INSMART

Integrative Smart City Planning

Geographical Information Systems

Energy Database Report

WP1 T1.3- Deliverable 1.9

October 2015

314164 (ENER/FP7/314164)

Project acronym:

InSMART

Project full title:

Integrative Smart City Planning

Coordination and support action (Coordinating Action)

FP7-ENERGY-SMARTICITIES-2012

Start date of project: 2013-12-01

Duration: 3 years

Deliverable D.1.9

Geographical Information Systems

Energy Database Report

Task 1.3. Geographical Information Systems Development

October 2015

Project co-funded by the European Commission within the Seventh Framework Programme		
Dissemination Level		
PU	Public	PU
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Version	**Submitted by**	**Review Level***	**Date Submitted**	**Reviewed**
V01	CRES	WPL	March 2015	March 2015
V02	CRES	WPL	October 2015	October 2015

Editors		
	Name (organization)	**e-mail**
Leading participant	V. Kilias (CRES)	vkilias@cres.gr
Contributing participants	Alexanros Rigopoulos	arigo@cres,gr
WP leader (WPL)	George Giannakidis (CRES)	ggian@cres.gr

Executive Summary	
The report presents the basic activities of the development of a 'Geographical Information System' for each participating city (Trikala, Nottingham, Evora, Cesena), as well as the design principles of the databases that have been developed	
Keywords	GIS, energy database

Table of Contents

Abbreviations

BAL Basic Aggregation Layer

CHP Cogeneration of Heat and Power

RES Renewable Energy Sources

1. Introduction

This report describes the progress of the third task of WP1 *'Development of the city's GIS platform on energy use and needs'* of INSMART project regarding the development of the GIS platform that will be used for the presentation of the data inputs and of the results of the project. The ultimate objectives of the cities GIS energy database are

The report presents the basic activities of the development of a *'Geographical Information System'* for each participating city (Trikala, Nottingham, Evora, Cesena), as well as the design principles of the databases that have been developed.

The GIS platform will play a central role in the methodology of INSMART in the sense that it will be the connecting point between the different work packages focusing into specific parts of the energy demand and supply in each city. The GIS platform will integrate and present the inputs to the different workpackages but it will also present the results of these workpackages. Building's energy demand calculated in WP2 and demand for mobility and the related energy consumption from WP3 will be shown on the city geographical background. Furthermore the integrated energy system analysis performed in WP5 with the use of the TIMES energy model will produce snapshot of energy demand per city sector in the future, through alternative scenarios. These results will also be presented using the GIS platform for each city.

2. Work package overview and tasks implemented

The first work package of the project, aims to set the basis of the methodological approach for a strategic urban planning as it will create the GIS platform. This platform will be used to supply all the thematic models that will developed for the participating cities and to visualize and analyse the results.

The ultimate objectives of the cities GIS energy database are:

- The full spatial presentation and analysis of existing energy consumption and production, for each city, together with the investigation of alternative scenarios and assessment of specific policies impact, in order to support detailed analysis and planning, thus the use of the spatial database developed as a decision support tool.
- The spatial-temporal analysis of the energy demand, by simulating the city structure in the past present and future, if such data are available, and the use of GIS as a development simulation tool.
- The monitoring of city energy consumption and production by using *'near real time'* information for specific blocks, buildings and road network networks by using semi-automation systems, or raw data.
- The communication of city energy information by publishing energy thematic maps and the communication with citizens, investors and planners.
- The modelling of specific topics related to the building, utilities and transportation sectors

It is obvious that the geographical information systems that are being developed, for each participating city, will be used as analysis, simulation, modelling and presentation tools.

At the same time, the operation of these systems will provide added value to the cities. The infrastructure and tools developed will be used, after project finalisation, as management tools for

city energy consumption and production, while they can be enhanced with real time systems, such as energy production from small systems data loggers, metering, transportation management tools etc

In the framework of this work package implementation the following tasks have been implemented during the first phase of project (months 1 to 12).

a. Analysis of existing sustainable policies and data availability for each city – Identification of gaps.

The project team has started with an analysis of existing status of each city regarding its sustainability planning. The analysis has focused especially on the issue of integrative approach and on the energy efficiency driver.

During the first and second project plenary meetings the four cities have exchanged views on existing strategic city planning for sustainability and plans driven by energy efficiency and low carbon objectives. Common gaps, constraints and aspirations have been identified in order to fine tune the approach to be developed in the next WPs, and to frame the design of the geographical databases for each city.

b. Implementation of a comprehensive survey for the building stock for each city.

The surveys have merely focuced at the recording and characterization of the city building stock and the energy consumption patterns especially in the residential sector. In addition, data availability regarding transportation and mobility in major city zones, water consumption and waste disposal as well as municipal urban spaces, street lighting and DH networks have been taken into consideration.

c. Development of a gis database for each city.

Each city has been divided at an appropriate number of city areas depending on the geographical spread of the city and its districts as well as on the availability and applicability of data. The GIS database will not only used to store and analyse already existing data (basic city layers, building stock, etc) but will also store and utilize data that will be outcomes of the consequent analysis, e.g. residential energy demand. Furthermore it will enable the production of informative maps such as building stock distribution; mobility maps etc and will be the basic platform for the graphical representation of the outcomes of the forthcoming technical analysis e.g. geographical distribution of heat demand, fuel consumption, energy savings potential etc. enabling the design of appropriate energy policies and measures (e.g. DH network expansion)..

3. Geographical Databases Design requirements

The Geographical Information System (GIS) will hold all ‘spatial’ and ‘spatial enabled’ information for each city. Aim of the city-GIS is to depict all energy related information about each city, thus supporting decision making, towards a smart and sustainable city planning.

In order to implement such a system, the basic information describing the city operation (basic city maps, land use) the energy sector (DH and NG networks, electricity production, RES potentials), as

well as the energy demand (in households, tertiary and transportation sectors) need to be organised inside the Geographical database.

Each city need to be divided at appropriate number of GIS city areas depending on the geographical spread of the city and its districts as well as on the availability and applicability of data.

The GIS database will be updated during the whole duration of the project with input and output information from the other WPs, especially WP2 (building typologies and estimation of households energy demand), WP3 (transportation), WP4 (energy production and street lighting), WP5 (city energy model)

By the end of this exercise each city GIS will provide

- The full spatial presentation and analysis of existing energy consumption and production,
- The spatial-temporal analysis of the energy demand / supply system, including the investigation of alternative scenarios, becoming an interface to the energy models applied
- The communication of city energy information by publishing energy thematic maps and the communication with citizens, investors and planners.

