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Land Use as an Aspect of Sustainable Building

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Abstract

This study discusses the validity and usability of land use as an aspect of sustainable building. Buildings have an effect on land use not only because of the extraction and processing of raw materials and disposal of wastes but also because buildings occupy land during their entire service life. In addition, location of buildings has an effect on the need of networks – such as traffic networks – and their land use. Land use related indicators are typically included in the European voluntary assessment systems of sustainable buildings. ISO 21929-1 defines two land use indicators for buildings: soil sealing and land use change. However, there is neither consensus nor a harmonised method to assess this issue. As an example, land use was not included in EN 15978:2011 due to lack of agreement on a calculation method. This study outlines the environmental aspects of buildings' land use, assesses the significance of land use that happens because of the land occupation of buildings compared to the land use because of the extraction of raw materials needed for the construction of buildings. The study has also includes information about the benchmarks of buildings in terms of land use related indicators, discusses, ands make conclusions about the compatibility of building level indicators with the urban level indicators.

Keywords: *land use, sustainable building, sustainable urban planning, sustainability indicators, sustainable development*

1. Introduction

Sustainable buildings are defined with the help of indicators; a number of different kinds of sets of sustainability indicators have been developed (Delem et al. 2010). Because of the large number and various kinds of indicator sets, there is a danger that this may decrease the general trust on the reliability of the assessment systems and impair the general understanding about their purpose. In order to improve the validity of sustainable building indicators as indicators of sustainability, a top-down approach should be chosen (Lützkendorf et al. 2011, Lützkendorf et al. 2012). Following a top-down approach, the development and selection of indicators starts by the definition of relevant subjects of concern of sustainable development. An indicator can be validated as an indicator of sustainable building only if it fulfils two minimum requirements: the indicator is related to an issue of concern of sustainable development; buildings have a significant impact on that issue (Häkkinen et al. 2011).

Buildings and building related infrastructure (streets, parking etc.) lead to the loss of ecosystems (habitats) and biodiversity, reduction of land

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potential for recreation and reduction of storm-water infiltration areas because of sealed soil.

Land use related indicators are typically included in the European voluntary assessment systems of sustainable buildings (Delem et al. 2010). ISO 21929-1 defines two land use indicators for buildings: soil sealing and land use change. Change of land use "measures the avoidance of consuming of green field lands through the reuse of brownfield and derelict areas, refurbishment, using infill sites and re-development of existing built environment". This indicator is also intended for measuring the utilization of existing infra-structures and networks. Soil sealing occurs because of covering earth with non-permeable or low permeable layers as a result of construction works for example, roads, buildings, parking and so on. The indicator measures the degree of soil sealing on a building plot.

The importance of land use indicator as a sustainability indicator needs further research. It is also important to study the significance of building materials and disposal of wastes with the help of life cycle approach. Different raw materials may have very different impacts on land use as such while not having corresponding impacts on land use change. Thus land use as such may not be the best choice for the land related indicator.

2. Objectives

This article outlines the environmental aspects of buildings' land use and assesses the significance of different factors' on buildings' overall land use. It is also an attempt to further analyse the signi-ficance of land use indicator in relation to buildings and to determine whether land use should be dealt with not only on the level of urban planning but also at building level. In this sense, a comparison between indicators related to land use may help to clarify its consistency and relevance in terms of key sustainability issues of concern and might open new possibilities.

Therefore, the objectives of the research were to:

– to assess and justify the validity of land use as an indicator for sustainable building;
– to discuss and make conclusions about the most important environmental aspects of the land use of buildings;
– to evaluate the importance of different factors on the land use of buildings, especially to assess the importance of land use that happens because of the land occupation of buildings compared to the land use because of the extraction of raw materials needed for the construction of buildings;
– to collect information about the benchmarks of buildings in terms of land use indicators
– to discuss and make conclusions about the compatibility of building level indicators with the urban level indicators.

The novel value of the study is based on two main issues: the study presents new results about the importance of different factors of the value chain; the study presents a comprehensive picture about the importance of land use as an aspect of sustain-able building.

3. Methods

The validity of land use as an indicator for sustainable building was studied with the help of literature review and by referring to the conclusions done by the UN's Commission on Sustainable development (CSD). The importance of different environmental aspects of the land use of buildings was assessed on the basis of literature and statistical data. The significance of different factors on buildings' land use was assessed with the help of a case study and by using life cycle assessment (LCA) method. Information about the typical land use of buildings was collected by searching information from the current assessment and benchmarking systems. The compatibility of building level and district level indicators was studied by comparing indicators used on the different levels.

4. Validity of Land as an Indicator for Sustainable Building

It can be defined in accordance with ISO 21929-1 (2011) that an indicator is a quantitative, qualita-tive or descriptive measure representative of one or more impact categories or issues of concern (areas of protection).

Validity means that the study measures what it is intended to measure (Yin 2002). Correspondingly a sustainability indicator is valid only if it measures what it is intended to measure, that is, impacts on sustainable development or more precisely impacts on the issues of concern of sustainable development.

Here the term "issues of concern" is considered as broadly equivalent to terms like "areas of protection" or "safeguard subjects" commonly found in LCA related literature (Finnveden et al. 2009). As an example, the safeguard subjects defined in the Rio Earth Summit Declaration in 1992 are: biological diversity, human health, production of biomass and fresh water, and resource use and aesthetic values. Land use is seen among the issues of concern of SD by UN's Commission on Sustainable development (CSD). UN's CSD has approved a follow-up to the two earlier sets of sustainability indicators (UN 2007); the themes and related indicators are claimed to cover the issues that are relevant to sustainable development (SD) in most countries. Land, biodiversity, atmosphere, and consumption and production patterns are among the chosen themes.

Today, there is a common acceptance that the protection areas of Life Cycle Assessment are human health, natural environment, natural resources, and to some extent man-made environment (Udo de Haes et al., 1999, Udo de Haes et al. 2002). Land use is related especially to the following issues of concern (Nibel et al. 2011): The availability of natural resources (soil materials, biomass, groundwater, etc.) and the protection of ecosystems, biodiversity, and climatic systems. According to Finnveden et al. (2009) land use will affect three of the areas of protection directly, namely, natural environment, natural resources and manmade environment, and human health indirectly. Global croplands, pastures, plantations, and urban areas have expanded in recent decades, accompanied by large increases in energy, water, and fertilizer consumption, along with considerable losses of biodiversity. Such changes in land use potentially undermine the capacity of ecosystems to sustain food production, maintain freshwater and forest resources, regulate climate and air quality, and ameliorate infectious diseases (Foley et al. 2005). Compared with the potential natural vegetation as a baseline, areas getting transformed by man (land transformations) as well as areas forced to maintain their current non-natural state (land occupations) may store reduced amounts of carbon in soil and vegetation, whereby the mobilized carbon is essentially transferred to the atmosphere in form of CO_2, contributing to global warming (Müller-Wenk and Brandão 2010).

