs dramatically, often by 25-60% (USAID, 2012) and reduce total energy use and CO_2 emissions. Therefore, measuring the energy performance of public lighting is one more tool for controlling and reducing total energy demand of an urban area.

Indicator S14: Percentage of total energy derived from solar power as a share of the area's total energy consumption

Brief Definition	The share of total energy consumed within the urban area, that has been derived from solar energy
Unit	%
Relevant Goal/Sub-goal	Generate power sustainably with renewable energy technologies/Solar energy
Type	Secondary Indicator

Purpose: This indicator measures the amounts of solar energy production, as an indication of sustainable energy production within the area/city. Solar energy production is already included in the key indicator K4 that measures the total renewable energy production. However, the specific indicator measuring only solar energy works as an explanatory indicator by giving an indication for the share of renewable energy production derived only from solar power.

Data needed to compile the indicator: The total energy consumed in the area that has been produced from solar power stations and the total energy consumed within the urban area.

Relevance to sustainable urban development: Solar power is one of the most advanced and widely applied renewable energy technologies. The amount of solar energy produced within the area is an indication of the levels of sustainability achieved and shows the commitment of the urban area to generate energy sustainably. Another indicator often used for measuring solar power, is the one that measures the capacity installed for solar energy production within the area. However, this specific indicator does not facilitate the comparison between different areas, with different climate conditions and different sizes. Hence, this specific indicator was not preferred.

Indicator S15: Percentage of total energy derived from wind power as a share of the area's total energy consumption

Brief Definition	The share of total energy consumed within the city/area, which has been derived from wind power
Unit	%
Relevant Goal/Sub-goal	Generate power sustainably with renewable energy technologies/Wind energy
Type	Secondary Indicator

Purpose: This indicator measures the amount of wind energy production, as an indication of sustainable energy production within the urban area. The indicator functions as explanatory indicator of key indicator K4 that measures the total renewable energy production.

Data needed to compile the indicator: The total energy consumed in the area that has been produced from wind power stations and the total energy consumed within the urban area.

Relevance to sustainable urban development: Wind power is one of the most developed and widely used renewable energy technologies in the world. Coastal cities have the advantage to generate energy with offshore wind farms, but urban wind turbines can be also installed within the urban built environment. This indicator, by measuring the share of total energy consumed within an urban environment that has been derived from wind power stations, gives a supplementary indication of the types of renewable energy used in the area and the levels of sustainability achieved so far. As with solar power, another indicator for wind power which is often encountered is the one that measures the capacity installed for solar energy production within the area. This indicator was not preferred for the same reasons mentioned above.

Indicator S16: Percentage of total energy derived from geothermal power station as a share of the area´s total energy consumption

Brief Definition	The share of total energy consumed within the area that has been derived from geothermal energy
Unit	%
Relevant Goal/Sub-goal	Generate power sustainably with renewable energy technologies/Geothermal energy
Type	Secondary Indicator

Purpose: This indicator measures the amount of electricity or heat produced from geothermal power stations, as an indication of sustainable energy production within the urban area. The indicator functions as explanatory indicator of key indicator K4 that measures the total renewable energy production.

Data needed to compile the indicator: The total energy consumed in the area that has been produced from geothermal power stations and the total energy consumed within the urban area.

Relevance to sustainable urban development: Geothermal power can be used either for electricity production or for direct use application for geothermal heating systems. Geothermal district heating systems and heat pumps for house heating are often used nowadays in the urban environment. This indicator measures the amount of geothermal power used within the area, either for electricity or for heat, as a supplementary indication of the types of renewable energy used in the area and the levels of sustainability achieved so far. As with the two previous indicators, another indicator which is often encountered for measuring geothermal power production, measures the capacity of geothermal power stations installed in the area. However, for the same aforementioned reasons this indicator was not preferred.

Indicator S17: Percentage of total energy derived from biomass power stations as a share of the area´s total energy consumption

Brief Definition	The share of total energy consumed within the area that has been derived from biomass power stations
Unit	%
Relevant Goal/Sub-goal	Generate power sustainably with renewable energy technologies/Biomass
Type	Secondary Indicator

Purpose: This indicator measures the amounts of energy that has been produced from biomass power, as an indication of sustainable energy production within the urban area. The indicator functions as explanatory indicator of key indicator K4 that measures the total renewable energy production.

Data needed to compile the indicator: The total energy consumed in the area that has been produced from biomass power stations and the total energy consumed within the urban area.

Relevance to sustainable urban development: Biomass, as a renewable energy source is derived from different energy sources as garbage, wood, waste and can be either used directly or converted into other energy products such as biofuels. The specific indicator measures the share of total energy consumption within the area, that is covered by biomass power and it includes all uses of biomass: for electricity generation, for heating systems (in the form of wood pellets) or for fuel use. As with the previous indicators, another indicator which is frequently encountered for measuring biomass power production, measures the capacity of biomass power stations installed in the area. However, for the same aforementioned reasons this specific indicator was not preferred.

Indicator S18: Percentage of total energy derived from hydropower stations as a share of the area´s total energy consumption

Brief Definition	The share of total energy consumed within the area that has been derived from hydropower stations
Unit	%
Relevant Goal/Sub-goal	Generate power sustainably with renewable energy technologies/Hydropower
Type	Secondary Indicator

Purpose: This indicator measures the amount of energy that has been produced from hydropower, as an indication of sustainable energy production within the area/city. The indicator functions as explanatory indicator of key indicator K4 that measures the total renewable energy production.

Data needed to compile the indicator: The total energy consumed in the area that has been produced from hydro power stations and the total energy consumed within the urban area.

Relevance to sustainable urban development: Hydropower, and especially micro-hydropower, is another form of renewable energy that can be used in the urban environment. It is a less applied technology, since it is heavily dependent on the morphology of the natural environment of the area. However, there are still micro-hydropower applications that can be used within or close to the urban environment and contribute to the total energy production from renewable sources in the area. This indicator, by measuring the share of total energy consumed within the area that has been derived from hydropower stations, gives a supplementary indication of the types of renewable energy used in the area and the levels of sustainability achieved so far. As with the previous indicators, another indicator, often employed for measuring hydropower production, measures the capacity of hydropower stations installed in the area. However, for the same aforementioned reasons, this specific indicator was not preferred.

Indicator S19: Percentage of total energy consumed within a year that has been produced by combined heat and power plants

Brief Definition	The share of total energy consumed in the area in one year, which has been produced by combined heat and power plants
Unit	%
Relevant Goal/Sub-goal	Generate power sustainably with highly efficient technologies/CHP
Type	Secondary Indicator

Purpose: This indicator measures the amount of energy produced by combined heat and power stations, as an indication of energy efficiency within the area. CHP power stations can be combined with renewable energy sources. Hence, this indicator can work as a supplementary indication of the levels of sustainability achieved in the area's energy system.

Data needed to compile the indicator: The total energy consumed in the area that has been produced from combined heat and power stations and the total energy consumed within the area/city.

Relevance to sustainable urban development: Combined heat and power or cogeneration is a highly efficient way to generate electricity and heat simultaneously. The main difference from traditional power stations is that CHP captures some of the by-product waste heat and uses it for building heat. This indicator measures the share of energy produced by combined power station, as an indication of the penetration of this technology in the energy systems of the area/city.

Indicator S20: Percentage of total heat demand that has been covered by district/community heating

Brief Definition	The share of total heat consumed in the area, which has been provided by district/community heating
Unit	%
Relevant Goal/Sub-goal	Generate power sustainably with highly efficient technologies/District or community heating
Type	Secondary Indicator

Purpose: This indicator measures the share of total heat demand covered by district/community heating system, as an indication of levels of energy efficiency achieved within the area.

Data needed to compile the indicator: The total heat consumed in the area that has been provided from district heating system and the total energy consumed within the area.

Relevance to sustainable urban development: Community or district heating systems, usually combined with cogeneration power plants, can provide better efficiencies than localized boilers. This indicator measures the share of buildings that are under the service of district heating systems, as an indication of sustainable heating within the area. However, district heating is usually combined with fossil fuel use, such as natural gas. Therefore, in such cases it is not preferable to renewable power generation. This indicator should be used taking into consideration the conditions of the area where applied.

Indicator S21: Percentage of total energy consumed within a year that has been stored for a period before being consumed

Brief Definition	The share of total energy consumed within a year in the area, which has been stored for some time before being consumed
Unit	%
Relevant Goal/Sub-goal	Generate power sustainably with highly efficient technologies/Energy Storage
Type	Secondary Indicator

Purpose: This indicator measures the amount of electricity or heat/cold, which is not needed for consumption immediately after their generation, and thus, gets stored for later use. It is an indication of energy recycling and hence, of reduction of total energy demand per year.

Data needed to compile the indicator: The amount of energy stored per year and the total amount of energy consumed yearly in the area.

Relevance to sustainable urban development: Energy storage is one of the ways to reduce total energy demand. Electricity or heat might not be needed at the moment when they are generated and hence, could be considered as a waste product. Storing energy for later use allows balancing the supply and demand of energy and subsequently, contributes to the reduction of total energy use. Despite its importance, energy storage systems have not been broadly applied at the urban level. Hence, this indicator works as evidence of more advanced areas/cities and as an indication of efficient energy systems.

4. Comparing the Four Assessement Tools for Sustainable Urban Communities

4.1 Introduction

This chapter focuses on the analysis and comparison of four different assessment tools for urban communities: BREEAM Communities, BREEAM –NL Gebiedsontwikkeling, GPR Stedenbouw, and LEED for Neighborhood Development. All these tools are new schemes, launched to assess sustainable development within the urban environment.

Before the development of these tools, most assessment systems and methods for urban sustainability had been limited to the field of environmental building design (Haapio, 2011). However, buildings are only one part of human lives and it is the cities as a whole that represent the modern urban style of living. The increasing acknowledgement and understanding that the path to sustainability passes through the broader context of the urban environment, led recently to the development of assessment tools for sustainable urban communities. Most of these tools were introduced by already existing assessment systems for buildings. Firstly, the Building Research Establishment's Environmental Assessment Method (BREEAM) in UK developed BREEAM Communities, in 2009. Secondly, the U.S. Green Building Council launched the final version of LEED for Neighborhood Development in 2010. Furthermore, the BREEAM-NL Gebiedsontwikkeling is the Dutch version of BREEAM Communities, which was launched in September 2011 and it was developed by the Dutch Green Building Council. Lastly, GPR Stedenbouw is the product of collaboration of a Dutch consultancy company and the municipalities of Tilburg and Groningen, and it can be purchased since October 2011.

These specific tools aim to work as an interface between architects/ urban planners, and decision makers by setting a framework that incorporates in the planning process specific targets related to sustainability. Planning authorities can benefit from it by having assistance for decision making, while the architects and urban developers use the tools for improving the efficiency and the sustainability of the project.

The choice of the four specific assessment tools, for the purpose of the present study, was made based on two criteria: first, the level of their international acceptance, and second, the case study area where the tools were applied for comparison. Therefore, the BREEAM Communities and LEED for Neighborhood Development were chosen, as they are the most accepted and prevailing methods in the industry for international sustainability assessments of urban developments. Although they were originally conceived as national rating systems, these two methods have, now, the highest amount of applications worldwide (Kyrkou et al, 2011). On the other hand, the BREEAM-NL Gebiedsontwikkeling and the GPR-Stedenbouw were included in the present study because the tools were applied on an area of Rotterdam, which is under development. For this reason, the Dutch tools were also chosen, in order to make a comparison between local urban sustainability assessment systems and international tools.

Owing to the fact that all these tools have been launched recently, the number of scientific articles or studies analyzing the tools is limited. Hence, the present study aims to enhance the currently limited research on urban sustainability assessment systems by analyzing and comparing the four tools. The analysis and comparison has been mostly directed to the theme of sustainable energy on the urban level.

The present chapter focuses on the four tools, analyzing, and comparing their methodologies. The analysis of the methods was based on the up to date literature review of urban sustainability assessments, city rankings, and the generic list of energy indicators for urban sustainable development, which was presented in chapter 2. Based on the created list of preferred energy indicators, the tools were assessed in order to examine how they address the energy issues and which energy indicators they use to assess urban sustainability. Furthermore, the different methodologies of the tools were compared and the first conclusions about their effectiveness were drawn.

4.2 The Tools

4.2.1 BREEAM Communities

BREEAM for communities is an independent, third party assessment and certification standard, launched by the Building Research Establishment Environmental Assessment Method in 2009. BREEAM was the first commercially available environmental assessment tool for buildings, established in the UK in 1990 (Grace,

2000) and BREEAM communities has been based on the same methodology. The tool assesses planning development projects within the built environment and focuses on enhancing the key environmental, social, and economic sustainability objectives of each project (BREEAM, 2011). Its goal is to help local authorities, developers, planners and urban designers take account of the full range of issues that must be considered from the earliest stages of the development process. To this end, BREEAM aims to provide a holistic sustainability label for development projects within the urban built environment and consequently, to facilitate the delivery of sustainable communities.

BREEAM communities has divided the issues recurrent in sustainable development in eight main categories:

- Climate Change & Energy - focuses on reducing the project's contribution to climate change
- Place Shaping - provides a framework for the design and layout of the local area
- Community - supports vibrant communities and encourages to integrate with surrounding areas
- Ecology and Biodiversity – aims at conserving the ecological value of the site
- Transport & Movement – focuses on sustainable transportation options, and encouraging walking and cycling
- Resources – emphasizes sustainable and efficient use of resources
- Business and Economy – aims at providing opportunities for local businesses and creating jobs in the region
- Buildings – focuses on the overall sustainability performance of buildings (BREEAM, 2011)

Each category of BREEAM communities consists of a different number of criteria (indicators). In total, there are 51 criteria, 23 of which are compulsory (meaning that if the mandatory criterion is not fulfilled, no points in the specific category will be given). Credits are awarded according to performance from one to three points and it is then multiplied against the corresponding regional weighting to provide the BREEAM for Communities score particular for that issue. The regional weighting factor has been determined by regional expert groups and provides regional variation between different issues (BREEAM, 2011). All scores from each credit are added together to produce a single overall score. 10 extra points can be gained from the category Innovation, which refers to sustainability related benefits, which are not awarded by other BREEAM issues. Ultimately, the final score of the plan of development is rated as it can be seen in the table below:

BREAM Communities Rating	Score
Unclassified	<25%
Pass	≥ 25%
Good	≥ 40%
Very good	≥ 55%
Excellent	≥ 70%

It has to be stressed that a development proposal cannot achieve a BREEAM for Communities Certificate and Rating without addressing all of the mandatory credit issues of each category. Where these issues are not met, the development proposal will not achieve a "pass", even if the rest of the performance is exceptional.

4.2.2 BREEAM-NL Gebiedsontwikkeling

BREEAM-NL Gebiedsontwikkeling is the Dutch version of BREEAM communities and it assesses the sustainability performance of an entire urban area. The Dutch Green Building Council developed a pilot version of the program in 2010, while since September 2011 the first official version has been available (BREEAM-NL Gebied, 2012). The structure and the methodology of the program have followed, as much as possible, the method of BREEAM communities.

The evaluation framework of BREEAM NL- Gebiedsontwikkeling is based on 6 categories:

- Resources – emphasizes sustainable and efficient use of energy, water, material, food, waste
- Spatial Development – provides a framework for the design and the materialization of the area
- Welfare and Prosperity – refers to both social welfare and economic prosperity within the area
- Climate – includes issues related to physical, chemical and biological aspects of urban climate, such as thermal outdoor climate, wind, air and water quality, soil, noise, light, radiation
- Management – focuses on the processes that ensure the establishment of sustainability on regional scale and the proactive participation of stakeholders in the area
- Synergy – focuses on all the interconnections between the different themes and the added value of these relationships

The last two categories are different from other methods, because they do not refer to environmental or social issues, but on the organizational ability and the connections between the previous themes. These aspects are also crucial for assuring the sustainability achieved.

Each category of BREEM NL- Gebiedsontwikkeling comprises of different number of indicators. In total, there are 40 indicators, of which four are mandatory. Credits are awarded according to performance from 1 to 7 points and they are added together to create a final score of 100 points. 10% maybe added to the final score from innovation points. An innovation is defined as an aspect of the current development that is not already widely applied and increases the sustainability of the project. Hence, the highest final score is 110 % and the plan of development is rated with a number of stars as it can be seen in the table below:

Rate in stars	Score	Old qualification
1 star	≥30%	Pass
2 stars	≥45%	Good
3 stars	≥55%	Very Good
4 stars	≥70%	Excellent
5 stars	≥85%	Outstanding

4.2.3 GPR-Stedenbouw

GPR Stedenbouw is another communication and monitoring tool for sustainable urban planning and aims to assess both new districts and redevelopment of existing areas. It is the product of collaboration between city of Groningen, Municipality of Tilburg, and W/E consultants from Utrecht. More municipalities, urban planners, developers, and corporations got involved, in a later stage of development, in order to deliver the official version of the project in 2011 (GPR Gebouw, 2012). Similar to the other area assessment tools, GRP Stedenbouw was based on an initial tool for assessing sustainability at the building level (GPR Gebouw) developed by the same group. GPR Stedenbouw aims to define sustainable goals and ambitions at the initial stage of planning, monitor the progress of the project and compare between different plans.

The main key themes of assessment in the tool are:

- Energy – focuses on reducing energy demand, CO_2 emissions and improving the general energy performance of the area

- Spatial planning – emphasizes the careful use of space balancing green, water, buildings, infrastructure
- Health – aims to a comfortable and healthy urban environment by preventing noise, odour, wind discomfort and improving air quality and external safety
- Practical value – provides a framework for the functionality of the area by improving mobility, amenities and enhancing sustainable social behaviour
- Future value – focuses on the adaptability of the area to future demands and unexpected conditions and aims to enhance a long-term view for urban planning

Each theme is divided in to different sub-themes. 255 different items of data are required for the complete score, but the indicators and the weightings are not publicly available.

For each theme, a score between 1 and 10 can be achieved. The scoring system of the tool has been based on an average calculation of data available from different Dutch cities. The average has been scored with 6 and that is the starting point for each area assessed by the tool. Every indicator adds positive or negative point to the initial score until the final score of the area is given. Based on the final score, a relevant number of stars is attributed to the project as presented on the table below:

Average Score	Stars
5,0 - 5,5	½ Star
5,5 - 6,0	1 Star
6,0 - 6,5	1 ½ Star
6,5 - 7,0	2 stars
7,0 - 7,5	2 ½ stars
7,5 - 8,0	3 stars
8,0 - 8,5	3 ½ stars
8,5 - 9,0	4 stars
9,0 - 9,5	4 ½ stars
9,5 - 10	5 stars

4.2.4 LEED for Neighborhood Development

The Leadership in Energy and Environmental Design for Neighborhood Development (LEED-ND) system for reviewing and rating neighborhoods was developed collaboratively by three organizations: the U.S. Green Building Council (USGBC), the Congress for the New Urbanism (CNU), and the Natural Resources Defense Council (NRDC). The actual rating system was launched a few years later, in 2010. Unlike previous LEED rating systems that focus primarily on green buildings practices, LEED for Neighborhood Development places emphasis on the site selection, design, and construction elements that bring buildings and infrastructure together into a neighborhood and relate the neighborhood to its landscape as well as its local and regional context (LEED ND, 2011).

LEED for Neighborhood Development scores the development projects in three categories:

- Smart Location and Linkage— favors development of cities and suburban areas. Development, revitalization, and services are important aspects. Protects areas, populations, and water bodies.

- Neighborhood Pattern and Design — emphasizes public transportation and reduction of auto dependency. Reaches for rich neighborhood by increasing social interaction.

- Green Infrastructure and Building — focuses on decreasing environmental impact caused by construction and maintenance of buildings and infrastructure. Energy and water efficiency are emphasized.

An additional category, Innovation and Design Process, addresses sustainable design and construction issues and measures not covered under the three categories. Moreover, the tool gives extra bonus credits for regional priority, as an acknowledgement of the importance of local conditions in determining best environmental design and construction practices as well as social and health practices.

As with the other tools, each main category consists of different criteria and prerequisites. In total, there are 53 criteria, which are evaluated differently: some are worth 10 points, others are worth only one point. From the main categories, the total score can be 100 points and from the additional categories, it is possible to earn 10 more points. The distribution of the points between categories is done in such a way that from Smart Location and Linkage" a project can earn maximum 27 points, from Neighborhood Pattern and Design 44 points, and from Green Infrastructure and Buildings 29 points. Finally, the total score of the project is rated as it can be seen in the table below:

LEED ND Rating	Points
Certified	40+
Silver	50+
Gold	60+
Platinum	80+

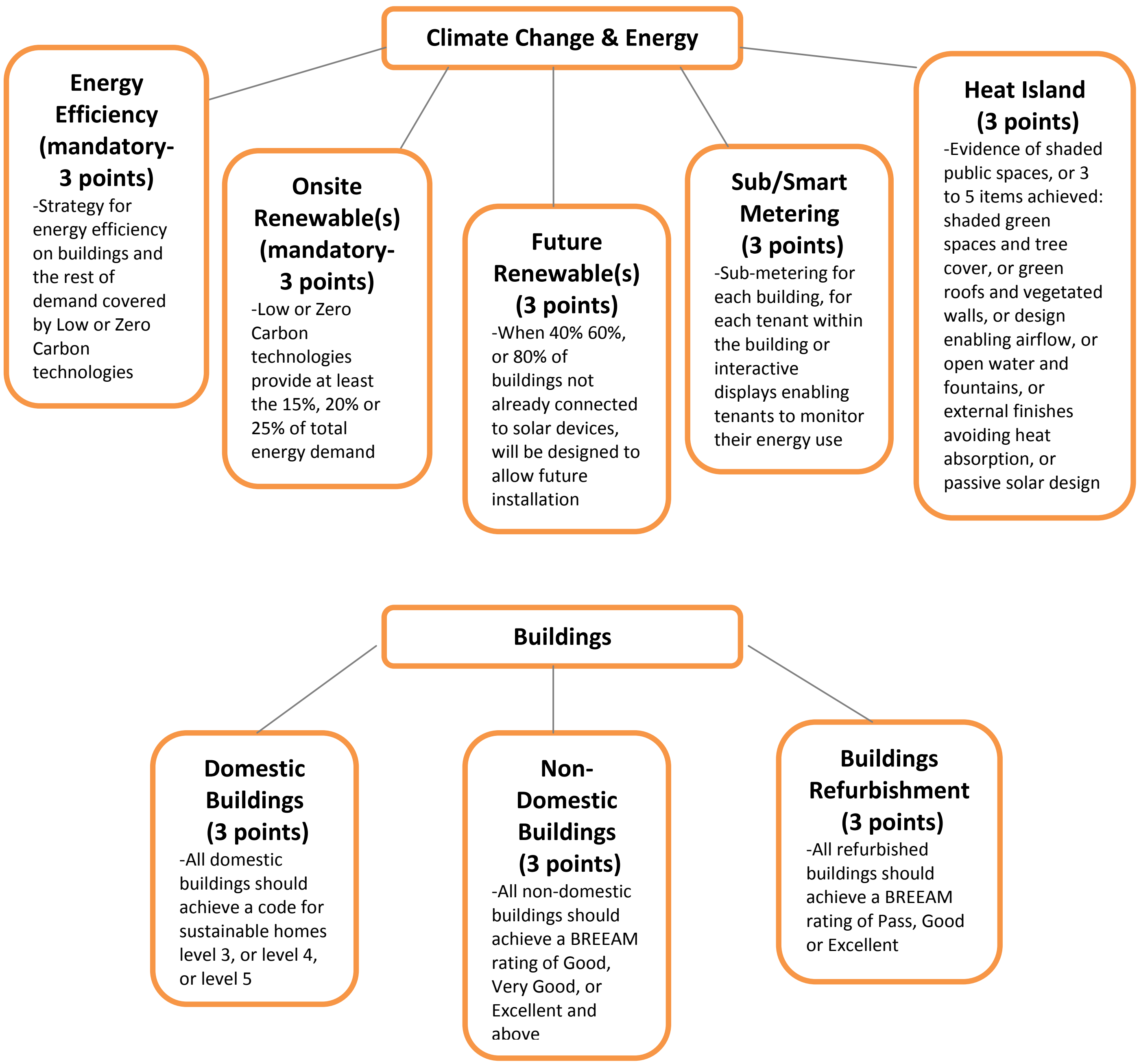
4.3 How sustainable energy issues are considered by the tools

The present study has been focused on energy issues related to urban sustainable development and the way they are assessed by different urban assessment methods and tools. Hence, while studying the four tools presented above, the focus has been how sustainable energy issues are assessed by the tools, which indicators are used and how much priority is given to sustainable energy goals and targets. The method for assessing the energy themes of the tools has been based on the three-steps-strategy presented in chapter two. The tools are examined, thus, for their approach on achieving the goals of "Reducing energy demand", "Reusing waste energy" and "Generating energy sustainably".

BREEAM Communities

On BREEAM Communities, there are five themes and indicators related to energy issues and three indicators assessing only sustainable buildings. The energy indicators are included in the category Climate Change and Energy, while the indicators measuring the performance of buildings are included on a separate category only for buildings. The following diagram gives an overview of the specific energy and buildings indicators used in BREEAM Communities, while the complete list can be found in Appendix II.

BREEAM Communities



Each of the energy and buildings indicators can add to the total score of the project from 1 to 3 points. However, five of the specific indicators include mandatory criteria that should be fulfilled in order to achieve a BREEAM certificate. If those mandatory criteria are not fulfilled, no points can be further rewarded to the project. The indicators are analyzed extensively in the following paragraphs, based on the division into the three main categories of reducing energy demand, reusing waste energy, and generating energy sustainably.

Reducing energy demand

As it can be seen from the diagram above, BREEAM Communities includes the following six indicators within the theme of reducing energy demand: Energy Efficiency, Sub/Smart Metering, Heat Island Reduction, and the 3 indicators assessing sustainability of buildings.

Firstly, the "energy efficiency" indicator is a qualitative indicator, which assesses the general existing strategy within the area for reducing energy demand by energy efficiency measures. This indicator also functions as a prerequisite criterion for achieving a BREEAM Communities certificate. More specifically, in order to achieve a certificate, every project should provide evidence of an existing strategy that optimises the incorporation of energy efficiency measures into the buildings of the site. The strategy should include as a minimum measures for a) minimising energy demand for the site through orientation and passive solar design, b) maximising the thermal efficiency of building envelopes and c) minimising consumption of energy used for water heating, space heating and cooling, lighting and power in individual buildings through efficient equipment and controls. Additional credits are rewarded to the project in case there is an additional study examining ways to cover the residual energy demand with low or zero carbon (LZC) technologies.

Secondly, the "smart metering" indicator assesses whether sub-meters are provided which monitor end energy use. Depending on whether the metering systems are installed at the building/plot level, at the tenant level, or whether there are interactive systems enabling occupants to monitor and reduce their energy use, 1 to 3 points are awarded to the development.