Design principles

The selection of the **spatial extend** of each system (i.e. the city boundaries) affects the type of analysis that will be performed. The inclusion of wide metropolitan areas, where industrial, agricultural or suburb areas, might be included, require the study of the relevant sectors in detail (ie estimation of energy demand for agriculture and industry, analysis of city expansion options, transportation, energy infrastructure etc)

On the other hand, the selection of *'pure'* urban areas leads to the deep analysis of the energy saving and dispersed RES generation potential in buildings as well as the sustainable transport

The selection between these two options need to take into account

- The availability of energy and spatial information
- The growth prospects of the city (cities of rapid development vs *'mature'* cities)

Since energy information covers a lot of statistical datasets with spatial / geographical variation (representing energy demand, production or potentials), the most important decision on the geographical database design and implementation, is **the identification of the basic geographical entities** that may represent the geographical distribution of the information that may be enabled spatially.

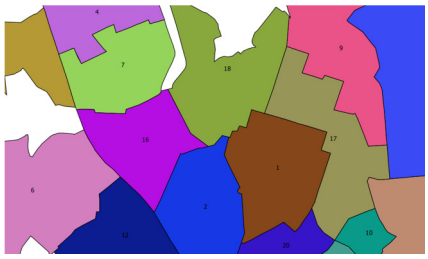
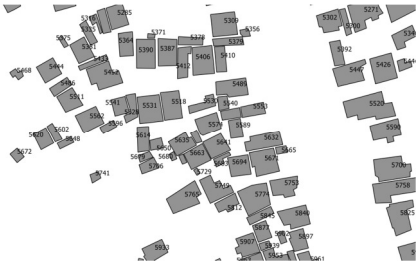
Appropriate geographical layers of this type might be (see Figure 1):

- The division of city into specific sectors according to planning criteria, where a great number of energy information would be effectively linked (as described in WP3-Transportation and WP5 –energy modelling).
- The city blocks (squares) or similar spatial units that can be used to express various statistical datasets at a great detail.
- The individual buildings, if there exists information on a building basis (usually for commercial or public buildings).

- The road network where information about transportation may be geographically linked.

The selection of the appropriate 'registration layers' is very crucial since the majority of energy information will be linked using the individual id's of each polygon or line segment.

Figure 1 Registration layers

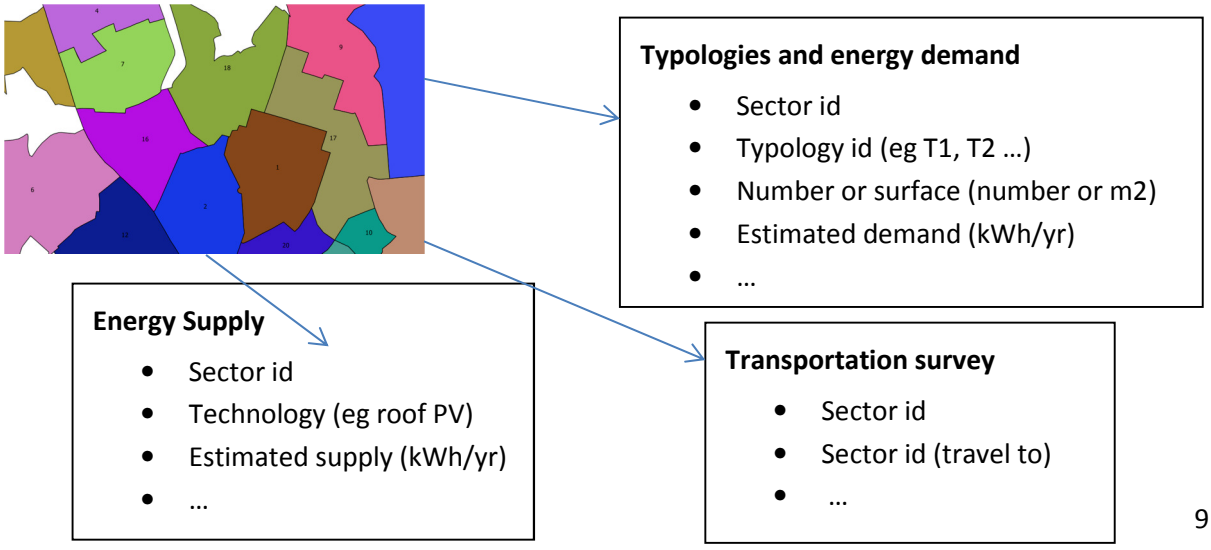
	
City sectors	Blocks
	
Road segments	Individual buildings

The information that will be linked to the selected base layers comprises of

- Building types and typologies
- Results from the transportation survey
- City energy modelling information
- Street lighting (open spaces) , waste production and energy supply (wp4)
- Any other information that may be elaborated by its primary sources

The statistical information that will be linked to each individual geographical object (i.e. each sector) may have *one-to-one* or *one-to-many* relationships according to the following example (figure 2)

Figure 2 Example: Simplified entity relationship diagram



City energy infrastructure includes **:**

- The district heating networks, providing information about the existing distribution of pipelines, the parts of the city that have access to it, as well as operational information (e.g. heat sales), to the extend and aggregation level that this information is available. It's is important also to depict the future expansion of the networks
- The Natural gas network providing similar to the above information
- The energy production facilities (electricity and CHP) bigger than a specified capacity (i.e. 1 MW)
- The important on going or planned energy projects in the city, such as Energy Conservation projects on big buildings or neighbourhoods, innovative technologies for RES generation, network expansion or improvement etc.

It is important to mention that 'infrastructure' layers may also include information about the planned expansion or future projects, in order to depict the city short term energy planning.

City operation – land use includes information on

- The basic geographical information of the city, such as road network and basic land use maps
- Public, or commercial buildings where energy use might be estimated at a deeper detail.
- The general expansion plan of the city
- Any other information, for example areas with specific building rules, real estate information.

RES and ES production or potential estimation includes information on

1. The geographical distribution and production estimation of dispersed renewable energy facilities where there might be included

- PV installations on buildings, represented by location or district summary
- PV installations on city areas, represented by location or district summary
- CHP installations, represented by location
- Big size solar hot water or heating systems represented by location (systems on pools, big buildings etc)
- Solar water or heating systems on the residential sectors represented by district summary
- Ground Heat Source pumps represented by location or district summary

Aim of these layers registration is the presentation of active renewable energy penetration on a city level, expressed as capacity or estimated production

2. The estimation of the technical potential of the above mentioned renewable energy sources, this estimation based on the basic city information (such as available areas, or building roofs for PV installation, buildings with intensive heating requirement etc).

3. The representation of usefull information for energy use and energy savings potential (big buildings with energy saving projects or potential, energy audits etc)

4. GIS database and communication among work packages

The development of geographical databases is, mainly, an horizontal task. Consequently all citie's GIS systems share or exchange information and operations with all separate project work packages. The following paragraphs present how each package exchanges information with the GIS database

WP2. Analysis of the city building stock

The city building stock will be analysed to identify a number of characteristic building typologies for each GIS building, city block, or city district (see figures 3, 4 and 5) . The energy profile of each building typology will be further investigated using specialised simulation software tools (CitySim and TRNSYS). Based on the corresponding simulations the specific energy demand as well as the specific energy savings potential from various energy efficiency measures will be calculated.