5. The Importance of Different Environmental Aspects of the Land Use of Buildings

Construction causes irreversible land changes. The use of land means consumption of resources both in terms of changing the potential end use and consumption of soil materials. Buildings use land directly by occupying land under construction assets, but also through embodied land-use in non-renewable and renewable raw materials and energy over the building's value chain. To understand the land use impacts of the whole building value chain, it is not sufficient to limit the land use impact assessment only to the building's location. A life-cycle of a building includes the harvesting and extraction of primary raw materials, manufacturing of construction products, construction process, use stage of building including maintenance, production of energy and main auxiliary inputs over the life-cycle of a building, demolition of building, and end of life stage (EN 15978: 2011). For example, gravel mining for concrete or forest management for wood have different land use implications and impacts on biodiversity and terrestrial carbon stocks, than what the occupation of land under construction assets does. The description of effects caused by buildings' value chain shows that the environmental impacts take place on different levels. This leads to the "impact chain approach". Changes at the beginning of the value chain for example, sealing, are often responsible for the other downstream effects like the loss of biodiversity.

The following sections characterise the different environmental aspects related to buildings' land use. The description is divided in accordance with the main land use aspects of buildings. On the basis of the review of literature these are soil sealing, soil compaction, change of land use, fragmentation, loss of biodiversity and the extraction of natural raw materials.

Soil Sealing

Buildings and other construction assets cause soil sealing as land remains below constructions. Soil sealing occurs when agricultural or other non-developed land is built upon. It normally includes the removal of top soil layers and leads to the loss of important soil functions, such as food production or water storage (as defined by EEA SOER Soil 2010). Soil sealing is a common consequence of urbanization and infrastructure construction. Contrary to natural sealing, artificial sealing is generally extensive and permanent (Scalenghe and Marsan 2009). When vegetated soils are replaced with impermeable surfaces, the result is the increase of overland flow, reduction of infiltration and bypass of the natural storage (Wheater and Evans 2009). There are major issues of flooding due to surface runoff within the urban environment (Wheater and Evans 2009). Soil sealing is seen in the functional interdependencies especially with soil compaction, erosion and flooding (Blum et al. 2004).Urban sprawl and land consumption is recognised as one of the major threats to soil in Europe (Vrscaj et al. 2008). In Europe, 4% of the total surface is covered by artificial areas. These areas include built-up areas and un-built surfaced areas such as transport networks and associated areas; 80% of this is allotted to housing, services and recreation (EEA SOER 2010 Soil p. 10). Table 1 presents the degree of soil sealing as percentage of total land area in European countries (source: EEA 2012).

Table 1

The degree of soil sealing as percentage of total land area in European countries

1	Malta	13.27
2	Belgium	7.37
3	Netherlands	7.33
4	Luxembourg	4.6
5	Cyprus	3.62
6	Denmark	3.53
7	United Kingdom	3.34
8	Czech Republic	3.19
9	Hungary	3.16
10	Portugal	3.10
11	Italy	2.81
12	France	2.77
13	Poland	2.36
14	Slovakia	2.35
15	Lithuania	2.0
16	Austria	1.92
17	Slovenia	1.84
18	Bulgaria	1.84
19	Romania	1.61
20	Ireland	1.59
21	Spain	1.42
22	Greece	1.35
23	Latvia	1.11
24	Estonia	0.87
25	Finland	0.51
26	Sweden	0.37
27	Norway	0.20

The French environmental statistical organization (IFEN) gives the following information about land use:

- Artificial areas reached 9.4% of the territory in 2008, 5.1 million hectares, which represents approximately 800m² per habitant.
- 16% of these surfaces are built on land (houses, buildings ...),
- 44% for coated or stabilized soil (roads, parking ...) and
- 40% to other artificial spaces (gardens, yards..)
- Artificial areas are growing by about 60.000 ha per year since 1993, mainly at the expense of farmland, but also semi-natural environments.

According to the European statistics the built-up area increases significantly faster than the population calculated with the help of an index that compares the corresponding figures in 1990 and 2000 (EEA 2012).

Soil Compaction

Building does not only cause soil sealing, but also soil compaction due to high loads caused by construction.

Compaction reduces the pore space between soil particles, increases bulk density, reduces the soil's absorptive capacity (as defined by EEA SOER 2010 Soil, p. 22) (Batey 2009). Finally, soil compaction influences water penetration and runoff, root penetration, and organism movement (Bone et al. 2012). As soil sealing and compaction influence the soil's function of environmental interactions (storage, filtering and transformation) they also have a great influence on changes in the quality and amount of groundwater.

Change of Land Use

Here, changes of land use means that land that was originally dedicated to other purposes for example, agriculture, forest, Greenland and so on, is turned into building areas. Artificial areas caused a net increase of land cover of roughly 600 000 hectares during 2000-2006 in Europe (EEA SOER Soil 2010) while the areas of arable land, semi-natural vegetation, pastures, open spaces and wetlands decreased at the same time. Changes in land use can have wide-ranging environmental consequences, including biodiversity loss, changes in emissions of gases affecting climate change, changes in hydrology and soil degradation (Marshall and Shortle 2005).

The higher the ecological value of the land area converted into built-up area the more significant the negative impacts on the environment. On the other hand, changes of land use may also have positive effects on the environment. This is the case if contaminated area is turned into building area and thus has to be decontaminated before conversion. The use of existing buildings (refurbishment) or the recycling of existing building plots, for example, demolition of the former building in order to construct a new building, does not require changes of land use.

Changes in land use from natural, rural and agricultural purposes to urban purposes typically increase sealed surfaces affecting the water balance of the area. The findings of a case study, carried out in the city of Leipzig, concluded that due to urbanisation and urban sprawl the water balance has shifted towards greater surface run-off (Haase 2009). Built-up surfaces on floodplains and water retention areas increase the risk of flooding and flood damage. The Rhine has already lost four fifth of its natural floodplains. Similarly, only 14% of the natural floodplains of the Elbe remain available for flooding (EEA SOER Land use 2010).

The way land is used is one of the main drivers of global environmental change. In turn, environmental change, in particular climate change, increasingly affects the use of land as communities strive to adapt to, and mitigate, the effects of a changing climate (Lobley and Winter 2009). Land consumption caused by residential development, economic growth and transportation belongs to the most serious environmental pressures on landscapes, particularly in urbanised areas (Nuissl et al. 2008).

Fragmentation

Fragmentation because of built-up areas causes the isolation of habitants and disruption of ecological corridors (Häkkinen 2007, p. 196). Fragmentation strongly affects landscape structure in urban landscapes and decreases landscape connectivity (Vergnes et al. 2012). The remaining woodland habitats become physically distant from each other and are isolated by buildings and streets (Gibb and Hochuli, 2002).