Moreover, the indicator assessing the reduction of "heat island" effect in the area aims to reduce heat absorption within the development and, thus, reduce the incidence of overheating and the need for powered cooling and consequently, the total energy demand of the area. One point is achieved when shaded public spaces and footpaths are provided within the area. Two or three points are achieved when, respectively, three or five of the following measures are applied: a) provision of appropriate shaded green space and tree cover, b) green roofs and vegetated walls, c) design to enable air-flow throughout the development, d) open water and fountains in public spaces, e) shaded public spaces and footpaths, f) appropriate choice of external finishes to avoid heat absorption, g) passive solar design.

Finally, three indicators assess sustainability and energy performance of buildings based on three different categories: "domestic", "non-domestic", "refurbished". The indicators for domestic and non-domestic buildings include also two prerequisite criteria. The first indicator for domestic buildings aims to ensure that all buildings within the development are assessed under the appropriate Code for Sustainable Homes Rating. The specific code is the national British rating system for houses and measures the sustainability of a home against different areas. Since 2008 in the UK, it is mandatory for all new homes to be rated against the Code for Sustainable Homes. For the BREEAM Communities assessment, it is a prerequisite that all domestic buildings within the area have achieved a rating 3 of the Code of Sustainable Homes. No certification is possible if that criterion is not fulfilled. The second indicator for non-domestic buildings aims to ensure that all non-domestic buildings within the development area are assessed under the BREEAM rating scheme for buildings. It is a mandatory criterion for BREEAM Communities that all buildings within the area have achieved a rating BREEAM Good. The last indicator for refurbished buildings aims to ensure that all retained buildings that are to be refurbished within the development are assessed under the appropriate BREEAM rating. Points from 1 to 3 are awarded to the development depending on the BREEAM rating achieved.

Generate power sustainably

In BREEAM Communities, there are two indicators assessing the theme of sustainable energy generation within the area and both of them refer to renewable energy.

The first indicator, "onsite renewable(s)", assesses the share of area's energy demand that has been covered by renewable sources. In order to achieve a BREEAM certification, it is prerequisite that at least 15% of the total energy demand of the buildings in the site is provided by low or zero carbon technologies

(LZC). Two additional points are awarded to the project when the share of energy demand of the area covered by renewable sources is raised to 20% or 25%. According to BREEAM Communities low or zero carbon energy technologies (LZC) are technologies that must produce energy from renewable sources and the installations can be located on/in the buildings or elsewhere on the site cartilage. These can be small-scale LZC technologies integrated in the fabric of the home, community based LZC technologies located within the area, and directly connected LZC heat (not necessarily generated on-site). Eligible LZC technologies, according to BREEAM Communities, are: solar photovoltaic (PV), solar thermal water heating, small and micro wind turbines, small scale micro electric generators, biomass (solid) fuelled heating, biofuel (liquid) fuelled heating, biogas (Gas) fuelled heating, air/ ground/water source heat pumps and waste Incineration (BREEAM Communities, 2011). According to BREEAM Communities, other technologies might still be acceptable as LZC technologies. However, it makes sense that no clear reference is made to geothermal technologies.

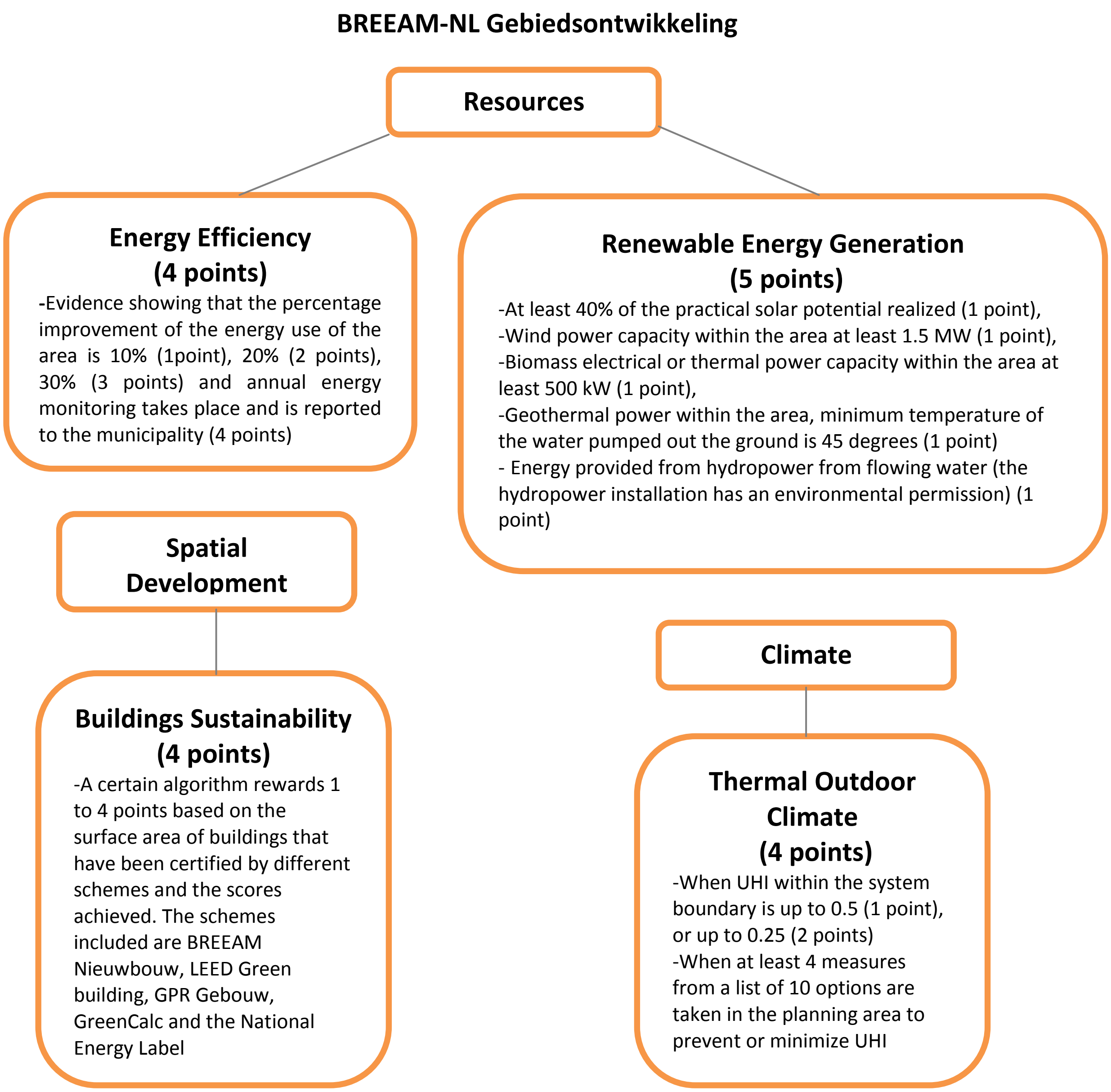
The second indicator, “future renewable(s)”, examines the preparedness of the area for future use of active solar technologies. More specifically, it examines what share of buildings, not already connected to any PV or solar thermal devices, are designed in that way to allow future installation by the occupiers. Suitable design features must include orientation and tilt angle of the roof, buildings structure allowing for additional roof loads, passive solar techniques, and proper space planning optimising the distribution systems relate to solar equipment use (piping, wiring, etc) and others.

BREEAM-NL Gebiedsontwikkeling

In BREEAM-NL Gebiedsontwikkeling, energy themes and indicators are encountered in three different categories: Resources, Spatial Development, and Climate. Energy indicators assessing energy efficiency and renewable energy production within the area are included in the category Resources, which in general includes themes such as sustainable use of energy, water, material, food, and waste. Indicators measuring the sustainability of buildings within the area are included in the category of Spatial Development, which in general includes themes about the design and the materialization of the area. Finally, indicators measuring the outdoor climate and the heat island effect within the area are included in the category Climate, which includes issues related to physical, chemical, and biological aspects of urban climate.

The following diagram shows the categories and energy indicators used in BREEAM-NL Gebiedsontwikkeling. The complete list of energy indicators used in the specific tool is included in Appendix II.

All of the indicators are valued 4 points, except for the indicator assessing renewable energy that awards maximum 5 points to project. None of these indicators includes any prerequisite criteria that should be fulfilled in order to achieve a BREEAM-NL Gebiedsontwikkeling certificate. The indicators are analyzed extensively in the following paragraphs, based on the division into the three main categories of reducing energy demand, reusing waste energy, and generating energy sustainably.



Reducing energy demand

As it can be seen from the diagram above BREEAM-NL Gebiedsontwikkeling includes 3 indicators within the theme of reducing the energy demand of the area: Energy Efficiency, Buildings Sustainability, Outdoor Climate.

Firstly, the indicator referring to "energy efficiency" rewards the project with 1-3 points, when evidence is provided showing that the energy performance of the area has been improved by 10%, 20%, or 30% after the development of the area. An additional point is added to the score when energy monitoring takes place within the area and the energy use is reported to the municipality. The improvement of energy performance of the area is based on the improvement of the energy performance of buildings and is expressed as a percentage improvement of the EPC current buildings requirements. The EPC, Energie Prestatie Coëfficiënt in Dutch, is an energy performance coefficient that indicates the energy efficiency of new buildings. It is used by the Dutch government and the formula of the calculation is:

EPC = (Building's Energy Consumption for lighting and HVAC) / (Standardized energy depending on the size and type of the house)

Lower numbers imply higher efficiencies achieved on buildings. In January 2011 the EPC required standard for new buildings in the Netherlands decreased from 0.8 to 0.6 (Agentschap, 2012). Hence, the specific indicator rewards points when the buildings within the area have EPC lower than the national prerequisite, by a factor of 0.1, 0.2 or 0.3.

Secondly, the indicator "buildings sustainability" assesses the number of certified buildings within the area as an indication of reduction of energy demand. For buildings sustainability, the tool uses an algorithm that provides a score based on the number of certified buildings, the certification scheme, and the scores rewarded for each building. The schemes considered are BREEAM-NL Nieuwbouw, LEED for Green Buildings, GPR Gebouw, GreenCalc and the national energy labels rating system. The tool provides an additional excel file in order to fill in the specific data.

Finally, the indicator "thermal outdoor climate" assesses the reduction of heat island effect in the area and consequently the reduction of total energy demand. One or two points are achieved when the Urban Heat Island Index within the system boundaries is up to 0.5 or 0.2 respectively. The calculation of UHI is based on the formula:

UHI= 0.04x urban density in radius 1.5km – 0.04x % of green per hectare

Three or four points are awarded when the area is in 500 m distance from a forest or 4 of the following measures are included in the planning: a) green verges and traffic lines along all roads in the area, b) street trees along all main roads in the area, c) 10% of grass in public space, d) green noise barriers, e) flowing water surface within 30 m of main residential functions, f) 30% of the pavement consists of open-paving, g) 40% of the paving surfaces are made of materials with high reflection, h) swimming water in the area, i) at least 5 water cooling elements in the area, j) a water park in the area, k) water playgrounds in the area.

Generate power sustainably

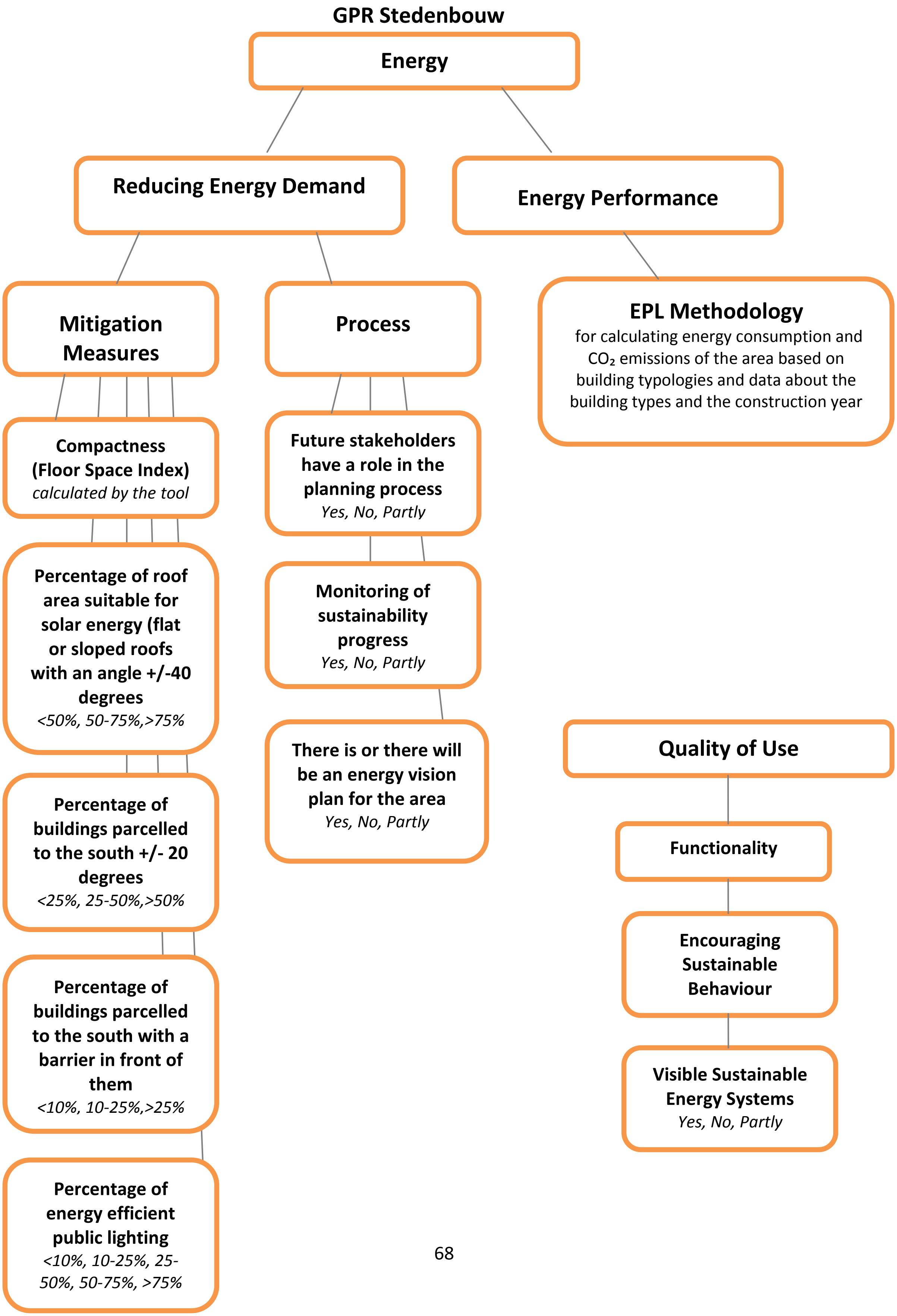
In BREEAM-NL Gebiedsontwikkeling, there is one indicator assessing the sustainable energy generation within the area and it refers to renewable energy. The indicator, "Renewable Energy Generation", values up to five points, more than all the other energy indicators of BREEAM-NL. One point is rewarded to the project when 40% of the solar potential of the area is realized (the solar potential is calculated by adding the horizontal roof surfaces and the sloped roofs with orientation to Southeast and Southwest). Another point is rewarded when the wind power capacity within the area is at least 1.5 MW. A third point is added when thermal or electrical power is generated from biomass, with a minimum of 500kW capacity of biomass power stations within the area. A fourth last point is added when there are geothermal power installations within the area, which pump water out of the ground with a minimum temperature of 45 degrees. Finally, a last point is added when energy demand is covered from hydropower, with the prerequisite that the hydropower installations complies with relevant environmental standards.

GPR Stedenbouw

On GPR Stedenbouw, energy is one of the five key assessment themes of the tool. An entire theme, hence, has been devoted to energy issues.

The category of energy is divided into two subcategories: Reducing Energy Demand and Energy Performance. The category of Reducing Energy Demand is subsequently subdivided in two different themes: 1) Mitigation Measures, referring to different measures that can reduce the total energy demand of the area and 2) Process, which refers to management techniques and strategies for reducing the energy demand of the area. On the other hand, the sub-category of Energy Performance is based on the EPL methodology.

Finally, one qualitative indicator referring to renewable energy is included in the category Quality of Use and more specifically in the sub-theme encouraging sustainable behaviour. The diagram below shows the themes, sub-themes and indicators of energy used in GPR Stedenbouw. The complete list of themes and energy indicators used in GPR Stedenbouw is included in Appendix II.



As it can be seen on the diagram above, GPR Stedenbouw does not use the same assessment methodology with the other tools. For most indicators the tool provides a list of answers. For each answer/choice from the list, different points are awarded, but the points do not seem to follow an obvious repetitive pattern. The methodology for the scoring system and the weightings applied to each indicator are not publicly available. Moreover, no additional manual, including definitions about the indicators and the requirements for each one, was provided by the developers of the tool. Hence, a rough evaluation can be made for the robustness of the methodology used. The indicators are further presented in the following paragraphs, based on the division in the three main categories of reducing energy demand, reusing waste energy, and generating energy sustainably.

Reducing energy demand

On GPR Stedenbouw, a whole sub-category within the Energy theme is focused on reducing energy demand. Within this sub-category, there are two groups of indicators: the "Mitigation Measures", which are quantitative indicators, and the "Process" indicators, which are qualitative indicators.

On the one hand, the "Mitigation Measures" group includes four quantitative indicators referring to measures that can reduce the energy demand of the area: "Compactness (Floor Space Index)", "Percentage of buildings parcelled to the south within +/-20 degrees", "Percentage of buildings parcelled to the south with a barrier in front of them", and "Percentage of energy efficient public lighting". It also includes the indicator "Percentage of roof area suitable for solar energy," which according to the author should be an indicator for renewable energy and it will be further presented on the relevant paragraph of sustainable energy generation.

Firstly, the indicator of "Compactness" assesses the density of buildings within the area as an indication of low energy demand- the higher the compactness of the area, the lower the total energy demand. The tool calculates the Floor Space Index by data given about the total surface area, and the total built area in m^2, which are asked at an initial stage of the tool, but the calculation and the score given for each case are not available.

Secondly, the indicator "Percentage of buildings parcelled to the south within +/- 20 degrees" assesses the solar orientation of the blocks and the buildings of the area. The higher the share of buildings orientated to the south, the higher the passive energy gains, and the less the total energy demand of the area. For the specific indicator there is a choice between three possible answers: <25%, or 25-50%, and >50% of total buildings within the area are parcelled to the south within +/- 20 degrees.

Thirdly, the indicator "Percentage of buildings parcelled to the south with a barrier in front of them" is complementary to the previous indicator and defines the exact share of buildings with an actual solar gain, since no barrier in front of them can block the sun. The answers for this indicator provided by the tool are <10%, or 10-25%, and >25%.

Lastly, the indicator "Percentage of energy efficient public lighting" measures the share of total public lights that are energy efficient. The possible answers for this indicator are <10%, 10-25%, 25-50%, 50-75%, >75%.

On the other hand, the group of "Process" indicators includes three qualitative indicators that measure the management and strategy of energy reduction measures in the area: "Future stakeholders have a role in the process", "Monitoring of sustainability progress," "There is or there will be an energy vision plan for the area."

The first indicator examines whether future stakeholders are included in the process of making the area more energy efficiency. Stakeholders that can play an important role in the planning process could be future residents of the area, housing associations, electricity provider companies etc. The more stakeholders are included in the decision making process, the more resilient the energy reduction measures are likely to be. For the specific indicator the tool provides three possible answers: Yes, Partly, No.

The second indicator, "Monitoring of sustainability progress," examines whether the whole planning process is monitored and whether the strategies adopted have brought the expected results. The possible answers for this indicator are again: Yes, Partly, No.

Finally, the third indicator, "There is or there will be an energy vision plan for the area," assesses whether there is or there will be a concrete plan for reducing energy demand in the area. The possible answers can be again: Yes, Partly, No.

Generate power sustainably

On GPR Stedenbouw, there are is no specific sub-category referring to sustainable energy or renewable power. The tool refers to the potential of the area for solar energy. The specific indicator, "Percentage of roof area suitable for solar energy," is included in the sub-category of "Reducing energy demand." The indicator measures the amount of flat or sloped roofs with an angle of +/- 45 degrees. Flat or sloped roofs with photovoltaic panels take full advantage of the solar gains. The possible answers for the specific indicator provided by the tool are <50%, or 50-75%, and >75%.

Another qualitative indicator, referring to renewable energy, is included in another theme of the tool measuring the functionality of the area. The indicator named "Visible Sustainable Energy Systems" examines whether sustainable energy installations or exemplary use of sustainable energy are located in visible spots within the area, with the aim to promote and stimulate sustainable behaviour. The possible answers for the specific indicator are Yes, Partly, or No.

In general, GPR Stedenbouw, instead of measuring the amount of energy that is provided from sustainable or renewable resources, uses a methodology for measuring the total energy use of the area and the equivalent amount of CO_2 emissions. The methodology used by the tool is called EPL (Energie Prestatie op Locatie in Dutch) and is used as a communication tool that ranks different areas based on their energy performance (EPL, 2011). The resulting data about the energy consumption and the CO_2 emissions for each area for different years are collected in a database created by Agentschap, the relevant Dutch agency within the Ministry of Economic affairs, Agriculture and Innovation. More specifically, the methodology scores areas based on their fossil fuel use in comparison to a reference use (an average of different areas).

The score is determined by three factors: energy consumption in buildings, the type of energy consumed (gas fuel, electricity or heat) and the energy production (the sources of energy). The maximum score of an area is 10, which indicates a CO_2 neutral area or without any use of fossil fuel. This could be achieved, for example, by efficient supply, high degrees of insulation of buildings, and a use of renewable energy sources.

The formula used for the EPL methodology for calculating the total fossil fuel use is:

$$EPL = 10 - 4 \times (B_{area\ of\ choice} / B_{reference\ area})$$

where B is the fossil fuel use, area of choice is the area where EPL is calculated and reference area is a district with standard gas and electricity use and buildings with EPC 1.0.

$B_{area\ of\ choice}$ is the sum of the fossil fuel consumption $B_{building}$, of the dwellings in the location, hence $B_{area\ of\ choice} = \Sigma\ B_{building}$

$B_{building}$ is determined by the energy E measured by the meter of the building, multiplied by a correction factor C for the various energy carriers:

$$B_{building} = E \times C = E_{electricity} \times C + E_{heating} \times C + (\ E_{gas} \times C)$$

where E is the energy consumption measured by the meter and C is a correction factor for the fossil fuel content of the delivered energy. Not every energy source has the same fossil fuel content. The C factor is dependent on the type of carrier, the modes of production and distribution losses (EPL, 2011).

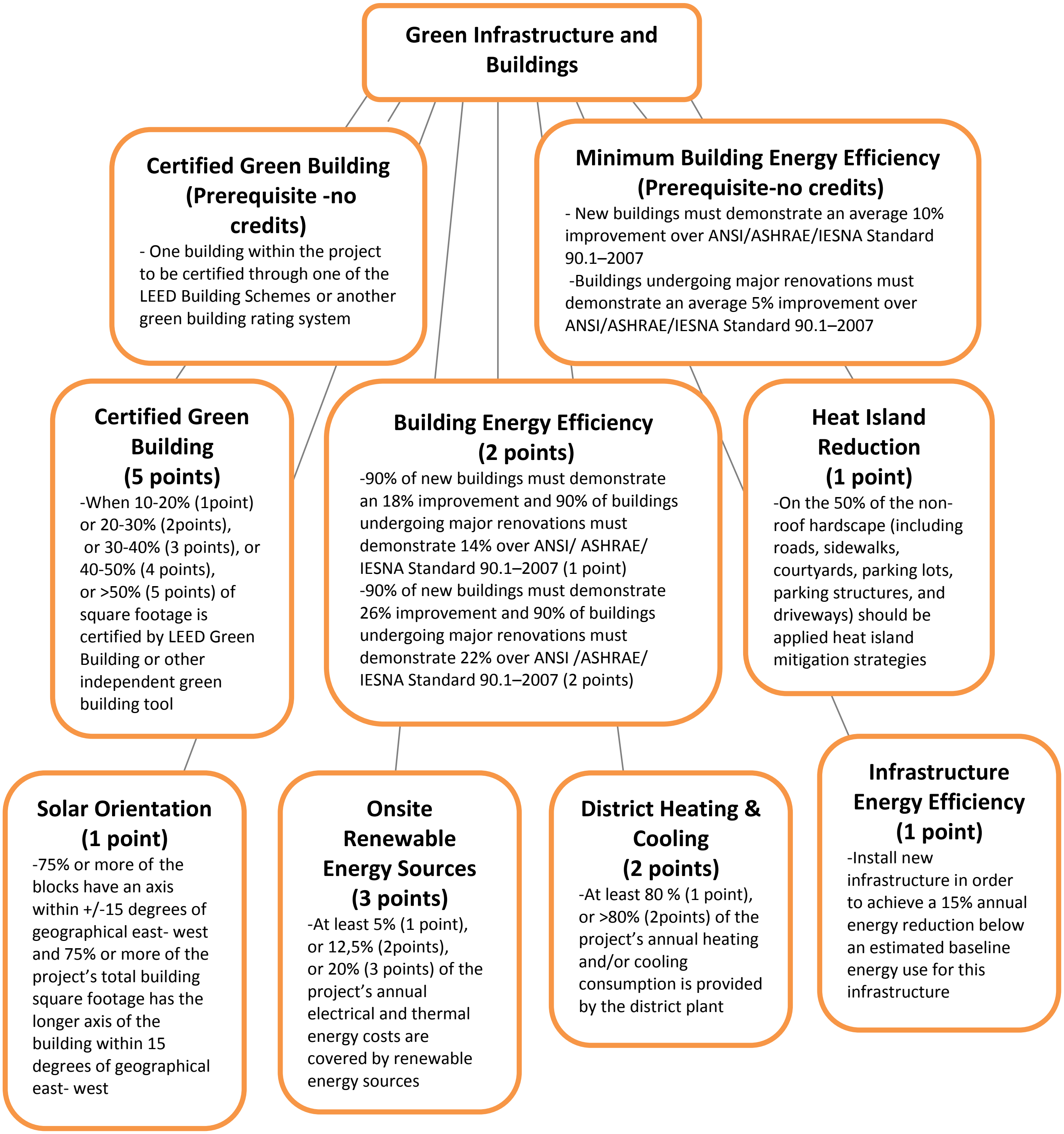
However, no real data measurements of the energy consumption of the buildings in the area are used for the specific calculations during the application of GPR Stedenbouw. On the contrary, the fossil fuel consumption of the area is estimated based on the number and types of buildings in the area and the relevant statistical database including information about the energy consumption of each building typology. Hence, in order to assess the energy performance of the area and subsequently, the CO_2 emissions, the tool does not require any actual data of the yearly energy use of the area. It only asks for the type and number of buildings in the area and then it sums up the statistical data about energy consumption of each type of building depending on the year of construction. The specific database has been developed and is updated by the creators of the EPL methodology.

