Project ICT 287534
Start: 2011-08-01
Duration: 36 months
Co-funded by the European Commission within the 7th Framework Programme

**SEMANCO Semantic Tools for Carbon Reduction in Urban Planning**

# Deliverable 2.3
# Impact Verification

**Revision:** 9
**Due date:** 2012-08-31 (m12)
**Submission date:** 2012-09-21
**Lead contractor:** CIMNE

| Dissemination level | | |
|---|---|---|
| PU | Public | X |
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| Deliverable Administration & Summary | | | | | |
|---|---|---|---|---|---|
| **No & name** | **D2.3 Impact verification** | | | | |
| **Status** | Final | **Due** | M12 | **Date** | 2012-09-15 |
| **Author(s)** | Gonzalo Gamboa, CIMNE | | | | |
| **Editor** | Gonzalo Gamboa, CIMNE | | | | |
| **DoW** | Task 2.3 *Impact evaluation*. This task is in charge of providing strategies which will enable to verify the impact of the integrated tools and associated methodologies, which will be then applied in WP 8 in three yearly cycles.<br>This report, specifically, deals with impact verification issues: strategies, results, impact and recommendations | | | | |
| **Comments** | During GM3 it was decided to re-read and re-focus T2.3 on a more useful aspect of the project which is the multi-scale integration, and particularly on helping to reduce CO2 emissions in the urban planning domain. As well, T2.3 would highlight the strategy for verifying the methodologies described in the indicators.<br>In effect, D2.3 will be monitoring D2.2, since D2.3 defines the theoretical basis to be considered in the development of the performance indicators in D2.2. D8.1 will then focus on how use-cases become demonstration scenarios: that is, it defines the implementation process in which the impact of the integrated tools will be demonstrated.<br>D2.3 identifies some challenges of energy efficient urban planning from a multi-scale perspective. Then, it proposes an accounting framework for the integrated tools and associated methodologies to be coherent across scales. In this way, we identify the methodological requirements necessary to both fulfil the expected functionalities of the integrated tools and produce reliable information.<br>Then, the document defines the strategies used to verify the impact of the integrated tools, which is based on the demonstration objectives expressed in D8.1 and the information presented here. | | | | |

**Document history**

| V | Date | Author | Description |
|---|---|---|---|
| 1 | 2012-07-06 | CIMNE | Preliminary proposal |
| 2 | 2012-08-13 | CIMNE | First version of the document. |
| 3 | 2012-09-12 | CIMNE | Second version. It deals with issues raised by Leandro Madrazo’s comments and completing the section about impact verification strategy. |
| 4 | 2012-09-15 | CIMNE | Version submitted to the coordination. In this version we address the link between tasks and deliverables. |
| 5 | 2012-09-18 | CIMNE | Version to be submitted to internal review. |
| 6 | 2012-09-19 | Ramboll | Internal review by Thomas Rønn. Minor corrections (with track changes) and comments. |
| 7 | 2012-09-20 | POLITO | Version with comments from internal reviewer (Ilaria Ballarini, POLITO) |
| 8 | 2012-09-21 | CIMNE | Final version addressing the comments of internal reviewers. |
| 9 | 2012-09-21 | UoT | Final proof-reading by Agnieszka Knera (UoT) |

## Disclaimer

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# EXECUTIVE SUMMARY

## Introduction

### Purpose and target group

When dealing with energy efficient urban planning we should be aware of the existence of urban elements operating simultaneously at different levels and dimensions. This fact entails several challenges that should be addressed in order to provide a reliable set of integrated tools. The present document identifies some of those challenges and provides the basis on which the integrated tools and associated methodologies should rely upon. That is, it presents the theoretical foundations guiding the definition of the accounting framework and of the calculation methodologies used to produce (energy related) performance indicators.

This document summarizes the strategies used to verify the impact of the integrated tools and associated methodologies which will be applied in three yearly demonstration cycles of SEMANCO's tools and methods. Those strategies include a development of a set of questions used in the preparation of intermediate report templates, which will be applied during the implementation process. These questions are aimed to assess the fulfilment of requirements. The questionnaires will be addressed to users, during the implementation, and to the expert domain responsible of each demonstration scenario.

### Relations to other activities in the project

Based on the identified challenges for energy efficient urban planning, this document provides the basis on which the integrated tools and associated methodologies rely upon. In this sense, Task 2.3 *Impact evaluation* monitors Task 2.2 *Strategies and indicators for data modelling and data analysis* since the set of indicators presented in D2.2 *Strategies and indicators for monitoring $CO_2$ emissions* should fulfil the guidelines developed here.

Also, the present deliverable is much related with Task 8.*1 Implementation plan development*. On the one side, D2.3 set the basis for the definition of a set of report templates aimed at assessing, from the user viewpoint, the degree of fulfilment of those expectations. On the other side, the report templates provided by D8.1 should consider the evaluation of the expected impact of the integrated tools and related methodologies, that is, to support the reduction of energy consumption and $CO_2$ emissions in the urban planning domain.

Also, this report initiates the exploration of land and time use classifications, which should be considered in the development of the tools and methods (WP5) and their integration through SEIF (WP3 and WP4).

## Challenges of energy efficient urban planning

The problem of $CO_2$ emissions reduction is difficult to delimit to a particular geographical area. It is a systemic problem in which multiple dimensions and geographical scales need to be integrated. The existence of multiple scales entails several challenges in the urban planning domain. The work carried out in Task 2.3 is intended to unravel those challenges and propose strategies to deal with them. That is, strategies needed to develop a set of integrated tools and associated methodologies aimed at perceiving and representing the energy performance and $CO_2$ emissions of urban areas.

The identified challenges can be summarized as follows:

- We can consider the energy system as a complex hierarchical system, in which we can find a complex network of relations between elements operating simultaneously at different levels. Those elements are very interrelated and they have high degrees of interdependence (i.e. vertical and horizontal coupling between the elements of the hierarchy). Each element of the hierarchy has to maintain coordinated operation with the elements of the same level of the hierarchy, and at the same time, it has to perform certain functions required by higher level elements of system to which it belongs to. In practical terms, it may happen that an energy efficient urban plan has good effects at one level but it may not be adequate at other levels. It may also happen that the urban plan is neither feasible nor viable because it breaks the balance between elements of the hierarchy. These complex relations between elements of the hierarchy entails the fact that we cannot study and analyse the behaviour of an urban element in isolated from isolation from its context. , and that we have to perform simultaneous assessments at different scales in order to both make decisions.

- We can consider an urban system as a complex one, a socio-economic and biophysical system whose relevant aspects cannot be captured using a single perspective (Funtowicz, Martinez-Alier, Munda & Ravetz, 1999; O'Connor, Faucheux, Froger, Funtowicz & Munda, 1996). Complex systems are those characterized by presenting multiple identities at multiple scales, which are subject to non-equivalent descriptions. For instance, different persons of diverse backgrounds would focus on different aspects of an urban area, according to what they consider relevant for the analysis. An architect would describe it in terms of volumes, shapes, materials and orientation, whilst a sociologist would consider demographic characteristics of the population living in the urban area, as well as its cultural and socio-economic background. The existence of multiple scales entails the need to use non-equivalent descriptive domains when describing and representing the system. Moreover, those perspectives are incommensurable due to "the absence of a common unit of measurement across plural values" (Martinez-Alier, Munda & O'Neill, 1998, p. 280).
- Complex systems present emergent properties across scales. There are some attributes possessed by the elements of the system but not by the system as a whole, and vice versa. For instance, an architect planning an urban environment sees the buildings as simple boxes, which create different public spaces depending on their layout. S/he models the height and depth of the building in order to obtain proportionate streets and squares. On the other hand, at the building level, an architect designs the building in detail (façade, windows, materials, systems, colours) according to the restrictions defined in the urban plan and building regulations. There are also emergent properties when we up-scale the perception and representation of the system. For instance, to analyse the distribution of income across households may have no sense at the building level. However, at the neighbourhood level, this sort of analysis may shed light on the effect of gentrification processes, which can be very important to prevent potential social conflicts within the neighbourhood. This issue highlights the fact that some performance indicators would be relevant at one scale, but not at another.
- Energy is a semantically open concept that needs an accounting framework formulating and providing coherent information across scales. The relationship between the energy sector and the rest of the society is very complex, where the demand for, and supply of, energy are two interdependent processes. The energy sector has to deliver a mix of energy carriers, whose amount and share is determined by the requirements of the rest of the society, in order to perform a set of final energy uses. Moreover, the profile of final energy uses depends on the ability of the energy sector to deliver the required energy carriers produced from the available mix of primary energy sources. The issue is that some primary energy sources are able to produce a limited set of energy carriers, and that we can expect a limited capability to substitute one primary energy source by a different one. The same happens with the transformation from energy carriers to final energy uses. We can expect a limited exchangeability between energy carriers in order to fulfil the expected final energy

uses. These two transformation steps from primary energy sources to final energy uses give us information on the internal and external constrains faced when dealing with energy issues. On the supply side, we can check the feasibility of the energy sector to deliver the quantity and mix of energy carriers required by the society from the mix of primary energy sources. On the demand side, we can check the viability of the consumption side to perform a set of final energy uses from the mix of energy carriers delivered from the energy sector. Therefore, we should keep the distinction between different energy related semantic categories (i.e. primary energy sources, energy carriers and final energy uses) in order to match the supply and demand (of energy carriers) in the energy system. In our case, this matching exercise takes place within an energy efficient urban planning framework and allows us to perform a useful energy analysis.

- The expected features of SEIF should meet a balance between providing detailed and relevant information, according to the objectives of relevant stakeholders. As stated in the Zadeh's Incompatibility Principle (Zadeh, 1973), our ability to make precise and yet relevant statements about the system diminishes as the complexity of the system increases. This applies when different energy modelling methods, at different scales, are used. Generally speaking, we can classify energy models as simplified or detailed methods. They require different levels of details as input data also providing diverse outcomes. As a general guideline, we would say that a simplified model would be more suitable to optimize energy demand of a group of buildings (i.e. to find the configuration of the urban area presenting lower energy consumption when compared with other evaluated alternatives) and that the use of a detailed model is closer to the definition of a building project, which would be subject of some energy efficiency requirements according to the law (i.e. technical code, building regulations).

## Strategies for energy efficient urban planning

The existence of urban elements operating simultaneously at multiple scales entails several challenges which need to be addressed in the energy efficient urban planning domain. The following table synthesizes the challenges identified in the previous section and matches them against guidelines and strategies to face those challenges.

*Table 1. The existence of multiple scales in the urban planning domain: challenges and strategies*

| ***Challenges*** | ***Strategies*** |
|---|---|
| In complex hierarchical system there is a complex network of relation between the elements operating simultaneously at different levels. Those elements are very interrelated and there are high degrees of interdependence (i.e. vertical and horizontal coupling between the elements of the hierarchy) | ▪ Evaluation of the performance of the urban area at different scales; e.g. micro, meso and macro.<br>▪ To assess the feasibility of the evaluated alternatives. In other words, we need to assess the requirements of other sectors in order to face the consequences of the analysed urban plan. |
| The existence of multiple scales entails the need to use non-equivalent descriptive domains when describing and representing the system | ▪ To use a multi-dimensional set of performance indicators |
| Complex systems present emergent properties across scales. There are some attributes possessed by the elements of the system but not by the system as a whole, and vice versa. In other words, some performance indicators would be relevant at one scale, but not at other levels. | ▪ To use an adequate accounting framework allowing us to up- and down-scale indicators across hierarchical levels |
| Energy is a semantically open concept that needs an accounting framework formulating and providing coherent information across scales. | ▪ To keep track of energy transformations series across scales. That is, to clearly differentiate energy carriers and primary energy sources across scales. |

| ***Challenges*** | ***Strategies*** |
|---|---|
| The expected features of SEIF should meet a balance between providing detailed and relevant information according to the objectives of relevant stakeholders | ▪ To use different methods with different degree of accuracy in their calculations depending on the scale of the analysis. Simplified methods are to be applied at urban level in order to optimise the energy performance of an urban area, to observe trends of energy consumption or to identify 'hot spots'. More detailed calculations would be implemented at a building level in order to know the energy performance of the building for the purpose of achieving a certification or improvement. |

In order to meet those requirements, we propose to use an accounting framework able to deal with a set of performance indicators across levels in a coherent way: the Multi-Scale Integrated Assessment of Societal Metabolism (Giampietro, 2004; Giampietro, Mayumi & Ramos-Martin, 2009). The same analytical framework provides the tools used in order to assess the viability and feasibility of alternative future scenarios of an urban plan. It would also allow us to keep track of the energy flows across scales differentiating between energy carriers and primary energy sources.

### Multi-scale integrated analysis: the proposed accounting framework

A metabolic system can be defined as a system able to stabilize a coordinated inflow of matter and energy resources, producing an output flow of products and waste (degraded matter and energy). This transformation process is driven by the production-consumption processes required for the reproduction of the system itself. In order to analyse the metabolic pattern of an urban area it is of fundamental importance to state the explicit distinction between those categories which must be: reproduced, which pass through the system, and those which change its identity during the time space of the representation.

The MuSIASEM approach is the operationalisation of the *fund-flow* model (Georgescu-Roegen, 1971), which emphasises that what we call production is in reality a transformation process of resources into useful products and waste products: a transformation of some materials into others (the flow elements) by some agents (the fund elements). On the time scale of the representation, *fund* categories (e.g. capital, people, Ricardian land) transform input flows into output flows, and flows (e.g. added value, water, energy, matter) are either consumed or generated in order to reproduce the funds categories.

### Using land uses as fund category

As mentioned in the previous section, we need to capture the complex interactions between the elements of the hierarchical urban system. This means we have to keep track of the flows of matter and energy across the elements of the hierarchy. In order to do so, the proposed approach defines a set of nested categories of the fund elements across scales.

In this case, the first step is to define an adequate classification of land uses. Then, we map the flows of energy carriers across the defined land use categories. From here, we can calculate the extensive variables[1] of land use (in $m^2$) and electricity consumption (in kWh) by means of aggregating and disaggregating the figures across levels. For instance, the land use of the household sector ($LU_{HH}$) is equal to the aggregation of the land use of different household typologies ($LU_{HH1}$, $LU_{HH2}$ and $LU_{HH3}$). The same applies to the electricity consumption or any other flow of energy carriers such as natural gas, liquid fuels and so on.

[1] Extensive indicators give an indication of the size of the different compartments of the urban system, either in terms of the fund or flow categories.

Additionally, we can assess the metabolic rate of the different compartments of the system in terms of flow/fund ratios (i.e. intensive indicators). In order to do so, we would calculate the intensive indicator Exosomatic Metabolic Rate –EMR–, in this case, by dividing the flow of kWh of electricity by the corresponding land use category (measured in $kWh/m^2$).

It is worth keeping in mind that the approach is extremely flexible and enables us to define the relevant land use categories according to the objectives of the analysis. For instance, we might be interested in analysing the energy performance of the household sector in relation to the whole urban area. In that case, we could define the land use categories within the household sector only, and define the rest of land uses as "other".

An overview suggest that there are major differences with conventional energy performance indicators used in the urban planning domain. The advantages of this method are related to the use of the accounting framework based on a specific land use categories. In this way, the accounting framework enables the analyst to up- and down-scale the information by means of aggregating or disaggregating extensive variables across scales, and then calculating intensive indicators of performance for the different urban levels (See Figure 1).

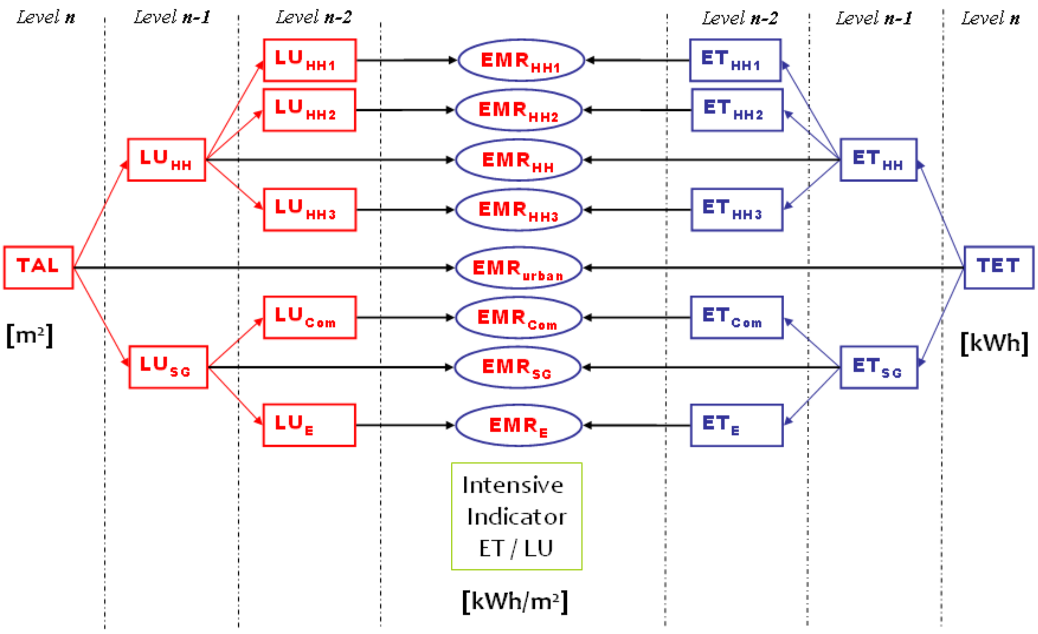


*Figure 1. Matching land use categories and flows of energy carriers, and calculation of intensive indicator Exosomatic Metabolic Rate (EMR). Acronyms: TAL: Total Human Activity, LU: Land use, TET: Total Energy Throughput ET: Energy Throughput, EMR: Exosomatic Metabolic Rate, HH: Household sector, SG: Service and Government sector, $HH_n$: Household typology n, Com: Commercial sector, E: Education sector*

We can use the same classification of land uses in order to analyse different type of flow categories (e.g. added value, matter and energy), which is also necessary in order to embrace the multiple dimensions involved in our analysis. Moreover, we can differentiate between energy carriers; a required feature in order to keep track of the energy transformations across scales.