The consequences of urban sprawl and infrastructural development are decreasing natural habitats, which also become more fragmented. 30% of the total area in Europe is moderately high or very highly fragmented, increasing the vulnerability of ecosystems to diffuse external pressures such as drainage, eutrophication and acidification (EEA SOER Biodiversity 2010).

Extraction of Aggregate Materials and other Raw Materials

Building and construction use big amounts of aggregate materials. A Finnish parametric study assessed the use of materials in typical residential blocks of flats (Ruuska et al. 2013). In the case of concrete buildings, the share of concrete (the main raw materials of which are aggregate materials and limestone), gravel and crushed aggregates form the main part of all building materials (typically roughly 90%), when renovation is not taken into account. The consumption of concrete and aggregate materials was assessed to be typically roughly 2 tonne per net square meter of a building. In addition, the needed soil materials for landfill may be high in worst cases. In the parametric study it was assessed that the land-filling -without considering the whole lot- may be a maximum of 0.6 tonne per net square meter.

Soil construction, hydraulic engineering and building construction are typically the biggest consumers of natural materials in economies. In Finland their overall share is 58% while the share of mere building construction is 4 % (Seppälä 2009). Because of the decrease of the availability of natural gravel, solid rock is more and more made use of (Husa and Teeriaho 2012). However, although aggregate materials typically form the biggest material resource of buildings those are not always responsible for the greatest land use effects. This is dealt with in more detail in Section 6.2 (Case study).

Reduction of Biodiversity

Soil represents one of the most important reservoirs of biodiversity (Gardi et al. 2009). Soil sealing and land use change because of buildings and other constructions have a relatively high potential effect on the loss of biodiversity amongst several main pressures (as presented by Jeffrey et al. 2010). Fragmentation because of built-up areas isolates areas from others, and also has a remarkable influence on bio-diversity.

6. The importance of Different Factors on Buildings' Land

6.1. Introduction

Buildings use land by directly occupying land under construction assets, but also because of embodied land-use in building materials. Life Cycle Assessment methodology helps to make a comprehensive analysis about a building's land use. The importance of land use evaluation has recently been recognised in LCA but there is still a considerable lack of definition, particularly concerning what parameters should be considered and what particular methodology should be used. Lack of adequate impact indicators (Weidema and Lindeijer 2001) and scarcity of data have been some of the causes (Cowell and Lindeijer 2000). Reviews of the different indicators used to calculate land use impact have been undertaken by several authors (Koellner 2001, Anton et al. 2007; Milà i Canals et al. 2007; Mattila et al. 2012).

Initial approaches for evaluating the occupation of a piece of land are the quantity of earth in m^2, with no distinction being made between the different ways that the earth is used and no consideration given to the original state of the soil. Nowadays, it is widely agreed that a qualitative evaluation of the soil quality changes is necessary (Guinée et al. 2002, Lindeijer 2000). Quality concepts consider that productivity of the soil as a resource is affected according to the results of a particular activity, and various indices have been presented to evaluate the influence of this activity (Mattsson et al. 2000, Wegener Sleeswijk et al. 1996, Brandão & Milà i Canals 2012).

A new framework on life cycle impact assessment (LCIA) for land use (Milà i Canals et al. 2007) describes how to link land use elementary flows, land occupation and land transformation, to selected environmental midpoint indicators and damage categories. Three impact pathways for land use are defined: impacts on biodiversity, biotic production potential and ecological soil quality. This enables consistent impact characterisation of land occupation (m2*a) and land transformation (m^2 from land use class to another) with respect to a reference land use situation. According to Koellner *et al.* (2012), an updated framework includes an approach for bio-geographical differentiation of land-use impacts.

The UNEP-SETAC work[1] has enabled the development of many midpoint and endpoint land use indicators for LCIA, for example, Schmidt (2008) and de Baan *et al.* (2012) on biodiversity, Brandão *et al.* (2010, 2012) on soil quality and biotic production, Müller-Wenk & Brandão (2010) on climate regulation potential and Ewing et al. (2008) on competition over productive land.

6.2. Case study

The effect of different factors on the building's land use was studied with the help of lifecycle assessment. The assessment was done on the basis of a case study. Ruuska et al. (2013) includes a description of a typical Finnish multi-floor residential building's value chain and material and energy needs over the life-cycle. The data presented in Ruuska et al. (2013) on construction product, heat and power and on-site land-area needs during building's life-span, 50 years, was applied in this study.

LCI data on land occupation and transformation needs of mineral construction products was sourced from Ecoinvent (2010) 2.2 life-cycle database, forest biomass from Metla (2011) and

[1] In 2002, the United Nations Environment Programme (UNEP) and the Society for Environmental Toxicology and Chemistry (SETAC) launched an International Life Cycle Partnership, known as the Life Cycle Initiative, to enable users around the world to put life cycle thinking into effective practice. For more information: http://lcinitiative.unep.fr

Finnish average power and heat supply mix from VTT KCL-Eco database (2012) based on IEA Energy statistics (2010). Maintenance and end-of-life of building were excluded from the assessment (See Electronic Supplementary material (ESM) for further details on LCI modelling and data sources). Finally the inventory data on all material and energy flows was connected to the information about land occupation and land transformation needs of these flows (the latter is only presented in ESM).

Life cycle inventory results (m2*a) are presented in Figure 1 a, b and in Figure 2 a, b. Because of the dominating role of biomass related land use, the results are presented separately for the flows that use forest land, that is, wood and other biomass from forests, and for other flows. For the sake of comparison, the results were also calculated assuming that the building uses average Central European heat and power. This was calculated in order to show the results in a case where forest biomass is either not used or used only in minor quantity, for the generation of heat and power and thus does not dominate the results.