LEED Neighborhood

On LEED for Neighborhood Development, energy themes and indicators are included in the category “Green Infrastructure and Buildings,” one of the three main categories of the tool. The category focuses, in general, on decreasing environmental impact caused by construction and maintenance of buildings and infrastructure. Themes such as energy efficiency, water efficiency, storm water management, waste management, and buildings reuse, are all included in the specific category. Therefore, there is not an entire category only for energy issues. In total, the LEED ND includes 7 indicators and 2 prerequisite criteria relevant to energy and buildings.

The diagram below gives an overview of the energy and buildings indicators used in LEED ND, while the detailed list can be found in Appendix II.

LEED NEIGHBORHOOD



Each of the energy indicators are awarded with 1 to 5 points. The indicator that values 5 points is the indicator of certified green buildings. The prerequisite criteria do not award any points, but the requirements are mandatory in order to achieve a LEED ND certificate. The indicators and the prerequisite criteria are analyzed extensively in the following paragraphs, based on the division in the three main categories of reducing energy demand, reusing waste energy, and generating energy sustainably.

Reducing energy demand

As it can be seen from the diagram above, LEED Neighborhood uses the following 2 prerequisite criteria and 5 indicators to assess the reduction of energy demand: "Certified Green Building (Prerequisite)", "Minimum Building Energy Efficiency (Prerequisite)", and the indicators "Certified Green Building", "Buildings Energy Efficiency", "Heat Island Reduction", "Solar Orientation", and "Infrastructure Energy Efficiency".

Firstly, the prerequisite "Certified Green Building" is a mandatory criterion that needs to be fulfilled in order to achieve a LEED ND certificate. According to this criterion, the area should include at least one certified building through one of the relevant LEED schemes for buildings or another green building rating system, requiring review by independent, impartial, third-party certified bodies (LEED ND, 2011). It is remarkable that the existence of one LEED certified building is a mandatory criterion for ensuring the sustainability levels achieved by the whole area.

Secondly, the prerequisite criterion "Minimum Building Energy Efficiency," requires that all new buildings within the development must demonstrate an average 10% improvement over ANSI/ASHRAE/IESNA Standard 90.1–2007, while buildings undergoing major demonstrations should demonstrate an average 5% improvement over the same standard. The ANSI/ASHRAE/IESNA Standard 90.1–2007 is the US energy standard for buildings performance and its newer version has been published in 2010 (BECU, 2010). Taking into consideration the fact that LEED ND aims to be an international tool, it is noteworthy that no "translation" of the specific standard has been done to numerical requirements or to precise details for the buildings' energy performance. The ANSI/ASHRAE/IESNA standard includes criteria for the envelope, HVAC systems, water heating, power, lighting, and other building systems that consume energy. However, a very extensive study would be necessary to assess all these criteria and translate them to international standards.

Apart from the prerequisite criteria, LEED ND includes also a number of indicators. The first indicator, "Certified Green Building" examines how many buildings have been certified through the LEED schemes for buildings, or other independent building schemes, based on the share of total built square footage. The more certified green buildings in the area, the more points achieved for the specific indicator. The specific indicator values maximum 5 points- the most points of all energy themes and indicators. It is again notable that buildings' sustainable performance is measured only by certified green buildings by LEED or other independent schemes and no other quantitative energy indicators, measuring the actual energy consumption of buildings are included.

The second indicator, "Buildings Energy Efficiency," assesses the energy efficiency of buildings based on the ANSI/ASHRAE/IESNA Standard 90.1–2007, which was also used for the respective prerequisite criterion. The specific indicator requires that 90% of new and renovated buildings within the area should demonstrate better performance than the national standards. The maximum points achieved for the specific indicator are 2.

The third indicator, "Heat Island Reduction," examines the measures taken within the area in order to reduce the heat island effect. The indicator awards the project with one point when in 50% of the area there have been applied urban heat mitigation techniques, such as shade from tree canopy, paving materials with high solar reflection (the Solar Reflectance Index is included), vegetated green roofs etc.

The fourth indicator, "Solar Orientation," examines the orientation of the blocks within the area and assesses whether it favours solar gains. One point is awarded when 75% or more of the blocks within the area have one axis within plus or minus 15 degrees of geographical east-west.

Finally, the fifth indicator, "Infrastructure Energy Efficiency," assesses the energy savings that can be gained from energy efficient infrastructure, such a traffic lights, streetlights, water and waste water pumps and others. More specifically, one point is awarded to the LEED ND project when new infrastructure is installed, which achieves 15% energy reduction to an estimated baseline energy use for these infrastructure items.

Generate power sustainably

On LEED ND there are two indicators assessing the sustainable energy generation within the area: "Onsite Renewable Energy Sources" and "District Heating and Cooling".

The first indicator assesses the "On-site Renewable Energy", by measuring the share of the area's annual electrical and thermal energy consumption that is covered by renewable(s). One point is awarded to the area when 5% of total energy demand within the area is covered by renewable energy sources. Two or three points are awarded respectively when 12.5% or 20% of the energy demand is covered by renewable(s).

The second indicator, "District Heating and Cooling," examines the incorporation of district heating and cooling within the area for space conditioning or water heating. One point is achieved when 80% of the project's annual heating and/or cooling consumption is provided by the district plan and an extra point is rewarded when the share is higher than 80%.

4.4 Comparison of the tools

The present section focuses on the comparison of the four different assessment tools according to the criteria and themes, the compatibility with the generic list of energy indicators, the weighting factors attributed to energy themes, and the energy prerequisite criteria. The comparison is presented with a series of tables and graphs.

4.4.1 Overall findings

Table 5 summarizes the categories and criteria included in the four different tools, and the different ratings.

In BREEAM Communities, there are 8 main categories, in BREEAM Gebiedsontwikkeling 6, in GPR Stedenbouw 5, and in LEED Neighbourhood 3. Although all tools use similar scoring (maximum score 100 points), it is difficult to compare the ratings, since the methodologies and weightings used differ a lot.

A first analysis and comparison of the four tools showed that all of them are designed to assess plans for development of new areas or redevelopment plans of existing areas. Hence, the tools give the opportunity to compare the area before and after specific measures of development and evaluate the progress of the area in time.

Table 5: Categories and rating of the four urban assessment tools

BREEAM Communities	**BREEAM Gebiedsontwikkeling**	**GPR Stedenbouw**	**LEED Neighbourhood**
-Climate Change & Energy -Place Shaping -Community -Ecology & Biodiversity -Transport & Movement -Resources -Business & Economy -Buildings Each category consists of a different number of criteria/indicators. 51 criteria/indicators; out of which 23 compulsory. All indicators are equal and can score from 1 to 3 points. Total maximum score is 100 points (+10 extra points from Innovation) Rating: Unclassified <25% Pass ≥25% Good ≥40% Very good≥50% Excellent ≥70%	-Resources -Spatial Development -Welfare & Prosperity -Climate -Management -Synergy Each category consists of a different number of criteria/ indicators. 40 criteria/indicators; out of which 4 compulsory. Indicators are valued from 1 to 7 points. Total maximum score is 100 points (+10 extra points from Innovation) Rating: Pass ≥30%,☆ Good ≥45%,☆☆ Very good ≥55%,☆☆☆ Excellent ≥70%,☆☆☆☆ Outstanding ≥85%, ☆☆☆☆☆	-Energy -Spatial Planning -Health -Practical Value -Future Value Each category is divided to different sub-themes. 255 different data are required to complete all categories. Points and weights for each indicator are not publicly available. Each category scores from 1 to 10 points. Total maximum score is 100 points. Rating: 5.0-5.5, ½☆ 5.5-6.0, ☆ 6.0-6.5, ☆ + ½☆ 6.5-7.0, ☆☆ 7.0-7.5, ☆☆ + ½☆ 7.5-8.0, ☆☆☆ 8.0-8.5, ☆☆☆ + ½☆ 8.5-9.0, ☆☆☆☆ 9.0-9.5, ☆☆☆☆ + ½ ☆ 9.5-10.0, ☆☆☆☆☆	-Smart Location & Linkage -Neighborhood Pattern & Design -Green Infrastructure & Building Additional categories: Innovation & design process, Regional priority. 53 criteria & 12 prerequisites. The criteria are evaluated differently: some are worth 10 points, some only 1 point. No points are gained from the prerequisites Total maximum score 100 points (+10 extra points from additional categories) Rating: Certified: 40+ points Silver: 50+ points Gold: 60+ points Platinum: 80+ points

4.4.2 Comparing the energy themes included in the tools

While comparing the four assessment tools, focus was given to the theme of energy. One of the main goals of the comparison was to define how the tools assess energy sustainability at the urban level and which energy themes are considered in their methodologies.

After the first analysis, the themes of energy that were addressed by the tools are summarized in table 6.

Table 6: Energy themes that were included in the assessment methodologies of the four tools

Energy themes included in the tools
Energy Efficiency/ Reduction of Energy Demand
Renewable Energy/Sustainable Power Generation
Sustainable/Green Buildings
Passive Design (Solar Orientation & Reduction of Heat Island Effect)
Energy Monitoring

All energy indicators that were included in the tools were within the aforementioned themes. Not all tools included indicators from each theme.

The following paragraphs give an overview of how each theme was assessed by the tools.

Energy Efficiency/Reduction of Energy Demand

BREEAM Communities assesses the reduction of energy demand in a qualitative way. More specifically, it examines whether there is a specific energy strategy for the future within the area and a plan for implementation of renewable(s). It is remarkable that no quantitative or semi-quantitative indicators for measuring reduction of energy demand are included within the tool.

On the other hand, BREEAM NL assesses the reduction of energy demand with a more quantitative approach. The tool actually measures the percentage reduction of energy demand of the area after the development. Points are awarded respectfully for reduction of energy demand from 10 to 30%.

In contrast, GPR Stedenbouw measures the reduction of energy demand by evaluating a series of measures applied in the area in order to minimize energy consumption (passive solar design, increased population density, efficient lighting). The tool does not use an indicator for measuring the numerical reduction of energy demand, but it only makes an estimation of the energy performance of the area based on the measures applied. Moreover, the tool assesses in a qualitative way the management of the process of improving the energy performance of the area.

Lastly, LEED ND measures the reduction of energy demand by considering the improvement of building's energy efficiency over the national standards. This indicator has been problematic for evaluation since it refers to the national standards of USA (ANSI/ASHRAE/IESNA Standard 90.1–2007) without translating them to numerical requirements for the energy performance. Therefore, it was impossible to asses further this indicator. Finally, LEED ND includes one extra indicator measuring the energy reduction that can be gained by replacing the public infrastructure with more energy efficient systems.

Renewable Energy/Sustainable Power Generation

BREEAM Communities assesses sustainable generation by measuring the share of energy demand covered by renewable(s). The tool requires that 15% of total building energy demand should be covered by renewable power. Extra points are achieved when the share rises to 20% or 25%. Moreover, it measures the potential of the area for future installations.

On the other hand, BREEAM NL has a particular method to assess sustainable generation. It uses different methodologies for assessing each different renewable energy technology; for solar energy, it assesses the potential of solar energy realized, while for wind energy and biomass, it measures the capacity installed within the area. Geothermal energy is measured by the temperature of the water pumped out of the ground, while for hydropower the tool examines if the environmental requirements for the installation are satisfied.

GPR Stedenbouw, similar to BREEAM Communities, measures the share of renewable energy locally generated.

Finally, LEED ND measures the share of the area's annual electrical and thermal energy costs covered by renewables. The indicator is similar to the one used by BREEAM Communities and GPR Stedenbouw, but instead of energy consumption it refers to energy costs. However, the minimum requirement that LEED ND asks is 5% coverage of total energy demand by renewable, which is much lower than the one asked from BREEAM Communities (15%). The fact could be explained because of the lower penetration of renewable energy sources in USA in comparison to Europe. Furthermore, LEED ND includes an additional indicator referring to district heating and cooling and awards points when at least 80% or more of the project's annual heating and/or cooling is provided by a district plan. However, it should be remarked that district heating based on non-renewable fuels is not as sustainable as individual systems based explicitly on renewable energy sources. Although this indicator could be useful in promoting the use of district heating and cooling in USA, where it is not so widespread, it might shift the focus from the use of renewable energy sources for heating and cooling. Hence, the indicator should be considered with attention.

Sustainable/Green Buildings

BREEAM Communities assesses sustainable domestic buildings by using the CODE for Sustainable Homes, the UK National Buildings Certification scheme and non-domestic or retrofitted buildings with the BREEAM scheme for buildings. The tool considers other certification schemes as well, which need to be first certified by BRE global as equivalent.

BREEAM NL assesses sustainable buildings by a certain algorithm, which is not publicly available. The tool evaluates the sustainability of the buildings in the area, by counting the buildings that have been certified within the area and the relevant rankings achieved. The tool considers various private certification schemes (BREEAM, LEED, GreenCalc, GPR Gebouw), as well as the Dutch national ranking label.

GPR Stedenbouw assesses buildings sustainability by considering their year of construction and the energy labels achieved. For older buildings, energy labels are also filled in approximately.

Lastly, LEED ND assesses green buildings by using the LEED rating scheme for buildings or other independent third party building rating tools.

Passive Design

Urban Heat Island

All tools, except for GPR Stedenbouw include indicators measuring the urban heat island effect.

BREEAM Communities assesses the urban heat island effect by examining the provision of shaded public spaces and other techniques, such as green roofs and vegetated walls, open water and fountains, external finishes that avoid heat absorption, and other measures that reduce the heat island effect within the area. The tool does not make use of any specific index for calculating the Urban Heat Island effect (UHI).

On the other hand, BREEAM NL makes use of the UHI index, an index developed especially for the purposes of the tool. Moreover, the tool examines, similarly to BREEAM Communities, the existence of measures that can prevent or minimize the UHI effect in the area. The list of measures in the specific tool mostly comprises of elements and techniques related to water, which can be explained by the fact that the tool comes from the Netherlands, where urban design is mostly focused on water management to avoid flooding etc.

Moreover, LEED ND assesses the reduction of heat island effect also by examining the provision of measures and strategies applied in the area. Most of the measures include surfaces with high solar reflectance index (SRI), green roofs, or shading techniques.

Solar Orientation

Only LEED ND and GPR Stedenbouw include indicators assessing the solar orientation of the buildings or blocks of the area. LEED ND requires that 75% of the blocks or buildings of the area should have one axis within plus or minus 15 degrees of geographical east-west. The requirements are higher than similar indicators in literature that require an angle of 25 degrees. Besides, 75% is also a very high share to be achieved in existing areas. However, such a requirement could be reasonable for developments of completely new areas. On the other hand, GPR Stedenbouw, measures the percentage of buildings parcelled to the south with an angle of 20 degrees.

Energy Monitoring

Only BREEAM Communities and BREEAM Gebiedsontwikkeling include indicators related to energy monitoring. BREEAM Communities examines the application of sub-metering systems at the building level, while BREEAM Gebiedsontwikkeling assesses whether the total energy demand of the area is monitored on annual basis and reported to the municipality.

4.4.3 Comparison of the tools against the generic list of energy indicators

The next step in the methodology was to compare and check the tools against the generic list of energy indicators, created for the present study and presented in chapter 3. The energy indicators of the tools, presented in the tables of Appendix II, were compared with the energy indicators included in the generic list of energy indicators. Tables 7, 8, and 9 present the results of the comparison. Table 7 presents the comparison with the key indicators of the generic list, while tables 8 and 9 present the secondary indicators.

Three different symbols were used to show the compatibility of energy indicators used in the tools with the energy indicators of generic list. The symbol ✓ shows that the tool includes the specific indicator from the generic list. The symbol ~ shows that the tool either includes a similar indicator with the one used in the generic list or that the tool includes the specific theme but it assesses it with a different method (e.g. qualitatively). The symbol ✗ shows that the tool did not consider the specific indicator in any way.

Table 7: Comparison of the tools with the key indicators of the generic list

Tools / *List of KEY indicators*	BREEAM Communities	BREEAM Gebiedsontwikkeling	GPR Stedenbouw	LEED Neighbourhood
K1. Total final energy consumption per capita/ or per m²	✗	✗	~	✗
K2.Total final electricity consumption per capita	✗	✗	~	✗
K3.Total CO_2 eq. emissions per capita, including emissions resulting from use of electricity	✗	✗	~	✗
K4.Percentage of total energy consumption produced by renewable energy sources	✓	~	✓	✓

✓ The indicator is included, ~ A similar indicator or theme is included, ✗ No reference to this indicator or theme

Table 8: Comparison of the tools with the secondary indicators of the generic list (part 1)

Tools / *List of SECONDARY indicators (I)*	BREEAM Communities	BREEAM Gebiedsontwikkeling	GPR Stedenbouw	LEED Neighbourhood
S1.Percentage of buildings' or blocks' surface orientated to the south within 25 degrees (for northern hemisphere) or to the north (for southern hemisphere)	~	✗	✓	✓
S2.Percentage of m^2 of roofs that are flat or have one primary south-facing slope	~	✓	✓	✗
S3.Population and jobs per m^2	✗	✗	✓	✗
S4.Percentage of Urban Tree Canopy Cover	~	~	✗	✓
S5.Total final Energy consumption of buildings within the area per m^2 floor area/ division for space heating and cooling, water heating, ventilation and lighting	✗	✗	✓	~
S6.Total final electricity consumption of buildings within the area per m^2 floor area /division for space heating and cooling, water heating, ventilation and lighting	✗	✗	✗	✗
S7.Total CO_2 eq. Emissions per m^2 floor area resulting from building sector/division for space heating and cooling, water heating, ventilation and lighting	✗	✗	✓	✗
S8.Share of floor area of buildings ranked with the maximum score on the national building rating system	~	~	~	~
S9.Share of floor area of passive buildings in the area	✗	✗	✗	✗
S10.Share of floor area of zero-energy buildings in the area	✗	✗	✗	✗

✓ The indicator is included, ~ A similar indicator or theme is included, ✗ No reference to this indicator or theme

Table 9: Comparison of the tools with the secondary indicators of the generic list (part 2)

Tools / *List of SECONDARY indicators (II)*	BREEAM Communities	BREEAM Gebiedsontwikkeling	GPR Stedenbouw	LEED Neighbourhood
S11.Net amount of waste heat generated that is imported/exported in/out of the area's boundaries	✗	✗	✗	✗
S12.Share of buildings with installed sub-metering systems	✓	~	✗	✗
S13.Share of energy efficient public lighting within the area	✗	✗	✓	✓
S14.Percentage of total energy derived from solar power as a share of the area's total energy consumption	✓	✓	~	~
S15.Percentage of total energy derived from wind power as a share of the area's total energy consumption	✓	~	~	~
S16.Percentage of total energy derived from geothermal power station as a share of the area´s total energy consumption	~	~	~	~
S17.Percentage of total energy derived from biomass power stations as a share of the area´s total energy consumption	✓	~	~	~
S18.Percentage of total energy derived from hydropower stations as a share of the area´s total energy consumption	✓	~	~	~
S19.Percentage of total energy consumed within a year that has been produced by combined heat and power plants	✓	~	✗	✗
S20.Percentage of total heat demand that has been covered by district/ community heating	✗	✗	~	✓
S21.Percentage of total energy consumed within a year that has been stored for a period	✗	✗	✗	✗

✓ The indicator is included, ~ A similar indicator or theme is included, ✗ No reference to this indicator or theme

Tables 10 and 11 summarize the results of the comparison of the indicators of the tools with the key indicators and the secondary indicators of the generic list, respectively.

Table 10: The results of the comparison of the tools with the key indicators of the generic list

Results for key indicators	✓	~	✗
BREEAM Communities	1	-	3
BREEAM Gebiedsontwikkeling	-	1	3
GPR Stedenbouw	1	3	-
LEED Neighbourhood	1	-	3

Table 11: The results of the comparison of the tools with the secondary indicators of the generic list

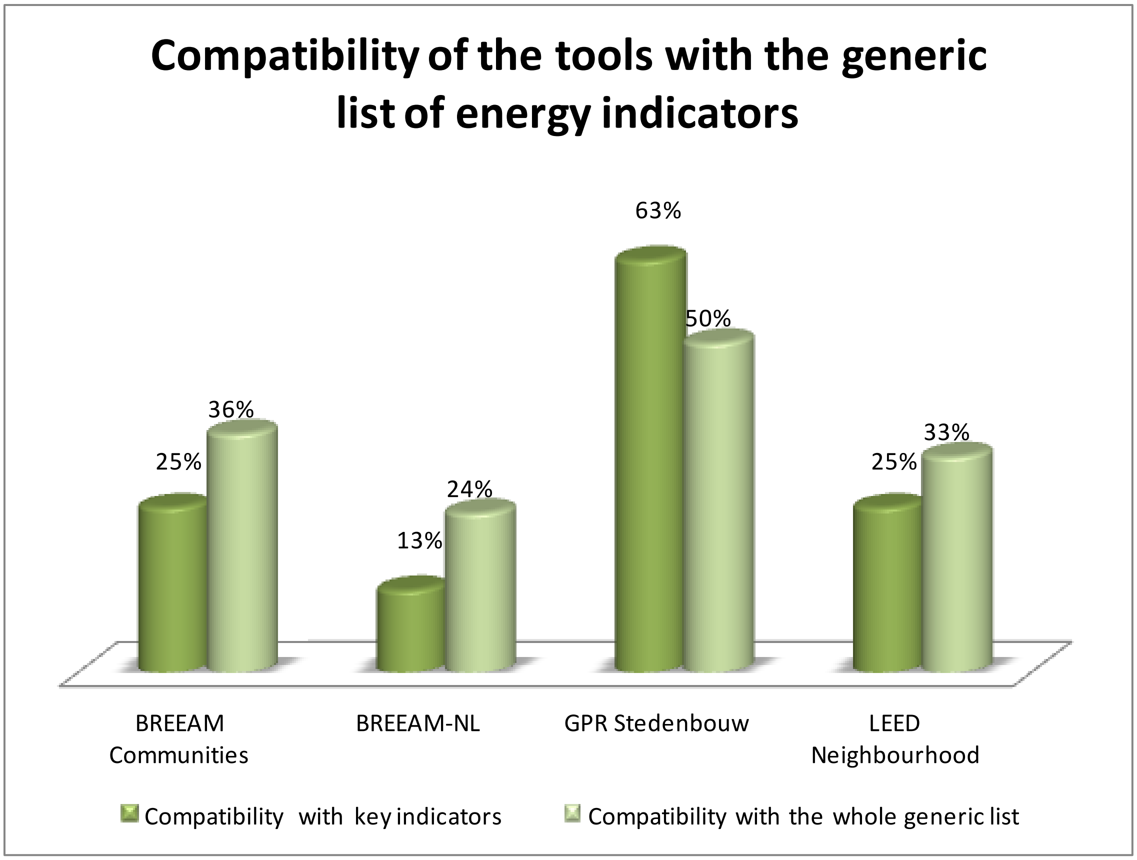
Results for secondary indicators	✓	~	✗
BREEAM Communities	6	5	10
BREEAM Gebiedsontwikkeling	2	8	11
GPR Stedenbouw	6	7	8
LEED Neighbourhood	4	7	10

The results of the comparison of the tools with the generic list of energy indicators showed that there is a significant incompatibility between the energy indicators used by the fours tools and the ones included in the generic list. More specifically, from tables 10 and 11 it is proved that the biggest share of energy indicators from the generic list is not included in the tools (amount of ✗ symbols), a smaller share of the indicators from the generic list is partly included (amount of ~ symbols), and only a few indicators from the generic list are exactly the same in the tools (amount of ✓ symbols).

It is important to note that, from the four key indicators of generic list, only the one measuring "the percentage of total energy consumption, produced by renewable sources" was included in all of the tools (BREEAM Gebiedsontwikkeling partly included it).

The incompatibility of the tools with the generic list of energy indicators can be explained by the fact that the generic list includes only quantitative energy indicators that measure the actual energy performance of the area, while the tools include mostly semi-quantitative indicators measuring the percentage improvement of the area in time. In fact, the comparison revealed that the methodology of the tools assesses the relative improvement of the energy performance of the area- its progress in time, but they do not give information about the actual energy consumption within the area. Since the tools assess development plans for urban areas, they stick at measuring the ambition of the plan and the relative improvement that it could bring about in the area; they do not measure the final actual energy performance of the area after the implementation of the plan though.

The results of compatibility of the tools with generic list, as presented in tables 7 - 11, were depicted in the Graph 1. A simple formula was used to calculate the percentage compatibility of the indicators of each tool with the generic list of energy indicators. If a tool had a ✓ within the table of key indicators 2 points were awarded, for a ~ 1 point, and for a ✗ no points. Likewise, for the secondary indicators 1 point was awarded for ✓, 0,5 points for ~ ,and no points for ✗. A distinction was made for the compatibility with the key indicators and the compatibility with the complete generic list.



Graph 1: The percentage compatibility of the tools as it was calculated based on a simple formula of weighting. Compatibility with key indicators weighted twice than with secondary indicators

As it can be seen from Graph 1, GPR Stedenbouw scores first in compatibility (50%) with the generic list of energy indicators. The compatibility with the key indicators was also high (63%), since it includes almost four key indicators (one the same, and three similar). GPR Stedenbouw includes also many secondary indicators of generic list.

BREEAM Communities is the second tool, after GPR Stedenbouw, compatible with the generic list of energy indicators with a percentage of 36%. The tool achieved this score because it includes many secondary indicators, but only one key indicator (the one referring to renewable energy).

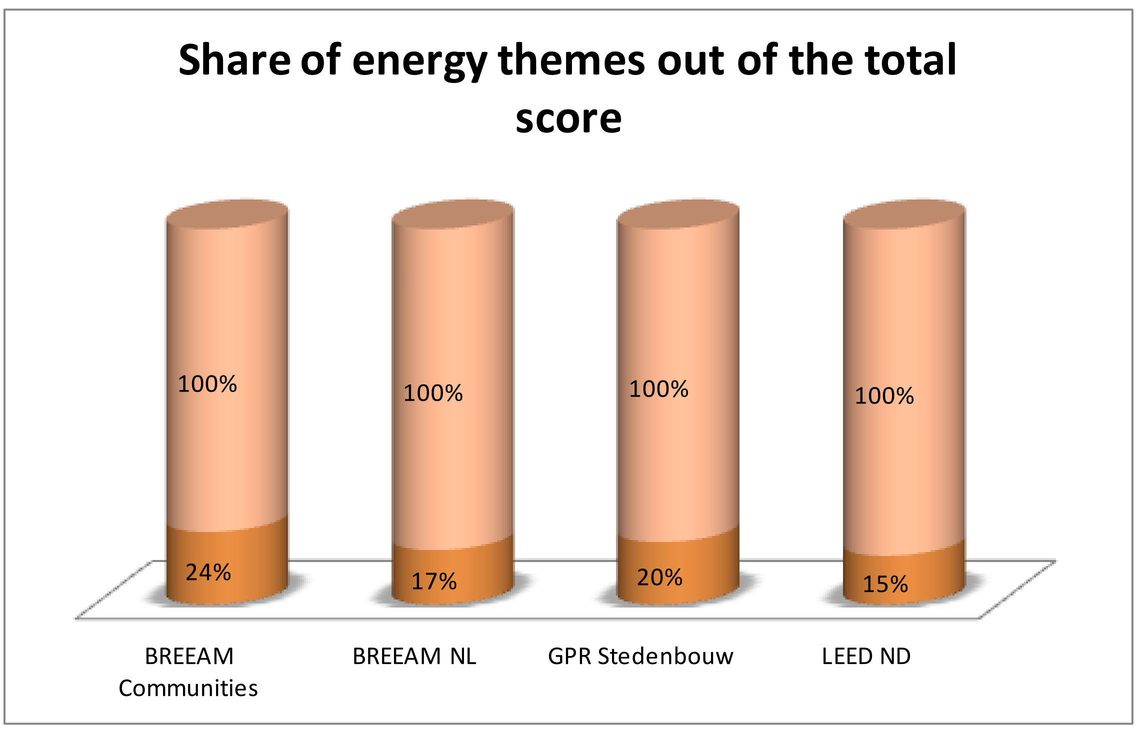
However, it should be noted that the percentages of 50% and 36% compatibility of the tools with the generic list do not imply that 50% or 36% of the indicators of the generic list are included in the tools. The percentages are higher because of the weighting factor of two given to the key indicators included in the tools.