The resulting information have been part of each city GIS database in order to provide graphical representation of the total energy demand from buildings in every GIS city block, thus creating a building energy demand map of each city and identifying regions of special interest (e.g. DH network expansion).

Figure 3 Building typologies per district – city of Cesena

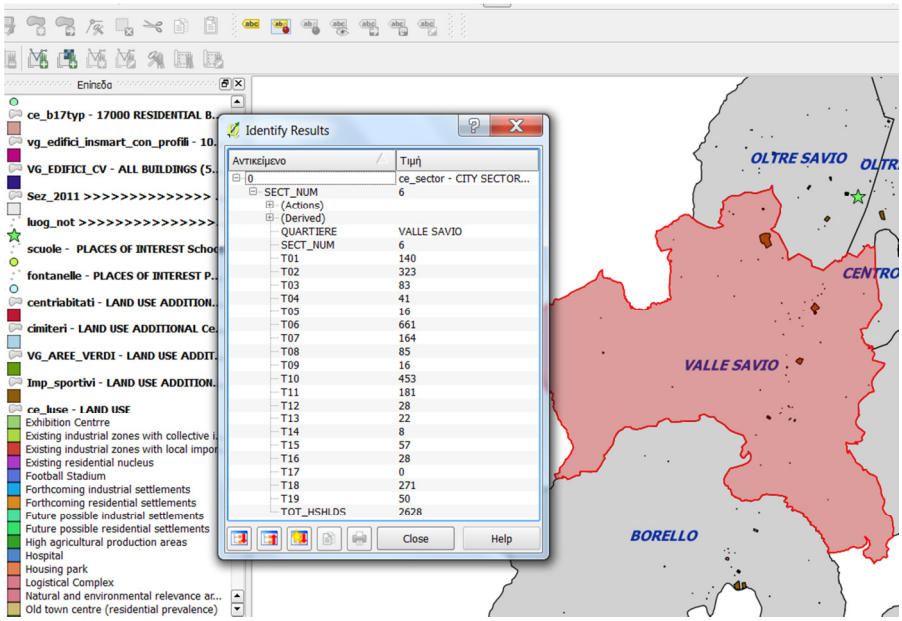


Figure 4 *Building typologies per building – city of Cesena*

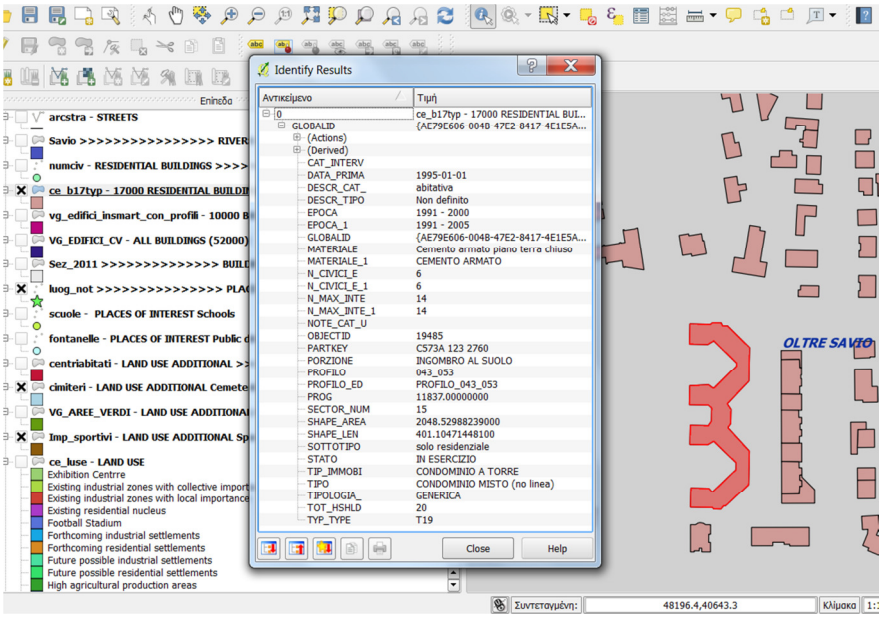
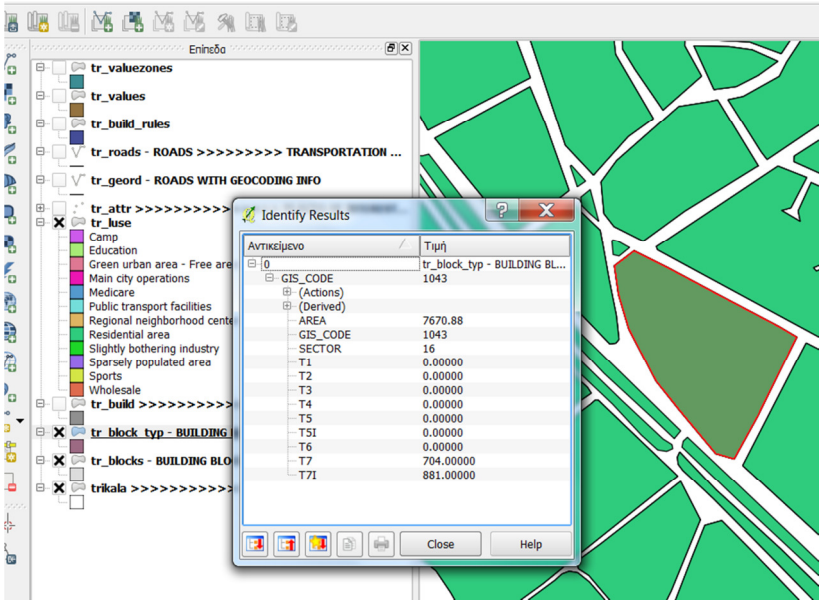


Figure 5 Building typologies per block – city of Trikala



WP3. Transport & mobility analysis

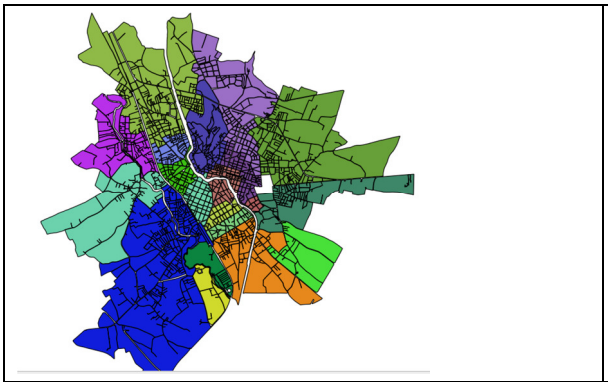
The information required for this work package implementation consists transport and population data for each city. This information consists of the spatial distribution of the local population and of employment ass well as locations and geometry of transport networks. Based on this data, models may build up a coherent picture of the distribution of trips (from origin to principle destination) and associated modes and from this estimate (with a corresponding uncertainty band) the total number of passenger kilometers traveled for each transport mode.