The accounting framework also facilitates the assessment of the feasibility of the alternatives. Changes in the urban environment, from changes in the building structures to socio-economic and demographic changes, would produce changes in the metabolic pattern of the different compartments of the urban hierarchy. This, in turn, would imply different requirements from the household sector in comparison with the educational, health and/or commercial sectors. It should be checked whether the modified household sector fits within the urban area; whether the rest of the compartments (i.e. sectors) of the society are able to provide the functions and services required from the household sector.

The proposed accounting framework presents additional advantages which are worth mentioning. Firstly, by using similar land use categories, it is possible to perform coherent comparison between urban areas, cities, countries or regions. It enables us to open the black box and understand differences of performance between elements at the same level, but in different hierarchies. For instance, if we compare the energy performance of two cities we may find big differences, but cannot immediately say that one of them is performing better than the other. By using the MuSIASEM approach we can open the black box and analyse, on one side, the internal structure of the city, while on the other the performance of those lower level compartments.

Secondly, we can characterise the metabolic pattern of different socio-economic sectors and subsectors by means of using the intensive variables. In this way we can define some external referents or expected values of the energy consumption per square meter of sectors and subsectors, which would become the base for their (energy) performance evaluation.

Thirdly, and due to the fact that the elements of the hierarchy are all linked one with each other, we can guess or obtain missing values, like of energy performance of some compartments of the hierarchy, if we know the energy performance of higher and lower elements.

**Using time use as fund category**

As mentioned before, the use of intensive indicators of energy performance per square meter of land use present no major differences with conventional energy performance indicators used in the urban planning domain. However, the differences clearly appear when we use different fund categories such as human activity. We very often make use of *per capita* indicators in order to compare the performance of different socio-economic systems (e.g. GDP per capita of two different cities). However, this practice misleads the analysis at multiple-scales due to the fact that figures *per capita* do not clearly reflect the flows of energy, added value or matter during the duration of the corresponding activity.

In the case of the land uses, we link certain flow of energy carrier with the activity performed in a certain area (e.g. electricity consumption in a building, in offices or in an industry). In the case of *time uses*, we can track the activities of people by considering the amount of time (measured in hours or any other units of time) spent by them in each compartment of the hierarchy. In this way, we can compare the energy consumption per hour of human activity within different compartments, identify activities of high energy consumption rates and define actions for improvement. For instance, if we compare the energy performance of schools; per hour of human activity performed there; we avoid the influence of different timetables across educational centres in the evaluation of indicators.

One of the main advantages of using this accounting framework is the fact that we can track human activities across the levels of the hierarchy. We can aggregate and disaggregate hours across scales, which is not possible when accounting people in *per capita* terms. However, we are aware of the fact that this sort of information is hardly available in much detail. But, we are also certain that it is not possible to link indicators across scales using per capita values, if so, it would produce misleading figures.

How to proceed then? The main source of information regarding *time uses* within the paid work sector are the Labour Force Surveys, which give information about the working time by economic activity. On the other hand, there are the national time use surveys, which generate information on time uses in a set of predefined activities. Those data sources would be complementary in order to develop a *time use* database encompassing activities developed within the paid work sector and activities developed within the unpaid sector (which includes the household sector).

### Defining cross-cutting categories of land and time uses

As already mentioned, the comparability across countries when using intensive indicators depends on the categories of fund variables (i.e. land and time uses), which determines the categories of flows of energy, matter and added value. Therefore, it becomes of fundamental importance to find common categories of land and time uses. In this sense, the American Planning Association[2] proposes the Land Based Classification Standards which classifies land uses across five different dimensions, one of them is the *activity*: the actual use of land based on what actually takes place in physical terms.

Within the SEMANCO project, we will evaluate the compatibility of the time and land use categories mentioned.

### Implementing the fund-flow model to define indicators of energy efficient urban planning

This section provides some guidelines for the identification of the relevant fund and flow categories needed to describe and represent the urban area under analysis. Also, it provides guidelines to calculate extensive and intensive indicators across scales.

In order to do so, we propose the following procedure:

1. to categorise the urban area according to relevant fund categories
2. to identify input and output flows which are relevant for the reproduction and maintenance of the system
3. to determine input and output flows which go through the different fund categories across levels.
4. to calculate extensive indicators across categories and scales
5. to calculate intensive indicators by means of dividing flow variables by their corresponding categories of fund variables.

This process aims at overcoming the identified drawbacks of other frameworks for indicators definition, in the sense that it defines general categories without determining the issue at stake. In this way, the framework leaves the definition of relevant categories open to be tailored to any urban context.

### Specific requirements for the SEIF

As it can be derived from the previous sections, the discussion developed in this document would entail a series of requirements for the tools and methods to be developed with SEMANCO and to be integrated in the SEIF.

**Regarding the use of land use categories**, it would be necessary to address the following issues:

- Perform a preliminary classification of land uses in the urban area under analysis; for instance, by referring to the land-base classification standard developed by the American Planning Association
- Allow the user to (partially) tailor the land use classification according to the relevant categories in his/her context.
- Aggregate and disaggregate the calculated extensive variables across scales and according

[2] See http://www.planning.org/lbcs/index.htm

to the land use categories defined in the previous steps.

- Calculate intensive indicators (per unit of square meters – $m^2$) across scales and according to the land use categories defined in the previous steps

**Regarding the viability and feasibility of future scenarios** of urban planning, there is still work to be done in order to define the tools that will enable the users to perform such quality checks. As a preliminary step, we will explore the possibilities of developing a tool to perform a "Sudoku effect" analysis (Giampietro et al., 2009) between consumption and production of energy supply.

In order to do so, it is of fundamental importance that the tools developed within the SEMANCO platform are able to keep track of the energy flows across scales differentiating between energy carries and primary energy sources, and avoid the storage of composite indicators but rather the variables used for their calculation.

## Strategies for impact evaluation

This section defines the procedure which we will adopt to verify the impact of the integrated tools and associated methodologies. In previous section we:

- Identify the challenges for an energy efficient urban planning when we deal with urban elements operating at multiple scales.
- Define the methodological strategies necessary to deal with those identified challenges. In other words, we have framed the integrated tools and associated methodologies according to what is expected from the epistemological and methodological point of view.

However, the evaluation of the impact of the implementation process also depends on what is expected from the users and expert domains. The impact of the implementation process depends on whether the SEMANCO tools fulfil the users' expected functionalities and whether the issues to be demonstrated (defined in D8.1) are addressed.

Therefore, this section is intended to match the expected features defined from the epistemological and methodological point of view with those features envisaged by the users and expert domains in order to define the strategies for impact verification (See Figure 2).

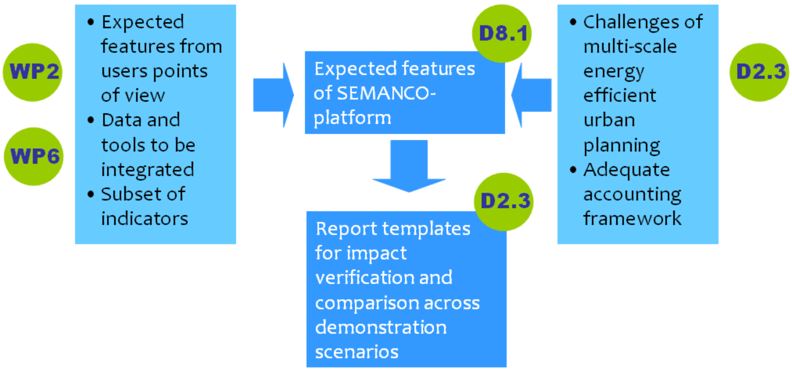


*Figure 2. integration of expected features of the SEMANCO platform from the methodological perspective and from the point of view of the users and experts domain*

Here, we define a set of questions, which set the base for developing intermediate report templates. Those questions are based on the methodological requirements identified in the previous sections and on the expected features of SEIF from the users point of view.

# Conclusions

### Contribution to overall picture

The main objective of Task 2.3 has been to provide strategies which will enable verifying the impact of the integrated tools and associated methodologies, which will be then applied in WP 8, in three yearly cycles. As such, it sets the basis for the constant evaluation and future technological development of the project.

In order to do so, it has been necessary to re-read and re-focus Task 2.3 on a more useful aspect of the project. In this sense, we think that it is necessary to identify some of the consequences and challenges of the existence of multiple scales in the energy efficient urban planning domain. Then, the document defines the strategies to deal with those challenges. In this way, we've been able to identify the requirements of the tools from the epistemological and methodological perspectives.

This information has been complemented with that coming from D8.1, which defines the issues to be demonstrated from the point of view of the potential users and expert domains.

Once we indentify the methodological requirements and the expected features of SEMANCO's integrated tools and associated methodologies, we develop a set of questions to verify the impact of the tools in the first implementation round.

### Impact on other WPs and Tasks

Overall, Task 2.3 provides valuable information needed in order to continue with the planned activities in the other WPs. It sets a basis for the development of the set of performance indicators (T2.2) and it defines the methods required as means to evaluate the impact of the integrated tools during the implementation process (T8.1).

D2.3 defines a set of preliminary requirements for the SEIF, which entails several issues to be addresses in the technological development of the project (WP4 and WP5). Regarding the use of *land use* categories, SEIF should be able, for instance, to perform a preliminary classification of land uses in the urban area under analysis and allow the user to (partially) tailor the land use classification according to the relevant categories in his/her context.

Regarding the development of indicators at different scales, the SEMANCO platform should provide the possibility of defining indicators *à la carte*, enabling the users and experts domain to redefine indicators according to the context. Also, it should provide indicators describing the relationships between lower level elements when aggregating data to obtain the performance of higher level elements

Regarding the viability and feasibility of future scenarios in urban planning, the document states that it is necessary to explore the possibilities of developing a tool to perform a "Sudoku effect" analysis (Giampietro et al., 2009) between consumption and production of energy supply

# 1 INTRODUCTION

## 1.1 Purpose and target group

In Task 2.1 *Case study design*, we have analysed and defined the problem domain in the three selected case study areas in order to provide an evidence-based understanding of the strategies required to reduce $CO_2$ emissions. That task has provided general information on the case studies and on the international, national and local policy frameworks and planning measures (among other information). The work contained in Deliverable 2.1 *Report of the case studies and analysis* sets the context for SEMANCO to develop a set of integrated tools and associated methodologies aimed at supporting $CO_2$ emission reduction in the urban planning realm.

To proceed with the development of the tools and methods, we have deployed a methodology based on use cases which puts together components from different work packages: stakeholders, data and tools (see Deliverable 1.8 *Project methodology*). The implementation of those use cases is done through the demonstration scenarios, which are the place in which the impact of the integrated tools are to be demonstrated and validated.

Along this process, we have identified some key aspects to be considered when dealing with the issue of energy consumption and $CO_2$ emissions in the urban planning domain, which should be incorporated to the SEMANCO integrated tools. On one hand, we observe the existence of (urban) elements operating simultaneously at different levels, which calls for the use of methodologies able to deal with multiple scales at the same time. On the other hand, urban planning practices are multidimensional in nature; as they encompass social, political, economic, technical and environmental aspects.

The present document identifies the challenges faced when dealing with complex systems operating at multiple levels; in this case, when dealing with energy efficient urban planning processes. Then, it provides the basis on which the integrated tools and associated methodologies rely upon. That is, it presents the theoretical foundations guiding the definition of the accounting framework and of the calculation methodologies used to produce energy related performance indicators (see Deliverable 2.2 *Strategies and indicators for monitoring $CO_2$ emissions*).

In parallel, Deliverable 8.1 *Implementation plan* defines the demonstration scenarios and the implementation process. That document also identifies the issues to be demonstrated: the expected features of the integrated tools and associated methodologies. Based on the objectives expressed in D8.1 and on the information produced in this document, the present document defines the strategies to verify the impact of the integrated tools and associated methodologies which will be applied in three yearly cycles.

Those strategies include: the development of a set of questions in order to design intermediate report templates to be applied during the implementation process. Report templates would contain a brief questionnaire to assess the fulfilment of requirements (those identified here and those presented in D8.1). This document provides a set of questions which will be the basis to develop the questionnaires, which will be addressed to users during the implementation and to the expert domain responsible of each demonstration scenario.

## 1.2 Contribution of partners

This report has been written by CIMNE as leader of Task 2.3 *Impact evaluation*.

The editing of the document has been performed by CIMNE in collaboration with FUNITEC.

Detailed reviews of the deliverable were conducted by Ramboll and POLITO; final proof-reading has been performed by UoT.

## 1.3 Relations to other activities in the project

This document provides the basis on which the integrated tools and associated methodologies rely upon. Therefore it presents the theoretical foundations guiding the definition of the accounting framework and of the calculation methodologies used to produce energy related performance indicators.

In this sense, the work done in Task 2.3 *Impact evaluation* is very much related with the work of Task 2.2 *Strategies and indicators for data modelling and data analysis*. The latter defines a set of multidimensional performance indicators to be applied in the energy efficient urban planning domain. Therefore, Task 2.3 is monitoring Task 2.2, since the indicators described in D2.2 are those used in the strategies outlined in this document. Section 4.1.4 proposes a framework allowing defining and calculating the indicators, which has been implemented in Task 2.2 and presented in D2.2. Also, the present deliverable is greatly related with D8.1, which defines both: the issues to be demonstrated in the three implementation rounds and the implementation processes itself. Therefore, the strategies for impact verification defined in this deliverable will be implemented in D8.1. On one hand, we have to verify the functionalities and expected features of the integrated tools and associated methodologies. In order to do so, D2.3 defines a set of questions for the development of report templates aimed at assessing, from the user viewpoint, the degree of fulfilment of those expectations. On the other hand, the report templates should consider the evaluation of the expected impact of the integrated tools and related methodologies, that is, to support the reduction of energy consumption and $CO_2$ emissions in the urban planning domain.

Also, this report start the exploration of land and time use classifications, which should be considered in the development of the tools and methods (WP5) and their integration through SEIF (WP3 and WP4) (See Section 4.2, which defines the specific requirements for the development of tools and methods).

# 2 CONCEPTS AND DEFINITIONS

**Energy carrier**

The substance or phenomenon that can be used to perform final energy uses (e.g. mechanical work or heating) or to operate chemical or physical processes (Adapted from technical standard EN 15603).

Energy carriers correspond to the various forms of energy inputs required by the various sectors of society to perform their functions. Examples of energy carriers include liquid fuel in a furnace, gasoline in a pump, electricity in a factory or a house and hydrogen in a tank of a car (Giampietro & Mayumi 2009, Giampietro & Sorman 2011). They are also referred as *secondary energy*, which are all sources of energy that result from transformation of primary energy sources.

**Energy end-uses**

In the context of urban planning, energy end-uses refer to useful tasks and works performed in a built environment which convert energy carriers into applied power. Examples of energy end-uses are lighting, heating, cooling sanitary hot water and electric appliances.

**Primary energy sources**

A source from which useful energy (i.e. energy carriers) can be extracted or recovered either directly or by means of a conversion or transformation process (Adapted from technical standard EN 15603).

Primary energy sources correspond to those sources that only involve extraction and capture. That is, the term refers to the energy forms required by the energy sector to generate the supply of energy carriers used by society. Examples of primary energy sources are below-ground fossil energy reserves (coal, gas, oil), blowing wind, falling water, solar radiation and biomass. It is extremely important to differentiate Primary Energy Sources from Energy Carriers. The concepts refer to energy forms of different quality and used at different hierarchical levels of the society. They cannot be aggregated since 1 MJ of an energy carrier is not the same than 1 MJ of primary energy source (Giampietro & Mayumi 2009; Giampietro & Sorman 2011).

**Energy System**.

In the context of the SEMANCO project, we understand an energy system as an interrelated network from energy sources to final energy uses, which are connected by transformation, transmission and distribution systems. There are numerous energy systems in nature, such as the food chain, the climate and ocean systems, and the cycles of elements such as water or carbon.