That GPR Stedenbouw had the highest overlap with the generic list of energy indicators can be explained by the fact that the tool includes more quantitative indicators compared to the other tools. GPR Stedenbouw measures the energy consumption per m^2 of the area and the CO_2 emissions related to this energy consumption. However, it should be noted that although GPR Stedenbouw adopts a more quantitative methodology, and includes quantitative calculations of the energy performance of the area, the data used for the calculations are not actual data of the area, but statistical average data based on the different typologies of buildings existing in the area. Hence, instead of using the actual data of energy use within the area, GPR Stedenbouw considers the types of buildings existing in the area and the average national statistical data of the energy use of these types of buildings.

Furthermore, despite having the highest overlap with generic list, GPR Stedenbouw still lacks some quantitative indicators. Firstly, the tool does not include any indicators (quantitative or qualitative) measuring the heat island effect and its consequences on the final energy use of the area. Secondly, the tool lacks indicators referring to energy monitoring on building level, such as the suggested indicator from the generic list measuring the share of buildings in the area with sub-metering energy systems. Thirdly, the tool does not include any indicators measuring the electricity consumption of buildings. The tool measures only the primary energy used, but to have a clear overview of the total energy use, it is necessary to know information about the electricity consumption as well. Moreover, the tool should consider dividing the indicators measuring energy and electricity consumption in the categories of space heating and cooling, water heating, ventilation and lighting; in that way, a clear overview of the distribution of energy consumption in the different functions would be achieved and measures and strategies for energy reduction could be devised more accurately. In addition, GPR Stedenbouw should include additional quantitative indicators in the theme of renewable energy. The tool includes only one indicator measuring the share of renewable energy generated in the area. However, as it is suggested by the generic list, different indicators measuring the share of energy consumption derived from each different renewable energy technology (solar, wind, biomass, geothermal, hydropower etc.) should be included in order to give an extensive overview of renewable energy production within the area. Finally, the tool should consider including quantitative indicators measuring: a) the amount of waste energy imported/ exported in/out of the area's borders, b) the share of energy consumed in a year that has been stored before being used, c) the share of energy that has been produced by CHP plants, and d) the share of heat demand covered by district heating.

4.4.4 Comparison of the weighting of energy themes out of the total score

Another important issue that was examined within the comparison of the tools was the "value" attributed by each tool to energy themes; i.e. the weighting of energy themes out of the total score. This weighting was measured based on the total amount of points that could be gained from energy indicators of each tool, as a ratio of the maximum score of each tool. This weighting reveals the priority and focus that has been given by the methodologies of the tools on energy sustainability. The results of the comparison can be seen in Graph 2 .



Graph 2: Share of points valued for energy themes and indicators as a ratio of the total score of each tool

It can be noted that all tools attribute a share of around 20% of their total score to energy issues, which does not seem sufficiently high at first sight. However, if we consider that this specific study has not been focused on energy indicators within transport and waste themes, it can be expected that the total share of energy themes out of the total score will be higher.

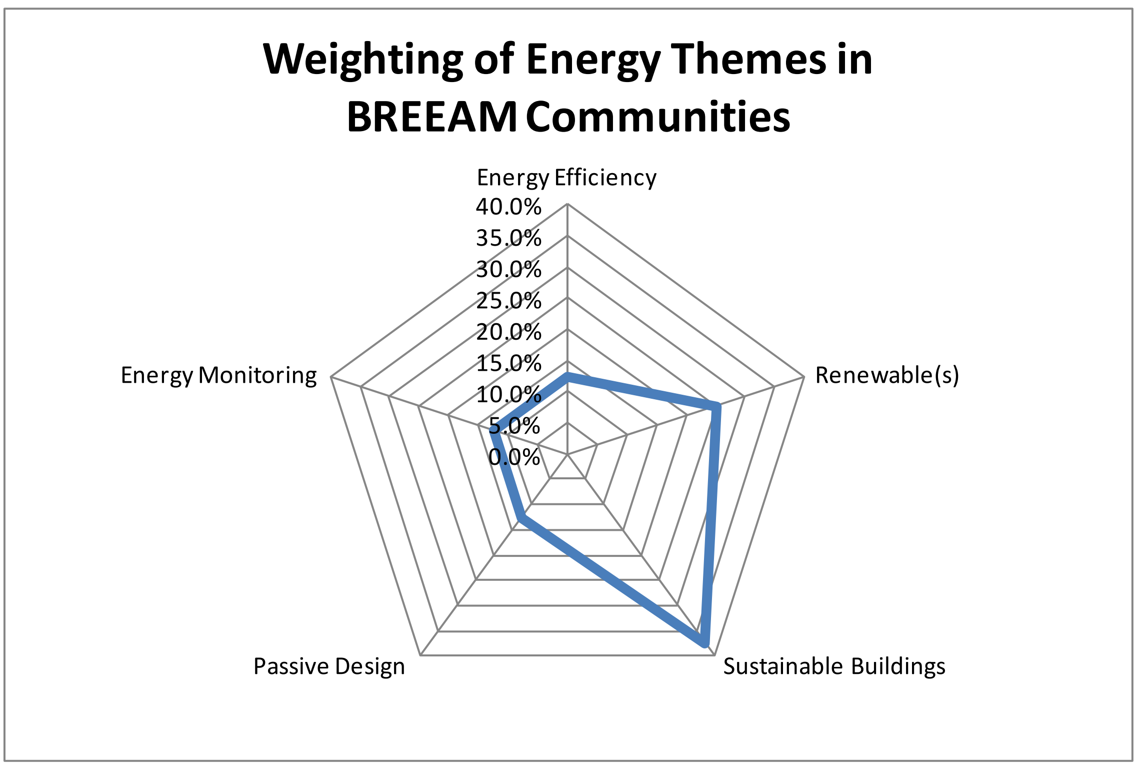
From the four tools, BREEAM Communities ranks first, by valuing 24 points out of 100 to energy issues, which is almost the 1/4th of the total score of the tool. The lowest share of energy themes, 15%, is given by LEED for Neighbourhood Development. This fact is rather remarkable, considering the title of the tool “LEED: Leadership in Energy and Environmental Design”, which creates the expectation that the tool would give primary focus to energy issues in urban design.

4.4.5 Comparison of the weightings of the energy indicators of each tool

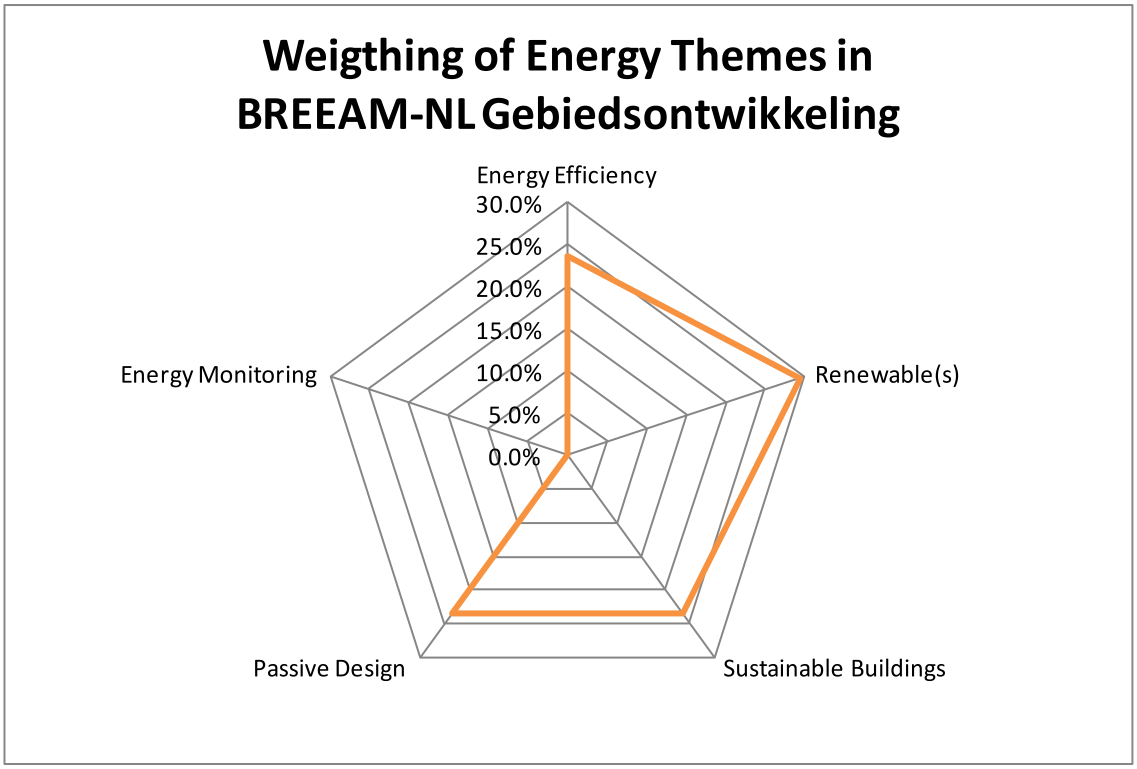
The tools were further compared based on the different “value” and weighting that was given to each of the energy themes that the tools included. The “value” was based, similar to the previous comparison, on the number points that could be gained from one specific energy theme, out of the total points attributed to all energy themes by the tool.

Spider diagrams were used in order to present the different weightings given to each energy theme by the tools. The energy themes compared were Energy Efficiency, Renewable(s), Sustainable Buildings, Passive Design, and Energy Monitoring, as presented in section 4.4.2.

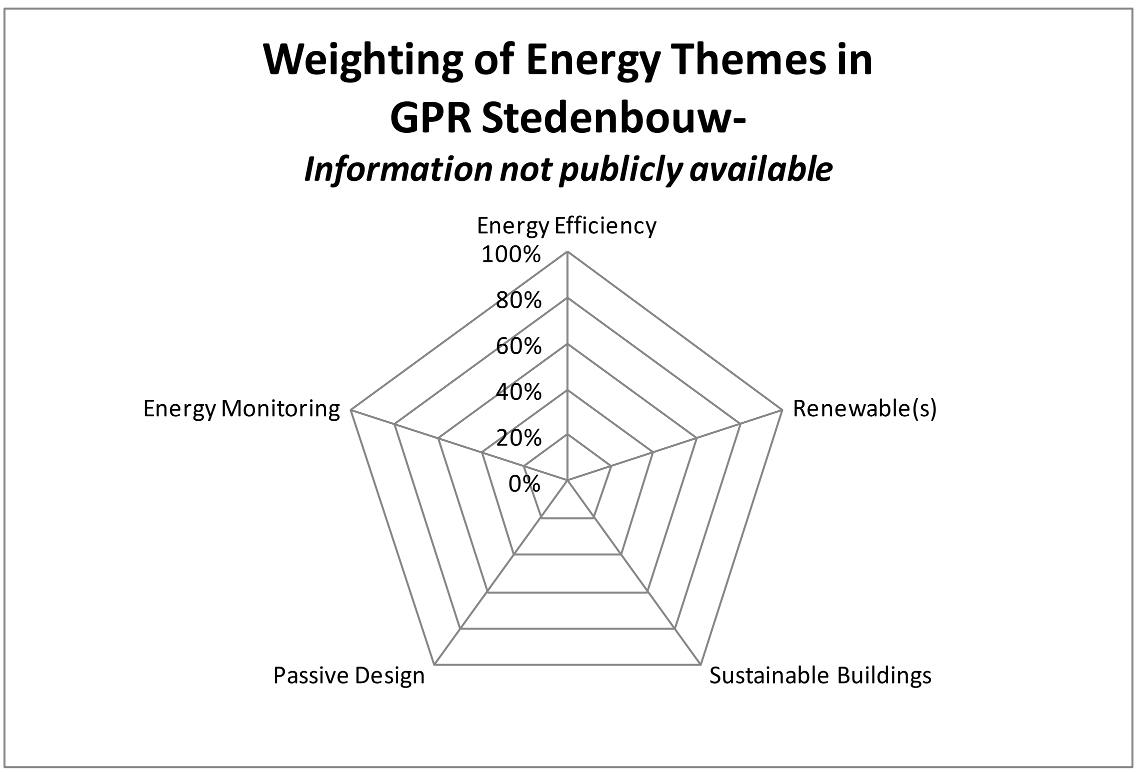
The results are presented in Graphs 3, 4, 5, and 6.



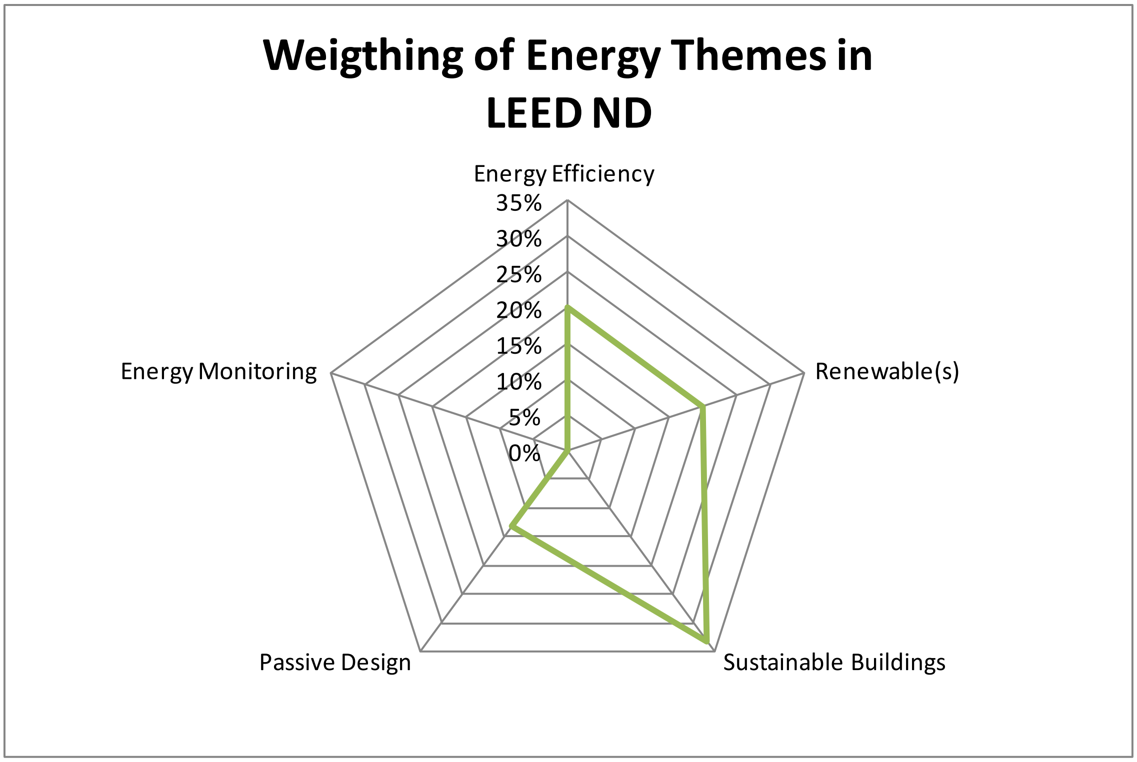
Graph 3: Weighting of the different energy themes in BREEAM Communities based on the points awarded for each indicator



Graph 4: Weightings of the different energy themes in BREEAM Gebiedsontwikkeling based on the points awarded for each indicator



Graph 5: Weighting of energy themes in GPR Stedenbouw- The information about points and weights of each indicator was not publicly available



Graph 6: Weighting of energy themes in LEED ND based on the points awarded for each indicator

As it can be seen from Graph 5, GPR Stedenbouw does not provide publicly the weighting factors and methodology used for scoring, thus, it was impossible to design a weighting diagram for the specific tool.

Furthermore, it is remarkable that the tools BREEAM Communities and LEED ND give primary focus to buildings' sustainability, meaning that the biggest share of points within energy themes is achieved from indicators referring to sustainable/green certified buildings. This focus on buildings' sustainability is not so unexpected, if one considers that these tools have been developed based on the methodologies of their preceding building rating schemes.

Moreover, from Graph 4, it is noteworthy that BREEAM-NL Gebiedsontwikkeling has the most distributed weighting between the different energy themes, which is a positive outcome for the tool. It is important to realize that in order to achieve energy sustainability in urban environment, focus should be given on all different aspects and themes. In addition, another positive feature of the methodology of BREEAM-NL Gebiedsontwikkeling is that it attributes the highest share of points (30%), between the fours tools, on renewable energy.

Finally, it should be mentioned that the indicator of District Heating and Cooling of LEED ND was not considered within the spider diagram of the tool. The indicator could be included in the theme of Renewable Energy/Sustainable Power Generation and increase the points attained by this theme. However, it would blur the results, by showing that LEED ND puts a considerable emphasis on renewable energy, while putting least between the tools. In fact, LEED ND attributes the least points on renewable energy and additionally, it requires much lower share of renewable power generation within the area (5% of total energy use) than BREEAM Communities (15% of total energy use).

4.4.6 Comparison of the prerequisite criteria of the tools

Lastly, the tools were compared based on the prerequisite energy criteria that have to be fulfilled by the area in order to award a certification. Figure 10 summarizes the prerequisite energy criteria of each tool.

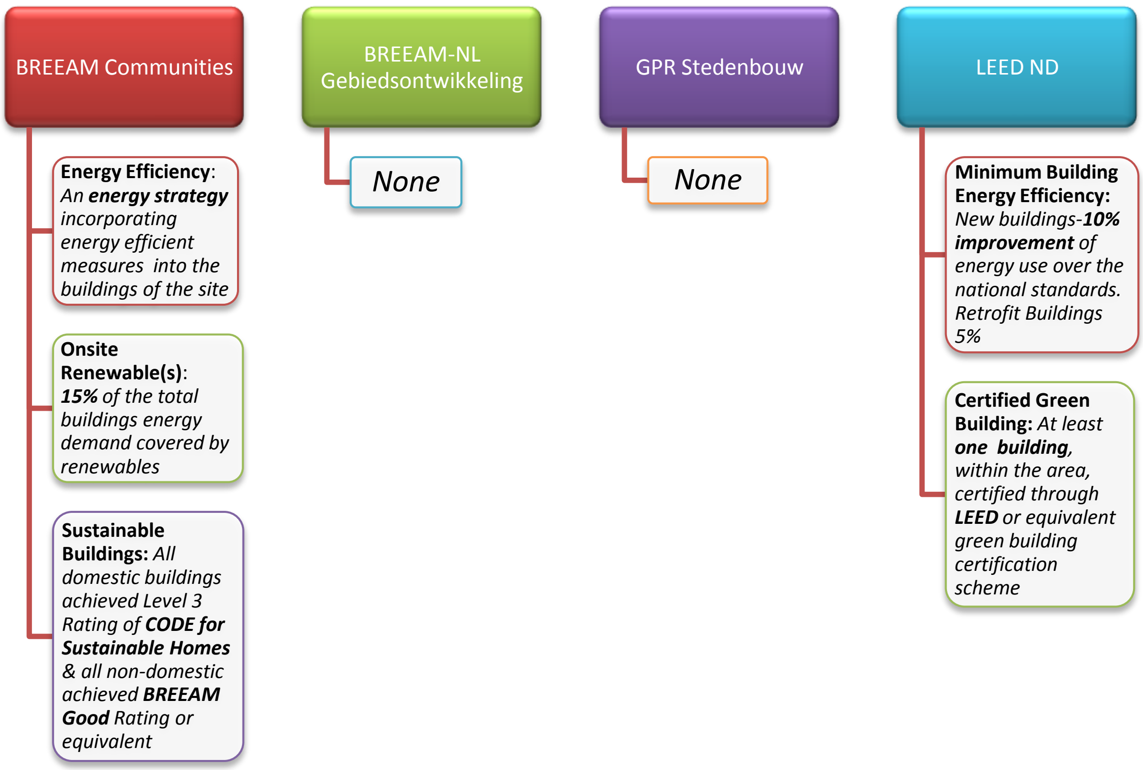


Figure 10: Prerequisite energy criteria that need to be fulfilled in order to get certified by each tool

As it can be seen from Figure 10, only BREEAM Communities and LEED ND include prerequisite energy criteria. Both of the tools include prerequisite criteria on Energy Efficiency and Sustainable/Green buildings, but BREEAM Communities includes a third prerequisite referring to Renewable Energy. BREEAM-NL Gebiedsontwikkeling does not include any prerequisite energy criteria for achieving certification. However, to achieve a rate higher than 3 stars, one point needs to be achieved within the category of sustainable buildings.

It is remarkable that the prerequisite criteria for sustainable buildings of BREEAM Communities and LEED ND require the existence of certified buildings by BREEAM or LEED building schemes within the area, a very limiting requirement, difficult to be fulfilled by regular urban areas since there are not so many BREEAM and LEED certified buildings worldwide.

Furthermore, it should be remarked that prerequisite criteria related to reduction of energy demand and to renewable energy are likely to cause a stronger impact on the final energy performance of the area, than a number of certified green buildings.

4.5 Summary of the results

The following section summarizes the main points and results that arose from the comparison of the tools.

Firstly, the comparison of the methodologies of the tools showed that the main energy themes included in all of the tools were: Reduction of Energy Demand, Renewable Energy, Sustainable Buildings, Passive Design (urban heat island effect & solar orientation), and Energy Monitoring. Not all tools included indicators in all of the themes.

Secondly, comparing the tools with the generic list of energy indicators revealed a significant incompatibility. The incompatibility can be explained by the fact that the generic list includes only quantitative energy indicators measuring the actual energy performance of the area, while the tools include mostly qualitative indicators measuring the percentage improvement of the area in time. GPR

Stedenbouw proved to be the most compatible tool with the generic list of energy indicators, with a score of 50% (compatibility with key indicators valued double). However, the tool still lacks a few additional quantitative indicators.

Furthermore, the tools were compared based on the weighting they attributed to energy themes as a fraction of the total score. The weighting was based on the maximum amount of points gained by energy indicators as a fraction of the total score. In general, the tools attribute around 20% of the total score to energy themes, except for BREEAM Communities that values 24 points out of 100 to energy issues. LEED for Neighbourhood development values energy themes the least (17%), which was a surprise considering the expectations that creates the full name of the tool "Leadership in Energy and Environmental Design".

Moreover, the tools were assessed for the weightings they attribute to the different energy themes. The weightings were again based on the amount of points gained by a specific energy theme divided by the points gained from all energy indicators. As a result, it was revealed that BREEAM Communities and LEED ND give primary focus to Sustainable/Green Buildings, which could be expected, considering their preceding rating schemes. On the other hand, BREEAM-NL Gebiedsontwikkeling has more distributed weightings between the different themes and gives the highest weighting to renewable energy, which is a positive outcome. GPR Stedenbouw does not provide the weighting factor and its rating methodology publicly.

Lastly, the tools were compared based on the mandatory energy criteria which need to be fulfilled by an area in order to receive certification. Only BREEAM Communities and LEED ND include prerequisite energy criteria, which are in the themes of sustainable buildings and energy efficiency. BREEAM Communities includes a criterion in the theme of renewable energy as well. The prerequisite criteria for sustainable buildings require only for one or more certified buildings within the area by BREEAM or LEED building rating tools. Such buildings are not very frequent in regular areas; thus, these prerequisite criteria cannot be easily fulfilled. Nevertheless, it should be remarked that prerequisite criteria related to reduction of energy demand or to increase of renewable energy production are likely to bring about a greater improvement to the final energy performance of the area than a few certified green buildings.

5. Application of the Four Tools to the Case Study Area

5.1 Introduction

After comparing the four assessment tools with each other and with the generic list of energy indicators, the second methodological step was to apply the tools to a "real-world" case study in order to check and analyze their practicality. To this end, the present chapter focuses on the application of the four tools in the area of Lijnbaan in the centre of Rotterdam, which was chosen for this purpose. The application was based only on the energy themes of the tools and not on the complete list of indicators. The results of the application, and the different scores that the area achieved by each tool, are further presented and interpreted. Finally, conclusions are drawn about the functionality of the tools and the weaknesses and strengths of the methodologies used.

5.2 The case study area: Lijnbaan, Rotterdam

For the case study area, the quarter of Lijnbaan in the centre of Rotterdam, was indicated by the group of Architecture in TU Delft as a good example. The area is undergoing redevelopment and hence, it served as a good example for the application of the tools; the plan for the future of the area could be assessed by the tools and compared with the present situation. Besides, the Municipality of Rotterdam had already decided to apply the GPR Stedenbouw tool in Lijnbaan, as a pilot application in collaboration with the developers of the tools. As a result, the application of the other three tools was combined with the application of GPR Stedenbouw in the same area. In that way, the municipality of Rotterdam could evaluate and promote the sustainability plans decided for the area and, besides, conclusions could be drawn from a comparison of the tools, in terms of their application.

The quarter of Lijnbaan is considered as the centre of Rotterdam, concentrating a mix of various facilities. Its main function, as a shopping traffic-free area was one of the results of the massive reconstruction that took place in the city of Rotterdam after its bombardment in the 2nd world war. The area comprises of different types of buildings, some of them from the pre-war period, which have, nowadays, a historical value, some other from the reconstruction period, and many commercial complexes and housing facilities.