The analysis will also take into account and will address future growth in transport demand and any large land use development or regeneration projects.

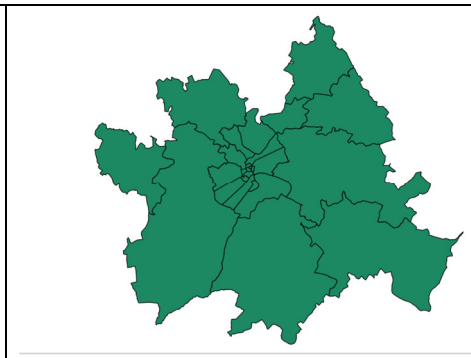
The necessary information will be gathered/provided by the cities with the technical support of one technical partner in every city and will be organized into the geographical database.

The resulting information (being in the form of two-entry tables for each city district) will give the opportunity to present the mobility reactions among city districts, in relation with land use and infrastructures.

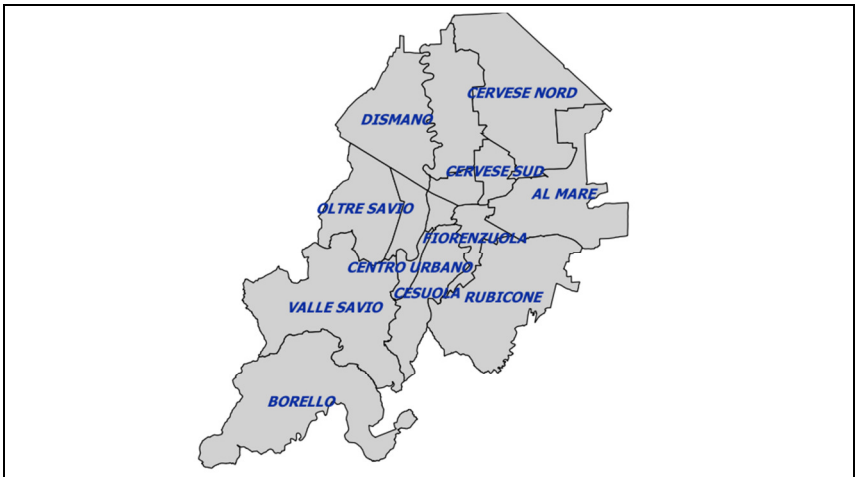
Figure 6 City sectors for the transportation modelling



City of Trikala

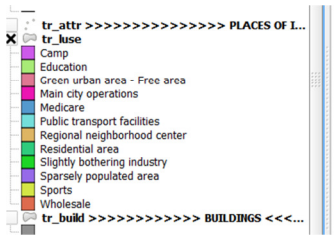


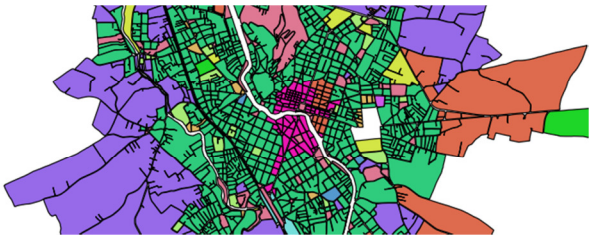
City of Evora



City of Cesena

Figure 7 Land use – city of Trikala





WP4. Analysis of the cities' energy systems and networks

In the framework of *'Task 4.1 Analysis of the urban spaces'*, the electricity consumption for lighting will be determined for each main street and public space (eg squares) either through specific metering data or through analysis of aggregate data. Consequently analysis of energy efficiency scenarios for the lighting of streets and public spaces will be conducted in order to identify promising technical solutions (efficient lamps, control systems etc.)

The results have been inserted into the GIS platform. Consequently analysis of energy efficiency scenarios for the lighting of streets and public spaces

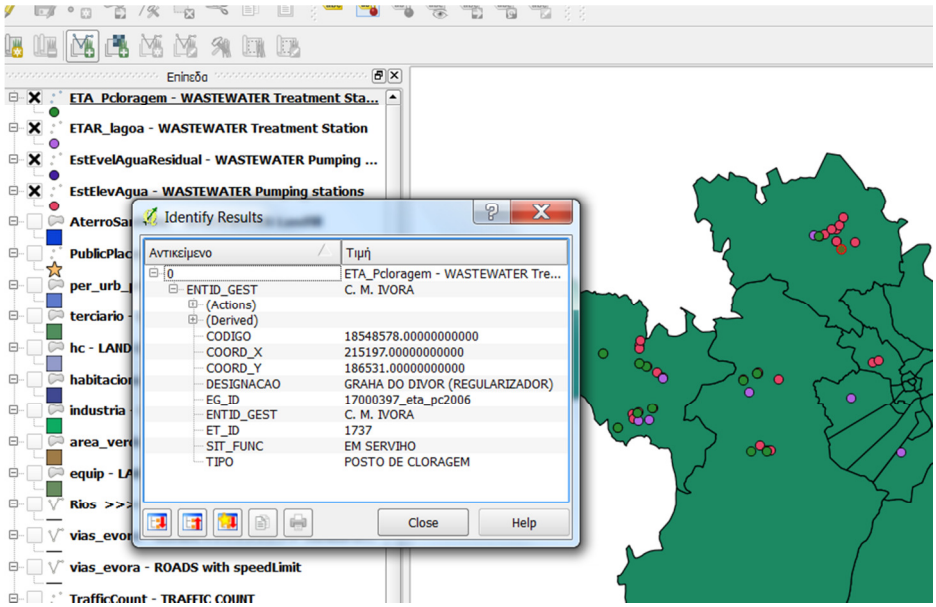
will be conducted in order to identify promising technical solutions (efficient lamps, control systems etc.)

Figure 8 Public Lighting – City of Cesena

During *'Task 4.2. Analysis of the waste collection and treatment processes regarding their energy use impact'* waste chain will be analysed merely on the basis of current waste disposal patterns, possibilities for on site waste reduction, recycling and energy utilisation of remaining waste quantities.

The data from the aforementioned analysis will be introduced to the city GIS database in order to form various GIS layers related to resource and energy use.

Figure 8 – Waste treatment points – city of Evora



Finally in the scope of '*Task 4.3 Analysis of the energy supply system*' data on the existing energy supply systems (DH/CHP, solar thermal, PVs etc) at a city level will be recorded and their technical status will be evaluated in order to identify further technical measures for energy efficiency

improvement (e.g. in case of thermal plants) or potential for further deployment (e.g. in the case of RES). Furthermore the potential of RES utilisation (e.g. PVs, solar thermal, geothermal heat pumps etc) will be analysed on a city specific case with the use of relevant simulation tools and databases (e.g. PV-GIS). All the above information will be inserted into and elaborated by each city GIS.

WP5. Integrated planning tool for the development of Strategic Sustainable Energy Plans

The main objective of the proposed methodology is the identification of an optimum mix of applicable measures and technologies that will pave the way towards the achievement of the cities' sustainable targets. This optimum path will be derived with the use of the TIMES energy system model, with the final selection of measures refined using a Multi-Criteria Decision Making approach.