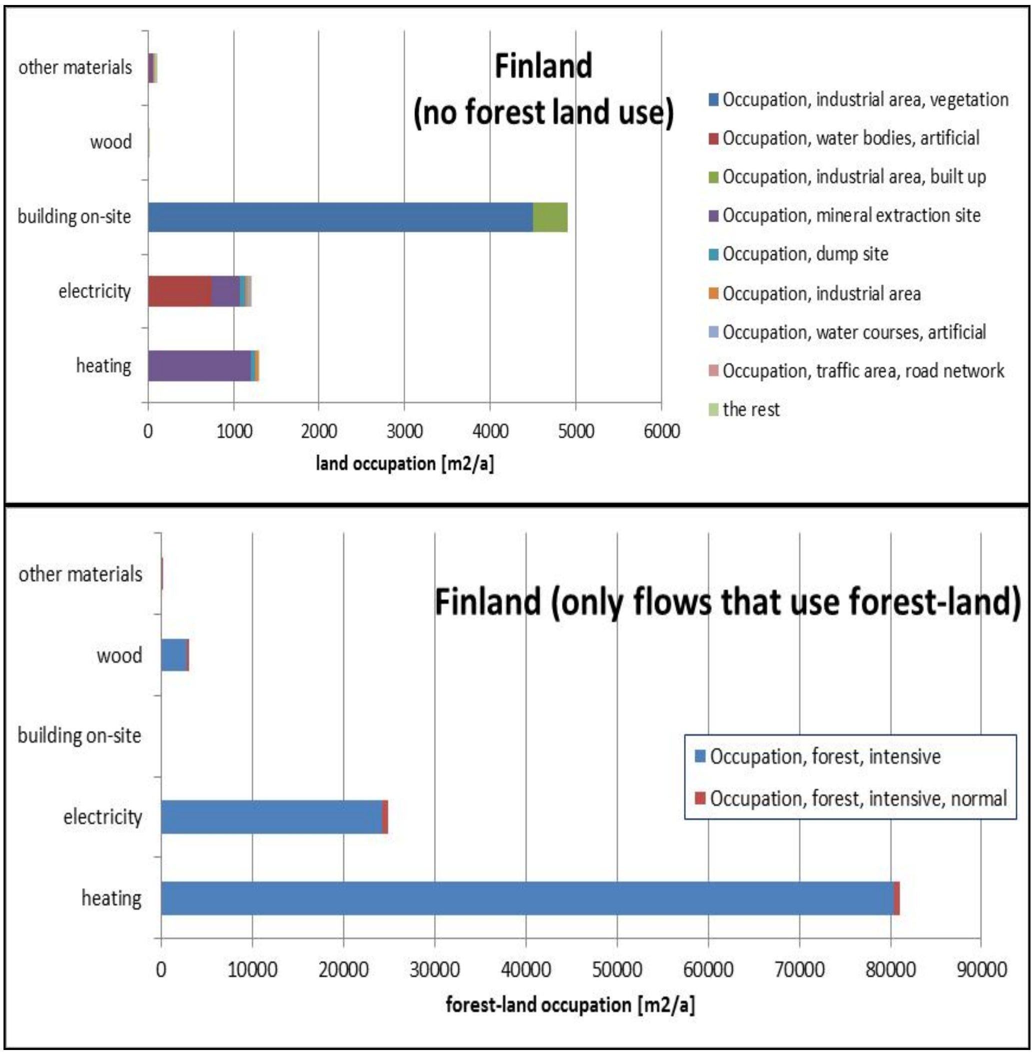

Figure 1: Life cycle inventory results (m2*a) divided into different life-cycle stages of building value chain. Finnish data for heat and power (a) land use flows that do not use forest land (b) land use of flows that use forest land. The land use of flows that use forest land is given in a separate picture because of the dominating role of it (note: the scale is 10 fold in the latter figure).

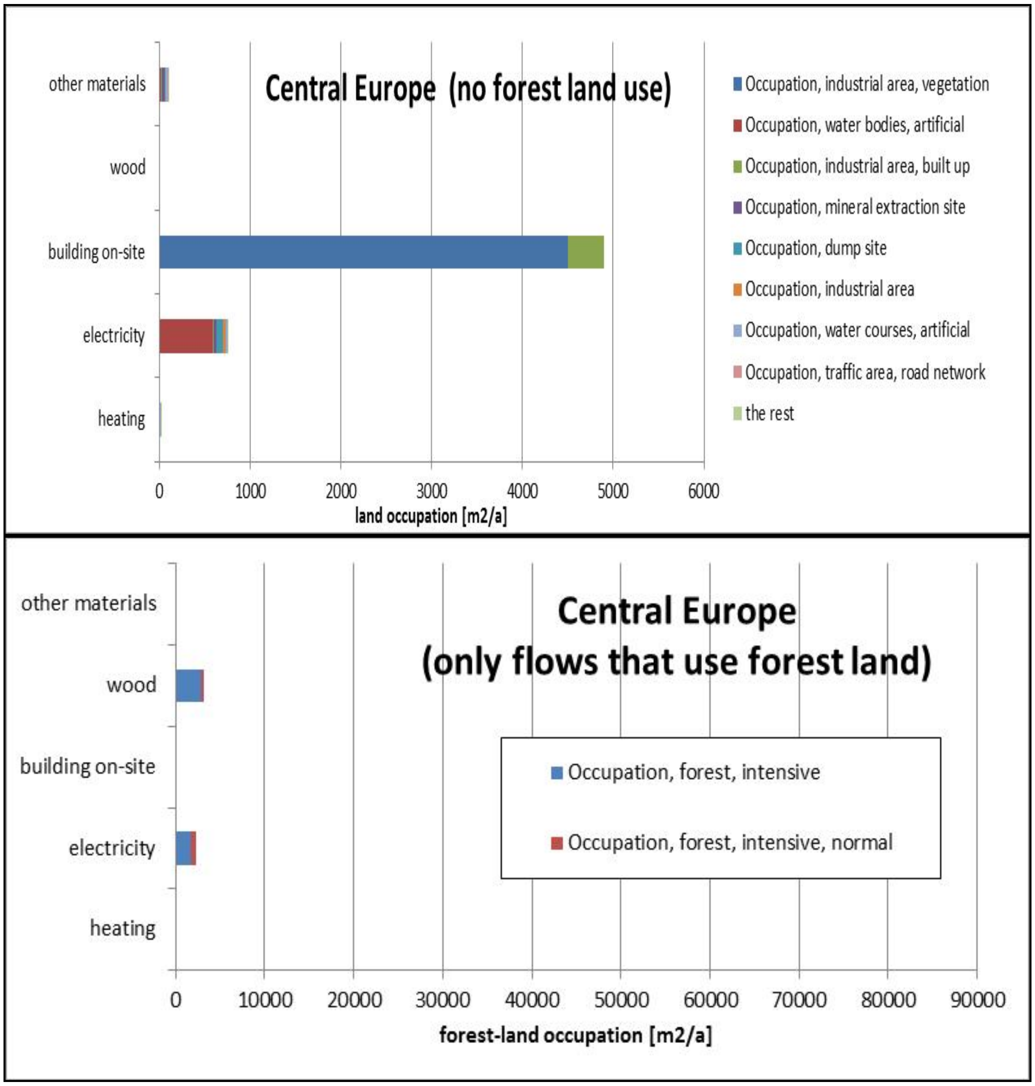

Figure 2: Life cycle inventory results (m2*a) divided into different life-cycle stages of building value chain. Central European data for heat and power (a) land use flows that do not use forest land (b) land use of flows that use forest land.

On the basis of the case study results, biomass used for the heat generation uses 80 000 m^2 land annually while the building correspondingly occupies roughly 5000 m^2 of land. The use of power and heat in the use phase of the building dominates the Finnish land occupation needs in the building value chain (Figure 1 and 2), especially through the occupation of large areas of managed (intensive) forest lands for forest bioenergy. This counter-intuitive result for energy supply stems from the large share of forest bio energy in the Finnish 2004-2008 average power and heat supply mixes, 11% and 28%, respectively (IEA 2010; ESM). On the basis of the results, land occupation and land transformation through the extraction of raw materials and manufacturing of construction products is insignificant compared to the building's use phase, with the only exception being wood construction materials.