We can differentiate between endosomatic and exosomatic energy systems. The former encompasses the collection of solar radiation and the transformations to stores of energy in food and to work, and subsequent dissipation of energy. In SEMANCO we deal with the exosomatic energy system, which encompasses the collection and extraction of primary energy sources, the transformation to energy carriers and the transport and distribution to the society to perform the final energy uses.

**Energy model**

The term Energy Model has been used to describe the elements and its relations of a specific energy domain. For example, the energy simulation tools like EnergyPlus or Ecotect model a building with its elements defining its attributes (U-value of the walls, glass type, or climate conditions) needed to perform the energy simulations. Energy modelling doesn't simply refer to a description of an object, e.g. a building, but the description of phenomena, e.g. energy flows through the building. In this context, the Energy Model entails a physical-mathematical representation. The concept can be applied at different scales e.g. a region, a town, a building or a construction component.

In SEMANCO project, the Energy Model provides the necessary language to understand and interpret the complexity of different datasets and their interrelations enabling semantic tools and users to use the data coming from different domains. Specifically, contains terms and attributes at an urban scale including regions, cities, neighbourhoods, buildings, and related energy data such as climate, as well as economic and social factors.

**Energy efficient urban planning**

In the context of SEMANCO, we understand energy efficient urban planning as a development of urban plans and projects aimed at saving energy consumption and reducing $CO_2$ emissions. Therefore, we consider energy efficiency differently than it is conventionally understood. We consider the increase in energy efficiency as an absolute reduction of energy consumption, and not as an increase in the ratio between output (e.g. service or final energy use) and input (e.g. supply of an energy carrier).

# 3 CHALLENGES OF ENERGY EFFICIENT URBAN PLANNING

The problem of energy efficiency and $CO_2$ emissions reduction in urban planning is difficult to delimit to a particular geographical area. It is a systemic problem in which multiple dimensions and geographical scales need to be integrated. For instance, we can focus the description and analysis of an urban system on different scales: for instance, at building, neighbourhood, district or city level, among others. The existence of multiple scales carries important challenges to be addressed in the analytical process concerning carbon emissions: the relevant aspect considered to perceive and represent the system would change depending on the chosen analytical scale.

The existence of multiple scales entails several challenges in the urban planning domain. This section is intended to unravel those challenges and propose the strategies to deal with them. Those are strategies needed to develop a set of integrated tools and associated methodologies aimed at perceiving and representing the energy performance and $CO_2$ emissions of urban areas.

## 3.1 Complex relations between the elements of the hierarchical system

From a physical point of view, we can conceptualize the urban environment as a hierarchical system in which, for example, buildings are grouped in neighbourhoods, neighbourhoods in cities, cities in regions, and so on. From this point of view, an urban area is a complex system made of smaller systems, whose elements work and relate with each other in a certain way. We can use the concept of *holon* in order to shed light on the implications of performing an energy analysis of an urban area; an analysis trying to link the performance of the whole system and the performance of the elements operating at different scales.

A *holon* is a component of a hierarchical system: it is a whole made of smaller parts and at the same time it is part of a greater whole. For instance, a neighbourhood is defined by households, buildings, communities, streets, among others. At the same time, the neighbourhood is a part of a city, of a municipality, of a country, and so on. This dual identity of the holon entails a constant tension between the elements of the hierarchy. The holon has to maintain coordinated operation with the holons of the same level of the hierarchy, and at the same time, it has to perform certain functions required by higher level elements of system to which it belongs (Koestler, 1969).

Let's consider, for example, the energy sector as a holon. On one hand, it has to "compete" with other socio-economic sectors for the resources needed to perform its tasks. Depending on the technologies and on the available primary energy sources the energy sector requires a certain amount of human activity (e.g. requirements of skilled labour) and land (e.g. whether to construct a wind-farm or to conserve the cultural landscape heritage to foster eco-tourism) in order to perform its expected functions[3].

On the other side, the holon energy sector should fulfil some specific functions expected by the upper-level elements of the hierarchy. In this case, it has to deliver a certain mix (in amount and quality) of energy carriers required by the rest of the society in order to perform some final energy uses.

[3] At a lower level, the energy sector as a whole has to keep control of the elements comprising it: that is, it has to assure coordinated operation between energy transformation plants, energy transport and energy distribution systems. These holons "compete" to get access to land, human time and other resources needed for their operation. At the same time, these lower level elements should perform certain tasks required by the energy sector as a whole.

We can also find some examples in the urban planning domain. Let's consider that we want to construct a district heating plant within a specific neighbourhood in order to reduce energy consumption. Within the neighbourhood, the district heating plant would compete for land with other socio-economic activities. For instance, this particular area of the city may require land to construct new buildings in order to deal with a demographic growth. As well, if demographic growth is an issue, the neighbourhood may require land to construct commercial, health and educational centres, or any other socio-economic activity that requires a place (i.e. land) to provide goods and/or services to the growing population. At the same time, the size of the district heating plant should fit within the available space and should provide the heat required by the surrounding buildings. In other words, it should be a balance between what is expected from, and required by, that heating system (e.g. it wouldn't be acceptable that the district heating plant uses half of the land of the neighbourhood and provides heat to only 10% of the households of the area).

These complex relations between the elements of the hierarchical system make it difficult to find policy interventions, or urban plans, which improve the performance of the urban environment at different levels. In other words, what is good at one level may not be adequate at different levels. Let's consider the case of an urban plan aimed at modernising an old neighbourhood by means of demolishing an old building and replacing it with a new one. The project of the new building would aim at reducing energy consumption for heating by means of getting as much solar radiation as possible: it may consider to widen streets and/or to enlarge the façade of the building[4]. At building level, we can obtain an important reduction in energy consumption, and therefore, in $CO_2$ emissions. However, the construction of this new building may increase shadows on neighbouring buildings (i.e. it competes with other buildings to capture solar energy), which would increase the energy consumption at the neighbourhood level.

Summarising, we can state that a holon should have a coordinated interaction with both: the elements of the same level of the hierarchy (horizontal coupling) and elements of different levels of the hierarchy (vertical coupling) (see Giampietro, Allen & Mayumi, 2006, for a detailed description of these concepts). The existence of horizontal and vertical couplings entails that we cannot study and analyse the behaviour of an urban element in isolation from its context, and that we have to perform simultaneous assessments at different scales in order to make decisions about energy efficient urban planning and developments.

## 3.2 The issue of multiple dimensions in urban planning

We can consider an urban system as a complex system: that is, a socio-economic and biophysical system whose relevant aspects cannot be captured using a single perspective (Funtowicz et al., 1999; O'Connor et al., 1996). Complex systems are those characterized by presenting multiple identities at multiple scales, which are subject to non-equivalent descriptions.

Consider, for instance, the well-known example of the group of blind people touching an elephant (See Figure 3). None of them can recognise what they are touching unless they communicate with each other and complement their perceptions. We can find similar situations in the urban planning domain. A building can be described using non-equivalent description of it. An architect would describe it in terms of volumes, shapes, materials and orientation, among other characteristics of a building. A sociologist would look at people living in the building, and describe it according to demographic, cultural and socio-economic characteristics. In that way, different persons of diverse backgrounds would focus on different

[4] The project can also consider high quality isolation systems to avoid heat losses in winter. Also, it can consider a configuration that facilitates natural cross ventilation in summer time to control high indoor temperatures.

aspects of the building, according to what they consider relevant for the analysis. Those perspectives are “incommensurable”[5] due to “the absence of a common unit of measurement across plural values” (Martinez-Alier et al., 1998, p. 280). This highlights the fact that the perception of the different stakeholders perceiving and describing the urban area, heavily depends on the background of each observer.

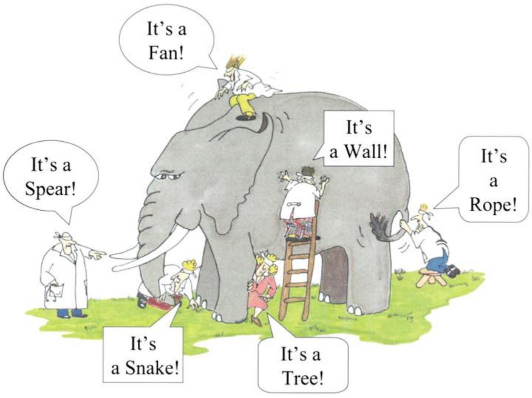


*Figure 3. The example of a group of blind people touching an elephant.*

## 3.3 Emergent properties across scales

The issue of non-equivalent descriptions of the same system is also present when we look at the system at different scales, even when the representation of the system is done by the same person.

An architect which plans an urban environment sees the buildings as gray-boxes, which create different public spaces, depending on their layout. The architect models the building as a box, making decisions about the height and depth of the building, in order to obtain proportionate streets and squares. At this level, the architect also decides about the uses of the buildings (e.g. whether it would be a residential, commercial, industrial building or an office ). But s/he doesn't define the specificities of the building[6].

On a building project level, an architect sees the building as it would become, according to the restrictions defined in the urban plan. S/he decides whether to break the façade, to include yards, to modify the orientation of the building, to explore different profiles and slopes of roofs. At this level, an architect usually has complete freedom in deciding materials and colours, size and arrangement of windows, and other construction details such as thickness and the type of isolation materials, width and disposition of ventilated chambers, pavement layers, and very importantly, such services as: sanitary hot water, heating and cooling systems, renewable energy generation, all in order to meet the technical code/building regulations.

It also works the other way around: there are emergent properties when we up-scale the perception and representation of the system. For instance, it may have no sense to analyse the

[5] Munda (2004) further distinguishes between technical and social incommensurability: the former comes from the multidimensional representation of complex systems by means of descriptive models and the last comes from the existence of diverse and legitimate values in society.

[6] The architect would base her decisions about shape and uses of the building on issues such as mobility, public services, distribution of squares, topography, sun exposure and climate. Usually, a good urban planner would consider sunlight exposure, but only in an intuitively way (e.g. it is well known that the façades of the building should go towards the north or south, and with adequate wide to allow cross ventilation)

distribution of income across households, at building level. However, at neighbourhood level, this sort of analysis may shed light on the effect of gentrification processes, which can be very important to prevent potential social conflicts within the neighbourhood.

## 3.4 Energy forms and energy transformations across scales

From the previous discussion it can be concluded that the relation between the energy sector and the rest of the society is very complex, especially in a society in which the demand for and supply of energy are two interdependent processes. As a socio-economic system, humans have to develop and perform a set of integrated processes required for producing and consuming energy, in different quantities and qualities[7] where production and consumption are two sides of the same coin.

The energy sector has to deliver a mix of energy carriers such as electricity, liquid fuels (diesel and gasoline), natural gas and liquefied petroleum gas. The amount and the share of each energy carrier is determined by the requirements of the rest of the society in order to perform a set of final energy uses such as heating, cooling, lighting, to heat sanitary water and to use electric appliances. Interdependence appears when we accept that the profile of final energy uses depends on the ability of the energy system to deliver the required energy carriers produced from the available mix of primary energy sources (such as below-ground fossil energy reserves (coal, gas, oil), blowing wind, falling water, solar radiation, geothermal, natural uranium and biomass). Figure 4 shows this complex network of transformations. There, we can see that some primary energy sources are useful in producing a limited set of energy carriers, and that we can expect a limited room in order to substitute one primary energy source by a different one (i.e. we cannot produce heat from hydro or wind power). In fact, there are some cases in which, for instance, different types of coal are not interchangeable at all. The same happens with the transformation from energy carriers to final energy uses: we can expect a limited exchangeability between energy carriers in order to fulfil the expected final energy uses.

Figure 4 shows that we are dealing with two different energy transformations based upon two different types of energy flows: primary energy sources and energy carriers. These two different semantic categories cannot be summed as such. They can only be reduced to each other, within a specific accounting scheme, using conversion factors (Giampietro & Sorman, 2011). For instance, we may have a flow of energy input (requirement of chemical potential energy for a boiler averaged over a year) or a flow of applied power (useful heat output from the boiler delivered in an hour).

[7] According to Georgescu-Roegen (1971) the economic process creates a reproducible system, which is able to perform a set of integrated processes required for producing and consuming goods and services, rather than producing commodities (i.e. goods and services).

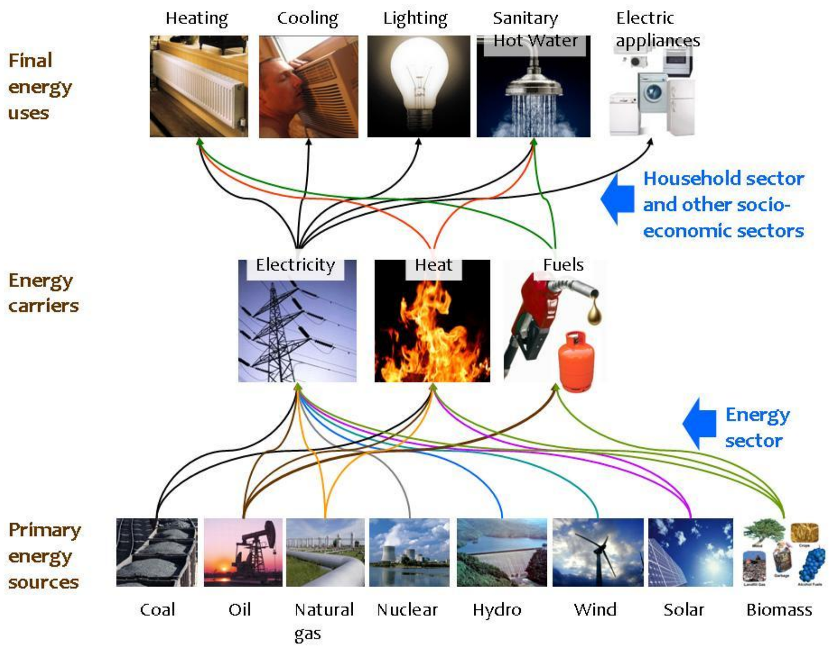


*Figure 4. Energy transformations from Primary energy sources to Energy carriers and Final energy uses (Source: Own elaboration based on Giampietro and Sorman, 2011)*[8]

Moreover, the two transformation steps from primary energy sources to final energy uses give us information on the internal and external constrains we face when dealing with energy issues. On the external constraints side, we can check the feasibility of the energy sector to supply the quantity and mix of energy carriers required by the society from the mix of primary energy sources (e.g. considering the availability of primary energy sources, of technology and of other resources such as land and human time). On the internal constrains side, we can check the viability of the consumption side to perform a set of final energy uses from the mix of energy carriers delivered from the energy sector.

Therefore, if we keep the distinction between different energy related semantic categories (i.e. primary energy sources, energy carriers and final energy uses), then we will be able to match the supply and demand of the energy system within the energy efficient urban planning framework.

Here, we would like to stress the fact that an energy efficient urban planning may act at both levels. The implementation of a district heating system or the exploitation of local renewable energy sources are examples of transformations from primary energy sources to energy carriers. On the other side, the replacement of electric appliances, the implementation of centralized heating systems or the implementation of architectural improvements aimed at reducing energy consumption are examples of energy transformations from energy carriers to final energy uses. In both cases we have to be aware of the fact that it is not possible to perform these energy transformations without some restrictions.

For instance, let's consider the case of a policy aimed at large scale programme focusing on replacing individual electric heaters by centralized systems powered by natural gas (e.g. centralized boilers, district heating). These changes may require an increase in the capacity of the natural gas network and a construction of a distribution system at building and neighbourhood levels. Which in turn requires new investments, additional labour, land and energy - which in some cases may not be available as, and when, needed.

[8] It is worth mentioning that heat (and fuels) can also be used for cooling via absorption refrigeration, though it is not that widespread.

## 3.5 Expected features of SEIF at different levels

Finally in this chapter, we would like to tackle another issue related to the urban planning practice at different levels. It concerns the use of different modelling methods at different scales. In order to do so, we would like to start the discussion recalling the Zadeh's Incompatibility Principle (Zadeh, 1973), which states that our ability to make precise and yet relevant statements about the system diminishes as the complexity of the system increases. This idea applies to the issue of using different energy modelling methods at different scales. Generally speaking, we can classify energy models into simplified and detailed methods. The former requires us to input general characteristics of the building or an urban area to be modelled: street layout, the basic shape of the buildings (footprint, height and shape), surface and coefficients of thermal transfer of enclosures (walls, windows, roof) and climatic data. Detailed models, on the other hand, require more precise information about the type and size of windows, doors, woodwork, among others.

Usually, the use of a detailed method to model an urban area would be very time consuming due to the huge amount of required information. At this scale, and considering the objectives of an urban planner discussed in Section 3.3, a simplified model would be more suitable in order to, let's say, optimise energy demand of a group of buildings (i.e. to find the configuration of the urban area with less energy consumption in relation to other evaluated alternatives). In that sense, the use of detailed model is closer to the definition of a building project, which would be subject of some energy efficiency requirements according to the law (i.e. technical code).

# 4 STRATEGIES FOR ENERGY EFFICIENT URBAN PLANNING

The existence of urban elements operating simultaneously at multiple scales entails several challenges that needs to be addressed in the energy efficient urban planning domain. The following table synthesises the challenges identified in the previous sections and matches them against guidelines and strategies to face those challenges.