There are a range of model outputs, representing at the most detailed level technology performance and costs,including -

• Total Discounted System Cost, providing the total costs associated with the urban energy system.

• Technology-specific information, including the level of total installed capacity, annual investments in new

capacity, annual fixed and variable operating costs, and associated fuel costs

• Energy consumed by each technology (sector)

• Emission level by resource/sector/technology for each period, and marginal costs, if constrained

These outputs will be expressed regionally for each district/area of the city, and will be organized into each city GIS giving the ability to depict the regional distribution of policy figures inside each city.

WP6. Development of Mid-term Implementation Action Plans

In the framework of *'Task 6.4 Presentation of the city plans to social, industrial and financial stakeholders'* the strategic sustainable city plan and the detailed mid-term action plan will be presented to cities' relevant stakeholders at a special event/workshop organized by the cities. In that respect, the GIS databases will be used as communication tools.

WP7. Dissemination and Exploitation

The WP is dedicated to the dissemination of the projects outcomes to local and national governmental

authorities (decision makers and planners), private technology and market associations (technology providers).

GIS systems will be used, as a base communication and dissemnination tool, giving the ablility

- To present energy and thematic maps of thw cities through web applications
- To present the model outputs as well as the implementation plans
- To publish open geo-data city information

5. Data requirements for city Geographical Information System

The information that need to be introduced and maintained in each city GIS is related to the profile of each city and the availability of raw data. It is driven also by the most developed, or promising RES and RUE options, as these are expected to be evaluated as priorities in the action plans developed

On the other hand, the work packages need to exchange information with the geographical database, thus a basic set of information is required for its efficient operation.

The following table provides an outline of the basic geographical layers that may constitute each geo-database. It is clear that the list is neither exhausted, nor mandatory for each case.

Table 1 Indicative geo-database contents

Layer	Description	Related information/ Notes
Buildings	Individual buildings	Survey information / typologies
Building blocks	City or statistical blocks	Survey information / typologies
City Districts	Planning districts	Statistical & modelling information
Land-use	Unified land use maps	Related info
Physical planning	City expansion, city planning areas	Related info
Real-estate	Market values	Related info (time parameters are significant)
Attraction points	Significant city operation points / public buildings inventory	Related info / Significant for public buildings EC monitoring
Road-network	Basic network	Including other transport information (bicycle routes, parkings etc ..)
Road-network geocoding	Roads with geocoding infrastructure	Geocoded tables (special buildings, energy audits residential RES etc)
Public transport	Public transport routes	Related info
Electricity networks metering	Useful information from distribution grids	Focus on services and consumption monitoring not in topology
Public lighting	Lines, points and areas of public spaces	Technology capacity and consumption
District heating network	Useful information from district heating	Focus on services and consumption monitoring not in topology
Natural gas network	Useful information from natural gas networks	Focus on services and consumption monitoring not in

Layer	Description	Related information/ Notes
		topology
Building PV installations	Installations on buildings and open spaces	Production monitoring
CHP installations	Installations on big buildings (public, private)	Production monitoring
Other RES installations (electricity)	Wind, geothermal biomass	Production monitoring
Significant RES – thermal installations	Ground Source heat pumps, Solar systems on big buildings etc.	Production monitoring

6. GIS Database Operational framework

In every day work, Cities' geographical databases cover a lot of information about city physical planning, cadastral, municipality operation, citizen services etc. In addition the utilities that operate at a city level (eg electricity, natural gas, district heating or water companies) hold and exploit a number of useful information regarding energy, water and waste collection networks.

Moreover the studies or the surveys that are implemented in city areas, such as population & building surveys, transportation & traffic studies, real estate estimations etc., provide additional resources of useful spatial and statistical information.

Usually, inside municipalities, departments specialized on Geographical information elaborate the geographical information that is produced by city operation, while they communicate information to the citizens according to open standards.

Given that small *'universe'* of every day work, how a city energy database could find its operational position, how could be properly maintained and effectively exploited?

In order to answer this question a list of essential parameters should be identified.

Parameter 1: Who is going to maintain the energy database?

Although the energy GIS database holds a lot of spatial information, requiring the relevant expertise and technical staff for its maintenance, it is actually used as a decision support and communication tool instead of an operational spatial information system.

In that respect, this system need to be used and maintained by the cities' personnel working close to the decision making process, such as energy auditing groups, or energy and environment departments. All four cities involved in INSMART have dedicated technical departments working on energy issues. These departments have participated in the INSMART project and will continue to work on the topic once the project is finished (since energy issues are part of their every day work). All the cities also have departments that are dedicated to the operation of the GIS database of the municipality. The maintenance from the Information Technology point of view will be handled by these departments.

Parameter 2: What is the operational requirements of the GIS database ?

The use of GIS database as a decision support tool leads also to the following design decisions:

a. The software tools that are going to be used need to be as simple as possible, so the use of open software is strongly recommended.
b. The database's information need to be easily communicated, so its design should always be as simple as possible and self – explanatory.
c. Given its use as a decision support tool, the geographical database should focus on data aggregation and harmonization, rather that detailed specialization and data disaggregation.