It is important to note that Finland has exceptionally high shares of bio energy in its electric power and heat production mix in comparison to most other OECD countries (IEA 2010). Embodied land occupation need for heat and power would be only 0,0035 ha*a and 0,03 ha*a, respectively, if natural gas would be used for heating needs and average European electricity production mix for power needs (Ecoinvent 2010, IEA 2010, ESM). Thus on European level it can be anticipated that building on-site has the largest contribution to land occupation of building value chain, followed by wood-based construction materials and power needs. This is also shown in Figure 2.

The low level of embodied land occupation in mineral construction materials might seem surprising from the viewpoint that, according to Ruuska et al. (2013), embodied energy consumption in construction materials is of the same order of magnitude as the energy consumption for heating of spaces in the use phase of a building. The reasons for the large difference are twofold: First, the land use data on construction materials is sourced from Ecoinvent (2010) where European average data on energy is often applied. European average power grid mix includes only 1.5% forest bio energy, thus embodied forest land occupation is significantly lower in the European energy mix than in the Finnish energy mix. Secondly, embodied energy profiles and assumption on forest biomass yields in commercial databases are of limited transparency and might differ significantly from actual nation-specific data applied for the use phase of building in this study.

To be able to distinguish between environmental relevance of, for example, mineral excavation site, managed forest or urban building, further impact assessment is needed. Different characterisation factors have been developed for life cycle impact assessment (LCIA) for different land use classes and for different environmental mid- and endpoints, areas of protection. In this case biodiversity damage potential (DBP) indicator (de Baan *et al.* 2012) was applied for biodiversity, soil organic matter (SOM) and biotic production potential (BPP) indicators (Brandão *et al.* 2010, 2012) for soil quality and biotic production, and ecological footprint (EF) (Ewing et al. 2008) and human appropriation of net primary productivity (HANPP) (Haberl et al. 2007) indicators on competition over productive land and resource use.

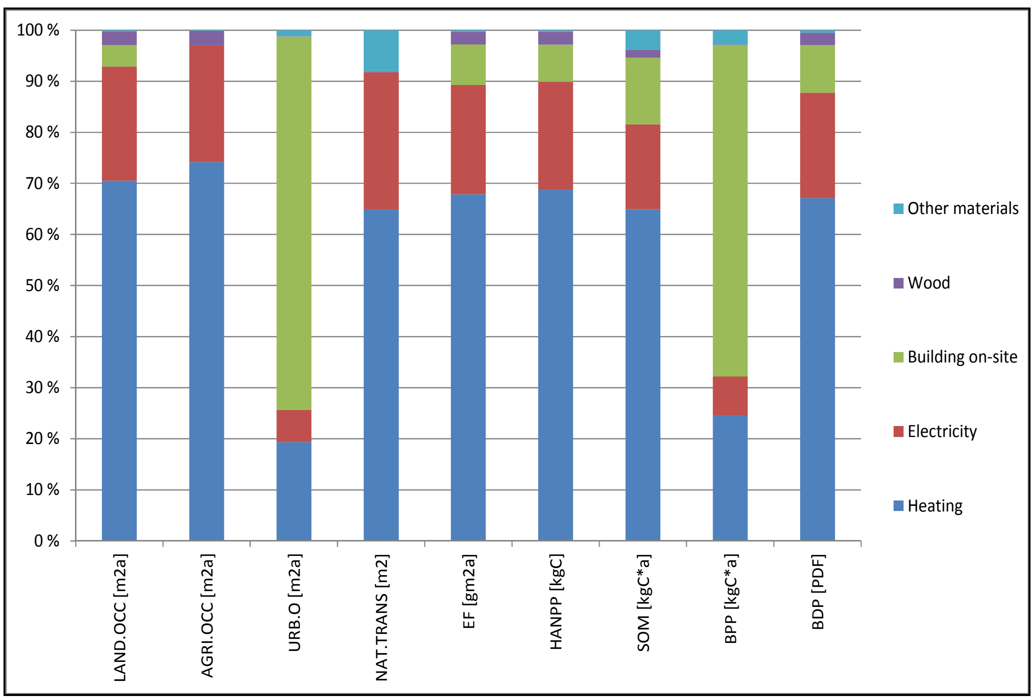

Figure 3: Life cycle inventory (4 columns in the left) and life cycle impact assessment results (5 columns in the right) for the studied building value chain for Finnish case presented by life cycle stages. Land occupation (LAND.OCC), agricultural & forest land occupation (AGRI.OCC), urban land occupation (URB.O) and natural land transformation (NAT.TRANS) describe inventory results with no impact characterisation. Ecological footprint (EF), human appropriation of net primary production (HANPP), soil organic matter (SOM), biotic production potential (BPP) and biodiversity damage potential (BDP) indicators include impact characterisation of different land use types. See ESM for detail.