*Table 2. The existence of multiple scales in the urban planning domain: challenges and strategies*

| ***Challenges*** | ***Strategies*** |
|---|---|
| In complex hierarchical system there is a complex network of relation between the elements operating simultaneously at different levels. Those elements are very interrelated and there are high degrees of interdependence (i.e. vertical and horizontal coupling between the elements of the hierarchy) | ▪ Evaluation of the performance of the urban area at different scales; e.g. building, neighbourhood, city.<br>▪ To assess the feasibility of the evaluated alternatives. In other words, we need to assess the requirements of other sectors in order to face the consequences of the analyzed urban plan. |
| The existence of multiple scales entails the need to use non-equivalent descriptive domains when perceiving and representing the system | ▪ To use a multi-dimensional set of performance indicators |
| Complex systems present emergent properties across scales. That is, there are some attributes possessed by the elements of the system but not by the system as a whole, and *vice versa*. In other words, some performance indicators would be relevant at one scale, but not at other levels. | ▪ To use an adequate accounting framework allowing us to up- and down-scale indicators across hierarchical levels |
| Energy is a semantically open concept that needs an accounting framework able to provide coherent information across scales | ▪ To keep track of the series of energy transformations across scales. That is, to clearly differentiate energy carriers and primary energy sources across scales. |
| The expected features of SEIF should meet a balance between providing detailed and relevant information according to the objectives of relevant stakeholders | ▪ To use different methods with different degree of accuracy in their calculations depending on the scale of analysis: Simplified methods are to be applied at urban level in order to optimize the energy performance of an urban area, to observe trends of energy consumption or to identify hot spots. More detailed calculations would be implemented at building level in order to know the energy performance of the building for certification or improvement. |

The following section presents in more detail an accounting framework able to deal with a set of performance indicators across levels in a coherent way: the Multi-Scale Integrated Analysis of Societal Metabolism (Giampietro 2004; Giampietro et al., 2009). The same analytical framework provides the tools in order to assess the viability and feasibility of alternative future scenarios of urban plan: the section would define some guidelines for evaluating the feasibility of urban planning scenarios at city or territorial level. Also, the proposed accounting framework would allow us to keep track of the energy flows across scales differentiating between energy carriers and primary energy sources.

## 4.1 Multi-scale integrated analysis: the proposed accounting framework

A metabolic system can be defined as a system able to stabilise a coordinated inflow of matter and energy resources, producing an output flow of products and waste (degraded matter and energy). This transformation process is driven by the production-consumption processes required for the reproduction of the system itself.

In order to analyse the metabolic pattern of an urban area it is of fundamental importance to establish an explicit distinction between those categories which must be reproduced, which pass through the system and those which change its identity during the time space of the representation.

The fund-flow model (Georgescu-Roegen, 1971) emphasizes that what we call production is in reality a transformation process of resources into useful products and waste products: a transformation of some materials into others (the flow elements) by some agents (the fund elements). To neglect this distinction results in a systematic indifference to the biophysical foundation of economic activities (Mayumi, 2009).

On the time scale of the representation, *fund* categories transform input flows into output flows, and flows are either consumed or generated in order to reproduce the funds categories. Therefore, *fund* categories remain "the same" over the duration of the representation (e.g. capital, people, Ricardian land). *Flow* categories refer to elements appearing and/or disappearing over the duration of the representation (e.g. added value, water, energy, matter).

We can use these categories in order to characterise the system in quantitative terms. **Extensive variables** are those which can be added. They characterise the size of the system and its compartments, in terms of either funds categories (e.g. hours of human activity or hectares of land) or flow categories (e.g. GJ of exosomatic energy per year or $hm^3$ of water per year). **Intensive variables** are those which represent a ratio: the pace of the metabolism in terms of a flow/fund or fund/fund ratios (e.g. flow of energy carriers per square meter, measured in $kW{\cdot}h/m^2$). They describe *how the system does what it does*.

This distinction has very important consequences for the definition of indicators of energy performance, CO2 emissions and socio-economic aspects. It is not adequate to use intensive indicators of the flow/flow type in order to represent the performance of the system (e.g. Economic Energy Intensity measured in MWh/€: the amount of energy required to produce one € of added value). These indicators do not have any meaningful reference value and they do not give any useful information about the structure of the system under analysis (Sorman & Giampietro, 2011).

### 4.1.1 Using land uses as fund category

As mentioned in the previous section, we need to capture the complex interactions of the elements of the hierarchical urban system. We have to keep track of the flows of matter and energy across the elements of the hierarchy. For instance, if we plan an urban development requiring additional flows of resources, then we should be able to capture the requirements and availabilities from other sectors in order to capture the interactions across levels.

In order to do so, the proposed approach defines a set of nested categories of the fund elements across scales. Let's consider, for instance, that we have to analyse the energy performance of the urban area presented in Figure 5. The first step would be to define the nested categories across scales of the fund element Land. In order to do so, we use an adequate classification of land uses.

*Figure 5. Urban area to be analysed*

At the higher level of the urban area (*Level n*) we have the land use "urban" ($LU_{urban}$). Then, in a lower level of the hierarchy (*Level n-1*) we can split the category $LU_{urban}$ in three categories according to the relevant land uses of that urban area. In this case, we classify the land uses into household sector, the service and government sector ($LU_{SG}$), and open spaces ($LU_{OpenSpaces}$). We can further split the classification of the land uses into lower elements compartments (in this case, *Level n-2*): where we have three different household typologies within the household sector ($LU_{HH1}$, $LU_{HH2}$, $LU_{HH3}$), the land use of an education centre ($LU_E$) and the land use of commercial purpose ($LU_{Com}$) within the service and government sector, and the land use of open spaces (See Figure 6).

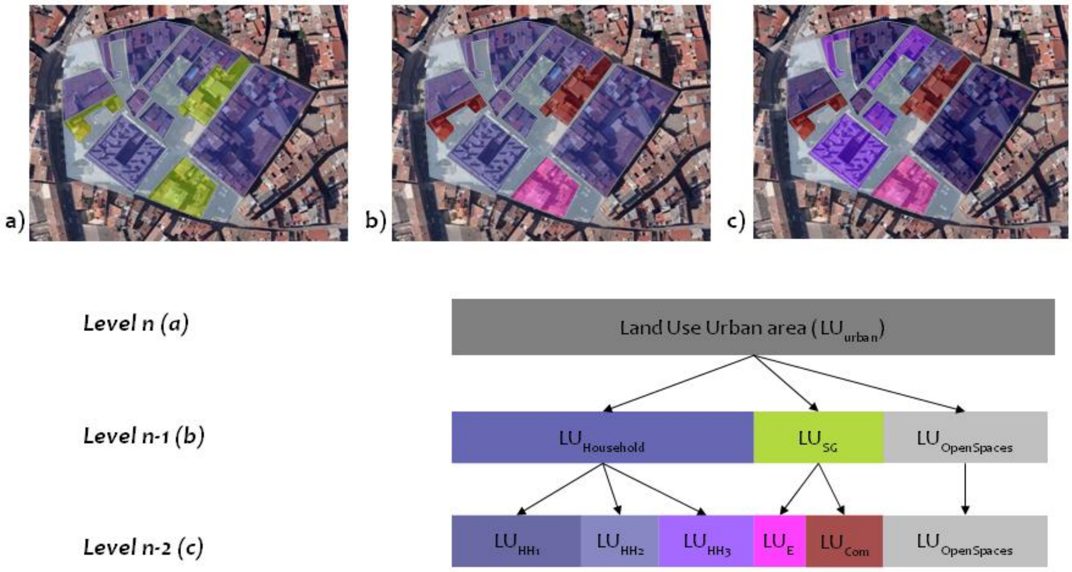


*Figure 6. Multi-scale classification of land uses of a defined urban area.*

It is important to bear in mind the fact that the approach is extremely flexible and enables us to define the relevant land use categories according to the objectives of the analysis. For instance, we might be interested in analysing the energy performance of the household sector in relation to the whole urban area. In that case, we could define the land use categories within the household sector only, and define the rest of land uses as "other". Also, the categorisation of land uses depends on the actual land uses in the urban area. In our example, it doesn't appear land uses relate to industrial activities. But, it could be the case when considering an urban area with a district heating plant. The next step for an energy analysis across scales would be to map the flows of energy carriers across land use categories. In order to do so, we proceed as presented in Figure 7, which presents a multi-level matrix matching land use categories and energy throughput. In this case, we can consider mapping the flows of the energy carrier electricity which passes through the different land use categories.

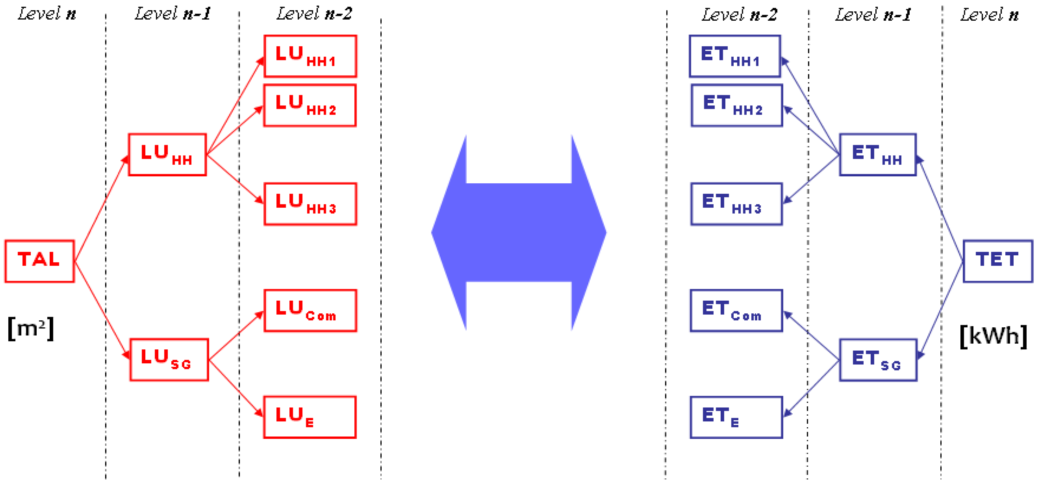


*Figure 7. Multi-level matrix matching land use categories and energy throughput. Acronyms: TAL: Total Human Activity, LU: Land use, TET: Total Energy Throughput ET: Energy Throughput, EMR: Exosomatic Metabolic Rate, HH: Household sector, SG: Service and Government sector, $HH_n$: Household typology n, Com: Commercial sector, E: Education sector*

From here, we can calculate the extensive variables land use (in $m^2$) and electricity consumption (in kWh/year) by means of aggregating and disaggregating the figures across levels. For instance, the land use of the household sector ($LU_{HH}$) is equal to the aggregation of the land use of different household typologies ($LU_{HH1}$, $LU_{HH2}$ and $LU_{HH3}$). The same applies to the electricity consumption or any other flow of energy carriers such as natural gas, liquid fuels and so on. As mentioned before, the calculation of the extensive indicators gives an indication of the size of the different compartments of the urban system, either in terms of the fund or flow categories.

Additionally, we can assess the metabolic rate of the different compartments of the system in terms of flow/fund ratios (i.e. intensive indicators) (see Figure 8). In order to do so, we would calculate the intensive indicator Exosomatic Metabolic Rate –EMR– in order to describe how the system *does what it does*. In this case, we do this by dividing the flow of kWh of electricity by the corresponding land use category in which the corresponding activity takes place. This can be done at the level of the urban area or at the level of its compartments. Moreover, we can keep splitting compartments in order to capture the internal functioning of the different sectors (e.g. using different residential building typologies in order to describe the residential sector). In this way we can also up- and down-scale indicators of energy performance and $CO_2$ emissions across levels.

The way of classifying land uses should be flexible enough in order to tailor categories according to the objectives of the analysis. For instance, we could be only interested in assessing the energy performance of the household sector and of the different types of residential buildings within this sector, and we could classify the rest of the urban area as “other”. Having this in mind, we would require that SEIF is able to perform different classification of land uses according to the objectives of the analysis. Also, it should be mentioned that Appendix C presents a land use classification according to performed activities that would be incorporated in the ontologies and used by SEMANCO’s platform

At the outset, there are major differences between energy performance indicators used in the urban planning domain. The advantages of this method are related to the use of the accounting framework based on a specific land use categories. More information on this issue is presented below. At this stage, we can say that the accounting framework enables the analyst to up- and down-scale the information by means of aggregating or disaggregating extensive variables across scales, and then calculating intensive indicators of performance for the different urban levels.

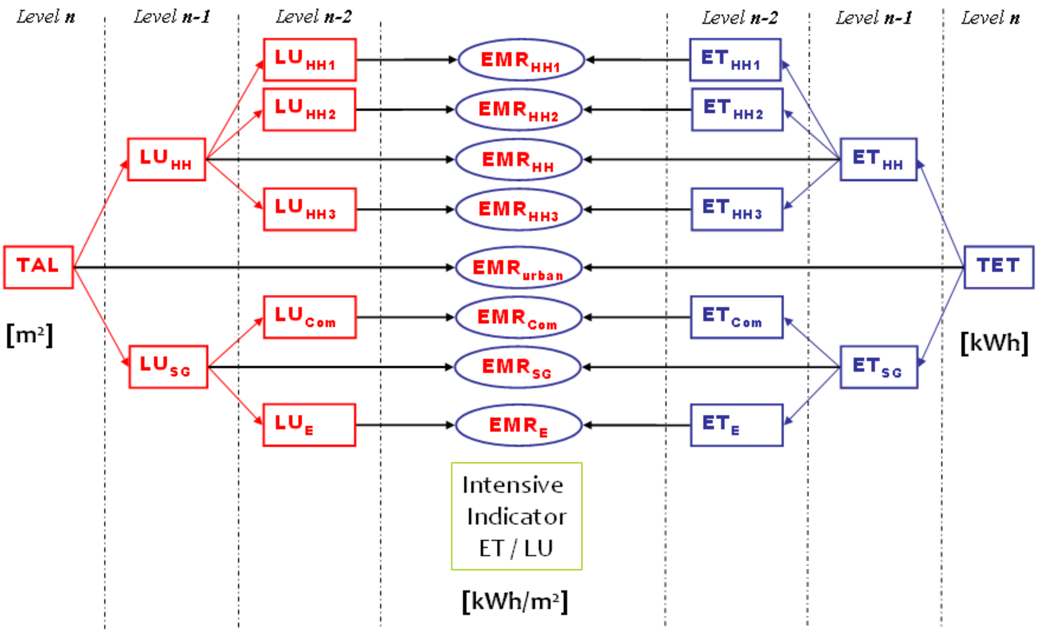


*Figure 8. Matching land use categories and flows of energy carriers, and calculation of intensive indicator Exosomatic Metabolic Rate (EMR)*

Also, we can use the same classification of land uses in order to analyse different type of flow categories, which is also necessary in order to embrace the multiple dimensions involved in our analysis. As mentioned before, we can differentiate between energy carriers, a required feature, in order to keep track of the energy transformations across scales. We can also analyse the flows of added value produced in the different socio-economic sectors, the flows of water consumed or the flows of generated waste.

This accounting framework also facilitates the assessment of the feasibility of the alternatives. Let’s consider, for instance, an urban plan aimed at demolishing old buildings and constructing new ones. Depending on the characteristics of the new buildings with respect to the old ones, this plan may change the socio-economic and demographic structure of the neighbourhood due to the arrival of different type of families. This, in turns, would change the energy consumption of the household sector. Then, it would be necessary to check the ability of the energy system to provide the new requirements of energy carriers. For instance, we should assess the capacity of the electric substation to transform the voltage of higher flow of electricity or whether the natural gas networks are able to transport the additional volumes of gas to a new district heating plant.

But the feasibility check is not only related to energy issues. Changes in socio-economic and demographic aspects would imply different requirements from the household as well as the educational, health and/or commercial sectors. Therefore we should check whether the modified holon (household sector) fits within the urban area: whether the rest of the holons are able to provide the functions and services required from the household sector. For instance, we should check whether the education centres holon is able to provide the functions (i.e. education) required by the rest of the residents. Recalling the previous sections, we should check the stability of the horizontal and vertical coupling between the elements of the hierarchy.

The proposed accounting framework presents additional advantages which are worth mentioning. Firstly, by using similar land use categories, it is possible to perform coherent comparison between urban areas, cities, countries or regions. It enables us to open the black box and understand differences of performance. For instance, if we compare the energy performance of two cities we may find big differences, but cannot immediately say that one of them is performing better than the other. By using the MuSIASEM approach we can open the black box, and analyse, on one hand, the internal structure of the city, and on the other, the performance of those lower level compartments. This issue is very relevant. The tools we develop should (rightly) include the possibility to compare performances of different cases. There might be a city with a high share of industrial activities while the other with high share of financial activities, which may explain big differences in energy performance. In case of small differences between the internal structures of the two cities, we can proceed to analyse the performance of the lower level compartments. We can proceed by comparing the performance of the different socio-economic sectors and, if necessary, by opening the black boxes in order to understand the differences of performance. When the internal structure of compartments and activities are similar, then we can look for an explanation of the differences in the use of diverse technologies, the level of activity, among other reasons.