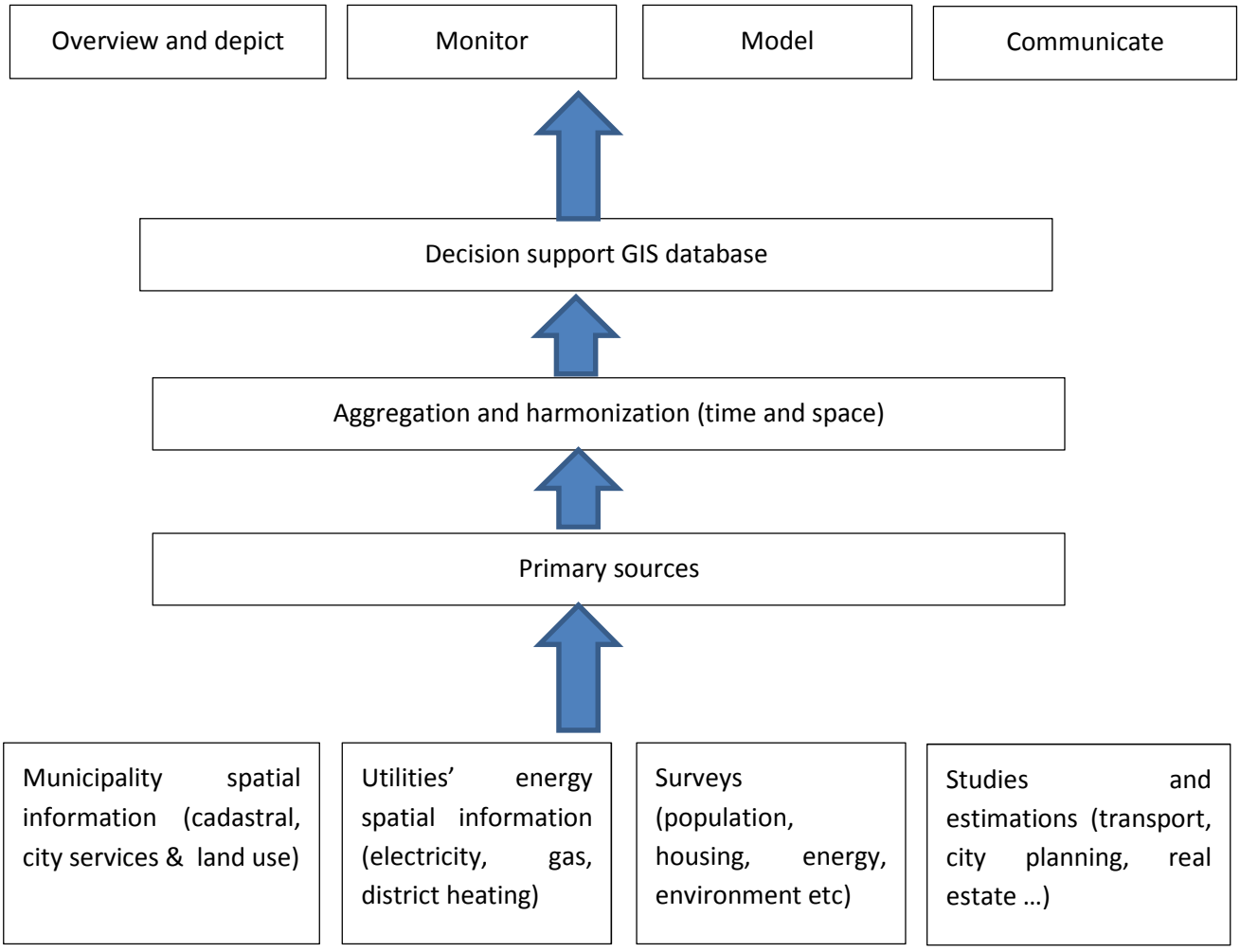
Parameter 3: What are the use types of the GIS database ?

In order to be effectively used as a decision support tool, the city GIS should operate in the following directions:

a. As a tool to *'overview and model'* the energy production and consumption at a city level, depicting how energy is produced, distributed and consumed inside the city, giving a picture of the special characteristics of each city district, thus integrating energy issues in the city planning process.
b. Monitor the changes of energy production and consumption patterns in the city over time, by depicting the development of energy networks, by estimating the changes in the energy consumption in buildings as a result of energy conservation policy implementation, by monitoring the energy consumption in open spaces as a result of Energy Conservation project development, by forecasting the spatial development of energy demand and production etc.
c. Model city information in order to be used by economic, energy, transport and environmental computational models, or acting as an input and output data repository for city studies
d. Communicate cities' energy information to citizens, the public sector and the market.

The flow of information from the primary sources up to the final layers of the decision support system and to the final uses of the tool is presented in Figure 9.

Figure 9 *City energy GIS operational diagram*



7. Detailed organization of energy geographical database

The heart of a geographical database is its content. The geographical layers as well as the spatially enabled (geo referenced) information produce a powerful tool for monitoring, decision making and communicating for all energy related issues in city planning and operation.

The challenges for a robust and smart design of a city energy GIS are:

- The selection of the useful output information that this database should provide, ie the information that produces an added value to decision making, rather than a detailed list of information that may be found in different places.
- The determination of the information that this database may provide to additional studies, and computational models,
- The smart exploitation of existing information (such as land use, cadastral etc) instead of production of new data layers.
- The aggregation level, i.e. the spatial level that makes the provided or produced information useful.

In order to target the above mentioned challenges, the city database should contain five basic information domains:

A: City geographical layers

This domain includes geographical layers that provide the basic spatial infrastructure of the city. This infrastructure provides the basis for registering and geo-referencing statistical or modeled information useful for describing the city energy system. It must be noted that among these layers a basic one is selected as the *basic aggregation layer* (BAL). This corresponds to the geographical layer at which all the information should be aggregated when presented on the GIS platform. The INSMART prototype defines 'city districts' as the basic aggregation layer, in order to provide the spatial reference for all energy information of the city.

A prototype for the detailed design of this domain is presented in the following table:

Layer	Description	Used for	Owner / update period
A1. Buildings	Building polygons	Register survey information for individual buildings (typology, energy consumption, public buildings)	City cadastral
A2.Building Blocks	City block polygons	Register statistical survey information (population, building surface by type and typology etc)	City, statistical service, updated by periodical census
A3. Open spaces	Open spaces polygons	Register information about land use, public lighting etc	City files, continuously updated
A4. Road network	Road lines	Register information for transport	City files,

Layer	Description	Used for	Owner / update period
			continuously updated
A5. Geocoded road network	Geocoding model, linked to layer A1. Buildings	Register information for individual buildings (eg RES installations)	City files, continuously updated
A6. City districts	**District polygons**	**Basic aggregation layer (BAL)**	**Energy & city planning group or dept.**

It must be noted that the column 'owner / update period' requires the definition of the owner / creator of that spatial data set, excluding information composed by open communities or crowd sourcing (eg 'open street map' info). It is assumed that the essential spatial information infrastructure exists inside city administration or technical support departments.

On the other hand, the definition of the basic aggregation layer provides the essential flexibility for the GIS database, since the required energy information should be geo-referenced at least in the BAL, even if detailed information at a deeper level is not present.

B. Energy networks & installations

This domain provides information about the natural gas, electricity and district heating networks. It provides also datasets for energy producing installations (PV, CHP etc). It is important also that useful information about smart networks, RES aggregators and energy storage facilities should be gradually incorporated, following the future deployment of decentralized renewable energy sources. In this regard the gradual development of 'smart' and distributed energy production and storage could be easily monitored thus providing a clear picture of the achievement of city clean energy targets, as well as the introduction of smart technologies in the city energy system.

A prototype for the detailed design of this domain is presented in the following table:

Layer	Description	Used for	Owner / update period
B1. Natural gas network	Natural gas (NG) distribution network	Provide information for the installed capacity of NG distribution, the areas that are served now and in the future, giving also the basis for the assessment of NG consumption in city areas	Utilities, continuously updated
B2. District heating network	District heating distribution network	Provide information for the installed capacity of district heating distribution, the areas that are served now and in the future, giving	Utilities, continuously updated

Layer	Description	Used for	Owner / update period
		also the basis for the assessment of district heating consumption in city areas	
B3. RES production	Specific points for RES & CHP energy generation or aggregated information on RES capacity	Provide information on RES installations and assess RES & CHP energy production by type (PV, small wind, small CHP, RES aggregators etc)	Energy market operator, continuously updated
B4. Smart grids and smart metering	Distribution of smart meters per city district, smart grids	Monitor the deployment of 'smart' energy city infrastructure	Energy Distribution companies, continuously updated

The information content of the datasets of this domain should always

- Present *'capacities'* i.e. the existence and future planning of networks in city districts, or the capacity of RES producing installations.
- Assess *'consumption'* i.e. the quantity of energy commodities that are consumed or produced by these networks or installations.
- Present *'technologies'* i.e. the deployment of new energy technologies inside city energy system.
- Aggregate all previous information on the level of the basic aggregation layer (BAL) in order to be modeled and compared with all city information

C. Statistical and survey data sets

This domain comprises non geographical data sets. The information elaborated inside these data sets is always geo-referenced upon the geographical layers of the first domain (figures for every building, city block or city district). Following the basic design principles of the database, this information need to be referenced at least to the Basic aggregation layer (BAL).