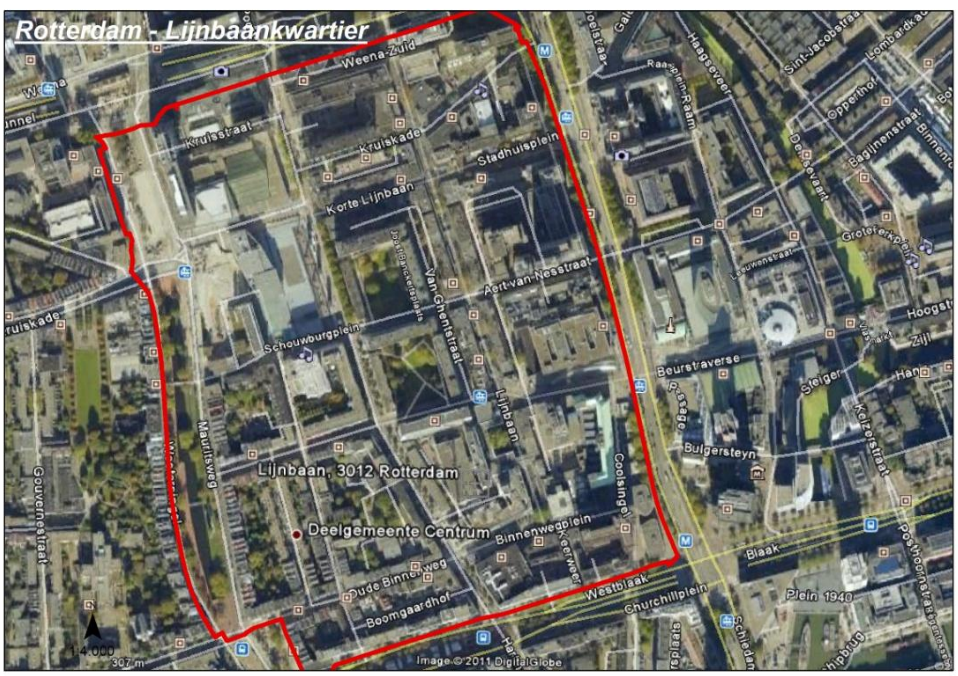


Figure 11: Satellite map of the Lijnbaan quarter in the center of Rotterdam, which served as a case study for the application of the 4 assessment tools *(Gemeente Rotterdam)*

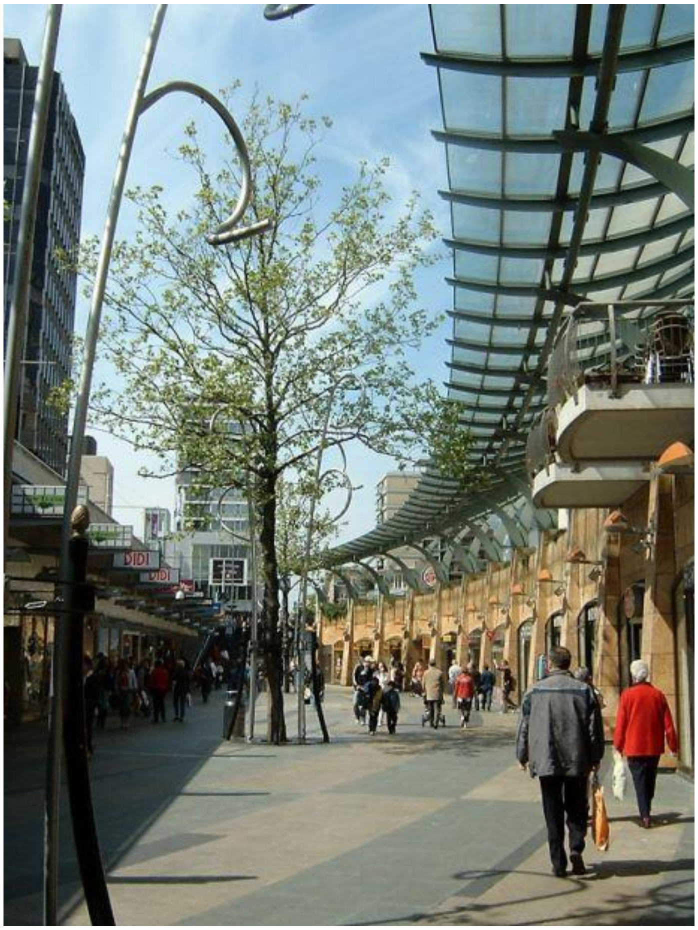


Figure 12: Lijnbaan, the car-free pedestrian shopping quarter, served as case study (ecoNODE)

The quarter of Lijnbaan is undergoing redevelopment, which was decided in 2010 and will be finished by the end of 2012. The specific redevelopment plan of Lijnbaan was the one chosen for the application of the tools in the area. The tools applied in order to assess the future situation of Lijnbaan by the end of 2012 and compare it with the current conditions. The specific process should normally take place at the beginning of the planning process, so that the tools could evaluate the plan, and decision could be taken whether to proceed with it or not. However, for the purpose of this study, which was to compare the methodologies of the assessment tools, the specific plan was enough to fulfill this goal.

The plan for the redevelopment of the area focuses on three main domains: densification of the area, urban green, and increased connectivity. In order to increase the density of the area, the plan sets as priority the construction of new housing and shopping facilities that will bring more residents and will transform the area into a vibrant city center. Moreover, in order to make the area greener, the few public open spaces will be transformed to green squares and the flat roofs of buildings to green roofs. More specifically, the municipality of Rotterdam has decided to subsidize 50% of the costs for the implementation of green roofs. Finally, to increase the connectivity of the area, emphasis is given to turning the public space into a linking space between different functions and between the neighbouring areas.

In total, the plan includes mostly the construction of many new residential and commercial blocks, renovation of old buildings to housing or commercial blocks, and the creation of new public green spots.

As far as energy is concerned, the specific strategic plan for the area does not include any clear and ambitious goals. However, the area is included in the general energy strategy applied for the whole city of Rotterdam; thus, the existing energy requirements for the whole city are also valid for the area of

Lijnbaan. According to these requirements, since 2011, all new buildings are required to have a EPC coefficient of 0,6. The previous prerequisite for buildings was an EPC of 0,8, thus, the energy performance of new buildings has been improved by 20%.

Overall, the future plan of the area of Lijnbaan, as received by the municipality of Rotterdam, can be found in Appendix III. Information about the new buildings and the retrofits that will take place within the area are included. However, no information was given about exact number, i.e. the total m^2 of new buildings, the total m^2 of retrofit buildings etc, a fact that brought implications during the application of the tools. However, the specific topic will be further explained in the following section.

5.3 Results

The specific section presents the results of the application of the energy indicators of the tools in the area of Lijnbaan in Rotterdam and the scores that the area achieved in every different tool. The points and the total scores achieved for each tool are presented in tables, and a short analysis of the results is given for each tool. The extensive tables of the application of the tools and the detailed scores achieved are included in Appendix III.

BREEAM Communities

Table 12: The score Lijnbaan area achieved in the energy indicators of BREEAM Communities

Results for BREEAM Communities		
Indicator	**Description**	**Points achieved**
CE 5 - Energy Efficiency (mandatory)	Energy strategy	3/3
CE 6 – On-site renewable(s) (mandatory)	Share of total building energy demand covered by Low or Zero Carbon Technologies	1/3
CE 7 - Future renewable(s)	Potential for future installation of renewable(s)	3/3
CE 11- Sub/Smart-Metering	Energy monitoring	0/3
CE 4 - Heat Island	Passive Design Principles	3/3
BLD 1 - Domestic (mandatory)	Code for Sustainable Homes/Eco homes	0/3
BLD 2 - Non- domestic (mandatory)	BREEAM Buildings (or equivalent)	0/3
BLD 3 - Building Refurbishment	BREEAM Buildings (or equivalent)	0/3
		Total: 10/24 = 0% *due to not fulfilled mandatory criteria*

As it can be seen in table 12, Lijnbaan area scored 10/24 points in the energy indicators of BREEAM Communities. However, the total score achieved was zero, due to non-fulfilment of the mandatory criteria that the tool required in the theme of sustainable buildings.

More specifically, full points were achieved for the indicator measuring "Energy efficiency", which was a qualitative indicator measuring the existence of a clear energy strategy for the future of the area. Full points were also achieved for the indicator "Future renewable(s)" measuring the potential of buildings in the area to connect (in the future) to active solar devices. The points were achieved because all buildings in the area have flat roofs and hence, maximum potential for solar panels. Full points were also achieved for the "Heat Island" indicator, because all the required criteria for heat island effect were fulfilled, due to the special focus that the specific redevelopment plan had given on green public spaces.

Furthermore, one out of three points was achieved in the indicator measuring "On-site renewable(s)" and that was based on the gas CHP power plant used to provide electricity and heating in the area of Lijnbaan. BREEAM Communities considers gas fuelled CHP power stations as Low Carbon Energy technologies, and thus, they are included in the indicator "On-site Renewable(s)".

Moreover, no points were achieved for the indicator referring to "Sub/smart Metering", and the indicators referring to "buildings". On the one hand, for energy monitoring, no plans exist in the area for installing sub-metering energy systems on new buildings. On the other hand, the indicator referring to domestic buildings made requirements based on the CODE for Sustainable Homes, which is a mandatory measure of the sustainability of new homes in England. However, these requirements referred only to rating levels and they were not translated into actual metric measurements of performance. Hence, it was not possible to make the correspondence. Besides, the indicators for non-domestic buildings and refurbishments required that all non-domestic and refurbished buildings should have achieved a BREEAM ranking of "good", but no buildings in Lijnbaan are certified by BREEAM. Due to the non-fulfilment of these mandatory criteria of buildings, the total score of Lijnbaan in BREEAM Communities was finally zero.

BREEAM-NL Gebiedsontwikkeling

Table 13: The score Lijnbaan area achieved in the energy indicators of BREEAM-NL Gebiedsontwikkeling

Results for BREEAM-NL Gebiedsontwikkeling		
Indicator	**Description**	**Points achieved**
BRO 1 - Reduce primary energy	Percentage improvement of the energy of the area	2/4
BRO 2 - Generating renewable energy	Solar, Wind, Biomass, Geothermal & Hydro power generation	0/5
RO 9 - Sustainable buildings	Certification schemes: BREEAM-NL, LEED Green Building, GPR Gebouw, GreenCalc, National Energy Label	1/4
KL 1 - Thermal Outdoor Climate	Urban Heat Island Index	3/4
		Total: 6/17 = 35%

As it can be seen in Table 13, Lijnbaan area scored 6/17 points in the energy indicators of BREEAM-NL Gebiedsontwikkeling or 35%. The tool does not include any prerequisite criteria that needed to be fulfilled. Hence, the final score of the area was the sum of all points achieved for each indicator.

However, no indicator was completely fulfilled, achieving all the points.

More specifically, for the indicator "Reduce Energy Demand", 2 out of 4 points were achieved, based on the 10% improvement of the energy performance of the area and the annual energy monitoring which takes place in the area and is reported to the municipality. The 10% improvement of the energy performance of the area was not explicitly calculated, because the energy performance of the buildings in the area was known only based on the EPC coefficient[4]. Hence, based on the share of new and existing buildings and the relevant EPC coefficients, the assumption was made that the total energy improvement of the area would be 10%.

Moreover, no points were achieved for the indicator measuring renewable energy, since no renewable power is generated within the area. The specific tool does not include the option of gas fuelled CHP within this category, as BREEAM Communities does.

Furthermore, one point was achieved within the "Sustainable Buildings" indicator, based on a certain amount of buildings within the area that had been certified by GPR Gebouw and GreenCalc schemes. BREEAM-NL Gebiedsontwikkeling considers also the specific Dutch buildings schemes, since it is also Dutch.

Finally, 3 out of 4 points were achieved within the "Thermal Outdoor Climate" indicator, due to the focus given on urban green within the specific plan for Lijnbaan area.

[4] Energie Prestatie Coëfficiënt: See chapter 4

GPR Stedenbouw

Table 14: The score Lijnbaan area achieved in the energy indicators of GPR Stedenbouw

Results for GPR Stedenbouw						
Theme	**Description**	**Indicator**	**Results**		**Points achieved**	
			Current	***Future Plan***	***Current***	***Future Plan***
Reducing Energy Demand	Measures for reducing energy demand and management of sustainability process	Compactness (Floor Space Index)	5.2	5.6	17/18	18/18
		Percentage of roof area suitable for solar energy	no	50-75%	0/18	0/18
		Percentage of buildings parcelled to the south (+/-20 degrees)	25-50%	>50%	0/9	9/9
		Percentage of buildings parcelled to the south with a barrier in front of them	10-25%	10-25%	0/5	0/5
		Percentage of energy efficient public lighting	25-50%	50-75%	0/9	5/9
		Future stakeholders have a role in the planning process	Partly	Partly	0/7	0/7
		Monitoring of sustainability progress	Partly	Yes	0/7	7/7
		There is or there will be an energy vision plan for the area	Partly	Partly	0/7	0/7
				Total:	**7.3/10**	**7.9/10**
Energy performance (EPL)	Energy performance of the area based on the types of buildings and their energy labels, the type of heating and the renewable energy production in the area	Energy labels of existing buildings	Various	Various	-	-
		Share of energy saved by new buildings energy performance (2010)	0%	20%	-	-
		Space heating and hot water systems	STEG 250 MWe	Gas Heating	-	-
		Renewable electricity locally generated	0%	0%	-	-
				Total:	**7.0/10**	**7.9/10**
				Final:	**7.1/10**	**7.9/10**

Results of Energy Performance Calculations for GPR Stedenbouw					
	Current	**Future**		**Current**	**Future**
Used Surface (m^2)			**CO_2 emissions per year (kton/year)**		
Residential	334,672	408,292	Residential	9.6	10.4
Utilities	1,633,900	1,702,800	Utilities	62.7	44.6
Total	1,968,572	2,111,092	Total	72.2	55
Primary Energy Use (TJ/year)			**CO_2 emissions per m^2 of used surface ($kg/m^2/year$)**		
Residential	149,9	141,6	Residential	28.6	25.4
Utilities	1,578.3	1,004.2	Utilities	38.4	26.2
Total	1,728.2	1,145.7	Total	36.7	26
Primary Energy Use per m^2 of used surface ($MJ/m^2/year$)			**EPL**		
Residential	448	347	Residential	6.79	7.17
Utilities	966	590	Utilities	7.03	8.02
Total	878	543	Total	7.0	7.90

As it can be seen from Table 15, Lijnbaan area scored 7.1/10 for the situation before the plan, and 7.9/10 for the future that will be developed according to the plan.

However, the system of scoring and rating of GPR Stedenbouw is completely different from the other tools.

Firstly, the tool assesses the area in two phases: the current situation and the area in the future, which will be developed based on the specific plan. For this reason, the tool gives two scores: one for the current situation and one for the future plan.

Secondly, another main difference of the scoring system of GPR Stedenbouw from the other tools is that any assessment of an area starts with 6 initial points as a basis, from which points are added or subtracted depending on the performance of the area for each indicator. Hence, the grade of 7.9/10 does not have the same value as the grade of 79% of the other tools. In the other tools the 79 points would be achieved starting from zero.

Thirdly, since the weighting factors and the points achieved for each indicator are not publicly available, it is difficult to interpret the final scores. Checking for example the score given for the current situation, the area achieved almost zero points for all indicators- except for the one referring to compactness- but still the final score was 7.3/10.

As for the future situation, full points were achieved for the indicators referring to compactness, south orientation and monitoring of sustainability progress. More than half points were also achieved for the energy efficient lighting in the area.

Finally, the tool calculates the final energy use, the CO_2 emissions, and the EPL coefficient of the area based on all data given about the surface area, the types of buildings, and the relevant energy labels. The average between the score achieved for the energy performance calculation and the category of reducing energy demand, gave the final score for the existing and the future area.

LEED for Neighborhood Development

Table 15: The score that Lijnbaan area achieved in the energy indicators of LEED for Neighbourhood Development

Results for LEED for Neighbourhood Development		
Indicator	**Description**	**Points achieved**
Certified Green Building (prerequisite)	One certified building in the area by LEED or other independent green building certification scheme	Not fulfilled
Minimum Building Energy Efficiency (prerequisite)	New buildings should demonstrate 10% improvement over national standard (ANSI/ASHRAE/IESNA Standard)	Fulfilled
Credit 1: Certified Green Buildings	Percentage of square footage certified by LEED or other green building certification	0/5
Credit 2: Building Energy Efficiency	Percentage improvement of new building or renovations over the national standard (ANSI/ASHRAE/IESNA Standard)	1/2
Credit 9: Heat Island Reduction	Measures applied for reducing urban heat island effect	1/1
Credit 10: Solar Orientation	Percentage of blocks with solar orientation	0/1
Credit 11: On-Site Renewable Energy Sources	Percentage of electrical and thermal energy costs covered by renewable power	0/3
Credit 12: District Heating and Cooling	Share of area's annual heat/cool consumption covered by district heating system	1/2
Credit 13: Infrastructure Energy Efficiency	New energy efficient infrastructure that achieves 15% annual energy reduction	1/1
		Total: 4/15 = 0% *due to not fulfilled prerequisites*

As it can be seen from table 15, Lijnbaan area scored 4 out of 15 points for energy indicators of LEED ND, but the final score achieved was zero, due to non-fulfilment of the prerequisite criterion that the tool required in the theme of certified green buildings.

More specifically, the first prerequisite criterion, "Certified Green Building", was not fulfilled, since there is no building within the area that is certified by LEED or another independent green building rating scheme. For the same reason, no points were achieved for the relevant indicator, "Certified Green Buildings", measuring the share of square footage that has been certified with independent green building rating schemes.

Furthermore, the second prerequisite criterion, "Minimum Building Energy Efficiency", was fulfilled in the area of Lijnbaan. The criterion required that all new buildings should demonstrate 10% improvement over the national standard, which is satisfied in the area of Lijnbaan, since new buildings are built with lower EPC than the national standards. In fact, the national standards for new buildings required EPC of 0.8 (in the beginning of the redevelopment plan-2010) and the buildings were built with EPC 0.6, i.e. 20% energy improvement. For this reason, one point was also achieved for the relevant indicator, "Buildings Energy Efficiency" measuring the improvement of new buildings' energy efficiency.

Full points were achieved for the indicator measuring the "Reduction of heat island" effect, due to the measures applied on the specific redevelopment to increase the urban green.

No points were achieved for the indicator measuring the "Solar orientation", because the requirements were too high; the indicator required that 75% of the blocks of the area should be orientated to the south. According to the urban planning experts of the municipality, this requirement can be achieved only in new built areas and not in existing areas.

Likewise, no points were achieved for the indicator referring to "On-site renewable energy sources", since the plan did not include renewable energy generation within the area. This indicator was a controversial point, since all new buildings in Lijnbaan are constructed with heat and cold underground storage systems to cover their heat/cold demand. However, the specific technology was not included in the options of renewable energy generation provided by the tool. The municipality experts insisted that it should be characterized as geothermal technology, but in fact, it is not.

One point was achieved for the indicator measuring the incorporation of "District heating in the area", requiring that 80% of the area's annual heating and cooling consumption would be covered by the district power plant. In the area of Lijnbaan, most buildings are covered by a city heating system, which uses the waste heat from a CHP gas fuelled power plant. Some old flats though, are not connected to the city heating.

Finally, full points were achieved for the indicator measuring the "Energy efficiency of infrastructure", which required a 15% annual energy reduction only from changes in infrastructure; according to the municipality estimations, the energy reduction achieved only from changing to energy efficient lighting could reach up to 67%.

Table 16 gives an overview of the scores Lijnbaan area achieved in the energy themes of the four different tools.

Table 16: Overview of the scores achieved in the energy themes of the four tools

BREEAM Communities	BREEAM-NL Gebiedsontwikkeling	GPR Stedenbouw	LEED ND
0%	35%	7.1/10 (current), 7.9/10 (future)	0%

5.4 Interpretation of the results

The area of Lijnbaan, which was used as a case study for the application of the four tools, did not score very high in the energy themes of the tools. However, many conclusions were drawn about the application process, the methodologies, and the practicalities of the tools.

5.4.1 Overall findings

One of the main lessons learnt from the application of the tools in Lijnbaan area was about the focus that is generally given to energy sustainability in redevelopment plans of urban areas. Although the specific plan was only one case study, it is still a representative example of a redevelopment plan of an area of a modern city like Rotterdam. As it became clear from the application of the tools, the specific plan did not include any clear and ambitious goals for the improvement of the energy performance of the area. Focus was mostly given to the improvement of urban greenery and to increasing the area's density. An overall energy strategy exists for the whole city, but the goals set were beyond the examined period of two years. This case seems to be a frequent phenomenon in planning of new urban areas or redevelopment of existing ones; energy still remains a neglected element. Architects and urban planners are usually more focused on the functional elements of an area and they tend to change or improve features that have a direct impact on the appearance of the area and the functions that take place within its borders. In general, they prefer to include characteristics that would attract more people into the area and which would increase its real estate value. Unfortunately, energy is still not considered as one of these characteristics and continues to languish at the bottom of the priorities list.

However, attention should always be given to energy sustainability in urban planning. In order to achieve ambitious goals and to shift towards a climate neutral urban environment as soon as possible, no opportunity should be missed to improve the energy performance of urban areas. Every plan for new areas or redevelopment of existing ones should ensure that it includes clear targets and goals of energy sustainability. Otherwise, once the design of the area is already complete, it is too late to incorporate sustainable energy goals.

Furthermore, if energy is not studied and considered from the beginning of development of an area, the synergies between the different features and elements are missed. It is important to realize that urban design should no longer be focused only on improving different elements of an area separately; because even if each element works excellently, the interdependencies between the different parameters and functions of an area, neighbourhood, or district are lost. These interdependencies are the synergies that should always be considered in order to achieve a thorough sustainable urban design; and energy is always part of these synergies.

Therefore, even if the specific plan for Lijnbaan was a short-term plan of two years and even if a general energy strategy were applied in the whole city of Rotterdam in the future, energy should still be considered at this stage as well. Even if the focus of the specific redevelopment was urban greenery, an additional study should be included assessing the improvements of the energy performance of the area and the potential improvements for the future based on the specific redevelopment plan.

5.4.2 Conclusions about the methodologies of the tools

Apart from the overall findings that came up from the application of the tools to the specific plan of Lijnbaan, many conclusions were also drawn about the methodologies of the four assessment tools that also explain the low scores that Lijnbaan area achieved.

Firstly, one very important issue that became clear after the application of the tools was that the BREEAM and LEED assessment methods are not the best to certify existing neighborhoods; their main purpose is to assess or certify new developments. Although the tools claim that they can be used to evaluate existing areas and identify their strengths and weaknesses, the application showed that their methods would apply best when at least 50% of the project's buildings floor area consists of new buildings; otherwise, the prerequisite criteria cannot be easily fulfilled and the scores achieved by the indicators are low. This is also one reason for the low scores achieved by Lijnbaan area.

Furthermore, another main feature of the methodologies of the tools that helps to explain Lijnbaan's low score were the prerequisite criteria. As previously outlined, two of the tools, BREEAM Communities and LEED Neighbourhood, include mandatory criteria that need to be fulfilled in order to award a final score to the development. The specific methodology of the tools with the mandatory criteria aims to ensure that a certified sustainable neighbourhood does not go below a certain level in all different themes and categories of assessment. For the category of energy, the prerequisite criteria refer to minimum energy efficiency, renewable energy production, and sustainable buildings. The Lijnbaan area did not fulfill the prerequisite criteria for sustainable buildings of the two tools, and consequently the final score achieved for both tools was zero.

The Lijnbaan area could not complete the requirements of BREEAM Communities for certified green buildings. However, the specific requirements are very specific and particular. The first criterion required that all domestic buildings in the area would have achieved a rating 3 of CODE for Sustainable Homes, which is the national building rating system in UK. No translation to internationally understandable quantitative criteria was available by the tool. Hence, the fulfillment of the specific criterion was not feasible. However, if BREEAM Communities aims to be an international tool, it should provide indicators that could be applied in different countries; otherwise the translation of national UK standards to general quantitative requirements by each assessor can be a very long process with ambiguous results.

In addition, the second criterion for certified green buildings of BREEAM Communities required that all non-domestic buildings in the area should have achieved a rating of BREEAM Good or another equivalent rating scheme. Lijnbaan area could not fulfill this criterion since no buildings had been certified in the area with BREEAM or another independent third-party rating scheme. However, not so many BREEAM or LEED certified buildings exist in urban areas regularly. Hence, the specific prerequisite cannot be easily fulfilled by a usual urban area.

Likewise, Lijnbaan area did not fulfill the prerequisite criterion of LEED ND for certified green buildings. The specific criterion required that one building within the area should be certified by LEED green building scheme or another independent third party green building rating system. The requirement was not fulfilled for the same reasons explained above.

Owing to the fact that these prerequisite criteria of the two tools, related to green buildings, were not fulfilled, Lijnbaan area could not achieve any final score, despite the points achieved in the other energy themes. Although BREEAM and LEED use the methodology of mandatory criteria to ensure that a sustainable area is above a certain level in all categories and it cannot be certified unless it performs well in all domains, it is questionable whether the specific criteria about certified buildings *do* ensure sustainability in the area. Considering the fact that there are not many BREEAM and LEED certified buildings around the world, the specific prerequisites preclude areas from being certified as sustainable even if they might have an exemplary performance in all domains of sustainability. Hence, instead of using only BREEAM or LEED certified buildings for assessing buildings sustainability, the tools should include also national buildings certification schemes or other quantitative indicators measuring the energy performance of buildings sector like the ones included in the generic list.

Another feature of the methodologies of certain tools (BREEAM-NL Gebiedsontwikkeling and LEED ND) that led to the examined area's low scores was the lack of consideration of the specific techniques such as heat and cold storage, that save energy for heating and cooling. Such a technique is broadly applied in the area of Lijnbaan and in fact, all new buildings are constructed with heat and cold storage systems in underground aquifers. During the summer time, cold water is pumped up with the help of a heat pump from an underground aquifer to the building for cooling. With the use of heat exchanger, heat is extracted and stored in another aquifer. During the wintertime, the system is reversed and the hot water is pumped to the building for space heating, while the cold is stored to the cold-storage aquifer. Despite the fact that this method is a sustainable method for heating and cooling, these tools had not included that option in the assessment and thus, no points were awarded to Lijnbaan for sustainable heating systems. BREEAM Communities, though, includes the technique of heat pumps in the Low Carbon Energy technologies and hence, points were awarded to the Lijnbaan area.

No tools, except for LEED ND, included in their methodology of assessment the use of district heating system, which is the main technology used for heating in the area of Lijnbaan. In fact, the whole city of Rotterdam is covered by a district heating system, using waste heat from a cogeneration heat and power plant fuelled with natural gas. The specific method is much more sustainable than traditional, individual heating systems. However, since most of the tools did not consider this technology, no points could be awarded to Lijnbaan for incorporating the district heating system. It should be remarked though, that a district heating system based on natural gas is not as sustainable as other individual heating methods based only on renewable energy resources. Hence, this indicator should be always considered with attention.

Finally, another issue lacking from the methodology of the tools, which became clear through the case of Lijnbaan, was the assessment of the potential for renewable energy production in the future. For example, in the area of Lijnbaan all new buildings were constructed with a design that allows future installation of renewable technologies, but no renewable energy production takes place yet. However, the area has already a future strategy for renewable energy but no points were awarded for the specific topic.

5.4.3 Problems with the required data

The application of the tools in Lijnbaan area revealed many issues and implications related to the application process and the data required for filling out the checklist of indicators for the tools.

Firstly, the application process took place in the Municipality of Rotterdam and it was a collaboration between the author and the urban planning department of the municipality ("Stadsontwikkeling dienst"). The process started in September 2011 and it was complete in March 2012, after a series of monthly meetings.