Secondly, we can characterise the metabolic pattern of different socio-economic sectors and subsectors by mean of using the intensive variables. If we calculate the exosomatic metabolic rate of the household, service and industrial sector, we will certainly obtain differences in the order of magnitude of the energy consumption per square meters of land use. In this way we can define some external referents or expected values of the energy consumption per square meter of sectors and subsectors, which would be the basis in order to judge their (energy) performance. For instance, different building typologies with their corresponding occupation rates will have different expected values of energy consumption per square meter. Based on these external referents we can identify potential mistakes in the calculation procedures.

Thirdly, and due to the fact that the elements of the hierarchy are all linked one each other, we can guess or obtain missing values of energy performance of some compartments of the hierarchy if we know the energy performance of higher and lower elements.

#### 4.1.2 Using time use as fund category

As mentioned before, the use of intensive indicators of energy performance per square meter of land use present no major differences with conventional energy performance indicators used in the urban planning domain. However, the differences clearly appear when we use different fund categories such as human activity. We very often make use of *per capita* indicators in order to compare the performance of different socio-economic systems (e.g. GDP per capita of two different cities). However, this practice misleads the analysis at multiple-scales due to the fact that figures *per capita* do not clearly reflect the flows of energy, added value or matter during the duration of the corresponding activity. In the case of the land uses, we link certain flow of energy carrier with the activity performed in a certain area (e.g. electricity consumption in a building, in offices or in an industry). In the case of *per capita* indicators, we link the energy consumption with the people which have been present is a specific area (e.g. the inhabitants of a household), but not with the activity of the people in that area (e.g. the amount of time spent by the people in their houses).

Consider, for example the case of Figure 9 below. It highlights the use of “hours” as a unit of measure of the human activity instead of using *per capita* figures. As presented in Figure 9, the work supply of 1.000 workers in China is higher than in Italy, which is due to the different workload in both countries. The same applies when we compare the different sectors of a socio-economic system. For instance, at European level, the average workload of the industrial sector is about 42 hours a week, while in the agricultural sector the average workload is about 46 hours a week. Due to this fact, if we compare the GDP per capita of the agricultural and industrial sectors, then we are comparing the added value generated in different work weeks. But, if we compare the GDP *per hour* generated in the agricultural and in the industrial sectors, then we can see better other differences between sectors (e.g. level of capitalisation, use of technology, among others).

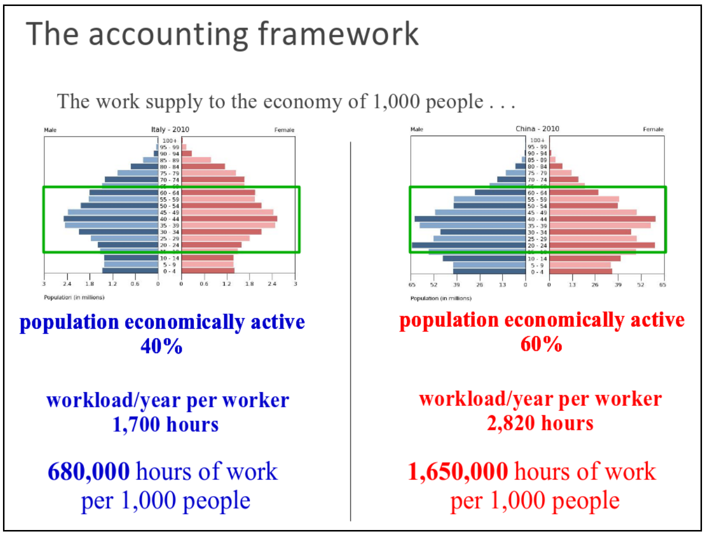


*Figure 9. The importance of using hours for measuring human activity*

In order to overcome this deficiency, the MuSIASEM approach proposes to account human activity in terms of hours (or any other unit of time). This way, we can represent the different compartments of the urban area in terms of human activity. In other words, we can indicate the amount of hours people spend on activities performed in the different compartments defined in Figure 5 to Figure 8, and hence to take into consideration the usage of the spaces (land uses) in the calculation of extensive and intensive indicators. In this way, we can compare the energy consumption per hour of human activity of different compartments, identify activities of high energy consumption rates and define actions for improvement. For instance, if we compare the energy performance of schools per hour of human activity performed there, we avoid the influence of different timetables across educational centres in the evaluation of indicators. The same applies to the analysis of energy consumption at the household level. The results would be very different if we calculate the electricity consumption *per capita* (i.e. the number of people living in the household) or in terms of time inhabitants spend at home. Certainly, the second option is more adequate if we want to track the flows of energy, matter and added value across scales. In other words, we would only be able to aggregate and disaggregate the fund human activity across scales if we use human time (e.g. measured in hours) rather than per capita figures.

Also, using *hours* as a unit of measure of the human activity we can link the levels of the hierarchy. This way we can aggregate the human activity allocated to different sectors across levels, for instance, to compare the time allocated to the household sector with respect to the rest of the society and the corresponding energy consumptions.

We are aware of the fact that this sort of information is hardly available in much detail. But, certainly it is not possible to link indicators across scales using per capita values, or at least, it would produce misleading figures.

How to proceed then? The main source of information regarding time uses within the paid work sector is the Labour Force Surveys, which give information about the working time by economic activity. The Labour Force Survey uses the International Standard Industrial Classification of all Economic Activities (ISIC-Rev.3) (See Appendix A).

On the other hand, there are the national time use surveys, which generate information on time uses in a set of predefined activities (See Appendix B). At European level, there is an initiative aimed at harmonizing national time use surveys[9], which aims at making the statistics on the organisation and activities of everyday life comparable across participating countries. This source of information would be complementary to the Labour Force Survey in order to develop a time use database encompassing activities developed within the paid work sector and activities developed within the unpaid sector (which includes the household sector).

### 4.1.3 Defining cross-cutting categories of land and time uses

As already mentioned, the comparability across countries by using intensive indicators depends on the categories of fund variables (i.e. land and time uses), which determines the categories of flows of energy, matter and added value. Then, we should use similar categorization of land uses across countries in order to be able to compare their performance.

In this sense, the American Planning Association[10] proposes a Land Based Classification Standard, which classifies land uses across five different dimensions: activity, function, structure (i.e. building types), site development character and ownership constrains. Within the SEMANCO project, we consider, in the first place, to use land use categories according to the activity dimension in order to map land and time uses using similar categorization of sectors (compartments of the system)[11]. In this sense, Appendix C presents the main land use categories according to the *activities* developed there: activity refers to the actual use of land based on what actually takes place in physical terms.

On the other side, and as mentioned before, we will use the ISIC classification in order to categorize time uses. Therefore, we have to match both land and time use classifications in order to be able to track flows of energy across sectors and subsectors (described in terms of equivalent land and time uses).

### 4.1.4 Implementing the fund-flow model to define indicators of energy efficient urban planning: Defining extensive and intensive indicators across scales.

As presented in the previous sections, we can represent a metabolic system by means of fund and flow categories. Fund categories are allocated to the different compartments of the system in order to perform certain functions. For instance, land and human time are allocated to different socio-economic sectors in order to perform activities aimed at maintaining and reproducing the system. In doing so, fund categories make use and transform some input flow categories (e.g. energy, matter or added value) into output categories (e.g. added value, goods and services, degraded energy, solid and liquid waste). Also, we can represent the system by using extensive and intensive variables (i.e. indicators), which can be up- and down-scaled

[9] See https://www.h2.scb.se/tus/tus/default.htm
[10] See http://www.planning.org/lbcs/index.htm
[11] During the implementation process, we will explore and evaluate the need to use different land use categories according to the objectives of the analysis. Land use can be also classified according to its function (related to the economic activity), to the structure (if the use of the building is not the use for which the building was erected), to the site (if the site is developed or not) or to the ownership. Each of these dimensions could be linked to the data collected in D3.1 and that will be semantically modelled: for example, urban planning data (linked to site and activity dimensions), socio-economic data (linked to ownership dimension), building technical data (linked to structure dimension), etc.

accordingly (see Section 0).

In the context of SEMANCO, the selection of fund categories will be restricted to land uses in the preliminary implementation round. But how to select the relevant flow categories used by the system in order to maintain its reproduction? Figure 10 shows a representation of an urban environment by means of using fund and flow categories. As we can see, it is a simplified model, which presents a limited and very broad list of input and output flows, which can be relevant for a current evaluation of the metabolic pattern of a city or urban area. Also, it only shows two fund categories: land and human time. From here we can develop a set of relevant indicators such as the flows of water or electricity per year, and their intensive versions related to land and time uses.

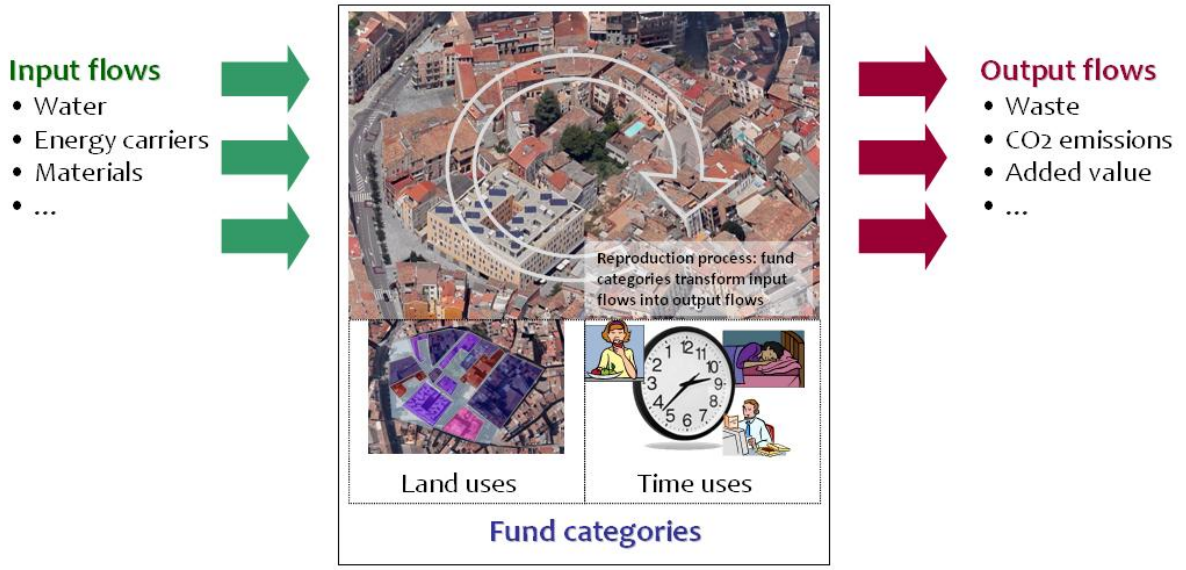


*Figure 10. Fund-flow representation of an urban area*

However, when dealing with (socio-economic) complex systems we have to acknowledge that they are evolving in time, meaning that the relevant aspects to assess the performance of an urban area may change with time. In other words, we have to acknowledge that complex systems are characterized by the presence of uncertainty or, even worse, genuine ignorance. In the case of uncertainty, outcomes are known, but in many cases there is no empirical base or an adequate theory to assign probabilities. There is emergence, novelty and variability. A clear example of that can be found in meteorological models and forecasting. Moreover, sometimes it is not about being unable to estimate probabilities (based upon empirical frequencies or on beliefs), but it is about not having any idea of possible outcomes. Ignorance implies that we don't know the set of attributes of a system which will be relevant in the future. Several examples of genuine ignorance can be found in former use of asbestos in construction, DDT in agriculture or chlorofluorocarbons in sprays, and their unknown effects on human health and on the environment.

For that reason, the analysis of the performance of an urban area clearly needs a dynamic set of indicators; adapting to changing conditions with time. It is true that D2.2 presents a list of indicators, but only those we have considered relevant at this stage of the project.

As also mentioned in D2.2, there are several frameworks aimed at guiding the definition and development of indicators. However, some of them run the risk of becoming obsolete with time, while others present some biases in the definition of analytical categories (DPSIR)[12].

Here, we propose the following procedure to define a relevant set of indicators for assessing the performance of urban areas.

1. to categorise the urban area according to relevant fund categories[13]
2. to identify input and output flows that are relevant for the reproduction and maintenance of the system
3. to determine input and output flows that go through the different fund categories across levels.
4. to calculate extensive indicators across categories and scales
5. to calculate intensive indicators by means of dividing flow variables by their corresponding categories of fund variables.

This process aims at overcoming the identified drawbacks of other frameworks for definition of indicators, in the sense that it defines general categories without determining the issue at stake. In this way, the framework leaves the definition of relevant categories open to be tailored to any urban context.

The guidelines to define indicators presented here deal mainly with indicators that describe the metabolic performance of a system or of its compartments: the flows controlled by the elements of the system and by the system itself, in absolute terms (extensive) and in relation to the land area in which the activity is performed (intensive).

However, we can think of different sort of indicators, those referring to the relationship between the elements of the system. For instance, and as mentioned previously, we may be interested in obtaining the distribution of income within a neighbourhood or a city. In this case, we can include some indicators mapping the relationships between the elements of a system each time we aggregate the performance of lower level elements. Let's consider that we have calculated the "energy requirement for heating" in each building of a neighbourhood. Then, if we aggregate data in order to calculate the extensive indicator "energy requirement for heating" at neighbourhood level, then the system would provide also an indication of the (in)equality within the neighbourhood in terms of energy use for heating.

Another important issue refers to the relevance of indicators across scales. In the sense that there are emergent properties when we down- and up-scale the perception and representation of the system. In practical terms, it means that there are certain indicators which are relevant at some scales but not at other (e.g. distribution of income). In this sense, it would be required that SEIF is able to define indicators *à la carte* to allow the user to define new indicators which are likely to become relevant with time. This is a fundamental feature of an assessment framework in order to deal with complex systems (i.e. with novelty, emergence and variability).

The possibility of redefining relevant indicators according to the context entails important degrees of flexibility in the SEMANCO platform. It affects the definition of calculation procedures (i.e. production rules) (WP5) and of the ontologies (WP4).

[13] As mentioned before, land use categorization is quite straight forward. Contrary, the use of time uses as fund categories need to be further explored. In this first implementation round, we expect only to use land use as fund categories. Following iterations will consider the incorporation of time use categories in the evaluation of energy performance of urban areas.

## 4.2 Specific requirements for the SEIF

As already mentioned here, the issues discussed in this document entail a series of requirements for the tools and methods developed in SEMANCO and to be integrated in SEIF. In practical terms, the SEMANCO-platform should be able to do the following tasks:

**Regarding the use of land use categories** (See Figure 6, Figure 7 and Figure 8)

- Perform a preliminary classification of land uses in the urban area under analysis. By default, SEIF should classify land uses according to the lower level of land-based classification standards chosen for that purpose. Regarding this last point, if we use the land-base classification standard developed by the American Planning Association, then we would use the third level of land use classification as the lower level
- Allow the user to (partially) tailor the land use classification according to the relevant categories in his/her context. For instance, the user may want to classify some irrelevant land uses as “other”.
- Aggregate and disaggregate the calculated extensive variables across scales and according to the land use categories defined in the previous steps.
- Calculate intensive indicators (per unit of square meters – $m^2$) across scales and according to the land use categories defined in the previous steps

This approach is extremely flexible and enables us to define the relevant land use categories according to the objectives of the analysis. That is why the user should be able to group, for instance, irrelevant categories of land use as “other” (or similar changes).

**Regarding the development of indicators at different scales**, we have mentioned that there might be indicators which are relevant at one scale but not necessarily at other scales. The SEMANCO platform should provide the possibility of defining indicators *à la carte*, enabling the users and experts domain to redefine indicators according to the context.

A preliminary option is when we aggregate data in order to calculate the extensive indicators at a higher scale (e.g. if we aggregate “energy requirement for heating” at building level to obtain the “energy requirement for heating” at neighbourhood level), the system would provide an indication of how the variable is distributed amongst the lower level elements (e.g. the (in)equality within the neighbourhood in terms of energy use for heating by buildings).

**Regarding the viability and feasibility of future scenarios** of urban planning, there is still work to be done in order to define the tools which will enable the users to perform such quality checks. As a preliminary step, we will explore the possibilities of developing a tool to perform a “Sudoku effect” analysis (Giampietro et al., 2009) between consumption and production of energy supply.

In order to do so, it is of fundamental importance that the tools developed within the SEMANCO platform are able to keep track of the energy flows across scales differentiating between energy carries and primary energy sources (See Figure 4). Then, the outcomes of the calculations should be recorded as disaggregate as possible, for instance, avoiding the storage of composite indicators but rather the variables used for their calculation.

In principle, SEIF should be able to perform internal and external feasibility checks. On one hand, the system should check whether the energy sector is able to supply the quantity and mix of energy carriers required by the urban area under analysis from the mix of available primary energy sources. On the other, the system should check whether the consumption side is able to perform a set of final energy uses from the mix of energy carriers delivered from the energy sector.