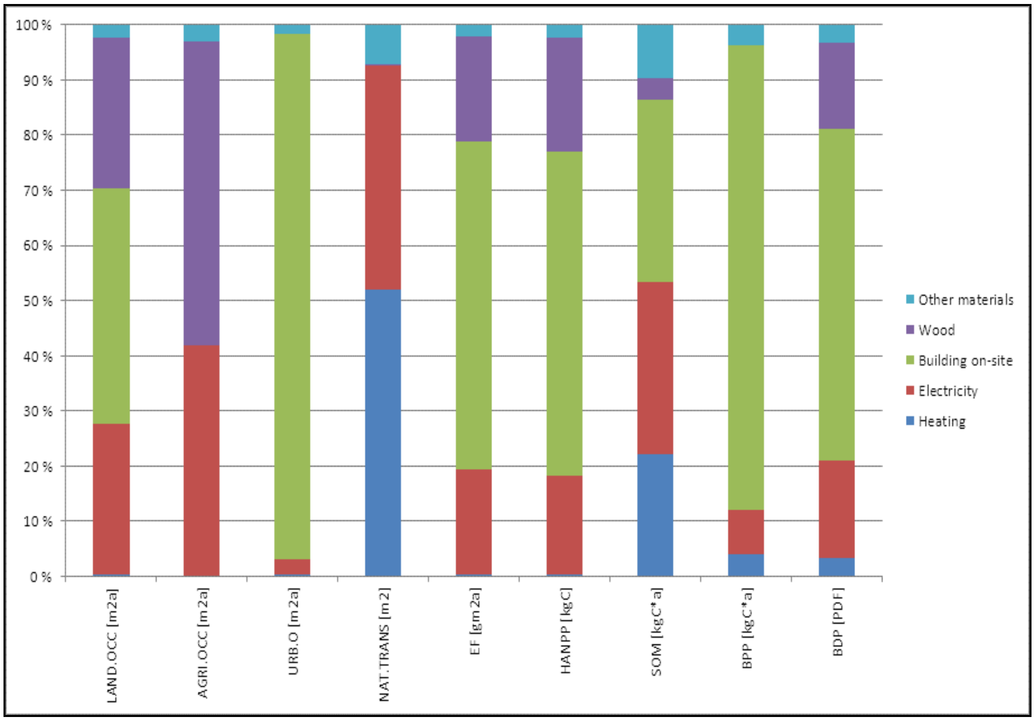

Figure 4: Life cycle inventory (4 columns in the left) and life cycle impact assessment results (5 columns in the right) for the studied building value chain for European case presented by life cycle stages. Land occupation (LAND.OCC), agricultural & forest land occupation (AGRI.OCC), urban land occupation (URB.O) and natural land transformation (NAT.TRANS) describe inventory results with no impact characterisation. Ecological footprint (EF), human appropriation of net primary production (HANPP), soil organic matter (SOM), biotic production potential (BPP) and biodiversity damage potential (BDP) indicators include impact characterisation of different land use types. See ESM X for detail.

All these indicators aim to describe environmental impacts of relevant safeguard subjects defined by Rio Earth Summit Declaration in 1992 on the so called midpoint level. Characterisation factors are presented in ESM. Additionally we present LCI results grouped into agricultural land occupation (AGRI.OCC), urban land occupation (URB.O) and natural land transformation (NAT.TRANS) according to ReCiPe 1.07 LCIA method (Goedkoop et al. 2012).

The LCIA results for two building value chains, average Finnish and average European, are presented in Figures 3 and 4 together with LCI results to ease their comparison. Although it is evident that all land use impact indicators give more weight on urban land use (artificial land cover) than for forest land use, still the largest share of potential environmental impacts through land use in Finnish building value chain seem to stem from forest biomass inputs for energy (Fig. 3). Building on-site dominates the potential environmental impacts if average European data is applied (Fig. 4). The results on potential environmental impacts do not differ significantly from LCI results but in one of the impact indicators. BPP indicator (Brandão *et al.* 2012) aims for describing potential impacts on biotic production in the near future, thus giving significantly higher weightage to artificial land use (URB.O in Fig 3). As expected, potential environmental impacts are mainly influenced by land occupation because the identified land transformation flows are insignificant in magnitude.

7. Building Level Land Use Indicators and Benchmarks

Land use indicators are included in many voluntary assessment systems of buildings (Delem et al. 2010). The used limit values give an indication of what is seen as typical levels or acceptable levels from the view point of sustainable buildings. Based on the information collected from Austria, Belgium, Czech Republic, France and Germany, the indicator soil sealing is typically included in the voluntary evaluation schemes (see also in Lebert et al. 2011). Tables 2 - 4 summarize European benchmarks for soil sealing, building density and land use change (). The soil sealing indicator expresses the share of sealed area compared to the area free of soil sealing on the plot.

Table 3 presents European benchmarks for the use of space (the area of the building in relation to the plot area)

Table 2

European benchmarks for soil sealing

Country	Assessment system	Indicator name	Formulation	Typical performance levels
Austria	TQB (Total Quality Building)	Area free of soil sealing	area free of soil sealing/ total area	Good level: >70% Mean levels: 30-70% Minimum levels: 10-30%
Germany	German government-led pilot scheme for assessing sustainability in housing	Level of soil sealing	area of soil sealing not dedicated to building/totaler area	Good level: Maximum of 10% of the area dedicated to the building
Belgium	Refentiekader Duurzame Woning and VALIDEO Referentieel Kantoorgebouwen	Biotope Area Factor	BAF = $A_{Ecologically\ useful}/(A_{total\ site}-A_{building})$	Good level: >0,7 Mean level: >0,6
France	HQE (High environmental Quality), Goal 1: Relation between the building and his immediate environment	Rate of vegetated area	% of plot area vegetated	Good level: 30% Mean level:20%
	HQE, Goal 5: Water management, 5.2:Management of rainwater	Soil sealing coefficient	Waterproofing of plot area (%)	Low urban site density: Good: <20% Mean:20% to 40% Low: 40% to 80% In High urban site density: (% of improvement of soil sealing) Good: >10% Mean: 2 to 10% Low: 0 to 2%
Czech Republic	SBToolCZ for residential buildings	Ratio of rainwater retained on site	% of rainwater retained, calculated taking into account permeability of surfaces, water storage tanks and other means	Good level : >90%

Type of land used or land use change refers to the former use of the site designed to build the building on. Many sustainability assessment systems consider this indicator (Delem et al. 2010). The main aim is to enhance the use of former built-up site or previous developed area to manage territory consumption. The land use change indicators measure the avoided consumption of green field land through the reuse of Brownfield and derelict areas, refurbishment, using infill sites and re-development of existing built environment. The type of land used is typically given as a qualitative description for example, use of an existing building, recycling of a previous building plot, development of new building areas etc. Examples, from best to worst case, are as follows: use of contaminated land, after decontamination, use of an existing building or recycling of a building plot / Brownfield site, building on already developed sites inside of an existing housing settlement, building on plots defined as building areas in addition to an existing housing settlement, development of new building areas (provision of services necessary), and building on re-designated, ecologically valuable areas. The lower the ecological value of a building plot, the better the assessment result is. Table 4 summarises the European benchmarks.

8. Buildings' Land Use and Urban Planning

Land use and land use change are important indicators within urban planning and have a considerable impact on urban sustainability. The Smart Communities Network (2012) stresses the importance of adequate land use practices to avoid the unsustainable urban sprawl that has characterized the growth of cities all around the US as well as in Europe in the past decades and that lies basically on:

- Mono-functional zoning that segregates different activities from each other for example, employment, shopping and services, housing.
- Low-density growth that highly increases land occupation and the use of private cars as main means of transportation.

Table 3

European benchmarks for building density

Country	Assessment system	Indicator name	Formulation	Detailed information about comparability	Typical performance levels
Austria	Zoning plan "Bebauungsplan"	Percentage of the plot that can be built-up	building footprint /plot area		35% to 70% (in some cases up to 100%)
		Floor space ratio	total gross floor area /plot area		
France	Local urban plan	COS	total Net floor area/plot area	total Net floor area="SHON" Depend on local context and urban plan	"COS" can be increased of 20% in case of low energy building (BBC level)
		CES	building footprint /plot area	Depend on local context and urban plan	

Table 4

European benchmarks for buildings and land use change.