The process of the application of the tools was highly time-consuming and a lot of data was required- either to be found or to be transformed to the format needed for the tools.

In the first place, the checklists of indicators for the tools was browsed, in order to identify the indicators used by each tool related to energy themes in the urban environment. This task was done by the author.

Secondly, when all the energy indicators used by the four tools were known, the person responsible for the data (in the urban planning department of the municipality) had to define which pieces of data were available, which needed to be transformed to a different format, and which were still missing.

However, this task was very time consuming, considering the fact that the collection of data only for GPR Stedenbouw tool (for the whole tool, not only for the energy indicators) was estimated to last 150-200 hours for the area of Lijnbaan.

The main problem was that most of the data that the municipality had was available in GIS (Geographic Information System) format; thus, they were displayed as maps. Therefore, in order to be used by the tools, they needed to be transformed into numbers. More specifically, all data about electricity, heat, and natural gas consumption of the whole city of Rotterdam was available in GIS format (examples can be seen in Figures 13 and 14). Hence, the data had to be transformed firstly into the required numerical format, such as energy consumption per m^2. Subsequently, owing to the fact that the existing data referred to the whole city, it had to be calculated proportionally from the whole city scale to the boundaries of Lijnbaan area. However, the process could be done only by an expert of the GIS system; hence, all responsibility was lying on one person's shoulders, a fact that brought delays in the process.

Another problem related to the application of the data was the difficulty in calculating the percentage improvement of the area's energy performance after the redevelopment project. The problem rested on the fact that the only data known about the energy performance of new buildings in the area was their EPC coefficient[5]. Hence, many transformations were necessary in order to have all data available in a per m^2 basis, which were not always possible due to either lack of time or lack of data.

[5] Energie Prestatie Coëfficiënt: See chapter 4

Moreover, another problem related to the required data that had implications to the process was the vagueness of the redevelopment plan of the Lijnbaan area. The problem was that the goals and the targets of the plan were presented in a conceptual way and not enough numerical data was available. For example, the plan referred to the new buildings that would be built or retrofitted in the area of Lijnbaan, but no data was directly available about the square footage of new built surface or retrofitted surface, which was necessary in order to calculate the ultimate energy consumption. In fact, in order to apply the tools the plan about buildings and retrofits should be translated to specific numbers of surface used and buildings energy labels. Since such data was not available, many assumptions had to be made about the percentage improvement of the area's energy performance, which somewhat attenuated the accuracy of the results.

To sum up the foregoing, from the application of the tools in Lijnbaan area, it became clear that the application of the four tools is a very time-consuming process and it demands a huge number of working hours to complete. In this specific case study, where the application of the tools was not carried out by an official assessor and there was nobody working full-time on this task, it was difficult to complete the whole process in a fully detailed way. This resulted in many assumptions having to be made while filling in the checklists of indicators of the tools.

In addition, given the problems with the GIS formatting of data, the conclusion was drawn that an extra tool would be necessary for the transformation of the data from the existing mapping format to the numerical data required. Considering also the fact that most Dutch cities and many European cities have their data in GIS format, the development of software, which could be used as an intermediate tool to transform data from GIS format to numbers, is definitely suggested.

Likewise, a similar software tool should be developed transforming the "EPC Coëfficiënt" data for Dutch buildings to actual energy use per m^2 of the area's used surface. The tool would receive as an input the square footage of each building of the area and its EPC coefficient and would give as an output the total energy use of the area per m^2 basis.

The suggested software tools for development are based on very simple calculations; nevertheless, they could save many hours of work needed to transform the available energy data to the required format of the tools.

Ultimately, given the vagueness of the redevelopment plan of the Lijnbaan area, it became clear that redevelopment plans should contain clear numerical information that could be directly applied to the assessment tools.

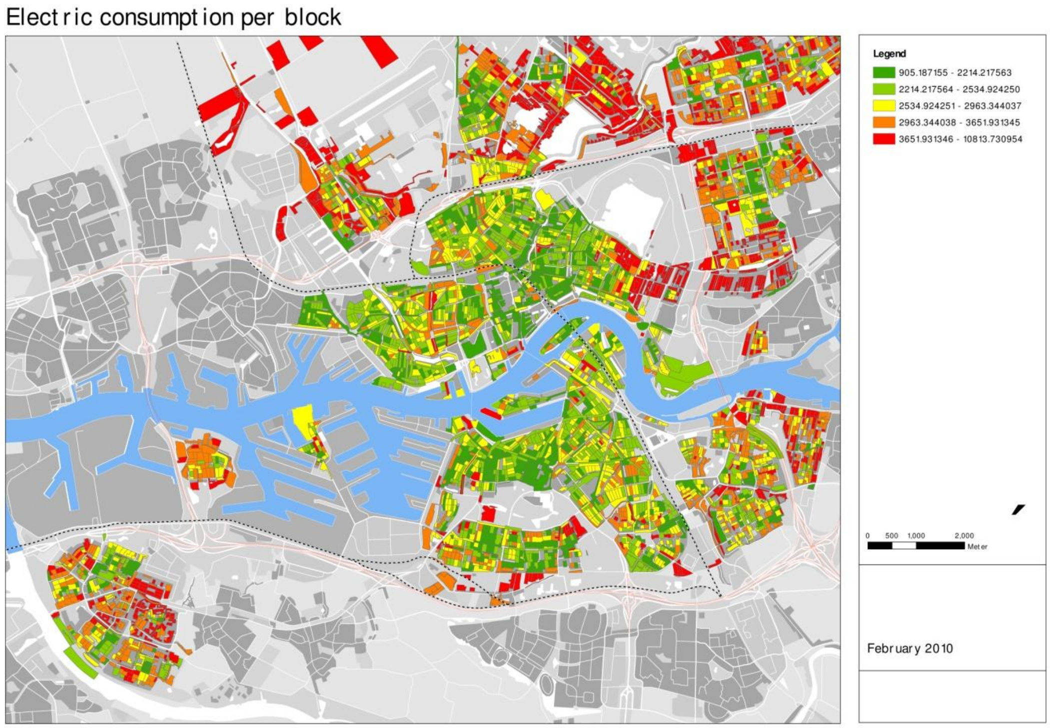


Figure 13: Example of data of electricity consumption in Rotterdam area, depicted on GIS map format. From there data for the electricity demand in the area of Lijnbaan should be extracted *(Gemeente Rotterdam)*

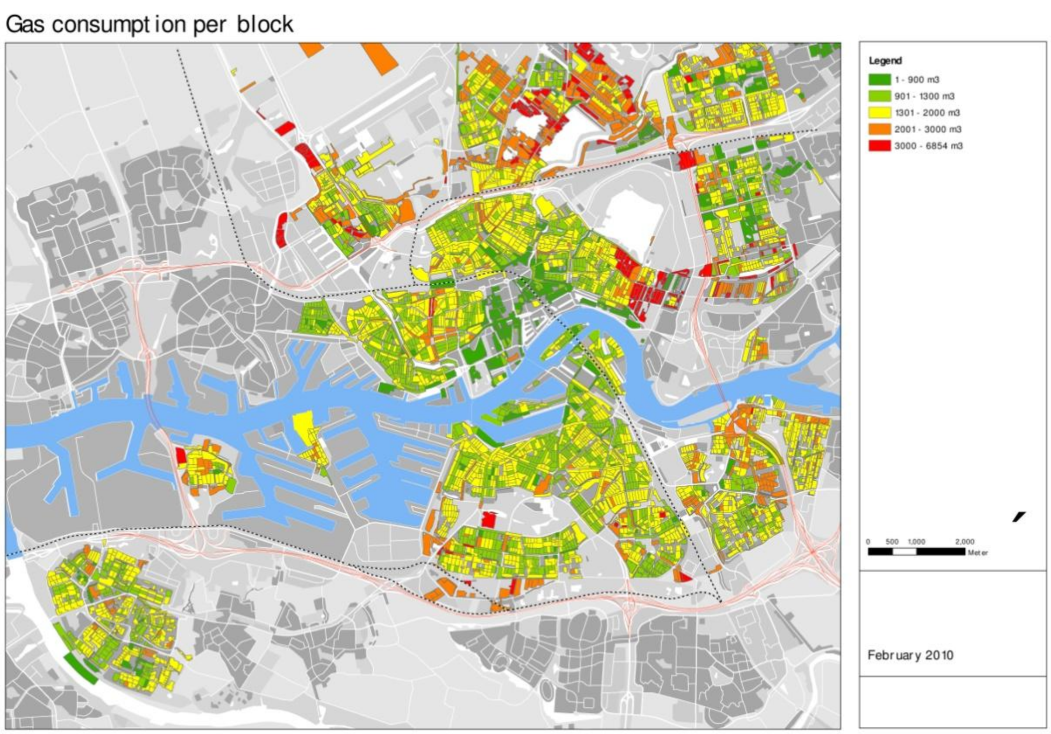


Figure 14: Example of data of gas consumption per block in Rotterdam, in GIS format. From the map data about the gas consumption should be extracted (Gemeente Rotterdam)

6. Conclusions & Recommendations

6.1 Conclusions

This chapter outlines the main findings of the study, which was focused on the comparison of four assessment tools for sustainable urban communities: BREEAM Communities, BREEAM-NL Gebiedsontwikkeling, GPR Stedenbouw, and LEED for Neighbourhood Development. These tools, all recently developed, have been designed with the purpose to quantify and rate the sustainability of urban areas. Their main function is to work as an interface between architects/urban planners and decision makers by setting a framework that incorporates specific targets related to sustainability.

The main objective of the study was to examine and compare how the four assessment tools for urban communities assess energy sustainability and to evaluate strengths and weaknesses of their methodologies, while drawing up suggestions for an improved tool.

To this end, the tools were firstly tested against theory and, secondly, against a "real-world" case study.

For the comparison and testing of the tools against theory, a review of the current literature review was done in order to identify which issues and themes are considered within the "area" of energy sustainability in the urban environment and which indicators are used in literature to assess these. This process led to the creation of a generic list of energy indicators for urban sustainable development, which was used to assess the methodologies and the indicators included in the four assessment tools.

On the other hand, for the comparison of the tools against a "real-world" case study, the tools were applied in the Lijnbaan area, the central quarter of the city of Rotterdam, and conclusions were made about the functionality and practicality of the tools.

6.1.1 Conclusions from the theory

In the first place, the tools were compared against the generic list of energy indicators. The results showed a significant incompatibility between the tools and the generic list. The tools proved to have a big deviation from the generic list of energy indicators, meaning that most of the energy indicators included in the generic list were not contained in the four tools. This incompatibility can be explained by the fact that the generic list consists of only quantitative indicators that measure the actual energy performance of the area, while the tools include mostly indicators that measure the relative improvement of the area in time. In fact, the comparison revealed that the tools assess the progress of the area in time, before and after the development plan, but they do not give information about the final actual energy performance of the area, as for example the total energy consumption and the CO_2 emissions related to it. It is important to realize that a rating system that is based on the relative improvement of the area cannot be used for comparing different areas, since it can lead to wrong assumptions. For example, we may assume that a neighbourhood in USA has improved its energy performance by 30% and has achieved a LEED certification with "golden" rating, while a neighbourhood in Europe has improved its energy performance by 10% and has received a LEED certification with Bronze rating. Nevertheless, the final energy consumption in the neighbourhood in USA can still be higher in comparison to the European one. Therefore, the results might be misleading and ratings, such as "pass", "good", "excellent" or one, two, three stars etc., might end to be used only for profiling and increasing the real estate value of the area, without giving primary focus to reduction of climate impacts. Thus, it should be stressed that since the tools do not focus on actual metrics, such as total energy consumption within the area and CO_2 or GHG emissions, they cannot be used for comparable international assessments.

Between the four tools, GPR was the one that showed the closest compatibility with the generic list of energy indicators (50% score), since it includes more quantitative indicators compared to the other tools. GPR Stedenbouw measures the energy consumption per m^2 of floor area of buildings in the area and the CO_2 energy consumption related to it. However, it should be stressed that the tool does not include actual data of the energy consumption, but average statistical data based on the typologies of buildings. Moreover, despite its highest score in the comparison with the generic list, GPR Stedenbouw still lacks several quantitative indicators within the themes of heat island effect, electricity consumption of buildings, energy monitoring at the building level, waste energy imported/exported within the boundaries of the area, energy storage, CHP production, district heating, as well as separate indicators measuring the renewable power production from each different type of renewable energy sources (sun, wind, biomass, geothermal, hydropower).

A further analysis and comparison of the tools with each other showed that the main themes of energy sustainability included in the tools are as follows in the table below:

Energy themes included in the tools
Energy Efficiency/Reduction of Energy Demand
Renewable Energy/Sustainable Power Generation
Sustainable/Green Buildings
Passive Design (Solar Orientation & Reduction of Heat Island Effect)
Energy Monitoring

All the indicators included in the four tools were within these five main themes of energy sustainability in urban environment. Only BREEAM Communities included indicators in all of the themes. The rest of the tools lacked indicators within the theme of Energy Monitoring.

The tools were compared based on the share of the total score they devote to energy themes. In general, the comparison showed that the tools devote on average 20% of their score to energy issues, with BREEAM Communities scoring first with 24%. The lowest score (15%) from LEED for Neighbourhood Development was remarkable, considering that the full title of the tool is “LEED: Leadership in Energy and Environmental Design”.

The tools were further analyzed and compared in order to identify whether some of the energy themes receive more focus than others do. The results showed that the tools BREEAM Communities and LEED for Neighbourhood Development give more points for sustainable/certified green buildings than any other theme. This fact can be explained if one considers their preceding systems for buildings certification. However, the “emphasis” of these tools on certified buildings shows that they consider an urban area as a sum of individual buildings, assuming that if all of them are certified, the whole area will become sustainable. Nevertheless, in that way, the tools miss the important synergies that exist within the area and make it a holistic system. Besides, the primary focus on certified buildings within the area shifts the attention from issues such as the increase of renewable power within the area, which could bring immense improvement in the total energy performance. Only the Dutch tool BREEAM-NL Gebiedsontwikkeling shows distribution of the points in the various themes and gives primary focus on renewable energy.

In addition, the comparison of the tools showed that BREEAM Communities and LEED ND set certain energy criteria as prerequisites for an area to achieve certification. These criteria are related to the existence of green/certified buildings by BREEAM or LEED schemes within the area- confirming the focus of the tools on sustainable/certified buildings- and the reduction of the total energy use. However, BREEAM Communities includes an extra important criterion demanding that at least 15% of the total building’s energy demand should be covered by renewable energy sources. With good judgment, one may remark that prerequisite criteria related to the reduction of energy demand or the increase of renewable energy within the area are likely to impact more strongly on the final energy performance of the urban area and the levels of sustainability achieved, than a certain number of certified green buildings.

6.1.2 Conclusions from the practical application

After the comparison of the tools on a theoretical basis, the tools were applied in the Lijnbaan area. The application process turned out to be more complex than expected; the availability of required data was critical, but often hard to cover.

The overall outcome from the application of tools was that the Lijnbaan area achieved either very low or zero scores for the energy themes examined by the tools.

The results can also be explained by the fact that the specific 2 -years-redevelopment plan of Lijnbaan did not include any clear energy targets or strategies. Consequently, the improvement of the energy performance of the area was rated very low. The specific redevelopment plan of Lijnbaan area should work as a lesson for sustainable urban planning. Energy often tends to be a painful necessity for urban designers and architects, who prefer to focus first on the architectural design and leave the energy as an afterthought. However, in that way, the important interdependencies and synergies for the design of an urban area are lost. It is important to realize that the energy performance of the area should be studied along with the design of the area. Otherwise, once the design of the area is already complete, it is too late to incorporate sustainable energy goals. Hence, every plan for new areas or redevelopment of existing ones should ensure that includes clear targets and goals for energy sustainability.

The application of the tools in the Lijnbaan area revealed certain issues related to the methodologies of the tools.

Firstly, it became clear that the tools are not the best to certify existing areas. Their methods work best when 50% of the total floor area consists of new buildings. Otherwise, the requirements of the tools cannot be complied.

Secondly, the prerequisite energy criteria related to certified green buildings that BREEAM Communities and LEED ND include in their methodology, could not be fulfilled by the Lijnbaan area, and consequently, the area received zero final score, despite the points that had been achieved from the other indicators. These mandatory criteria of the tools required the existence of LEED or BREEAM certified buildings within the area. However, as it was also remarked during the theoretical analysis of the tools, the specific criteria are very limiting, since BREEAM or LEED certified buildings are not very frequent around the world. Therefore, the specific prerequisites preclude areas from being certified as sustainable even if they have an exemplary performance in all other domains of sustainability. Apart from these buildings certifications, the tools should better include national buildings certification schemes or other quantitative indicators measuring the energy performance of buildings sector like the ones included in the generic list.

Thirdly, the application of the tools in the Lijnbaan area revealed that the tools did not include in their assessment methodologies specific techniques for sustainable heating, such as heat and cold storage and district heating in combination with waste heat. However, these technologies are broadly applied in Rotterdam and in the Lijnbaan area, but they could not be assessed and graded by the tools.

Furthermore, the application of the tools in Lijnbaan brought about certain issues related to the practicality of the tools and the required data.

The main problem was that most of the data that Rotterdam municipality had available for the Lijnbaan area was not in the format required by the indicators of the tools. In order to fill in the checklists of indicators of the tools, data about the energy use per m^2 of the buildings in the area was needed. However, most of the data available in the municipality was in GIS format thus, they were displayed into maps. In addition, the energy performance of buildings was mostly expressed by the EPC coefficient (see chapter 4.3, GPR Stedenbouw). As a result, the transformation of the data to the required format was a highly time consuming process, and one that could only be done by a GIS expert, a fact that brought implications to the procedure. Accordingly, many assumptions had to be made while filling out the checklists of indicators of the tools.

Taking these implications with the required data into account, it would be recommendable to develop software that transforms information from GIS format into energy numerical data on a per square meter basis. Moreover, it would be useful to additionally develop a software tool that transforms data of the EPC coefficients of buildings to total energy use of buildings of the area per square meter of floor area. These two instruments would facilitate immensely the application of these tools in urban areas of the Netherlands and other European countries that have most of their energy data available on GIS format.

6.2 Suggestions for an improved tool

Considering all the conclusions made about the four tools studied and the outcomes from their application in the Lijnbaan area, we came up with a suggestion for an improved tool, which combines some positive characteristics of the existing tools, but also resolves some of the practical implications that were encountered during the application process. The suggestions and the recommendations made only refer to the assessment of energy sustainability, which was the topic examined in this study.

Therefore, an improved assessment tool for urban communities, or more specifically an improved tool that assesses the sustainability levels achieved by an urban area, should provide information about the actual energy performance of the area and not only measure the relative improvement before and after the development plan.

More specifically, an improved assessment tool should provide and compare two results: the current/initial situation of the urban area with the future situation of the area after the implementation of the development plan, similarly to GPR Stedenbouw. However, in contrast to GPR Stedenbouw that uses only average statistical data about the energy performance of buildings, the improved tool should assess the initial situation of the area based on real and actual data about the energy performance of buildings within the area. The tool should include in the assessment at least two main indicators measuring the actual energy consumption of buildings in the area per m^2 of the total floor area, and the share of this consumption covered by renewables.

As soon as the initial energy consumption is calculated and the initial floor area of buildings is known, the future energy performance of the area could be easily deducted based on minimum assumptions. Firstly, the future buildings' floor area would be the initial floor area plus/minus the square meters of new and renovated buildings. For these new and retrofitted buildings, the energy performance should be known, since it must comply with the existing regulations. Hence, if the worst-case scenario is considered - that these buildings would only perform based on the required levels (and not better) - the future energy use of these buildings per m^2 can be calculated, knowing their expected energy performance and their floor area.

Ultimately, the future energy consumption of the area per m^2 will consist of the initial energy consumption per m^2, plus/minus the energy consumption of the new and renovated buildings per m^2. Based on this data, the initial and future CO_2 emissions of the area can also be calculated by the tool.

Providing the initial and future energy performance, as well as the respective CO_2 emissions, the tool would give the opportunity to both assess the improvement of the area in time, but would also allow the comparison of the area with other areas around the world; a fact that was not possible with the examined tools that measure the relative improvement of the area. Therefore, each area could achieve two scores: one for its final energy performance, in order to be compared with other areas, and one for the relative improvement of the area, in order to evaluate the progress in time.

Finally, considering the suggestions of urban planners and architects from TU Delft and the municipality of Rotterdam, the improved tool should provide the results in a mapping format as well, so that the designers could better see in which areas the performance is low and propose interventions.

6.3 Recommendations for further research

Since this research was focused on the broad theme of assessing energy sustainability at the urban level, many interesting topics emerged that could not be investigated in considerable depth.

Firstly, two very important areas that stand out of the present study are the themes of transport and waste and their great impact on energy sustainability of urban communities. Transport accounts for a very large share of energy consumption of urban areas, while the amounts of energy that can be recovered from waste-to-energy processes or saved by recycling are likewise extremely large. Indicators measuring the energy savings by sustainable transport and recycling, and the energy recovered from waste should be further studied and included in every assessment tool for urban sustainability.

Second, another significant theme that would be worthy of further research is how to assess the public participation and the role of stakeholders in the energy performance of urban areas. This study was only focused on assessing quantitatively the energy sustainability at urban level. However, qualitative indicators should also be included in the assessment tools for urban communities to assess the future targets for the energy performance of the area, the active participation of the residents in fulfilling these targets, and the whole progress towards urban energy transition.

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1st Chapter

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Appendix I

Lists of Indicators for Sustainable Urban Development

Appendix I includes all the extensive lists of indicators that were researched during the literature review in order to collect energy indicators for sustainable urban development. The sources of indicators examined were the "European common indicators for urban sustainability" (included only in chapter 2), the "ICLEI's STATUS tool", and eight of the most popular international city assessments and rankings the "European Green Capital Award", "European Green City Index", "Smart Cities", "Smarter Cities", "Sustainable Cities Index", "Sustainable Cities Report", "SustainLane", and "Quality of living-Global City Rankings". The extensive lists of indicators are presented in the tables below. The energy indicators that were collected for the present study are highlighted with yellow colour.

Table 17: Extensive list of themes and indicators used by ICLEI-STATUS tool for urban sustainability

ICLEI STATUS Tool		
Themes	**Sub-themes**	**Indicators**
1. Governance	Capacity Building	Share of all Local Authority (municipal) employees to complete sustainability training
		Existence of a regular programme of awareness raising in schools on sustainable development issues
		Existence of a cross departmental working group on sustainable development
	Participation	Percentage of statutory planning processes involving stakeholders before a draft plan is developed.
		Existence of a strategy and related activities to involve difficult to reach groups in local decision making
	Transparency	Share of publicly available municipal documents published on Internet
		Share of population regularly informed on Local Government Environmental activities
2.Sustainable Local Management	Integration of environment in other plans	Adoption of an Environmental Management Plan
		Percentage of all statutory plans subject to a environmental assessment
	Adoption of environmental management systems	Number of Local Authority departments with certified Environmental Management Systems (IS014001/EMAS or other national system)
		Number of private companies located in the municipality with certified Environmental Management Systems (ISO14001/EMAS or other national system)
3.Natural Environment	Water quality	Proportion of rivers classified at least as of 'good' status (according to EU classification)
		Compliance with EU standards on wastewater treatment
		Proportion of population connected to a wastewater treatment plant
	Biodiversity	Local trend in EU threatened/protected species
		Trend in locally relevant species and/or habitats (birds/ trees/other species)
	Air quality	Number of days per year EC limit value was exceeded for PM10 (daily mean)
		Number of days per year EC target value/long-term objective was exceeded for Ozone (8h mean)
		Annual mean concentration of NO2
		Annual mean concentration of PM10
4.Sustainable Consumption	Waste	Per Capita amount of waste
		Proportion of total/biodegradable waste production sent to landfill
		Share of Municipal waste collected separately
	Sustainable Procurement	Percentage of the food purchased by the local authority which is EC certified as organic production
	Water Consumption	Proportion of urban water supplies subject to water metering
		Domestic consumption

		Water loss in pipelines
5.Planning and Design	Re-use of land	Proportion of new developments on brown field sites
	Accessibility to basic public services	Population living within 300 metres to basic public services
	Sustainable Urban Design	Population density for new developments
	Sustainable Urban Construction	New buildings and renovations assessed in terms of environmental sustainability
		New buildings and renovations assessed in terms of environmental sustainability
6.Sustainable Transport	Transport infrastructure	Length of dedicated cycle lanes
		Share of population living within 300 m from an hourly (or more frequent) public transport service
	Transport Use	Proportion of all journeys under 5 km by private car use
	Low Emission Vehicles	Proportion of public transportation classed as low emission
7.Health	Decent Housing	Proportion of dwellings classed as being of adequate or decent standard
	Access to Green Areas	Proportion of population able to access public open areas within 300 m
	Quietness	Share of population exposed to noise values of L (den) above 55 dB (A)
		Share of population exposed to noise values of L(night) above 45 dB(A)
	Traffic Safety	Number of pedestrian and cyclist fatalities as a result of road traffic accidents/year/10000 inhabitants
		Number of car driver or passenger fatalities/year/10000 cars
8.Vibrant and Sustainable Local Economy	Support and develop local employment	Percentage of early school leavers within the municipality
		Percentage of the working-age population employed in the locality
		Proportion of children under the mandatory school age for whom childcare is provided by the local authority
		Existence of a social and community enterprise strategy
		Percentage of new business start-ups in the locality each year
		Existence of regular forums between local government and local business representatives on issues of local concern
	Support markets for high quality local and regional produce	Existence of a farmer’s market co-ordinator in a local authority
	Promote sustainable local tourism	Existence of a Sustainable Tourism strategy for the locality
9.Social Equity and Justice	Poverty	Local Unemployment rate in %
		Share of households reliant upon social security
		Ratio of first to fifth quintile earning
	Social Inclusion and Gender Equality	Share of Women in local leading positions
		Female unemployment compared to male unemployment
		Number of homeless people
		Literacy rate (%) in population aged 15+
	Safety/Security	Percentage of residents who feel safe whilst outside during the day / after dark
		Children's journeys to and from school (ECI)

10.Global Responsibility	Greenhouse gas emissions	Total CO2 equivalent emissions per capita (Tones/cap/year)
		Total electricity consumption per capita (kWh/cap/year)
	Renewable Energy	Share of energy consumption produced by renewable sources (% of energy produced by renewables out of all energy produced by the whole population)
		Capacity installed for renewable energy production (KW/inhabitant)

City Assessments and Rankings

Table 18: Extensive list of themes and indicators used for European Green Capital Award- the energy indicators are highlighted

European Green Capital Award		
1	Local contribution to Global Climate Change	Total CO_2 equivalent per capita, including emissions resulting from use of electricity;
		CO_2 per capita resulting from use of natural gas;
		CO_2 per capita resulting from transport;
		Grams of CO_2 per kWh used.
2	Energy performance	Energy consumption & performance of municipal buildings per square meter.
		The development and goals for renewable energy share of all energy (heat and electricity).
		The strategy of renewable vs non-renewable mix as well as the renewable energy mix (different renewable energy sources) dynamics for the coming two decades.
		Integration and performance of renewable energy technology in municipal buildings and homes.
		Development of compatible and integrated district systems and the facilitation of more sophisticated city-wide control.
3	Local transport	Length of designated (only for bicycles) cycle lanes in relation to total number of inhabitants in the city (Meters per inhabitant)
		Share of population living within 300 metres of an hourly (or more frequent) public transport service
		Proportion of all journeys under 5 km by private car;
4	Water consumption	Proportion of urban water supply subject to water metering;
		Water consumption per capita (in l/capita/year for households and business);
		Water loss in pipelines;
		Compliance with the EU Water Framework Directive and related Directives.
5	Waste water treatment	Access to waste water service;
		Flood occurrences and management;
		Economic sustainability;
		Infrastructures sustainability (treatment capacity, treatment level, drainage systems rehabilitation);
		Environmental sustainability (energy efficiency, renewable energy, pollution prevention efficiency; sludge treatment and final disposal, public health;
		Integration into water management in general closing the cycle (efficient water use, treated waste water reuse).
6	Waste production and management	Amount of waste per capita; Household, Municipal;

		Proportion of total/biodegradable waste sent to a landfill;
		Percentage of recycled municipal waste.
7	Green urban areas incorporating sustainable land use	The percentage of citizens living within 300m of public green urban areas,
		Percentage of green areas, water areas, residential areas, industrial / economic areas, mixed areas, brownfields (this will provide important background information on the character of the city and is not an evaluation criterion in itself);
		New developments: proportion of brownfield sites, densification in the inner-city or urban cores, on green fields;
		Population density in built-up areas in inhabitants per hectare (city area minus green and water areas);
		Population density for new developments in inhabitants per hectare.
8	Quality of local ambient air	Number of days per year on which EU limit values were exceeded for PM10 (daily mean of 50µg/m3);
		Number of days per year on which EU limit value/long term objective for ozone was exceeded (8h mean of 120µg/m3) ;
		Annual mean concentration of NO2 PM10 and PM2.5.
9	Environmental management of the local authority	Number of municipal departments with certified environmental management systems
		Percentage of consumed eco-labelled and organic products by municipalities, measured as a share of the total product consumption within similar category
10	Eco innovation and sustainable employment	Innovations that address material security and/or resource efficiency (substitution, minimisation of material use, closing loops, etc) and reduce environmental impacts;
		Awareness raising and training to encourage the development and take-up of environmentally friendly technologies, particularly through training in industrial and business settings.
		Social innovation, including for example community programmes, that shows entrepreneurship and new ways of organisation in order to promote sustainable development and protect the environment locally and globally
		Number of jobs created in green sectors such as renewable energy and waste recycling, in total and as share of total jobs in the city and total jobs created during a period of one year.
		Share of energy provided in the city that is sourced from renewable energy sources. Renewable energy sources to be specified.
		Share of hybrid or fully electric cars sold in total car sale
11	Nature and Biodiversity	Action plan for: Managing areas designated for nature protection and biodiversity;
		Action plan for: Protecting nature in other open spaces
		Action plan for: Promotion of public knowledge and understanding of nature and biodiversity, particularly among young people
12	Noise pollution	Share of population exposed to noise values of L (day) above 55 dB(A);
		Share of population exposed to noise values of L (night) above 45 dB(A).