# 5 STRATEGIES FOR IMPACT VERIFICATION

This section defines the procedure that we will adopt to verify the impact of the integrated tools and associated methodologies. In previous section we have identified the challenges for an energy efficient urban planning when we deal with urban elements operating at multiple scales. We have also defined the methodological strategies necessary to deal with those identified challenges. In other words, we have framed the integrated tools and associated methodologies according to what is expected from the epistemological and methodological point of view. In this way, we intend to make sure that the outcomes of the integrate tools are reliable and produce positive impacts during the implementation of the demonstration scenarios.

However, the evaluation of the impact of the implementation process also depends on what is expected from the users and expert domains. The impact of the implementation process depends on whether the SEMANCO tools fulfil the users' expected functionalities and whether the issues to be demonstrated (defined in D8.1) are met.

Therefore, this section is intended to match the expected features defined from the epistemological and methodological point of view with those features envisaged by the users and expert domains in order to define the strategies for impact verification.

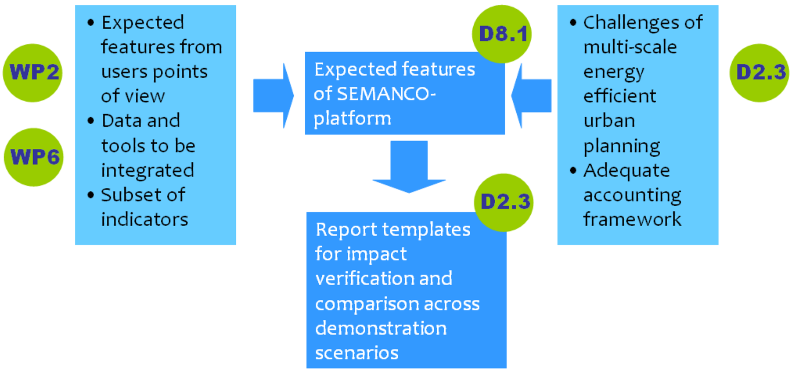


*Figure 11. integration of expected features of the SEMANCO platform from the methodological perspective and from the point of view of the users and experts domain*

Also, as mentioned in the Annex I- *Description of Work*, the objective of SEMANCO is to develop a platform able to integrate data, tools and users in order to support the reduction of $CO_2$ emissions in the urban planning domain. Therefore, the main impact to be verified is the ability of the integrated tools developed by SEMANCO to support $CO_2$ emissions reduction in the demonstration scenarios.

Therefore, the following sections define a set of questions, which sets the basis to develop intermediate report templates.

## 5.1 Methodological requirements

The following table presents the relationship between identified challenges for energy efficient urban planning, the strategies defined in this deliverable to deal with those challenges and the questions to develop the intermediate report templates.

*Table 3. Challenges and strategies for energy efficient urban planning, and question to verify the impact of the SEMANCO's integrated tools and methods*

| ***Challenges*** | ***Strategies*** | ***Questions*** |
|---|---|---|
| In complex hierarchical systems there is a complex network of relations between the elements operating simultaneously at different levels. Those elements are very interrelated and there are high degrees of interdependence (i.e. vertical and horizontal coupling between the elements of the hierarchy) | ▪ Evaluation of the performance of the urban area at different scales; e.g. micro, meso, macro | ▪ Is the system able to calculate extensive indicators at different levels?<br>○ Is the system able to aggregate data from lower level elements to obtain indicators of higher level elements?<br>○ Is the system able to disaggregate data from higher level elements to obtain indicators of lower level elements?<br>▪ Is the system able to calculate intensive indicators across levels?<br>▪ Have you been able to identify lower level elements with poor energy performance?<br>▪ Has the system provided an adequate land use classification?<br>▪ Are the nested categories of land uses coherent?<br>▪ Have you been able to group irrelevant land use categories as "other"? |
| | ▪ To assess the feasibility of the evaluated alternatives. In other words, we need to assess the requirements of other sectors in order to face the consequences of the analyzed urban plan. | ▪ Is the system able to check ability of the energy sector to supply the quantity and mix of energy carriers required by the urban area under analysis from the mix of available primary energy sources?<br>▪ Is the system able to check the ability of the consumption side to perform a set of final energy uses from the mix of energy carriers delivered from the energy sector? |
| Complex systems are those characterized by presenting multiple identities at multiple scales, which are subject to non-equivalent descriptions. The existence of multiple scales entails the need to use non-equivalent descriptive domains when perceiving and representing the system | ▪ To use a multi-dimensional set of performance indicators | ▪ Are the relevant dimensions (i.e. flows) considered within the set of indicators? |
| Complex systems present emergent properties across scales. That is, there are some attributes possessed by the elements of the system but not by the system as a whole, and vice versa. In other words, some performance indicators would be relevant at one scale, but not at other levels. | ▪ To use an adequate accounting framework allowing us to up- and down-scale indicators across hierarchical levels | ▪ Have you been able to redefine the set of indicators?<br>▪ Are there some indicators that are irrelevant at specific scales? Are you able to remove them from the analysis?<br>▪ When aggregating extensive indicators, is the system able to provide an indication of how the variable is distributed amongst the lower level elements? |
| Energy is a semantically open concept that needs an accounting framework able to provide coherent information across scales | ▪ To keep track of the series of energy transformations across scales. That is, to clearly differentiate energy carriers and primary energy sources across scales. | ▪ Is the system able to provide information on energy consumption differentiating between energy carriers and final energy uses? |

| ***Challenges*** | ***Strategies*** | ***Questions*** |
|---|---|---|
| The expected features of SEIF should meet a balance between providing detailed and relevant information according to the objectives of relevant stakeholders | ▪ To use different methods with different degree of accuracy in their calculations depending on the scale of analysis: Simplified methods at urban level, and more detailed calculations building level | ▪ Do the calculation methods at building level provide useful information, for instance, to know the energy performance of the building for certification or to identify hot spots of poor energy performance?<br>▪ Do the calculation methods at urban level provide useful in order to optimize the energy performance of an urban area, to observe trends of energy consumption or to identify hot spots of poor energy consumption?. |

## 5.2 Issues to be demonstrated: Expected features

In general terms, the implementation of use case 10 across countries is intended to meet the following requirements:

- To integrate data from different sources
- To visualise the urban environment and it characterisation according to socio-economic (e.g. income, origin, energy poverty) and biophysical (e.g. energy consumption) information.
- To visualise interrelations between urban and climatic elements. Specifically, to visualise shadows effects between urban elements (in order to support preliminary urban planning).
- To obtain (from different sources) the necessary data to perform energy simulations with the chosen methods in each demonstration scenario.
- To integrate methodologies in order to perform energy simulations at urban level (the case of Newcastle: SAP is not an urban model; it operates at building level. However, we can calculate shadows with other tools (e.g. 3D maps) in order to obtain shadows as input for SAP.

The following table presents the relationship between use case activities and issues to be demonstrated across demonstration scenarios, and also the questions to verify the impact of the SEMANCO's integrated tools and methods:

*Table 4. Issues to be demonstrated across demonstration scenarios and corresponding questions for impact verification*

<table>
<tr><th rowspan="2">Activities</th><th colspan="3">Issues to be demonstrated</th><th rowspan="2">Questions to verify the impact</th></tr>
<tr><th>Manresa</th><th>Newcastle</th><th>North Harbour</th></tr>
<tr><td>Creation of alternatives</td><td>▪ To create alternatives through the 3D maps</td><td>▪ To develop alternative renewable energy and energy efficiency alternatives</td><td>▪ To combine supply technology and energy performance levels, and benchmark them according to overall costs and CO2 reduction</td><td>▪ Has the system the ability to develop alternative scenarios of urban planning?<br>▪ Has the user interface facilitated the development and definition of alternative scenarios of urban planning?</td></tr>
<tr><td>Integration of socio-economic data and occupation parameters</td><td rowspan="3">▪ To integrate data from different sources<br>▪ To generate input variables for calculation methods (i.e. URSOS)<br>▪ To visualize interrelations between urban and climatic elements. Specifically, to visualize shadows effects between urban elements</td><td rowspan="3">▪ To integrate data from different sources<br>▪ To visualize socio-economic data in 3D maps<br>▪ To classify domestic buildings according to their SAP rating</td><td rowspan="3">▪ To integrate data from different sources</td><td rowspan="3">▪ Has the systems been able to integrated data from different sources?<br>▪ Is the system able to generate input files for external energy simulation models?<br>▪ Is the system able to provide a spreadsheet with the necessary information to feed an energy simulation model?<br>▪ Is the system able to visualize socio-economic data through 3D maps?<br>▪ Are the 3D maps containing socio-economic information ease to understand?<br>▪ Is the system able to classify buildings?<br>▪ Is the system able to visualize shadows? Is this visualization useful for a preliminary urban planning?</td></tr>
<tr><td>Integration of geometrical and climatic data of the urban environment</td></tr>
<tr><td>Integration of architectonic characteristics of the building(s) to be modelled.</td></tr>
<tr><td>Calculation of energy performance</td><td>▪ To calculate requirements of energy carriers according to final energy uses, for the different alternatives</td><td>▪ Calculation and analysis of energy performance of existing domestic buildings as existing and after application of energy efficiency and CO2 emissions saving measures.</td><td>▪ To calculate the building performance level via the simulation software IES.</td><td>▪ Is the system able to calculate energy performance differentiating energy carriers and final energy uses?<br>▪ Is the system able to provide sound/reliable outcomes?<br>▪ Are you able to identify hot spots of energy performance based on those outcomes?</td></tr>
<tr><td>Calculation of $CO_2$ emissions</td><td>▪ To calculate CO2 emissions according to final energy uses</td><td>▪ To calculate CO2 emissions according to established energy uses</td><td>▪ To calculate CO2 emissions according to final energy uses</td><td>▪ Is the system able to calculate CO2 emissions?<br>▪ Are the CO2 emissions in accordance to the expected values?<br>▪ Are you able to redefine the energy mix used to calculate CO2 emissions?</td></tr>
</table>

| ***Activities*** | ***Issues to be demonstrated*** | | | ***Questions to verify the impact*** |
|---|---|---|---|---|
| | ***Manresa*** | ***Newcastle*** | ***North Harbour*** | |
| Calculation of investment and maintenance costs | ▪ | ▪ To calculate the costs of alternative energy efficiency and renewable energy interventions | ▪ To calculate the investment and maintenance cost for each supply and demand measure. | ▪ Is the system able to calculate investment, operation and maintenance costs?<br>▪ Are those costs reliable?<br>▪ Are those values useful for urban planning? |

# 6 Conclusions

## 6.1 Contribution to overall picture

The main objective of Task 2.3 has been to provide strategies which will enable verifying the impact of the integrated tools and associated methodologies, which will be then applied in WP 8 in three yearly cycles. As such, it sets the basis for the constant evaluation and future technological development of the project.

In order to do so, it has been necessary to re-read and re-focus Task 2.3 on a more useful aspect of the project. In this sense, we thought that it is necessary to identify some of the consequences and challenges of the existence of multiple scales in the energy efficient urban planning domain. As a result, the document defines the strategies to deal with those challenges. In this way, we've been able to identify the requirements of the tools from the epistemological and methodological perspectives.

If we want to verify the impact of the integrated tools, we should primarily assure that the outcomes produced are reliable for the end user, that the outcomes of the integrated tools and associated methodologies don't mislead the analysis of the energy performance and $CO_2$ emissions of an urban area. That's why it is important to identify a set of features required by the theoretical perspective. In practical terms, this document identifies some challenges of energy efficient urban planning from a multi-scale perspective. Then, it proposes an accounting framework for the integrated tools and associated methodologies to be coherent across scales. In this way, we identify the methodological requirements necessary to produce reliable information. In other words, we can say that Task 2.3 is monitoring Task 2.2, since the set of multidimensional performance indicators presented in D2.2 should meet some of requirements presented here (D2.3).

This information has been complemented with that coming from D8.1, which defines the issues to be demonstrated from the point of view of the potential users and expert domains. Once we indentify the methodological requirements and the expected features of the SEMANCO's integrated tools and associated methodologies, we develop a set of questions to verify the impact of the tools in the first implementation round.

## 6.2 Impact on other WPs and Tasks

Overall, Task 2.3 provides valuable information to continue with the planned activities in the other WPs. It sets the basis for the development of the set of performance indicators (T2.2) and it defines the methods to evaluate the impact of the integrated tools during the implementation process (T8.1).

The feedbacks from the impact verification strategy (i.e. the information to be contained by the report templates) will be of fundamental importance for the technological development of the integrated tools and associated methodologies (WP5). This information will enable the SEMANCO's team to develop adequate and relevant tools to meet the requirements of the potential users.

Moreover, D2.3 has defined a set of preliminary requirements for the SEIF, which entails several issues to be addresses in the technological development of the project (WP4 and WP5). Regarding the use of land use categories, SEIF should be able to perform the following tasks:

- To do a preliminary classification of land uses in the urban area under analysis.
- To allow the user to (partially) tailor the land use classification according to the relevant

categories in his/her context.

- To aggregate and disaggregate the calculated extensive variables across scales and according to the land use categories defined in the previous steps.
- To calculate intensive indicators (per unit of square meters – $m^2$) across scales and according to the land use categories defined in the previous steps

Regarding the development of indicators at different scales, the SEMANCO platform should provide the possibility of defining indicators *à la carte*, enabling the users and experts domain to redefine indicators according to the context. Also, it should provide indicators describing the relationships between lower level elements when aggregating data to obtain the performance of higher level elements

Regarding the viability and feasibility of future scenarios of urban planning, the document states that it is necessary to explore the possibilities of developing a tool to perform a "Sudoku effect" analysis (Giampietro et al., 2009) between consumption and production of energy supply. In principle, SEIF should be able to perform external and internal feasibility checks: whether the energy sector is able to supply the quantity and mix of energy carriers required by the urban area under analysis from the mix of available primary energy sources, and whether the consumption side is able to perform a set of final energy uses from the mix of energy carriers delivered from the energy sector.

Also, it is of fundamental importance that the tools developed within the SEMANCO platform are able to keep track of the energy flows across scales differentiating between energy carries and primary energy sources (See Figure 4).

## 6.3 Contribution to demonstration

As mentioned in the DoW, the framework and tools developed by SEMANCO will be used within each case study to demonstrate quantifiable and significant reductions in energy consumption and $CO_2$ emissions, achieved by means of application of the ICTs developed by SEMANCO.

Within the demonstration and validation process, the Semantic Energy Information Framework (SEIF) is expected to support the following tasks:

*Table 5. Contribution of D2.3 to the demonstration phases*

| ***Tasks in the demonstration phases*** | ***Contribution of Deliverable 2.3*** |
|---|---|
| The automated identification and classification of buildings for energy analysis within a geographic area | Not applicable |
| The identification and visualisation of 'energy use hot spots' to support the effective targeting of urban energy efficiency and renewable energy interventions | It proposes an accounting framework able to track the different forms of energy flows and to calculate adequate performance indicators in order to identify 'energy use hot spots' |
| Assessment of the potential of different technical and social interventions and strategies to reduce $CO_2$ emissions at different geographic scales; | Recognition of the complexities and challenges entailed by the definition of the analytical scales.<br>It proposes an accounting framework able to perform energy related assessments across scales and dimensions. |
| Optimisation or trade-offs between conflicting social, economic, political and environmental constraints within planning and design practice to support stakeholder decision making; | Provides the theoretical framework and the accounting framework to perform multi dimensional evaluation of urban planning |
| Extracting guidelines to apply to other areas and | Provides the theoretical framework and the accounting |

| | |
|---|---|
| projects, providing planning authorities (local, national and European) with appropriate indicators for monitoring and reporting that can be used to establish future planning strategies; | framework to perform multi dimensional evaluation of urban planning |
| Predicting future demand following demographic and economic changes by identifying patterns of growth and sustainable urban developments which reduce energy consumption | Provides an accounting framework that enables the analyst to produce reference values or external references to judge the metabolic pattern of urban environments.<br>It also provides the strategies to assess the viability and feasibility of future scenarios based on demographic or socio-economic changes. |

In summary, D2.3 offers the theoretical basis against which the expected impact of the integrated tools and associated methodologies will be verified.