The list of this type of information cannot be exhaustive, since the determination of energy demand figures may exploit data found in a number of different surveys and specialized studies.

However a minimal prototype for the detailed design of this domain may be found in the following table:

Data set	Description	Used for	Geo referenced to
C1. Population and building surveys	Survey usually implemented by national or regional statistical	Provide the basis for assessment of • number and surface of the buildings according to their typology	Buildings or blocks layer, aggregated to BAL

Data set	Description	Used for	Geo referenced to
	services,	• Energy demand in households • Population indicators	
C2. Specific building surveys	Specific surveys or studies that elaborate information on the existing building stock (tertiary or households), real estate figures etc	Assess information for the typologies of buildings, as well as their usage and energy demand	BAL
C3. Transportation studies	Traffic, or transportation studies	Assess the energy use in transportation	Road network, BAL
C4. City energy consumption records	Public lighting, public buildings consumption etc	Assess municipal energy consumption	Buildings, open spaces, BAL

D. City specific layers

This domain comprises additional city layers that would facilitate the computation of city energy figures. The most important layers of this category are land use maps, maps of attraction points in the city, temperature files etc.

The following prototype would be used as reference

Layer	Description	Used for	Owner / update period
D1. Land use	Land use maps	Used as a primary source in order to frame city sections and areas,	City infrastructure
D2. City attraction points	Various points regarding specific buildings and areas	Used as a primary source in order to locate energy consumption points	Various maps
D3. Meteorological info	Meteorology	Calculate and normalize energy consumption information on heating and cooling	Meteorological services

E. Modeling the energy demand

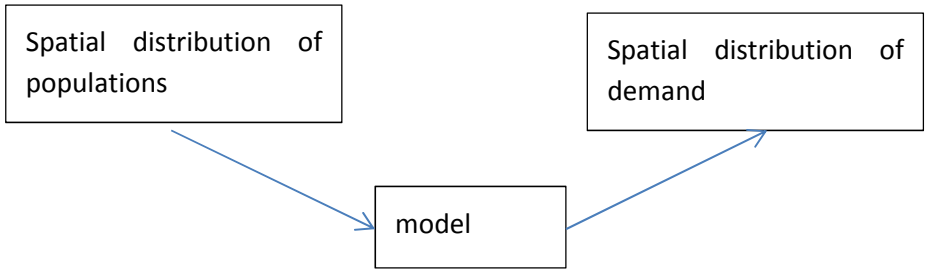
The ultimate goal of the GIS city energy database is to store and present figures for the demand of energy commodities, either in the form of final or useful energy. While final energy consumption

could be measured by the assessment of the real figures of energy commodities sales, thus being a challenge for data gathering and statistical methodology, the computation of useful energy requires a number of inputs by

- starting from the number of real *'population'* i.e the spatial distribution of the surface for buildings for a specified typology,
- using the assessed *'specific consumption'* i.e. the unit consumption in the form of kwh/m2 and finally
- producing the total consumption for the specified typology.

Similar methods can be used for the computation of energy demand in the transport sector, the demand for street lighting etc.

Following the above basic principles, it may be concluded that the city energy GIS database would act both as a data provider for computational models as well as data receiver from them. So all results could be incorporated inside the database following the diagram below.



The following prototype would be used as reference

Layer / Data set	Description	Referenced to
E1. Spatial distribution of energy demand for buildings	Number of buildings or surface for each specified typology, estimated consumption for each specified typology	BAL
E2. Spatial distribution of energy demand for transport	Number of trips from each city district to other districts, energy consumption from each city district to other districts,	BAL
E3. Spatial distribution of energy demand for open spaces (street lighting)	Number and types of lighting equipment and spatial distribution of energy consumption in open spaces	BAL
C4. Spatial distribution of energy demand for water and sewage services	Number and types of water services equipment and spatial distribution of energy consumption	BAL

8. Final outputs and communication

The city database will present in a self explanatory way the spatial distribution of energy demand and production expressed in the different city districts.

The basic outputs will represent in the form of thematic maps aggregated at the basic aggregation level the following:

1) Energy demand in households
    - Number of buildings or total surface for each specified building typology.
    - Total Energy demand for each specified building typology which could be further analysed to:
        - Energy demand for heating for each specified building typology.
        - Energy demand for cooling for each specified building typology.
        - Energy demand for hot water for each specified building typology.
2) Energy demand in buildings of the tertiary sector
    - Number of buildings or total surface for each category (i.e. offices, retail etc)
    - Total energy demand for each category, which could be further analysed to:
        - Energy demand for heating for each specified category.
        - Energy demand for cooling for each specified category.
3) Energy consumption in municipal open spaces
    - Capacity and number of equipment per type and city district.
    - Energy consumption per city district.
4) Energy consumption in waste water systems
    - Energy consumption per district
5) Energy consumption in transportation
    - Demand for transport form one city district to the others.
    - Energy consumption for transport per city district (assuming that the energy consumption is allocated to the district of the origin of the trips). This can be furter analysed to:
        - Energy consumption per type of vehicle (private cars, busses, light duty vehicles, heavy duty vehicles, trains, motorcylces).
6) Energy networks
    - Natural gas estimated consumption per district.
    - District heating estimated consumption per district.
7) Energy production
    - Estimation of PV installed capacity and energy production per district.
    - Estimation of solar water heaters capacity and energy production per district.

- Estimation of CHP installations and energy production per district.

The above structure identifies the common outputs that the database should elaborate. It provides also the standards for the communication of the energy information to the citisens, to the interested society and market groups as well as to the decision makers. Finally it provides the standard for the communication of the database with other information systems inside the city as well as computational models. In this regard the final outputs of the database justify the operational guilediles that are presented in the chapter 6 – GIS database operational framework. On the other hand the above output standards require the harmonisation of the contained information in order to be updateable and comparable.