Table 19: Extensive list of themes and indicators used for European Green City Index- the energy indicators are highlighted

European Green City Index		
1	CO_2	CO_2 emissions
		CO_2 intensity
		CO_2 reduction strategy
2	Energy	Energy consumption
		Energy intensity
		Renewable energy consumption
		Clean and efficient energy policies
3	Buildings	Energy consumption of residential buildings
		Energy-efficient buildings standards
		Energy-efficient buildings initiatives
4	Transport	Use of non-car transport
		Size of non-car transport network
		Green transport promotion
		Congestion reduction policies
5	Water	Water consumption
		Water system leakages
		Wastewater treatment
		Water efficiency and treatment policies
6	Waste and land use	Municipal waste production
		Waste recycling
		Waste reduction and policies
		Green land use policies
7	Air quality	Nitrogen dioxide
		Ozone
		Particulate matter
		Sulphur dioxide
		Clean air policies
8	Environmental governance	Green action plan
		Green management
		Public participation in green policy

Table 20: Extensive list of themes and indicators used for Smart Cities ranking- the energy indicators are highlighted

Smart cities – Ranking of European medium-sized cities			
1	Smart Economy	Innovative spirit	R&D expenditure in % of GDP
			Employment rate in knowledge-intensive sectors
			Patent applications per inhabitant
		Entrepreneurship	Self-employment rate
			New businesses registered
		Economic image & trademarks	Importance as decision-making centre (HQ etc.)
		Productivity	GDP per employed person 2001 local
		Flexibility of labour market	Unemployment rate
			Proportion in part-time employment
		International embedment	Companies with HQ in the city quoted on national stock market
			Air transport of passengers
			Air transport of freight
2	Smart people	Level of qualification	Importance as knowledge centre
			Population qualified at levels 5-6 ISCED
			Language skills
		Affinity to lifelong learning	Book loans per resident
			Participation in life-long-learning in %
			Participation in language courses
		Social and ethnic plurality	Share of foreigners
			Share of nationals born abroad
		Flexibility	Perception of getting a new job 2006 national
		Creativity	People working in creative industries
		Cosmopolitanism/Open-mindedness	Voters turnout at European elections
			Immigration-friendly environment
			Knowledge about the EU
		Participation in public life	Voters turnout at city elections
			Participation in voluntary work
3	Smart governance	Participation in decision-making	City representatives per resident
			Political activity of inhabitants
			Importance of politics for inhabitants
			Female city representatives
		Public and social services	Expenditure of the municipal per resident in PPS
			Children in day care
			Perception of quality of schools
		Transparent governance	Perception on transparency of bureaucracy
			Perception on fight against corruption
4	Smart mobility	Local accessibility	Public transport network per inhabitant
			Access to public transport

			Quality of public transport
		(Inter-)national accessibility	International accessibility
		Availability of ICT-infrastructure	Computers in households
			Broadband internet access in households
		Sustainable, innovative and safe transport systems	Green mobility share
			Traffic safety
			Use of economical cars
5	Smart environment	Attractiveness of natural conditions	Sunshine
			Green space share
		Pollution	Summer smog
			Particulate matter
			Fatal chronic lower respiratory diseases
		Environmental protection	Individual efforts on protecting nature
			Opinion on nature protection
		Sustainable resource management	Use of water per GDP
			Use of electricity per GDP
6	Smart living	Cultural facilities	Cinema attendance
			Museums visits
			Theatre attendance
		Health conditions	Life expectancy
			Hospital beds per inhabitant
			Doctors per inhabitant
			Perception on quality of the health system
		Individual safety	Crime rate
			Death rate by assault
			Perception on personal safety
		Housing quality	Share of housing fulfilling minimal standards
			Average living area per person
			Satisfaction with personal housing situation
		Education facilities	Students per inhabitant
			Access to the educational system
			Quality of the educational system
		Touristic attractiveness	Importance of tourist location
			Overnights per year per resident
		Social cohesion	Perception on personal risk of poverty
			Poverty rate

Table 21: Extensive list of themes and indicators used for Smarter Cities ranking- indicators related to energy issues are highlighted

Smarter Cities		
1	Air Quality	US EPA AirData: median AQI (7 points)
		Americans for Non-smokers' Rights: 100% smoke free workplaces (1 point), 100% smoke-free restaurants (1 point), 100% smoke-free workplaces (1 point)
2	Energy Production and Conservation	US DOE Green Power Network and Survey: Top three fuels used for power generation (6 points)
		Survey: Energy conservation incentives offered (2 points), green power offered by utility (2 points)
3	Environmental Standards and Participation	Survey: Number of city department that have environmental standards incorporated into their policies (7 points); provision of environmental commissions on which citizens may served (3 points)
4	Green Building	USGBC LEED Project Directory: Number of total LEED-certified buildings (4 points) and any number of LEED-platinum buildings (1 point)
		EPA Energy Star: Any number of Energy Star-rated buildings (2 points)
		Survey: Use of an alternative green building certification system (1 point); sprawl reduction strategies (2 points)
5	Green Space	Survey: Total number of different types of greenspace, including athletic fields, city parks, community gardens, public gardens, trail systems, waterfront and other (6.5 points); presence of an integrated pest management plan (1 point)
		Survey and Research on web sites: percentage of land that is green space (2.5 points)
6	Innovation	Survey: Innovative policies or practices with supporting documentation (5 points)
7	Recycling	Survey: Total items included in recycling program (3 points); total items picked up by recycling program (3 points); public recycling bins (1 point); percentage of waste diverted from landfill (2 points)
		EPA Municipal Solid Waste State Data and Earth 911 were consulted on occasion to check survey responses.
8	Standard of Living	US Census Bureau: Percentage of owner-occupied housing (2 points); families living below the poverty line (2 points); median household income (2 points)
		National Association of Home Builders: Housing Opportunity Index (4 points)
9	Transportation	Survey: Number of green commuting options for citizens including bicycle paths, bike sharing, bus system, carpool lanes, car sharing, dedicated bicycle lanes, light rail, park and ride, sidewalks and trails, subway, trolley and other (8 points)
		American Public Transportation Association: documented ridership for public transportation (2 points)
10	Water Quality and Conservation	US EPA Safe Drinking Water Information System: Health-based violations (3 points); reporting-based violations (3 points)
		Survey: Water-conservation incentives including rebates, tax credits, conservation pricing and other (4 points)

Table 22: Extensive list of themes and indicators used for Sustainable Cities index- indicators related to energy issues are highlighted

Sustainable Cities Index		
1	Environmental impact basket	Air quality – annual mean background concentrations of Nitrogen Oxides as NO_2, measured in parts per million (µg m-3) (2008).
		Ecological footprint – the impact of services, food, housing, transport and consumables on the environment (2004 estimates).
		Household waste collected per head – a partial proxy for resource use per capita (2007/8).
		Biodiversity – the percentage of local biodiversity sites that have undergone conservation management
2	Quality of life basket	Life expectancy from birth – a measure of health and longevity (2005-7).
		Green spaces – the number of Green Flag or Green Pennant awards that the city has received per 100,000 members of its population (2009).
		Transport – the number of minutes spent per person per month travelling to food stores, their GP, secondary school and further education (2008). This indicator reflects the accessibility of a city's services.
		Unemployment – the number of benefit claimants as a percentage of working age population (2009).
		Education – percentage of the working age population with NVQ2 or equivalent (2008). This indicator reflects a broader scope of attainment and qualification than the solely academic
3	Future-proofing basket	Local authority commitments on climate change – local authorities were given points based on nine key criteria which sought to cover council adaptation and mitigation strategies and commitments within their own estates and operations as well as city-wide. Climate Change Action Plans and/or strategy documents were downloaded from council websites and assessed during September 2009.
		Economy – number of VAT registrations per 10,000 residents of the city (2007), intended to show the vibrancy of a city's economy
		Recycling – the percentage of household waste recycled or composted (2007/8)
		Food – the number of allotment plots per 1,000 residents (2008/09), intended to show participation in local food production.

Table 23: Extensive list of themes and indicators used for Sustainable Cities report- indicators related to energy issues are highlighted

Sustainable Cities Report		
1	Ecological Integrity	Air Quality Index > 50 in 2007
		current diversion levels
		current GHG reduction levels
		Provision for dedicated per cent of annual budget to be allocated for conservation
		Total environmental footprint
		Water use: Average Daily Flow - domestic
		Water use: Average Daily Flow - overall
2	Economic Security	% in low income before tax - All persons - 2006
		Appropriate compliance
		Core expenditure/household
		Employment participation rate - October 2008
		General accountability
		Household expenditures spent on shelter - 2008
		Long-term debt per household
		Money Sense 2008 "Best Places to do Business" Ranking
		Special Tax Incentives to attract Green/Cleantech Businesses
		Total financial disclosure
		Unemployment rate - Oct 2008*
		Unemployment rate of immigrants - 2006
3	Governance and Empowerment	Bulk water pricing
		City council gender diversity
		City council ethnic diversity
		Does municipality's commercial and private water pricing cover cost of delivery and maintenance?
		Existence of a ban on insecticide
		Existence of compost/green bin programs
		Garbage bag limit
		GHG emissions target
		Has the community adopted a policy to use sustainability as a filter to inform every planning decision that pertains to the future of the community?
		Is municipality measuring its own performance in key sustainability areas?
		Number of sustainable planning staff
		Recycling programs - number of materials accepted
		Voter turn-out, last municipal election
		Waste diversion target
4	Infrastructure and Built Environment	Community/Business Solar/geothermal/retrofit programs
		Developer Incentives for Green buildings (geothermal/solar/green roof/grey water/bike parking)
		Median commuting distance (km) - 2006
		Mode of Transportation to Work [Green Commute = (public transit, walked/bicycled, other)/total: all modes]

		Number of LEED-certified buildings
		Population density per km2
		Total KM bikepaths (offroad paths/bike lanes/shared roadways that are designated)
5	Social Well-Being	% population with less than high school diploma - 2006
		% population with university degree - 2006
		Affordable Home Ownership Programs (units)
		Farmer's Markets
		Home ownership
		Large retail space/city area
		Life Expectancy
		Life satisfaction
		Number of "top ten" fast food outlets per 10,000 people
		Number of total homeless shelter beds/population
		Number/Ha of community gardens
		Obesity rates (%) - 2006
		Occupations in art, culture, recreation and sport(percent of total industries) - 2006
		Property crimes - 2006
		Public arts events / festivals
		Trust in neighbours
		Violent crimes - 2006

Table 24: Extensive list of themes and indicators used for Sustainlane- indicators related to energy issues are highlighted

SustainLane		
1	Commute to Work	Public transportation-ridership percentage
		walk-to-work percentage
		bike-to-work percentage
		carpool-to-work percentage
		drive-alone-to-work percentage
2	Metro Transportation	Amount of public transit ridership
3	Metro Congestion	Regional freeway and surface road congestion by metro region (average time spent waiting in traffic)
4	Air Quality	Average Air Quality
5	Tap Water Quality	Pollutants in tap water
6	Green (LEED) Building	Number of US Green Building Council's Leadership in Energy and Environmental Design (LEED) certified and registered buildings (number of LEED buildings per 100,000 people)
7	Local Food & Agriculture	Number of community gardens
		Number of farmers markets per city, with additional credit given to those farmers markets accepting WIC (women, infant, children) and food stamps.
8	Planning/Land Use	Urban sprawl
		Percent of city land area devoted to parks
		pedestrian and bicycle access and planning
		transit-oriented development
		regional planning efforts
9	Housing Affordability	Median US housing prices and median US incomes. Cities with living wage ordinances were given extra credit.
10	Natural Disaster Risk	Cumulative measure of hurricane risk, flood risk, tornado super outbreaks, earthquake risk, and devastating hail risk
11	Green Economy	Green, or LEED (Leadership in Energy and Environment) buildings per capita
		Farmers' markets per capita
		Presence of a city or public-private incubator for clean technology industries, including renewable energy, advanced transportation, advanced water treatment, alternative fuels, green building, and energy efficiency
		Presence within the city of a green business directory, either public or private
12	Energy and Climate Change Policy	City greenhouse gas tracking and carbon emission inventories
		Carbon emission reduction goals
		Overall renewable energy use
		Percentage for each city's alternative fueled vehicles as part of the total vehicle fleet was credited to cities with such fleets of greater than 12 percent of total fleet
		Additional credit was given to cities that had formally signed onto the US Mayor's Climate Protection Agreement begun by Seattle Mayor Greg Nickels, had instituted significant, wide-ranging mitigation or adaptation programs, or had mounted significant city-wide planning efforts as of December 2007
13	City Innovation	Environmentally preferable purchasing programs
		City commercial green building incentives
		City residential green building incentives
		Carpooling coordination
		Car sharing programs (public or private)
		At least one other significant city innovation or program not accounted for in the other five areas
14	Knowledge Base/Communications	Whether the city has an overall plan for sustainability

		Whether it has a sustainability or environmental department that manages and tracks sustainability efforts across the city
		Whether the city is working in collaboration with a major federal research laboratory or research university
		Whether the city is working with a non-governmental organization across the city, rather than in only a single neighbourhood
15	Water Supply	Distance in miles from primary source of untreated drinking water, dependence of water on snowpack
		Level of drought or other conflict
		Population growth rate
		Gallons of water consumed per person per day
16	Waste Management	Percentage solid waste diversion

Table 25: Extensive list of themes and indicators used for the Quality of Living global city rankings- indicators related to energy issues are highlighted

Quality of Living global city rankings		
1	Political & Social Environment	Relationship with other Countries
		Internal Stability
		Crime
		Law Enforcement
		Ease of Entry and Exit
2	Medical & Health Considerations	Hospital Services
		Medical Services
		Infectious Diseases
		Water Potability
		Sewage
		Air Pollution
		Troublesome & Destructive Animals & Insects
3	Public Services & Transport	Electricity
		Water Availability
		Telephone
		Mail
		Public Transport
		Traffic Congestion
		Airport
4	Consumer Goods	Meat & Fish
		Fresh Fruits & Vegetables
		Daily Consumption Items
		Alcoholic Beverages
		Automobiles
5	Economic Environment	Currency Exchange Regulations
		Banking Services

6	Schools & Education	Schools
7	Recreation	Variety of Restaurants
		Theatrical & Musical
		Performances
		Cinemas
		Sport & Leisure Activities
8	Housing	Housing
		Household Appliances & Furniture
		Household Maintenance & Repair
9	Socio-Cultural Environment	Limitation on Personal Freedom
		Media & Censorship
10	Natural Environment	Climate
		Record of Natural Disasters

Appendix II

The Checklists of Energy Indicators of the Four Sustainability Assessment Tools for Urban Communities

BREEAM COMMUNITIES					
Code	**Category**	**Description**	**Max. Points**	**Points**	**Requirements**
CE 5 - Energy Efficiency (mandatory)	Climate and Energy	Energy management	3	1 (mandatory)	Where evidence is provided to demonstrate that an energy strategy will be developed for the proposed development to optimise the incorporation of energy efficiency measures into the buildings on the site – including as a minimum: a. Minimising energy demand for the site through orientation and passive solar design. b. Maximising the thermal efficiency of building envelopes c. Minimising consumption of energy used for water heating, space heating and cooling, lighting and power in individual buildings through efficient equipment and controls.
				1 (Good)	In addition to the optimising the energy efficiency of all buildings on site, a feasibility study will be conducted to: a. Calculate the residual energy demand for the site. b. Maximise the amount of the residual demand which can be met efficiently by Low or Zero Carbon (LZC) technologies
				1 (Best)	Once the first and second credit have been achieved, the energy strategy will aim to meet the remaining demand through an appropriate Allowable Solution (as defined by current government policy)
CE 6-Onsite renewable(s) (mandatory)	Climate and Energy	Energy management	3	1 (mandatory)	Where there is a commitment to install Low or Zero Carbon energy technologies to provide a net contribution of at least 15% of the total building energy demand (kWh/m2).
				1 (Good)	Where there is a commitment to install Low or Zero Carbon energy technologies to provide a net contribution of at least 20% of the total building energy demand (kWh/m2).
				1 (Best)	Where there is a commitment to install Low or Zero Carbon energy technologies to provide a net contribution of at least 25% of the total building energy demand (kWh/m2).
CE 7-Future renewable(s)	Climate and Energy	Energy management	3	1 (minimum)	Where 40% of buildings not already connected to active solar devices will be designed to allow future installation by the occupier.
				1 (Good)	Where 60% of buildings not already connected to active solar devices will be designed to allow future installation by the occupier.
				1 (Best)	Where 80% of buildings not already connected to active solar devices will be designed to allow future installation by the occupier.
CE11-Sub/Smart-Metering	Climate and Energy	Energy Monitoring	3	1 (minimum)	Sub-metering will be provided at the building/plot level to monitor end energy use at each building
				1 (Good)	The building plot developer will be required to provide appropriate sub-metering to individual units/ tenants in the building
				1 (Best)	Smart metering will be installed within the development. In residential buildings standard displays will be provided to each dwelling. In non residential buildings interactive displays (including software of internet accessible displays) will be provided to enable the occupants to monitor and reduce their energy use at the industrial unit/tenant level

CE 4- Heat Island	Climate and Energy	Passive Design Principles	3	1 (minimum)	Where evidence is provided to demonstrate that the development seeks to reduce the likelihood of contributing to a heat island effect through the provision of shaded public spaces and footpaths.
				1 (Good)	Where evidence is provided to demonstrate that the development seeks to reduce the likelihood of contributing to a heat island effect by achieving three (3) of the items listed below: a. Provision of appropriate shaded green space and tree cover, b. Green roofs and vegetated walls, c. Design to enable air-flow throughout the development, d. Open water and fountains in public spaces, e. Shaded public spaces and footpaths, f. Appropriate choice of external finishes to avoid heat absorption, g. Passive solar design.
				1 (Best)	Where evidence is provided to demonstrate that the development seeks to reduce the likelihood of contributing to a heat island effect by achieving five (5) of the items listed above
BLD 1- Domestic	Buildings	Code for Sustainable Homes /Eco Homes	3	1 (mandatory)	Where evidence demonstrates there is a commitment for all domestic buildings to achieve a rating of CODE for Sustainable Homes Level 3 Rating or equivalent
				1 (Good)	Where evidence demonstrates there is a commitment for all domestic buildings to achieve a rating of CODE for Sustainable Homes Level 4 Rating or equivalent
				1 (Best)	Where evidence demonstrates there is a commitment for all domestic buildings to achieve a rating of CODE for Sustainable Homes Level 5 Rating or equivalent
BLD 2- Non-domestic	Buildings	BREEAM Buildings (or equivalent)	3	1 (mandatory)	Where evidence demonstrates there is a commitment for all non- domestic buildings to achieve a rating of BREEAM Good pr equivalent
				1 (Good)	Where evidence demonstrates there is a commitment for all non- domestic buildings to achieve a rating of BREEAM Very Good or equivalent
				1 (Best)	Where evidence demonstrates there is a commitment for all non- domestic buildings to achieve a rating of BREEAM Excellent or above or equivalent
BLD 3- Building Refurbishment (BREEAM)	Buildings	BREEAM Buildings (or equivalent)	3	1 (minimum)	Where evidence demonstrates there is a commitment for all non- domestic refurbished buildings to achieve a rating of BREEAM Refurbishment Pass OR Where evidence demonstrates there is a commitment for all domestic refurbished buildings to achieve a rating of : Pass
				1 (Good)	Where evidence demonstrates there is a commitment for all non- domestic refurbished buildings to achieve a rating of BREEAM Refurbishment GOOD OR Where evidence demonstrates there is a commitment for all domestic refurbished buildings to achieve a rating of : GOOD
				1 (Best)	Where evidence demonstrates there is a commitment for all non- domestic refurbished buildings to achieve a rating of BREEAM Refurbishment VERY GOOD or Above Where evidence demonstrates there is a commitment for all domestic refurbished buildings to achieve a rating of : EXCELLENT

BREEAM-NL Gebiedsontwikkeling

Code	Category	Description	Max Points	Points	
BRO 1- Reduce primary energy	Resources	Energy efficiency	4	1	Where evidence shows that the percentage improvement of the energy of the area is at least 10%
				1	Where evidence shows that the percentage improvement of the energy of the area is at least 20%
				1	Where evidence shows that the percentage improvement of the energy of the area is at least 30%
				1	Where evidence shows that annual energy monitoring takes place and reported to the municipality
BRO 2 - Generating renewable energy	Resources	Generating renew able energy	5	1	At least 40% of the practical potential for solar energy is realized [1]
				1	Renewable energy is generated by wind, within the boundaries of the site, (at least 1.5 MW capacity installed)
				1	Renewable energy is generated by biomass power plants, within the boundaries of the site (the electrical or thermal capacity of biomass plants is at least 500kW)
				1	Renewable energy is generated by geothermal energy, within the boundaries of the site (the water pumped out of the ground should have a minimal temperature of 45 degrees)
				1	Renewable energy is generated by hydropower from flowing water (the hydropower installation has an environmental permission)
RO 9 - Sustainable buildings	Spatial development	Buildings Sustainability	4	There is a certain algorithm that gives different points based on the surface area of buildings that have been certified and the scores they have gained in each certification scheme. The certification schemes included are: BREEAM NL Gebouw, LEED Green Building, GPR Gebouw, GreenCalc, National Energy Label.	
KL 1 -Thermal Outdoor Climate	Area Climate	Thermal outdoor climate	4	1	Where evidence provided demonstrates that the UHI within the system boundary is up to 0.5.
				2	Where evidence provided demonstrates that the UHI within the system boundary is up to 0.25.
				2	Where evidence provided demonstrates that measures are taken in the planning area to prevent or minimize the UHI (either forest area in 500 m distance from residential function or 4 of the following measures should be included in the planning: 1. green verges and traffic lines along all roads in the area 2.street trees along all main roads in the area 3. 10%of grass in public space 4. green noise barriers 5. flowing surface water within 30 m of main residential functions 6. 30% of the pavement consists of open-paving 7. 40% of the paving is made of materials with high reflection 8. Swimming in the area 9. Minimum 5 water cooling elements in the area 10. water park in the area 11. water playgrounds in the area

[1] The solar potential is calculated in 5 steps: 1. The current and the added roof volume within the area is mapped. The roof surfaces needed for monumental reason or to protect urban/ village scenes should not to be counted 2. The sum of all horizontal roof areas (m^2) is determined. The practical horizontal potential (m2) is 50% of this total. 3. The total of all sloped roof areas (m2)

is determined. The practical potential (m^2) includes roof surfaces with an angle between 20 and 50 degrees, with an orientation between Southeast and Southwest. 4. Determine the total practical potential for solar energy as the sum of 2 and 3 in m^2. 5. The practical solar energy potential is at least 40% of the total of all sloped roofs. The total realized solar surface is at least 40% of the total determined under 4. The surface of photovoltaic and solar thermal systems maybe added together