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# Appendix A. International Standard Industrial Classification of all Economic Activities (ISIC-Rev.3)[14]

*Table A1. Main categories of all economic activities*

| Sector | Main categories |
|---|---|
| Agriculture and fishing | A- Agriculture, hunting and forestry |
| | B- Fishing |
| Industry, building and manufacture | C- Mining and quarrying |
| | D- Manufacturing |
| | E- Electricity, gas and water supply |
| | F- Construction |
| Service and government | G- Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods |
| | H- Hotels and restaurants |
| | I- Transport, storage and communications |
| | J- Financial intermediation |
| | K- Real estate, renting and business activities |
| | L- Public administration and defence; compulsory social security |
| | M- Education |
| | N- Health and social work |
| | O- Other community, social and personal service activities |
| | P- Private households with employed persons |
| | Q- Extra-territorial organizations and bodies |

*Table A2 Sub-categories of all economic activities*

| Main category | Sub-categories |
|---|---|
| A- Agriculture, hunting and forestry | 01- Agriculture, hunting and related service activities<br>02- Forestry, logging and related service activities |
| B- Fishing | 05- Fishing, operation of fish hatcheries and fish farms; service activities incidental to fishing |
| C- Mining and quarrying | 10- Mining of coal and lignite; extraction of peat<br>11- Extraction of crude petroleum and natural gas; service activities incidental to oil and gas extraction excluding surveying<br>12- Mining of uranium and thorium ores<br>13- Mining of metal ores<br>14- Other mining and quarrying |

[14] For full details see United Nations: Statistical papers, Series M, No. 4/Rev.3 (New York, 1990)

| Main category | Sub-categories |
|---|---|
| D- Manufacturing | 15- Manufacture of food products and beverages<br>16- Manufacture of tobacco products<br>17- Manufacture of textiles<br>18- Manufacture of wearing apparel; dressing and dyeing of fur<br>19- Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear<br>20- Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials<br>21- Manufacture of paper and paper products<br>22- Publishing, printing and reproduction of recorded media<br>23- Manufacture of coke, refined petroleum products and nuclear fuel<br>24- Manufacture of chemicals and chemical products<br>25- Manufacture of rubber and plastics products<br>26- Manufacture of other non-metallic mineral products<br>27- Manufacture of basic metals<br>28- Manufacture of fabricated metal products, except machinery and equipment<br>29- Manufacture of machinery and equipment n.e.c.<br>30- Manufacture of office, accounting and computing machinery<br>31- Manufacture of electrical machinery and apparatus n.e.c.<br>32- Manufacture of radio, television and communication equipment and apparatus<br>33- Manufacture of medical, precision and optical instruments, watches and clocks<br>34- Manufacture of motor vehicles, trailers and semi-trailers<br>35- Manufacture of other transport equipment<br>36- Manufacture of furniture; manufacturing n.e.c.<br>37- Recycling |
| E- Electricity, gas and water supply | 40- Electricity, gas, steam and hot water supply<br>41- Collection, purification and distribution of water |
| F- Construction | 45- Construction |
| G- Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods | 50- Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel<br>51- Wholesale trade and commission trade, except of motor vehicles and motorcycles<br>52- Retail trade, except of motor vehicles and motorcycles; repair of personal and household goods |
| H- Hotels and restaurants | 55- Hotels and restaurants |
| I- Transport, storage and communications | 60- Land transport; transport via pipelines<br>61- Water transport<br>62- Air transport<br>63- Supporting and auxiliary transport activities; activities of travel agencies<br>64- Post and telecommunications |
| J- Financial intermediation | 65- Financial intermediation, except insurance and pension funding<br>66- Insurance and pension funding, except compulsory social security<br>67- Activities auxiliary to financial intermediation |
| K- Real estate, renting and business activities | 70- Real estate activities<br>71- Renting of machinery and equipment without operator and of personal and household goods<br>72- Computer and related activities |

| **Main category** | **Sub-categories** |
|---|---|
| | 73- Research and development<br>74- Other business activities |
| L- Public administration and defence; compulsory social security | 75- Public administration and defence; compulsory social security |
| M- Education | 80- Education |
| N- Health and social work | 85- Health and social work |
| O- Other community, social and personal service activities | 90- Sewage and refuse disposal, sanitation and similar activities<br>91- Activities of membership organizations n.e.c.<br>92- Recreational, cultural and sporting activities<br>93- Other service activities |
| P- Private households with employed persons | 95- Private households with employed persons |
| Q- Extra-territorial organizations and bodies | 99- Extra-territorial organizations and bodies |

# Appendix B. TIME USE SURVEYS.

*Table B1. Main activity codes of the of the Harmonised European Time Use Survey*

| Code | Activity categories | Original HETUS codes | Inconsistensies/national deviations |
|---|---|---|---|
| | | **See the sheet: HETUS main activity codes** | |
| **1 - 3** | **Personal care total** | **000 – 039** | |
| 1 | Sleep | 01 | In France, long time periods spent on rest were coded as sleep, whereas in the other countries rest is included in free time. |
| 2 | Eating | 02 | |
| 3 | Other personal care | 000, 03 | |
| **4 - 5** | **Employment total** | **100 – 139, 911, 912** | In Germany, short breaks during working hours have been excluded, resulting in a reduction of approximately 30 annual working hours. In France, the survey was carried out in 1998, before working hours were reduced to 35 hours per week. |
| 4 | Main and second job | 11, 12, 911, 912 | |
| 5 | Activities related to employment | 100, 13 | Norway: Having lunch included here |
| **6 - 8** | **Study total** | **200 – 221** | |
| 6 | School and university | 210-211, 219, 200 | |
| 7 | Homework | 212 | |
| 8 | Freetime study | 22 | Except for Norway where it is included in unspecified leisure, code 41 |
| | | | |
| **9 - 24** | **Domestic total** | **300 – 391** | |
| 9 | Food preparation | 310, 311, 312, 314, 319 | |
| 10 | Dish washing | 313 | |
| 11 | Cleaning dwelling | 321 | France: HETUS code 322, cleaning yard included here |
| 12 | Other household upkeep | 320,322-329 | Norway: HETUS codes 320 in 300, 322 in 341, 324 not used, 329 in 311 |
| 13 | Laundry | 331 | |
| 14 | Ironing | 332 | |
| 15 | Handicraft | 330, 333, 339 | |
| 16 | Gardening | 340, 341, 349 | Except for Norway, where HETUS code 341 includes 322 |
| 17 | Tending domestic animals | 342 | Except for Belgium, Finland and Norway, the HETUS code not used. |
| 18 | Caring for pets | 343 | In France HETUS code 344 walking the dog incl. here |
| 19 | Walking the dog | 344 | In France HETUS code 344 included in 343 pet care |
| 20 | Construction and repairs | 35 | |
| 21 | Shopping and services | 36 | |
| 22 | Physical care and supervision of child | 380-381, 384, 389 | |
| 23 | Teaching, reading and talking with child | 382, 383 | |
| 24 | Other domestic work | 300, 37, 39 | Norway: HETUS codes 319, 320 included here |
| **25 - 41** | **Leisure total** | **400 – 832, 998** | |
| 25 | Organisational work | 41 | |
| 26 | Informal help to other households | 42 | Except for Belgium, the HETUS code not used, included in domestic work |
| 27 | Participatory activities | 400, 43 | |
| 28 | Visits and feasts | 512, 513 | Socialising, i.e. 'Visits and feasts' and 'Other social life' is not comparable between Norway and the other countries because reporting conversation as main activity in the diary - here included in 'Other social life' - was encouraged only in the Norwegian diary instructions. In Estonia Feasts are included in Other social life |

| Code | Activity categories | Original HETUS codes | Inconsistensies/national deviations |
|---|---|---|---|
| 29 | Other social life | 510, 511, 514, 519 | |
| 30 | Entertainment and culture | 52 | |
| 31 | Resting | 53 | In France a long time period spent on rest was coded as sleep. |
| 32 | Walking and hiking | 611 | |
| 33 | Other sports and outdoor activities | 600, 610, 612-619, 62-63 | |
| 34 | Computer and video games | 733 | Except for France, the HETUS code not used. |
| 35 | Other computing | 722-725 | |
| 36 | Other hobbies and games | 71, 720, 721,726, 729, 730-732, 734, 739 | |
| 37 | Reading books | 812 | France: in other reading. |
| 38 | Other reading | 810, 811, 819 | |
| 39 | TV and video | 82 | |
| 40 | Radio and music | 83 | |
| 41 | Unspecified leisure | 500, 700, 800, 998 | Except for Finland and UK (HETUS code 998 not used); Norway: free time study included here |
| **42-48** | **Travel total** | **900, 901, 913—982** | Germany and UK: Journeys were coded without a turning point. |
| 42 | Travel to/from work | 913 | |
| 43 | Travel related to study | 921, 922 | In Belgium 'Travel related to school, university' for students only. "Travel related to free time study' included in Norway in 'Travel related to leisure', in Belgium and France in 'Unspecified travel' |
| 44 | Travel related to shopping | 936 | France: in HETUS code 900 |
| 45 | Transporting a child | 938 | In UK also transporting an adult to education |
| 46 | Travel related to other domestic | 931, 939 | France: in HETUS code 900, Belgium: the HETUS code not used |
| 47 | Travel related to leisure | 941-943, 951, 952, 961, 971, 981, 982 | France: in HETUS code 900 |
| 48 | Unspecified travel | 900, 901 | France: includes some travel related to domestic work and free time, Norway: the HETUS code not used. |
| **49** | **Unspecified time use** | 995, 999 | |
| **1-49** | **Total main activity** | | |

# Appendix C. LAND BASED CLASSIFICATION STANDARDS

**Land-Based Classification Standards** 01-Apr-2001

## LBCS Color Codes for 1-Digit Level Coding

## Activity

| Red, Green, Blue Values | Color* | LBCS Code | |
|---|---|---|---|
| RGB(255,255,0)<br>RGBHex(FF00FF) | yellow | 1000 | Residential activities |
| RGB(255,0,0)<br>RGBHex(FF0000) | red | 2000 | Shopping, business, or trade activities |
| RGB(160,32,240)<br>RGBHex(A0F020) | purple | 3000 | Industrial, manufacturing, and waste-related activities |
| RGB(0,0,255)<br>RGBHex(00FF00) | blue | 4000 | Social, institutional, or infrastructure-related activities |
| RGB(190,190,190)<br>RGBHex(BEBEBE) | gray | 5000 | Travel or movement activities |
| RGB(47,79,79)<br>RGBHex(2F4F4F) | dark slate gray | 6000 | Mass assembly of people |
| RGB(144,238,144)<br>RGBHex(9090EE) | light green | 7000 | Leisure activities |
| RGB(34,139,34)<br>RGBHex(22228B) | forest green | 8000 | Natural resources-related activities |
| RGB(255,255,255)<br>RGBHex(FFFFFF) | white | 9000 | No human activity or unclassifiable activity |

*Specify the RGB (red, green, blue) values, instead of relying on color names, for consistent reproduction of colors on a printer, plotter, or computer screen. Using RGB values can sometimes avoid differences in how software and hardware render colors. Some colors, no matter what, differ how they look on screen from their printed version. Also, if you are reviewing this document on a computer screen, note that some software (web browsers, for example) limit the number of colors displayed. If your software can only accept hexadecimal values, as many GIS and plotting software do, then use the corresponding RGBHex value. For CMYK values and other color coding details, check the LBCS website.

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*Table C1. Land-based classification standards*

| Code | Main activity | Second level activity | Third level activity | Fourth level activity | Description | Color |
|---|---|---|---|---|---|---|
| 1000 | Residential activities | | | | Includes activities that occur in all types of residential uses, structures, ownership characteristics, or the character of the development. | #FFFF00 |
| 1100 | | Household activities | | | Includes those activities normally associated with single-family, multifamily, town homes, manufactured homes, etc. | |
| 1200 | | Transient living | | | Activities associated with hotels, motels, tourist homes, bed and breakfast, etc. Note that the distinction between various residential activities is independent of the definition of a family. | |
| 1300 | | Institutional living | | | Residential living activity associated with dormitories, group homes, barracks, retirement homes, etc. These activities may occur in any number of structural types (single-family homes, multi-family homes, manufactured homes, etc.), but the activity characteristics of such living is not the same as the other subcategories under residential activities. Also note that the distinction between various residential activities is independent of the definition of a family. | |
| 2000 | Shopping, business, or trade activities | | | | This category captures all uses that are business related. Use it as a catch-all category for all retail, office, commercial, and industrial activities when the subcategories are either too specific or otherwise unknown (as in comprehensive plan designations). | #FF0000 |

| Code | Main activity | Second level activity | Third level activity | Fourth level activity | Description | Color |
|---|---|---|---|---|---|---|
| 2100 | | Shopping | | | Primarily for all retail shops and stores. If the shop sells both goods and services, or if it is not clear which of the two more detailed categories to assign, then use this one. Increasingly, distinguishing between a store (that sells goods) and shop (that sells service) will become difficult and for many planning-related applications even irrelevant. Even economic applications that employed such distinctions are reconsidering because of the difficulty in distinguishing between goods and services. However, for those planning applications that require this distinction, or for existing land-use data sets that already employ such distinctions, apply the subcategories. Otherwise, for routine land-use data classification, apply the Shopping category only. | |
| 2110 | | | Goods-oriented shopping | | Activities in stores that trade retail goods. The distinction is in the physical attributes of activities associated with goods (buying, selling, repairing, etc.) and not the type of goods. | |
| 2120 | | | Service-oriented shopping | | Those shops that primarily sell services on site. The distinction is in the physical attributes of activities associated with services, such as hairdressing. Business services, such as accounting, legal services, advertising, etc., belong in the office category. | |
| 2200 | | Restaurant-type activity | | | Eating, dining, and such activities associated with restaurants and other establishments that serve food, drink, and related products that may have seating but has drive-through facilities. Such activities, although commonly associated with fast-food restaurants, may also occur at restaurants and food establishments that do not serve fast food. | |
| 2210 | | Restaurant-type activity with drive-through | | | | |
| 2300 | | Office activities | | | Typical office uses should be categorized here including those that are primarily office-use in character. Use this category as a catch-all designation for all office-type uses. | |

| Code | Main activity | Second level activity | Third level activity | Fourth level activity | Description | Color |
|---|---|---|---|---|---|---|
| 2310 | | | Office activities with high turnover of people | | Especially those that have counters for customer service, or waiting areas for customers or visitors. Use this category to indicate an activity characterized by a steady stream of people when such activity is part of normal operations of the office use. | |
| 2320 | | | Office activities with high turnover of automobiles | | Typically associated with drive-through windows at banks, department of motor vehicles, and other businesses. Traditionally, these activities were associated with banks, post offices, and financial institutions, but they may also occur at other kinds of establishments. | |
| 3000 | Industrial, manufacturing, and waste-related activities | | | | All manufacturing, assembly, warehouse, and waste management activities. Use this as a catch-all category for anything not specified in subcategories below. | #A020F0 |
| 3100 | | Plant, factory, or heavy goods storage or handling activities | | | All industrial activities. Use this as a catch-all category for anything not specified in subcategories below. | |
| 3110 | | Solid waste management activities | Primarily plant or factory-type activities | | Assembly plants, manufacturing facilities, industrial machinery, etc. | |
| 3120 | | | Primarily goods storage or handling activities | | Characterized by loading and unloading goods at warehouses, large storage structures, movement of goods, shipping, and trucking. Includes self-storage activities. | |
| 3200 | | | | | Includes storing, collecting, dumping, waste processing, and other related operations. | |
| 3210 | | | Solid waste collection and storage | | Solid waste activities at source or intermediate locations, such as recycling centers. Use this category for large sites that have their own recycling areas where solid waste is separated or pre-treated. Solid waste includes demolition waste, street sweepings, sewage sludge, industrial solids and sludges, agricultural manure, and crop wastes. The term garbage refers to food waste portion of solid waste and refuse or trash refer to mixed solid wastes. This category also includes activities associated with recycling (or refuse reclamation) and other related operations with land filling. | |

| Code | Main activity | Second level activity | Third level activity | Fourth level activity | Description | Color |
|---|---|---|---|---|---|---|
| 3220 | | | Land filling or dumping | | Activities that typically occur at landfills and resource recovery facilities. Also useful to mark those areas not necessarily identified as landfills, but used as dumps. The term sanitary landfill is sometimes used to differentiate public landfills from others. | |
| 3230 | | | Waste processing or recycling | | Activities normally associated with incinerators, recycling facilities, resource recovery facilities, etc. | |
| 3300 | | Construction activities (grading, digging, etc.) | | | During the construction stage of a development, especially if it is a large-scale one and is a multiyear project, the characteristics of the use is quite different from what it may eventually become. When local plans need to track such activities, use this category. Once completed, the activity code should reflect its actual use. | |
| 4000 | Social, institutional, or infrastructure-related activities | | | | Use this category for all institutional activities. This broad category may also be used for land-use designations in comprehensive and general plans. | #0000FF |
| 4100 | | School or library activities | | | Mainly those associated with educational, instructional, or teaching activities. Administrative functions, especially those where school board or administrative offices are located, should be assigned office categories.<br>Likewise, sports, school-bus parking, or maintenance activities should be assigned appropriate categories. But if the data being classified is generalizing over large areas, then use this category | |
| 4110 | | | Classroom-type activities | | Those that occur in school buildings, lecture rooms, etc. This category may include other related activities only if the data is being generalized and the predominant activities are classroom-type instructions. | |
| 4120 | | | Training or instructional activities outside classrooms | | Driving, flying, or other instructional activities that occur outside a typical school building. | |
| 4130 | | | Other instructional activities including those that occur in libraries | | Include all other instructional activities here. | |