	Good level of practice	Mean level of practice	Low level of practice
Austria-TQB system	Building refurbishment operation or recycling of building site plot and increase of the previous built-up area or densification of existing structures	Building on previously developed sites or inside of an existing housing settlement	Development of new building area or Building on re-designated, ecologically valuable areas
Germany- BNB system	Very contaminated brownfield sites OR somewhat contaminated land with additional compensatory measures.	Use of land recycling / brownfield sites- i.e. reuse of industrial or military sites with low contamination OR non-contaminated land with additional compensatory measures.	Non contaminated previously developed sites or in-fill sites that previously served other uses than for buildings or Greenfield site that had already been designated as construction sites
Czech Republic – SBToolCZ for residential buildings	Contaminated land after decontamination (10 points on 10)	Brownfield (8 points/10)	Site with mature growth up to 30 % (4 points/10) Site with mature growth of more than 30 % (2 points/10) Conservation area (0 points/10)
France – HQE (tertiary)	Practical dispositions are justified to “limit territory consumption and to optimize urban refurbishment”	Building project is coherent with the local policy about territory sustainable territory management.	- Other
Belgium- Valideo	Requirement means: – Use of land with low ecological value; – Use of formerly built-on area, evaluated based on former use of the site for industrial, commercial or residential buildings during the past 50 years; – Use of cleaned, formerly polluted area, evaluated based on soil examination (qualitative evaluation); – Protection and/or enhancement of the ecological value of the site, evaluated based on measures taken.		

The objectives of cities’ Agenda 21 Indicators can also be related to land use practices. Table 5 shows the land use related Agenda 21 indicators of the city of Barcelona (2003).

The potentialities of land use can only be achieved in association with other key indicators like density, complexity, green areas and accessibility to public services and public transport. As an example, following this rationale, the European project TISSUE (Häkkinen 2007) defined the following core indicators related to urban land use. The indicators are divided in two groups, Core 1 and Core 2, depending on the assessed feasibility in such a way that Core 2 includes indicators that are less feasible than Core 1 indicators:

- resident population density (Core 1), the total resident population divided by the urbanized area of the municipality

- Brownfields vs. Greenfield development (Core 1), the ratio of new developments on Brownfields to the new developments on Greenfields
- accessibility to open areas (Core 1), the share (%) of inhabitants living within 300m from open areas (> 5000 m^2) and the share (%) of inhabitants living within 300m from open areas of any size
- accessibility to public transport (Core 1), the share (%) of inhabitants living within 300m from public transport accesses
- consumption of land (Core 2), the ratio (%) of the surface of urbanized areas to the total municipal area
- accessibility to basic services (Core 2), the ratio (%) of inhabitants within 300m from basic services to all inhabitants
- population and jobs density (Core 2), inhabitants+jobs/surface of the urbanized area (present people/urbanized km^2)
- jobs/housing ratio (Core 2), the total number of workplaces divided by the total number of population living in houses within the boundary of the city/neighbourhood.

Table 5

Land use related indicators in Barcelona Agenda 21

Objectives	Indicators
Protection of green spaces and biodiversity and increasing urban green spaces	Green area per inhabitant Bird biodiversity
Defence of a compact and diverse city, with a quality public space	Availability of public spaces and basic services Index of urban renovation
To improve the mobility and to make pedestrian life a welcoming setting	Modes of transportation used by the population Proportion of roads with priority to pedestrians
To reduce the city's impact on the planet and promote international cooperation	Annual equivalent CO_2 emissions
Commitment to sustainability	Degree of citizen satisfaction

The following sections discuss land-use related issues in urban planning. At the same time the compatibility of urban and building level land-use indicators is discussed. The urban references used here, Vancouver, Barcelona, Bogotá, Curitiba, Finland, Melbourne, have been chosen because they represent globally acknowledged good practices in urban planning, quality of life, sustainable public transport, high quality public space, land management and/or participatory mechanisms, to name some of them. In addition, they are also representative of very different geographical, cultural, social and economic conditions.

Density

Density is a tool to create a more sustainable city while at the same time helping to preserve agricultural land and the open space beyond its borders. Furthermore, strategic densification offers positive benefits far beyond an individual metropolitan area; the densification of all urban settlements –when done properly- can play a critical role in sustainable communities (Toderian and Holland 2008).

As an example, the Eco Density initiative (Ecodensity 2008) launched by the City of Vancouver was a systematic strategy of densification and diversification of housing. However, density is a controversial issue on the one hand, there is the argument that very low density results in urban sprawl and fosters the use of private cars, therefore increasing the environmental impacts and contributing to climate change (Atlas 2007); on the other hand, there's the risk of compromising the citizens' quality of life and the character of the place if the densification process is not done properly.

The concept of urban density cannot be directly related to buildings but density can be dealt with on different levels. For example, in Finland the limit values between dense and not-dense building are considered as 0.2 – 0.3 on the level of neighbourhoods, 0.3 – 0.4 on the level of blocks of buildings and 0.4 – 0.5 on the level of lots, where building efficiency ratio is calculated based on the gross are of buildings. In principle we can continue on building level by trying to improve the space utilization of a building.

Land Use Change

Land use change can be made use of both on urban level as well as on building level.

TISSUE indicator Brownfield vs. Greenfield development considers the avoided consumption of green land thanks to the reuse of Brownfields for new urban development. The indicator is adopted as a building level indicator for example by ISO 21929-1.

Complexity / Mixed Use

Complexity relates to mixed-use and is determined by *"the greater diversity of different uses and activities, and at the same time the greatest number of absolute values, existing in a limited area, as opposed to the zoning's disperse city, the suitable context for an increase in exchange of information"* (Ecodensity 2008). The CAT-MED project (Marín Cots 2011) is built around the belief that the traditional Mediterranean city, compact and complex, is a more desirable model than the one resulting from mono-functional zoning. It takes up less space and allows a wide range of different activities which in turn fosters human relationships and transfer of knowledge and information. Complexity may be related also to the Jobs/Housing ratio and population and jobs density (TISSUE Core 2). Aspects of mixed use can also be considered on building level by measuring the access to relevant services.

Green Areas

The UN Indicators for Urban and Human Settlements includes the Green Space indicator within the Module Environmental Management/ Urban Enhancement, defined *as "percentage of green space in built up area"*. The Barcelona Agenda 21 Indicators from Table 5 include the indicator *"Green area per inhabitant"*. Green areas have a positive environmental impact, from the view point of GHG emissions and biodiversity, but the social impacts in terms of their contribution to citizens' quality of life is equally important. The quality of public spaces, of which green areas are a very important part, are fundamental to social integration and equality, *"for the poor, the only alternative to television for their leisure time is the public space. For this reason, high- quality public pedestrian space, and parks in particular, are evidence of a true democracy at work"* (PPS 2012).

That is why, in order to make sure that green areas can be easily reached and enjoyed by all citizens alike, the formula "Green area per inhabitant" should be completed with information related to walking distance and/or accessibility by means of public transport (TISSUE indicator Accessibility to open areas). However, the concept of open area is broader than green area and includes other type of spaces like free access open-air sport facilities, free access private areas, and so on.