GPR Stedenbouw			
Theme	**Sub-theme**	**Indicator**	**Unit**
Reduction of Energy Demand	Mitigation measures	Compactness (Floor Space Index)	Automatically calculated
Reduction of Energy Demand	Mitigation measures	Percentage of roof area suitable for solar energy	%
Reduction of Energy Demand	Mitigation measures	Percentage of buildings parcelled to the south (+/-20 degrees)	%
Reduction of Energy Demand	Mitigation measures	Percentage of buildings parcelled to the south with a barrier in front of them	%
Reduction of Energy Demand	Mitigation measures	Percentage of energy efficient public lighting	%
Reduction of Energy Demand	Process	Future stakeholders have a role in the planning process	Yes/party/not at all
Reduction of Energy Demand	Process	Monitoring of sustainability progress	Yes/party/not at all
Reduction of Energy Demand	Process	There is or there will be an energy vision plan for the area	Yes/party/not at all
Energy Performance (EPL)	Energy Labels (on average) of existing houses	Houses stacked	Construction Period
Energy Performance (EPL)	Energy Labels (on average) of existing houses	Houses in row	Construction Period
Energy Performance (EPL)	Energy Labels (on average) of existing houses	Houses 2/1 cap	Construction Period
Energy Performance (EPL)	Energy Labels (on average) of existing houses	Detached houses	Construction Period
Energy Performance (EPL)	Energy labels (on average) of existing Utility Area	Offices	Construction Period
Energy Performance (EPL)	Energy labels (on average) of existing Utility Area	Health Clinic	Construction Period
Energy Performance (EPL)	Energy labels (on average) of existing Utility Area	Health (but not clinics)	Construction Period
Energy Performance (EPL)	Energy labels (on average) of existing Utility Area	Meeting spaces	Construction Period
Energy Performance (EPL)	Energy labels (on average) of existing Utility Area	Education	Construction Period
Energy Performance (EPL)	Energy labels (on average) of existing Utility Area	Sport function	Construction Period
Energy Performance (EPL)	Energy labels (on average) of existing Utility Area	Lodging	Construction Period
Energy Performance (EPL)	Energy labels (on average) of existing Utility Area	Stores	Construction Period
Energy Performance (EPL)	Share of energy saved by new buildings energy performance (2010)	Houses	%
Energy Performance (EPL)	Share of energy saved by new buildings energy performance (2010)	Utility buildings	%
Energy Performance (EPL)	Space Heating and Hot water systems	Most common systems	Gas heating/ Electric heating/ Electric heat pump/ Waste incineration/ STEG 250MWe/ Biomass heat power/ Other types
Energy Performance (EPL)	Renewable electricity locally generated	Houses	%
Energy Performance (EPL)	Renewable electricity locally generated	Utility buildings	%
Functionality	Encouraging Sustainable Behaviour	Visible Renewable Energy	Yes/Partly/No

GPR Stedenbouw Outcome for Energy Performance of the area	
Result	**Unit**
Used Surface	(m^2)
Primary Energy Use	(TJ/ year)
Primary Energy Use per m^2 of used surface	(TJ/ m^2 used surface/year)
CO_2 Emissions	(kTones/year)
CO_2 Emissions per m^2 of used surface	(kg/year)
EPL	(Number)

LEED NEIGHBOURHOOD				
Category	**Indicator**	**Max Points**	**Points**	**Requirements**
Green Infrastructure and Buildings	Certified Green Building	Prerequisite 1	-	Design, construct, or retrofit one whole building within the project to be certified through LEED for New Construction, LEED for Existing Buildings: Operations & Maintenance, LEED for Homes, LEED for Schools, LEED for Retail: NewConstruction, or LEED for Core and Shell (with at least 75% of the floor area certified under LEED for Commercial Interiors or LEED for Retail: Commercial Interiors), or through a green building rating system requiring review by independent, impartial, third-party certifying bodies that have either been accredited by an IAF accreditation body to, or could demonstrate compliance to, ISO 17021 or ISO/IEC Guide 65, and, when subsequently available, ISO/IEC 17065.
Green Infrastructure and Buildings	Minimum Building Energy Efficiency	Prerequisite 2	-	-New buildings must demonstrate an average 10% improvement over ANSI/ ASHRAE/IESNA Standard 90.1–2007 (with errata but without addenda). -Buildings undergoing major renovations must demonstrate an average 5% improvement over ANSI/ASHRAE/IESNA Standard 90.1–2007 demonstrate compliance with ENERGY Home Energy Rating System

Green Infrastructure and Buildings	Credit 1: Certified Green Buildings	5	1	When ≥ 10% and < 20% percentage of Square Footage is certified by LEED Green Building or other independent green building rating tool
			1	When ≥ 20% and < 30% percentage of Square Footage is certified by LEED Green Building or other independent green building rating tool
			1	When ≥ 30% and < 40% percentage of Square Footage is certified by LEED Green Building or other independent green building rating tool
			1	When ≥ 40% and < 50% percentage of Square Footage is certified by LEED Green Building or other independent green building rating tool
			1	When ≥ 50% percentage of Square Footage is certified by LEED Green Building or other independent green building rating tool
	Credit 2: Building Energy Efficiency	2	1	90% of new buildings must demonstrate an average 18% improvement over ANSI/ASHRAE/ IESNA Standard 90.1–2007. AND 90% of buildings undergoing major renovations as part of the project must demonstrate an average 14% improvement over ANSI/ASHRAE/ IESNA Standard 90.1–2007
			2	90% of new buildings must demonstrate an average 26% improvement over ANSI/ASHRAE/ IESNA Standard 90.1–2007. AND 90% of buildings undergoing major renovations as part of the project must demonstrate an average 22% improvement over ANSI/ASHRAE/ IESNA Standard 90.1–2007
	Credit 9: Heat Island Reduction	1	1	Use any combination of the following strategies for 50% of the non roof site hardscape (including roads, sidewalks, courtyards, parking lots, parking structures, and driveways): a. Provide shade from open structures, such as those supporting solar photovoltaic panels, canopied walkways, and vine pergolas, all with a solar reflectance index (SRI) of at least 29. b. Use paving materials with an SRI of at least 29. c. Install an open-grid pavement system that is at least 50% pervious. d. Provide shade from tree canopy (within ten years of landscape installation). OR Use roofing materials that have an SRI ≥ 78 for low roof slope or SRI ≥ 29 for steep roof slope and for a minimum of 75% of the roof area of all new buildings within the project; or install a vegetated (“green”) roof for at least 50% of the roof area of all new buildings within the project. OR A combination of the above criteria

Green Infrastructure and Buildings	Credit 10: Solar Orientation	1	1	Locate the project on existing blocks or design and orient the project such that 75% or more of the blocks have one axis within plus or minus 15 degrees of geographical east-west, and the east-west lengths of those blocks are at least as long as the north-south lengths of the blocks. OR Design and orient 75% or more of the project's total building square footage (excluding existing buildings) such that one axis of each qualifying building is at least 1.5 times longer than the other, and the longer axis is within 15 degrees of geographical east-west. The length-to-width ratio applies only to walls enclosing conditioned spaces; walls enclosing unconditioned spaces, such as garages, arcades, or porches, cannot contribute to credit achievement. The surface area of equator-facing vertical surfaces and slopes of roofs of buildings counting toward credit achievement must not be more than 25% shaded at the time of initial occupancy, measured at noon on the winter solstice.
	Credit 11: On-Site Renewable Energy Sources	3	1	Incorporate on-site non-polluting renewable energy generation, such as solar, wind, geothermal, small-scale or micro hydroelectric, and/or biomass, with production capacity of at least 5% of the project's annual electrical and thermal energy cost (exclusive of existing buildings)
			1	… of at least 12.5% of the project's annual electrical and thermal energy cost (exclusive of existing buildings)
			1	… of at least 20% of the project's annual electrical and thermal energy cost (exclusive of existing buildings)
	Credit 12: District Heating and Cooling	2	1	Incorporate a district heating and/or cooling system for space conditioning and/or water heating of new buildings (at least two buildings total) such that at least 80% of the project's annual heating and/or cooling consumption is provided by the district plant. Single-family residential buildings and existing buildings of any type may be excluded from the calculation.
			1	…more than 80% of the project's annual heating and/or cooling consumption is provided by the district plant
	Credit 13: Infrastructure Energy Efficiency	1	1	Design, purchase, or work with the municipality to install all new infrastructure, including but not limited to traffic lights, street lights, and water and wastewater pumps, to achieve a 15% annual energy reduction below an estimated baseline energy use for this infrastructure. The baseline is calculated with the assumed use of lowest first-cost infrastructure items.

Appendix III

Extensive Results of the Application of the Tools in Lijnbaan area

Fysieke projecten Lijnbaankwartier

Peildatum juli 2010

Bouwprojecten

1	B-Tower	3.500m² winkels, 78 appartementen	In uitvoering, oplevering 2010
2	De Karel Doorman	10.500m² winkels, 105 woningen	Weer in uitvoering, oplevering 2011
3	Calypso		In uitvoering, oplevering 2011
4	Marskramer	Winkels en horeca	Opgeleverd
5	Van Oldebarneveltstr	Renovatie	Oplevering 2010
6	Schoeverspand	Renovatie	Oplevering 2010
7	Mauritsstraat		Oplevering 2010
8	Mauritsstraat		Oplevering 2010
9	Schouwburg	Interne renovatie, koppeling hal aan Floor	Voorbereiding uitvoering gestart, oplevering 2010
10	Pathé	Interne verbouwing, kleine uitbreding met horeca aan zijde Doelen, verbeteren gevel	Studie, geplande start uitvoering 2012
11	ABN-Amro locatie	14.000m² Leisure, 100 woningen, programma 16.000m² kantoren wordt heroverwogen, meer woningen	Randvoorwaarden vastgesteld, geplande start 2011, oplevering 2015
12	Postkantoor	20.000m² winkels, vier sterren hotel	Randvoorwaarden vastgesteld, geplande start 2011, oplevering 2014/15
13	Lijnbaanhoven	Onbekend	
14	Rotterdam Building	400 woningen, voorzieningen (SKVR, Codarts, publiekfuncties in de plint	Twee planstudies, geplande start in 2015
15	Hilton (renovatie)	Renovatie, ingang aan noordzijde	Geplande start 2011
16	Coolsingeltoren+Luxor	Onbekend, Luxor voor vijf jaar handhaven	Onbekend
17	SOR	X 55+ woningen	Initiatief, geplande start in 2012
18	Skihut	Renovatie gevel en gebouw, verbeteren terras in kleinere serre over twee verdiepingen	Geplande start in 2011, oplevering in 2012

Buitenruimteprojecten

1	Karel Doormanstraat	Oplevering 2010
2	Schouwburgplein	Visie en maatregelen verhoging vastgesteld, oplevering verhoging en randen in 2011
3	Kruisplein	In uitvoering, oplevering 2013, onderdoorgang 2014
4	Inrichting Lijnbaan en Korte Lijnbaan	Definitief ontwerp, uitvoering 2010, oplevering 2011
5	Inrichting Binnenwegplein en Keerweer	In uitvoering, oplevering eind 2010
6	Inrichting Kruiskade	Oplevering 2011
7	Inrichting Van Oldenbarneveltstraat en -plaats	Studie, tramkwestie
8	Revitaliseren Coolsingel	Studie
9	Inrichting Lijnbaanhoven	Onbekend
10	Inrichting Aert van Nesstraat	

Quick wins, lopend programma

1	Onderhoud lantarenpalen en wildparkeren fietsen	2010
2	Paviljoens	2010
3	Palenwoud en wildparkeren fietsen	2010
4	Vuilnisbakken en wildparkeren fietsen	2010

Lijnbaan en omgeving - een nieuwe toekomst 19

Figure 15: The redevelopment plan for Lijnbaan area, as it was received from the Municipality of Rotterdam

BREEAM COMMUNITIES Total Points Achieved: 10/24, Final Score: 0

Code	Category	Description	Total Points	Points	Requirements
CE 5 – Energy Efficiency (mandatory)	Climate and Energy	Energy management	3/3	1 (mandatory) ✓	Where evidence is provided to demonstrate that an energy strategy will be developed for the proposed development to optimise the incorporation of energy efficiency measures into the buildings on the site – including as a minimum: a. Minimising energy demand for the site through orientation and passive solar design. b. Maximising the thermal efficiency of building envelopes c. Minimising consumption of energy used for water heating, space heating and cooling, lighting and power in individual buildings through efficient equipment and controls.
				1 (Good) ✓	In addition to the optimising the energy efficiency of all buildings on site, a feasibility study will be conducted to: a. Calculate the residual energy demand for the site. b. Maximise the amount of the residual demand which can be met efficiently by Low or Zero Carbon (LZC) technologies
				1 (Best) ✓	Once the first and second credit have been achieved, the energy strategy will aim to meet the remaining demand through an appropriate Allowable Solution (as defined by current government policy)
CE 6-Onsite renewable(s) (mandatory)	Climate and Energy	Energy management	1/3	1 (mandatory) ✓	Where there is a commitment to install Low or Zero Carbon energy technologies to provide a net contribution of at least 15% of the total building energy demand (kWh/m2).
				1 (Good) ✗	Where there is a commitment to install Low or Zero Carbon energy technologies to provide a net contribution of at least 20% of the total building energy demand (kWh/m2).
				1 (Best) ✗	Where there is a commitment to install Low or Zero Carbon energy technologies to provide a net contribution of at least 25% of the total building energy demand (kWh/m2).
CE 7-Future renewable(s)	Climate and Energy	Energy management	3/3	1 (minimum) ✓	Where 40% of buildings not already connected to active solar devices will be designed to allow future installation by the occupier.
				1 (Good) ✓	Where 60% of buildings not already connected to active solar devices will be designed to allow future installation by the occupier.
				1 (Best) ✓	Where 80% of buildings not already connected to active solar devices will be designed to allow future installation by the occupier.
CE11-Sub/Smart-Metering	Climate and Energy	Energy Monitoring	0/3	1 (minimum) ✗	Sub-metering will be provided at the building/plot level to monitor end energy use at each building
				1 (Good) ✗	The building plot developer will be required to provide appropriate sub-metering to individual units/ tenants in the building
				1 (Best) ✗	Smart metering will be installed within the development. In residential buildings standard displays will be provided to each dwelling. In non residential buildings interactive displays (including software of internet accessible displays) will be provided to enable the occupants to monitor and reduce their energy use at the industrial unit/tenant level

CE 4- Heat Island	Climate and Energy	Passive Design Principles	3/3	1 (minimum) ✓	Where evidence is provided to demonstrate that the development seeks to reduce the likelihood of contributing to a heat island effect through the provision of shaded public spaces and footpaths.
				1 (Good) ✓	Where evidence is provided to demonstrate that the development seeks to reduce the likelihood of contributing to a heat island effect by achieving three (3) of the items listed below: a. Provision of appropriate shaded green space and tree cover, b. Green roofs and vegetated walls, c. Design to enable air-flow throughout the development, d. Open water and fountains in public spaces, e. Shaded public spaces and footpaths, f. Appropriate choice of external finishes to avoid heat absorption, g. Passive solar design.
				1 (Best) ✓	Where evidence is provided to demonstrate that the development seeks to reduce the likelihood of contributing to a heat island effect by achieving five (5) of the items listed above
BLD 1- Domestic	Buildings	Code for Sustainable Homes /Eco Homes	0/3	1 (mandatory) ✗	Where evidence demonstrates there is a commitment for all domestic buildings to achieve a rating of CODE for Sustainable Homes Level 3 Rating or equivalent
				1 (Good) ✗	Where evidence demonstrates there is a commitment for all domestic buildings to achieve a rating of CODE for Sustainable Homes Level 4 Rating or equivalent
				1 (Best) ✗	Where evidence demonstrates there is a commitment for all domestic buildings to achieve a rating of CODE for Sustainable Homes Level 5 Rating or equivalent
BLD 2- Non-domestic	Buildings	BREEAM Buildings (or equivalent)	0/3	1 (mandatory) ✗	Where evidence demonstrates there is a commitment for all non- domestic buildings to achieve a rating of BREEAM Good pr equivalent
				1 (Good) ✗	Where evidence demonstrates there is a commitment for all non- domestic buildings to achieve a rating of BREEAM Very Good or equivalent
				1 (Best) ✗	Where evidence demonstrates there is a commitment for all non- domestic buildings to achieve a rating of BREEAM Excellent or above or equivalent
BLD 3- Building Refurbishment (BREEAM)	Buildings	BREEAM Buildings (or equivalent)	0/3	1 (minimum) ✗	Where evidence demonstrates there is a commitment for all non- domestic refurbished buildings to achieve a rating of BREEAM Refurbishment Pass OR Where evidence demonstrates there is a commitment for all domestic refurbished buildings to achieve a rating of : Pass
				1 (Good) ✗	Where evidence demonstrates there is a commitment for all non- domestic refurbished buildings to achieve a rating of BREEAM Refurbishment GOOD OR Where evidence demonstrates there is a commitment for all domestic refurbished buildings to achieve a rating of : GOOD
				1 (Best) ✗	Where evidence demonstrates there is a commitment for all non- domestic refurbished buildings to achieve a rating of BREEAM Refurbishment VERY GOOD or Above Where evidence demonstrates there is a commitment for all domestic refurbished buildings to achieve a rating of : EXCELLENT

BREEAM-NL Gebiedsontwikkeling					**Total Points Achieved: 6/17**
Code	**Category**	**Description**	**Total Points**	**Points**	
BRO 1- Reduce primary energy	Resources	Energy efficiency	2/4	1 ✓	Where evidence shows that the percentage improvement of the energy of the area is at least 10%
				1 ✗	Where evidence shows that the percentage improvement of the energy of the area is at least 20%
				1 ✗	Where evidence shows that the percentage improvement of the energy of the area is at least 30%
				1 ✓	Where evidence shows that annual energy monitoring takes place and reported to the municipality
BRO 2 - Generating renewable energy	Resources	Generating renew able energy	0/5	1 ✗	At least 40% of the practical potential for solar energy is realized [1]
				1 ✗	Renewable energy is generated by wind, within the boundaries of the site, (at least 1.5 MW capacity installed)
				1 ✗	Renewable energy is generated by biomass power plants, within the boundaries of the site (the electrical or thermal capacity of biomass plants is at least 500kW)
				1 ✗	Renewable energy is generated by geothermal energy, within the boundaries of the site (the water pumped out of the ground should have a minimal temperature of 45 degrees)
				1 ✗	Renewable energy is generated by hydropower from flowing water (the hydropower installation has an environmental permission)
RO 9 - Sustainable buildings	Spatial development	Buildings Sustainability	1/4	There is a certain algorithm that gives different points based on the surface area of buildings that have been certified and the scores they have gained in each certification scheme. The certification schemes included are: BREEAM NL Gebouw, LEED Green Building, GPR Gebouw, GreenCalc, National Energy Label.	
KL 1 -Thermal Outdoor Climate	Area Climate	Thermal outdoor climate	3/4	1 ✓	Where evidence provided demonstrates that the UHI within the system boundary is up to 0.5.
				2 ✗	Where evidence provided demonstrates that the UHI within the system boundary is up to 0.25.
				2 ✓	Where evidence provided demonstrates that measures are taken in the planning area to prevent or minimize the UHI (either forest area in 500 m distance from residential function or 4 of the following measures should be included in the planning: 1. green verges and traffic lines along all roads in the area 2.street trees along all main roads in the area 3. 10%of grass in public space 4. green noise barriers 5. flowing surface water within 30 m of main residential functions 6. 30% of the pavement consists of open-paving 7. 40% of the paving is made of materials with high reflection 8. Swimming in the area 9. Minimum 5 water cooling elements in the area 10. water park in the area 11. water playgrounds in the area

[1] The solar potential is calculated in 5 steps: 1. The current and the added roof volume within the area is mapped. The roof surfaces needed for monumental reason or to protect urban/ village scenes should not to be counted 2. The sum of all horizontal roof areas (m^2) is determined. The practical horizontal potential (m2) is 50% of this total. 3. The total of all sloped roof areas (m2) is determined. The practical potential (m^2) includes roof surfaces with an angle between 20 and 50 degrees, with an orientation between Southeast and Southwest. 4. Determine the total practical potential for solar energy as the sum of 2 and 3 in m^2. 5. The practical solar energy potential is at least 40% of the total of all sloped roofs. The total realized solar surface is at least 40% of the total determined under 4. The surface of photovoltaic and solar thermal systems maybe added together

GPR Stedenbouw			
Theme	**Sub-theme**	**Indicator**	**Unit**
Reduction of Energy Demand	Mitigation measures	Compactness (Floor Space Index)	Automatically calculated
		Percentage of roof area suitable for solar energy	%
		Percentage of buildings parcelled to the south (+/-20 degrees)	%
		Percentage of buildings parcelled to the south with a barrier in front of them	%
		Percentage of energy efficient public lighting	%
	Process	Future stakeholders have a role in the planning process	Yes/party/not at all
		Monitoring of sustainability progress	Yes/party/not at all
		There is or there will be an energy vision plan for the area	Yes/party/not at all
Energy Performance (EPL)	Energy Labels (on average) of existing houses	Houses stacked	Construction Period
		Houses in row	Construction Period
		Houses 2/1 cap	Construction Period
		Detached houses	Construction Period
	Energy labels (on average) of existing Utility Area	Offices	Construction Period
		Health Clinic	Construction Period
		Health (but not clinics)	Construction Period
		Meeting spaces	Construction Period
		Education	Construction Period
		Sport function	Construction Period
		Lodging	Construction Period
		Stores	Construction Period
	Share of energy saved by new buildings energy performance (2010)	Houses	%
		Utility buildings	%
	Space Heating and Hot water systems	Most common systems	Gas heating/ Electric heating/ Electric heat pump/ Waste incineration/ STEG 250MWe/ Biomass heat power/ Other types
	Renewable electricity locally generated	Houses	%
		Utility buildings	%
Functionality	Encouraging Sustainable Behaviour	Visible Renewable Energy	Yes/Partly/No

GPR Stedenbouw Outcome for Energy Performance of the area	
Result	**Unit**
Used Surface	(m^2)
Primary Energy Use	(TJ/ year)
Primary Energy Use per m^2 of used surface	(TJ/ m^2 used surface/year)
CO_2 Emissions	(kTones/year)
CO_2 Emissions per m^2 of used surface	(kg/year)
EPL	(Number)

LEED NEIGHBOURHOOD			**Total Points Achieved: 6/15**	
Category	**Indicator**	**Max Points**	**Points**	**Requirements**
Green Infrastructure and Buildings	Certified Green Building	Prerequisite 1	- ✗	Design, construct, or retrofit one whole building within the project to be certified through LEED for New Construction, LEED for Existing Buildings: Operations & Maintenance, LEED for Homes, LEED for Schools, LEED for Retail: NewConstruction, or LEED for Core and Shell (with at least 75% of the floor area certified under LEED for Commercial Interiors or LEED for Retail: Commercial Interiors), or through a green building rating system requiring review by independent, impartial, third-party certifying bodies that have either been accredited by an IAF accreditation body to, or could demonstrate compliance to, ISO 17021 or ISO/IEC Guide 65, and, when subsequently available, ISO/IEC 17065.
Green Infrastructure and Buildings	Minimum Building Energy Efficiency	Prerequisite 2	- ✓	-New buildings must demonstrate an average 10% improvement over ANSI/ ASHRAE/IESNA Standard 90.1–2007 (with errata but without addenda). -Buildings undergoing major renovations must demonstrate an average 5% improvement over ANSI/ASHRAE/IESNA Standard 90.1–2007 demonstrate compliance with ENERGY Home Energy Rating System

Green Infrastructure and Buildings	Credit 1: Certified Green Buildings	0/5	1 ✗	When ≥ 10% and < 20% percentage of Square Footage is certified by LEED Green Building or other independent green building rating tool
			1 ✗	When ≥ 20% and < 30% percentage of Square Footage is certified by LEED Green Building or other independent green building rating tool
			1 ✗	When ≥ 30% and < 40% percentage of Square Footage is certified by LEED Green Building or other independent green building rating tool
			1 ✗	When ≥ 40% and < 50% percentage of Square Footage is certified by LEED Green Building or other independent green building rating tool
			1 ✗	When ≥ 50% percentage of Square Footage is certified by LEED Green Building or other independent green building rating tool
	Credit 2: Building Energy Efficiency	1/2	1 ✓	90% of new buildings must demonstrate an average 18% improvement over ANSI/ASHRAE/ IESNA Standard 90.1–2007. AND 90% of buildings undergoing major renovations as part of the project must demonstrate an average 14% improvement over ANSI/ASHRAE/ IESNA Standard 90.1–2007
			2 ✗	90% of new buildings must demonstrate an average 26% improvement over ANSI/ASHRAE/ IESNA Standard 90.1–2007. AND 90% of buildings undergoing major renovations as part of the project must demonstrate an average 22% improvement over ANSI/ASHRAE/ IESNA Standard 90.1–2007
	Credit 9: Heat Island Reduction	1/1	1 ✓	Use any combination of the following strategies for 50% of the non roof site hardscape (including roads, sidewalks, courtyards, parking lots, parking structures, and driveways): a. Provide shade from open structures, such as those supporting solar photovoltaic panels, canopied walkways, and vine pergolas, all with a solar reflectance index (SRI) of at least 29. b. Use paving materials with an SRI of at least 29. c. Install an open-grid pavement system that is at least 50% pervious. d. Provide shade from tree canopy (within ten years of landscape installation). OR Use roofing materials that have an SRI ≥ 78 for low roof slope or SRI ≥ 29 for steep roof slope and for a minimum of 75% of the roof area of all new buildings within the project; or install a vegetated ("green") roof for at least 50% of the roof area of all new buildings within the project. OR A combination of the above that meet a specific formula criteria p. 95

Green Infrastructure and Buildings	Credit 10: Solar Orientation	0/1	1 ✗	Locate the project on existing blocks or design and orient the project such that 75% or more of the blocks have one axis within plus or minus 15 degrees of geographical east-west, and the east-west lengths of those blocks are at least as long as the north-south lengths of the blocks. OR Design and orient 75% or more of the project's total building square footage (excluding existing buildings) such that one axis of each qualifying building is at least 1.5 times longer than the other, and the longer axis is within 15 degrees of geographical east-west. The length-to-width ratio applies only to walls enclosing conditioned spaces; walls enclosing unconditioned spaces, such as garages, arcades, or porches, cannot contribute to credit achievement. The surface area of equator-facing vertical surfaces and slopes of roofs of buildings counting toward credit achievement must not be more than 25% shaded at the time of initial occupancy, measured at noon on the winter solstice.
	Credit 11: On-Site Renewable Energy Sources	0/3	1 ✗	Incorporate on-site non-polluting renewable energy generation, such as solar, wind, geothermal, small-scale or micro hydroelectric, and/or biomass, with production capacity of at least 5% of the project's annual electrical and thermal energy cost (exclusive of existing buildings)
			1 ✗	… of at least 12.5% of the project's annual electrical and thermal energy cost (exclusive of existing buildings)
			1 ✗	… of at least 20% of the project's annual electrical and thermal energy cost (exclusive of existing buildings)
	Credit 12: District Heating and Cooling	1/2	1 ✓	Incorporate a district heating and/or cooling system for space conditioning and/or water heating of new buildings (at least two buildings total) such that at least 80% of the project's annual heating and/or cooling consumption is provided by the district plant. Single-family residential buildings and existing buildings of any type may be excluded from the calculation.
			1 ✗	…more than 80% of the project's annual heating and/or cooling consumption is provided by the district plant
	Credit 13: Infrastructure Energy Efficiency	1/1	1 ✓	Design, purchase, or work with the municipality to install all new infrastructure, including but not limited to traffic lights, street lights, and water and wastewater pumps, to achieve a 15% annual energy reduction below an estimated baseline energy use for this infrastructure. The baseline is calculated with the assumed use of lowest first-cost infrastructure items.