| Code | Main activity | Second level activity | Third level activity | Fourth level activity | Description | Color |
|---|---|---|---|---|---|---|
| 4200 | | Emergency response or public-safety-related activities | | | Broad category to group all fire, police, rescue, EMS, and other public safety activities. Use this category for joint or co-located facilities if the application needs a single activity code. | |
| 4210 | | | Fire and rescue-related activities | | The classic example is a fire station with fire trucks in standard bays with associated training, resting, office, and equipment storing activities on the site. Use this category for sites that do not necessarily look like a fire station, but serve the same purpose (e.g., on-site fire and rescue stations for large-scale developments). | |
| 4220 | | | Police, security, and protection-related activities | | Policing and police-related activities that typically occur in a police station. It also includes community policing centers located in neighbourhoods, which may occupy store-front locations. | |
| 4230 | | | Emergency or disaster-response-related activities | | Many look like a typical office building but are distinct in the operations in them. Often they have the 911 emergency centre, disaster coordination facilities, and essential communication facilities for disaster recovery and response. Note that this category is not for coding schools and other community facilities used in disaster recovery operations. | |
| 4300 | | Activities associated with utilities (water, sewer, power, etc.) | | | Group all utilities: water, sewer, power, gas, etc. | |
| 4310 | | | Water-supply-related activities | | Category for water supply-related, including irrigation-related activities. Use this category for any activity associated with water supply. | |
| 4311 | | | | Water storing, pumping, or piping | Activities primarily associated with linear features, such as pipelines, water channels, etc., located in easements and point features, such as air vents, pumping stations, piping junctions, etc., that may or may not be located in easements. | |
| 4312 | | | | Water purification and filtration activities | Associated with large-scale plants, many of which appear industrial in character. This category should also include all the related activities associated with a water purification and filtration facility, such as water storage, water pumping, etc. | |

| Code | Main activity | Second level activity | Third level activity | Fourth level activity | Description | Color |
|---|---|---|---|---|---|---|
| 4313 | | | | Irrigation water storage and distribution activities | This category includes activities associated with urban and rural water distribution systems. Although not as common as the water purification plants, these activities are commonly associated with wells and reservoirs for water supply. | |
| 4314 | | | | Flood control, dams, and other large irrigation activities | Associated with dams, reservoirs, and other large-scale storage and distribution of water. Primarily industrial in character, many such sites also host other activities, such as sightseeing, power generation, leisure activities, environmental monitoring, etc. | |
| 4320 | | | Sewer-related control, monitor, or distribution activities | | This activity is characterized by sewer-related activities, such as pumping, piping, storing, treating, filtering, etc., whether urban or rural, private or public. Use this category for any activity associated with sewers. | |
| 4321 | | | | Sewage storing, pumping, or piping | Activities primarily associated with linear features, such as pipelines, channels, etc., located in easements and point features, such as air vents, pumping stations, piping junctions, etc., that may or may not be in | |
| 4322 | | | | Sewer treatment and processing | Associated with sewer treatment plants, many of which appear industrial in character. This category also includes related activities associated with a sewer treatment and processing facility, such as storage, pumping, etc. | |
| 4330 | | | Power generation, control, monitor, or distribution activities | | This activity is characterized by electrical power generation, control facilities, distribution centers, etc. Use this category for any activity associated with power supply and distribution. | |
| 4331 | | | | Power transmission lines or control activities | Activities primarily associated with linear features, such as transmission lines, conduits, etc., located in easements and point features, such as air vents, pumping stations, piping junctions, etc., that may or may not be in | |
| 4332 | | | | Power generation, storage, or processing activities | Power generation, storage, or processing activities primarily associated with switching centers, transformer locations, and other power-related facilities that serve as storage or transit points in the distribution system. | |

| Code | Main activity | Second level activity | Third level activity | Fourth level activity | Description | Color |
|---|---|---|---|---|---|---|
| 4340 | | | Telecommunications-related control, monitor, or distribution activities | | Activities associated with telecommunications encompass communication tower facilities, antennae locations, repeater stations, and distribution centers. | |
| 4350 | | | Natural gas or fuels-related control, monitor, or distribution activities | | Activities associated with natural gas encompass production facilities, distribution lines, and control and monitor stations. | |
| 4400 | | Mass storage, inactive | | | Activities associated with large storage areas for water, fuels, waste, and other products where such storage is not associated with utilities. These facilities may be associated with a private or public establishment to serve functions not associated with utilities. | |
| 4410 | | | Water storage | | Not related to utilities, but may be related to an industrial or commercial enterprise. This may include tanks, tank farms, open storage, etc., above or below ground. | |
| 4420 | | | Storage of natural gas, fuels, etc. | | Not related to utilities, but may be related to an industrial or commercial enterprise. This may include tanks, tank farms, open storage, etc., above or below ground. | |
| 4430 | | | Storage of chemical, nuclear, or other materials | | Not related to utilities, but may be related to an industrial or commercial enterprise. This may include tanks, tank farms, open storage, etc., above or below ground. | |
| 4500 | | Health care, medical, or treatment activities | | | Activities in this category encompass those associated with clinics, hospitals, and other facilities that treat, house, or care for patients. | |
| 4600 | | Interment, cremation, or grave digging activities | | | This category encompasses activities associated with cemeteries, cremation facilities, funeral homes, and the like. | |
| 4700 | | Military base activities | | | Military bases are typically complex collection of activities that include a wide range of activities associated with military training, living and recreational facilities for military personnel, storage and maintenance facilities, and other related facilities. | |
| 4710 | | | Ordnance storage | | Activities primarily associated with storing and moving of military ordnance. | |

| Code | Main activity | Second level activity | Third level activity | Fourth level activity | Description | Color |
|---|---|---|---|---|---|---|
| 4720 | | | Range and test activities | | These activities encompass large areas for range and test activities of arms, ammunitions, war games, and related military activities. Although such activities are part of a military base, identifying this special category is useful for planning around bases for land-use compatibility. | |
| 5000 | Travel or movement activities | | | | This category encompasses activities associated with all modes of transportation. It includes rights-of-way and such linear features associated with transportation. | #BEBEBE |
| 5100 | | Pedestrian movement | | | Use this category for classifying pedestrian-only roads and open mall areas in | |
| | | | | | road rights-of-way. Although comprehensive plans may not depend on such distinctions, many site plans and urban designs use them for circulation components of their plans. | |
| 5200 | | Vehicular movement | | | This is a catch-all category for all forms of automobile movement on roads, parking areas, drive-through facilities, etc. Use the subcategories to further distinguish them. | |
| 5210 | | | Vehicular parking, storage, etc. | | Activities associated with parking or storing of automobiles. | |
| 5220 | | | Drive-in, drive through, stop-n-go, etc. | | Activities associated with serving customers in their automobiles from a fixed location, such as a drive-through window. Assign this code to those uses that have drive-through window facilities. This also includes activities associated with car washes and such where the customers drive through specialized facilities. | |
| 5400 | | Trains or other rail movement | | | Includes activities associated with movement of rails and other vehicles on railroads. It includes activities associated with rail maintenance, storage, and rights-of-way for railroads. | |
| 5410 | | | Rail maintenance, storage, or related activities | | Use this category for identifying rail maintenance and storage activities, which are industrial in character, from rail movement and railroad rights-of-way. This category also includes railroad switching activities. | |

| Code | Main activity | Second level activity | Third level activity | Fourth level activity | Description | Color |
|---|---|---|---|---|---|---|
| 5500 | | Sailing, boating, and other port, marine and water-based activities | | | This category includes activities associated with water and marine based travel, movement, and their related activities. Use the subcategories to distinguish areas of marine movement from marine storage activities. | |
| 5510 | | | Boat mooring, docking, or servicing | | Use this subcategory for activities associated with docks and marinas where boats and ships are anchored, moored, or serviced. | |
| 5520 | | | Port, ship-building, and related activities | | These activities include a complex collection of shipping, storing, repairing and other similar activities that are industrial in nature. Passenger terminals are not included in this category. | |
| 5600 | | Aircraft takeoff, landing, taxiing, and parking | | | These activities encompass all aspects of air travel and transportation that occur at ground facilities, such as airports, hangars, and similar facilities. Passenger terminals are not included in this category. | |
| 5700 | | Spacecraft launching and related activities | | | These activities include space vehicle control, storage, movement, and viewing areas. Although they appear similar to air transportation facilities, spacecraft related activities entail several other activities. | |
| 6000 | Mass assembly of people | | | | This is a catch-all category for activities associated with mass assembly of people for either transportation, spectator sports, entertainment, or other social and institutional reasons. Use the subcategories to further classify the type of mass assembly. | #2F4F4F |
| 6100 | | Passenger assembly | | | This category is for activities primarily associated with bus, train, and airport terminals. | |
| 6200 | | Spectator sports assembly | | | Spectator sports assembly may occur in stadiums, open grounds, or other venues occasionally used for such purposes. Identifying such activities may be required for public safety related applications. | |
| 6300 | | Movies, concerts, or entertainment shows | | | Besides performance viewing, this category also includes related activities associated with such performances: food and souvenir vending, purchasing tickets, and related activities. This category also includes mass assembly at theatres and planetariums. | |

| Code | Main activity | Second level activity | Third level activity | Fourth level activity | Description | Color |
|---|---|---|---|---|---|---|
| 6400 | | Gatherings at fairs and exhibitions | | | Mass assembly of people at fairs and exhibitions includes activities associated with food and souvenir vending, purchasing tickets, and related activities. This category also includes activities associated with entertainment shows, park rides, etc., at fairs. | |
| 6500 | | Mass training, drills, etc. | | | Includes activities in parade grounds and drill fields associated with institutions. | |
| 6600 | | Social, cultural, or religious assembly | | | Use this category for mass assembly of people for social (eg., city hall), cultural (eg., parades), or religious (eg. churches) purposes. It also includes large outdoor ceremonies for religious, cultural, or other purposes. Although such activities may occur infrequently and may not involve any functional or structural characteristics (for example a spontaneous gathering that occurs on an annual basis on a hilltop), identifying where mass assembling of people occurs is essential for many planning applications. Use this category to capture such use information. Often this may mean assigning a mass assembly category to areas that already have other activity categories assigned. Apply this category when other more specific mass assembly categories are inappropriate. | |
| 6700 | | Gatherings at galleries, museums, aquariums, zoological parks, etc. | | | Public assembly gatherings at galleries, museums, aquariums, zoological parks, and similar exhibition services are characterized by a steady stream of people as opposed to mass congregation of viewers at movie theatres and such. Although the distinction may not be significant, certain public assembly activities require this information separate from other kinds of gatherings in planning for public safety. | |
| 6800 | | Historical or cultural celebrations, parades, re-enactments, etc. | | | These are usually annual gatherings, parades, and cultural celebrations that may involve shows, amusement park-like assembly of people, and selling food, drink and souvenirs. | |

| Code | Main activity | Second level activity | Third level activity | Fourth level activity | Description | Color |
|---|---|---|---|---|---|---|
| 7000 | Leisure activities | | | | This is a catch-all category for classifying all forms of leisure activities. It includes the customary active and passive kinds of leisure activities although such distinctions are difficult to define. Although LBCS provides active and passive subcategories, for new data classification purposes either apply this category (for top level coding) or identify the precise nature of activities (which are at the third-level coding). | #90EE90 |
| 7100 | | Active leisure sports and related activities | | | This category refers to an arbitrary second-level coding to accommodate existing data classified as either active or passive leisure activities. Although the distinction between active and passive are difficult to separate, use this category only if more precise lower-level categories are combined in existing data. For new data classification purposes either apply this category (for top level coding) or identify the precise nature of activities (which are at the third-level coding). | |
| 7110 | | | Running, jogging, bicycling, aerobics, exercising, etc. | | Although these activities are normally associated with bike paths, jogging trails, sidewalks, and such facilities, they also include the kinds that happen on athletic tracks and playgrounds. Exercising and aerobic activities include those that take place in health clubs and gymnasiums besides outdoor facilities. | |
| 7120 | | | Equestrian sporting activities | | This category is for all equestrian-related leisure activities including riding, mounting, horsemanship, and equestrian games, such as polo, hurdles, dressage training and show jumping. The related categories include those incidental to maintaining stables, feeding, caring, and housing horses. | |
| 7130 | | | Hockey, ice skating, etc. | | This is a broad category to include activities normally associated with ice rinks and skating on ice. Hockey and other sports on ice are also included in this category. | |
| 7140 | | | Skiing, snowboarding, etc. | | This is a broad category that includes leisure sport activities on snow: skiing, luge, bobsled, toboggan. | |

| Code | Main activity | Second level activity | Third level activity | Fourth level activity | Description | Color |
|---|---|---|---|---|---|---|
| 7150 | | | Automobile and motorbike racing | | This is a broad category to include the myriad forms of vehicular sports including automobile racing, dirt racing, motorcycle racing, and other cross-country type events. | |
| 7160 | | | Golf | | Includes other leisure activities, such as pall-mall, tipcart, croquet, golf, curling, and pall one besides golf. | |
| 7180 | | | Tennis | | Because of its unique site development characteristic, traditionally lawn tennis (as opposed to table tennis) has been classified distinct from other sporting activities. It also includes related sports, such as racquet ball. | |
| 7190 | | | Track and field, team sports (baseball, basketball, etc.), or other sports | | This includes activities associated with playing baseball, basketball, and other related games. | |
| 7200 | | Passive leisure activity | | | This category refers to an arbitrary second-level coding to accommodate existing data classified as either active or passive leisure activities. Although the distinction between active and passive are difficult to separate, use this category only if more precise lower-level categories are combined in existing data. For new data classification purposes either apply this category (for top level coding) or identify the precise nature of activities (which are at the third-level coding). | |
| 7210 | | | Camping | | Camping is a broad category that includes parts of activities associated with of shelter, recreation, and other related activities, such as hunting, fishing, sailing, etc. The designation applies to only those camping areas and camp grounds where camps are allowed. | |
| 7220 | | | Gambling | | Casinos normally host gambling, wagering, and those establishments that serve the gaming aspects of leisure activities. However, many other types of establishments also provide slot machines, and other gambling and gaming facilities (shopping centers in Las Vegas, for instance). | |
| 7230 | | | Hunting | | Hunting activities include live and also clay pigeon and skeet shooting. | |

| Code | Main activity | Second level activity | Third level activity | Fourth level activity | Description | Color |
|---|---|---|---|---|---|---|
| 7240 | | | Promenading and other activities in parks | | This is a catch-all category for all other areas of parks and recreational areas that do not qualify under any of the other more specific categories. | |
| 7250 | | | Shooting | | | |
| 7260 | | | Trapping | | | |
| 7300 | | Flying or air-related sports | | | | |
| 7400 | | Water sports and related leisure activities | | | | |
| 7410 | | | Boating, sailing, etc. | | | |
| 7420 | | | Canoeing, kayaking, etc. | | | |
| 7430 | | | Swimming, diving, etc. | | Includes activities associated with lifeguard services and other related activities. | |
| 7440 | | | Fishing, angling, etc. | | | |
| 7450 | | | Scuba diving, snorkeling, etc. | | | |
| 7460 | | | Water-skiing | | | |
| 8000 | Natural resources-related activities | | | | | #228B22 |
| 8100 | | Farming, tilling, plowing, harvesting, or related activities | | | Agricultural activities, such as farming, plowing, tilling, cropping, seeding, cultivating, and harvesting for the production of food and fiber products. Also includes sod production, nurseries, orchards, and Christmas tree plantations. Excludes forest logging and timber-harvesting operations. | |
| 8200 | | Livestock related activities | | | Activities associated with feeding and raising of livestock in pens and confined structures. | |
| 8300 | | Pasturing, grazing, etc. | | | Activities normally associated with feeding and grazing in open ranges. | |
| 8400 | | Logging | | | Activities normally associated with forestry. | |
| 8500 | | Quarrying or stone cutting | | | Includes activities normally associated with borrow pits. | |
| 8600 | | Mining including surface and subsurface strip mining | | | Includes crushing, screening, washing, and flotation activities. Beneficiating is another common term used to describe such activities. | |

| Code | Main activity | Second level activity | Third level activity | Fourth level activity | Description | Color |
|---|---|---|---|---|---|---|
| 8700 | | Drilling, dredging, etc. | | | Includes activities normally associated with on and off-shore drilling for oil and natural gas operations, dredging for beach control, expanding waterways, and cleaning of canals or channels. | |
| 9000 | No human activity or unclassifiable activity | | | | May also be used as a placeholder for areas of no habitation (desert areas, for example). | #FFFFFF |
| 9100 | | Not applicable to this dimension | | | Use this code as a permanent code for those records that will never be classified in this dimension. It is normal for land-use databases to have records that may never be classified and be left blank instead. But LBCS recommends that all records have a code because some computer applications may not be able handle blank entries (null values in database terminology). | |
| 9200 | | Unclassifiable activity | | | Use this category as a temporary placeholder for activities that cannot be grouped anywhere until the classification scheme is updated. Check the LBCS web site to see how others have dealt with such unique activities before revising the classification scheme. | |
| 9300 | | Subsurface activity | | | Use this category for activities that occur below the surface that are of no interest to the applications that will use this data set and assigning one of the unknown categories may be inappropriate. | |
| 9900 | | To be determined | | | Use this code as a placeholder until an appropriate code can be assigned. It is normal for land-use databases to have records that may never be classified and left blank instead. But LBCS recommends that all records have a code because some computer applications may not be able handle blank entries (null values in database terminology). This code could also be used as the default value for data-entry work. The subcategories serve the same purpose for other coding levels. | |