Access to green areas as well as access to public services and public transportation can be and are dealt with on building level (Delem 2010). Corresponding indicators are also included in the list of core indicators defined by ISO 21929-1.

Accessibility to Public Services and Facilities, Accessibility to Public Transport

These are related to density and complexity and to *"Complete, Walkable Community"* (Holland 2012). Ideally, a sustainable city should have *"the majority of its services and activities within a pedestrian radius of 500 to 1.000 metres or 20 to 30 minutes walking, without having to use the motor vehicle"* as formulated by the above-mentioned CAT-MED project (Marín Cots 2011). This can result in a city less dispersed and segregated than the examples that spread out around the world during the 20th century and that are still very common, and in which urban sprawl and intensive use of private vehicles are dominating features. Proper integration of transport systems and land use planning is essential, as proved by Curitiba's RIT (Rede Integrada de Transporte), the public transport network. The adoption of the new bus system was supported by a new Master Plan that promoted the growth of the city along designated linear corridors through zoning and land use policies leading to high density industrial and residential development. Along the years, Curitiba's successful and affordable transport system has resulted in a clear reduction of automobile travel and fuel consumption and, as a consequence, in an improvement of the City's air pollution rate (Goodman et al. 2005).

TISSUE indicators Accessibility to public transport and basic services help discover how accessible services are to local people and whether their needs are likely to be met in the vicinity.

Land Use and Decision Making on Different Levels

Further consideration is needed to be able to consistently include land use, and other related sub-indicators, among core sustainability indicators for buildings. There is still a lack of understanding regarding the needs of and choices available for the main stakeholders involved, urban planners, developers, owners, users, contractors. These can be organized as follows:

- Public Administration or more specifically, municipal authorities in charge of urban planning including politicians and technical experts.
- Developers and constructors, owners and users.

A key factor that differentiates one group from the other is their position in relation to the regulatory framework. The first group sets the regulations under which the second group has to operate. Even accepting that this division is simplifying since nowadays regulatory processes increasingly include participatory mechanisms, it helps to clarify the margin of decision left for each of the stakeholders. The higher the level of detail and restriction of the regulatory framework in terms of urban planning and development set by the first group, the narrower the margin of decision available to the second group. As a consequence, when the margin of decision of the second group is considerably restricted, the effectiveness of land use and its associated indicators occurs rather at urban level, whereas when their margin of decision is wider the potentialities of land use at building level increase considerably.

Moreover, when developers and constructors are able to choose between developing and building on Greenfield or Brownfield lands as an example, then reliable information, tools and economic and social incentives to assist them in decision making become more important. In the same way, when owners and users, including both companies and individuals, are able to choose between different locations for their offices and/or homes, information and decision-enabling tools may support a shift in consumer preferences, therefore driving urban change. For example, the "Save: My Life" is a personal rating tool guiding consumer choices in relation to housing to provide *"relative measures of various criteria relating to financial, health and lifestyle considerations for any particular dwelling which is for sale or rental"*. Research underpinning this application indicates that *"a moderately more expensive dwelling purchase can potentially form a much less expensive and financially beneficial option, when considered over the extended period of living in the dwelling"* (McPherson and Haddow 2011).

9. Conclusions

Land use is related especially to the following issues of concern of sustainable development: The availability of natural resources, and the protection of ecosystems, biodiversity and climatic systems. Land use directly affects three areas of protection - natural environment, natural resources and man-made environment - and human health indirectly. Changes in land use potentially undermine the capacity of ecosystems to sustain food production, maintain freshwater and forest resources, regulate climate and air quality, and ameliorate infectious diseases. Buildings have a significant impact on the overall land use and land use change. In Europe, 4% of the total surface is covered by artificial areas. Artificial areas include built-up areas and un-built surfaced areas such as transport networks and associated areas. 80% of this is allotted to housing, services and recreation. These reasons support the consideration of land use as a sustainability indicator of buildings.

On the basis of the review of literature, the most important land use aspects of buildings are soil sealing, soil compaction, change of land use, fragmentation, and the extraction of natural raw materials, and the resulting loss of biodiversity because of these issues.

Buildings use land directly by occupying land under construction assets, but also through embodied land-use in non-renewable and renewable raw materials and energy over the building's value chain. First estimates made from life cycle perspective of a Finnish residential multi-storey building suggest that energy supply in the use phase of building dominates the environmental impacts through land occupation when biomass is considerably utilized for the generation of heat and electricity. On-site artificial land occupation is the second-most influential in terms of potential environmental impacts through land use. Although artificial, often sealed, land use has higher impacts than other land use types per occupied square-meter, this does not compete in significance with the larger needs of forest land occupation in energy supply for the modelled Finnish building value chain. Construction materials and fossil fuel inputs contribute with insignificant share to land-use impacts in the life-cycle of the Finnish building, as mineral and fossil raw materials and fuels have low embodied land-use needs. It needs to be noted, however, that this result is significantly influenced by the high share of bio energy in Finnish energy production, low annual increment in boreal forests, and low share of harvests compared to annual increment in Europe. When the same case is calculated with using the Central European energy supply mix data, building's land occupation dominates the result.

Caution should be applied in drawing far reaching conclusions based on current energy production mixes, as the energy production structure in Europe is expected to change considerably over life spans of buildings built today and the result proved to be very sensitive to the share of bio energy in the supply.

The study supports the use of such indicators that express the effects on sealing and land use change as land-use related indicators for buildings. Although a comprehensive LCA approach is recommended for the assessment of harmful emissions, its additional value is not equally high for land use related impacts because of the importance of building's land occupation in building's value chain. However, more attention should be paid to the need to consider the effect of energy supply on land use related impacts on LC basis.

Land use indicators are included in many voluntary assessment systems of buildings. Indicators used frequently are soil sealing and land use change. Soil sealing is typically measured on building level by calculating the share of the plot area free of soil sealing. The land use change indicators measure the avoided consumption of Greenfield land through the re use of Brownfield and derelict areas, refurbishment, using infill sites and re-development of existing built environment. The type of land used is typically given as a qualitative description.

The study also supports the consideration of land use aspects – not only on urban level – but also on building level decision making to support sustainable building and sustainable development. Although central decisions about urban land use developments are done on urban level, building owners also have much freedom to decide about the location of buildings. Thus good tools and indicators that show the land use impacts of building alternatives are needed. It is also important that the indicators are compatible from urban level to building level. Such building level indicators as soil sealing, land use change and access to public services well fit together with the typical urban level sustainability indicators, density, mixed use, green areas, and accessibility of public services. Density can be dealt with on different levels with having appropriate target values for neighbourhoods, blocks and lots, even for buildings as space efficiency is one of the important issues with the help of which building's energy use and GHGs can be managed.

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