The required functions for this harmonistation requires the agregation of information at a specific level. This aggregation is

- Spatial aggregation, meaning that the highest level should incorporate information aggregated by lower levels (ie the total surface of the buildings of a specified typology is the sum of the surface at a block level plus the required corrections of missing information).
- Domain aggregation, where the information of a specific domain has been the result of grouping form sub domains (for example the total consumption of public lighting is the sum of the consumption by different types of equipment).
- Time correction. In this regard the statistical or operational information that is being elaborated inside the geographical database is harmonised at specific time intervals in order to express datasets correted at common time intervals (ie existing studies for specific energy behavior of specific typologies implemented this year should be adjusted to a common year

In chapter 7 the contents of city database have been prototyped in order to be used as a common reference for each database instance. However an information system of any type cannot be architectured effectivelly by just desribing its contents. The required functions that manipulate thse contents should be listed and analysed as well. The following table should be used as a prototype for the descriprion of the required functions that are performed in order to elaborate the desired outputs:

Function / dataset	**Relies on**	**Spatial aggregation procedure**	**Doman aggregation procedure**	**Time harmonistation procedure**	**Comments**
01-surface of b uileding typologies	Census data Typologies analysis study	City blocks to city districts	Selected typologies	Census data to be corrected for study year	Change of typology structure from year to year may produce non – comparable data sets

Function / dataset	Relies on	Spatial aggregation procedure	Doman aggregation procedure	Time harmonistation procedure	Comments
02-Demand for transport from one city district to an other	Transporation cencus / study	Study performed directly at district level	-	Related information (ie car sales, new attraction points would correct the results if the study cannot be effectivelly updated)	Study methodology should remain the same for comparable results
03-estimated district heating consumption	District heating network Consumption indicators Building typologies	Access to network and number of connections aggregated on a city district level	Consumption indicators grouped by typology	Each year data should be computed independently	Commercial data from district heating companies should be requested at an aggregate level in order to ensure accessibility

The abobe prototype need to be further analysed for each database instance (ie new city database) in order to reflect the special conditions for data availability and quality in each city. The prototype contents should be used just as an indicative example since the exact atttributes of information differ from instance to instance. It must be stressed also that the detailed definition of each database function, is the key concept for city database sustainability and quality control.

Database sustainability

The above mentioned design aims at maximising database sustainability. To this end the following design parameters have been followed:

- The use of 'open data' in all database contents, in combination with the initiatives that are launched in the four participating municipalities. These initiatives follow the INSPIRE directive that encourages the establishment of infrastructures for spatial information to support environmental policies. In this regard city GIS energy databases support actively the implementation of this directive.

- The use of high level aggeragation wich facilitates information disclosure in the cases that the publication of primary and low level information is been restricted by market rules (for example in the case of energy network or energy sales data owned by local or national utilities)

- The use of of information produced by studies implemented on behalf of the cities or by municipality departments, for example transportation and city planning studies.
- The use of easily deployed computational models, such as energy modelling and transportation models used in INSMART project.
- The organisation of a database working team inside the municipalities working to support energy and environment decision making, as depicted in chapter 6.
- The use of simple functions for data elaboration by avoiding complex spatial procedures such as network modelling and simulation.
- The use of 'open source' software in order to maximise accesibility and minimise maintenance costs.
- The use of simple and self explanatory outputs, as these are presented in this chapter, in order to provide comparable results among database instances

9. Appendix: List of Geographic Layers in INSMART

Layer	Description	Related information/ Notes	Additional notes	Important layer's fields	Information domain
Buildings	Individual buildings	Survey information / typologies	Potential basic geographical entity for building typologies' data, depending on the scale of the data availability (i.e. building,building block, city district). Also useful for the estimation of PV potential for building roofs.		Building stock
Building blocks	City or statistical blocks	Survey information / typologies	Potential basic geographical entity for building typologies' data, depending on the scale of the data availability (i.e. building,building block, city district)		Building stock
Building typologies (Spatially enabled statistical information)	Classification of buildings based on their energy-related characteristics	Survey information / statistical information	Data for the total square meters, as well as the energy consumption (heating, cooling, hot water & electricity) for each building typology, per basic geographical entity. The basic geographical entity used, may be buildings, building blocks or city districts, depending on the data availability.	Total energy consumption (KWh) per City District or Building Block, for all the Building Typologies of the residential building stock.	Building stock
City Districts	Planning/transportation districts	Statistical & modelling information	Potential basic geographical entity for building typologies' data, depending on the scale of the data availability (i.e. building, building block, city district). Also used for the outputs of the transportation study. The transportation districts are not necessarily identical to the city districts.		General

Layer	Description	Related information/ Notes	Additional notes	Important layer's fields	Information domain
Attraction points	Significant city operation points / public buildings inventory	Related info / Significant for public buildings EC monitoring	This layer consists of points of various activities or land use (i.e. public buildings, education, health, entertainment etc.)		General
Road-network	Basic network	Including other transport information (bicycle routes, parkings etc ..)	The road network can be used not only as a background in various maps, but also for transport calculations.		General
Road-network geocoding	Roads with geocoding infrastructure	Geocoded tables (special buildings, energy audits residential RES etc)	Geocoding infrastructure in the road network layer enables the geographical representation of various points of interest, for which the available primary information is the city address (Geocoding). For example, energy audit results and building PV installations can be geocoded by address.		General
Rivers					General
Urban centers					General
Land-use	Unified land use maps	Related info			General

Layer	Description	Related information/ Notes	Additional notes	Important layer's fields	Information domain
District heating network	Useful information from district heating	Focus on services and consumption monitoring not in topology	Information about the existing distribution of pipelines, the parts of the city that have access to it, as well as operational information (e.g. heat sales), to the extend and aggregation level that this information is available. It's is important also to depict the future expansion of the networks		Energy systems and networks
Natural gas network	Useful information for natural gas networks	Focus on services and consumption monitoring not in topology	The Natural gas network providing information similar to the above.		Energy systems and networks
PV installations	Installations on buildings and open spaces	Production monitoring	Points or polygons with data for the installed capacity of PV instalaltions.	Installed capacity.	Energy systems and networks
CHP installations	Installations on big buildings (public, private)	Production monitoring			Energy systems and networks
Other RES installations (electricity)	Wind, geothermal biomass	Production monitoring		Installed capacity.	Energy systems and networks
Significant RES – thermal installations	Ground Source heat pumps, Solar systems on big buildings etc.	Production monitoring			Energy systems and networks

Layer	Description	Related information/ Notes	Additional notes	Important layer's fields	Information domain
Public lighting	Lines, points and areas of public spaces	Technology capacity and consumption		Lamp type & power (KW) per public lighting area.	Energy systems and networks
Electricity networks					Energy systems and networks
Landfills					Energy systems and networks
Water treatment systems	Useful information for water treatment systems	Water consumption			Energy systems and networks
Wastewater treatment systems	Useful information for wastewater treatment systems				Energy systems and networks

Layer	Description	Related information/ Notes	Additional notes	Important layer's fields	Information domain
Transportation modeling results	Transportation modeling outputs	Transportation modeling outputs for the present, as well as suggested future dates	Transportation modeling results (Demand per transportation sector and for various vehicle types, for the chosen scenarios).	Daily Demand (persons) & Energy Consumption (MJ) per Transportation Sector for different vehicle types: Petrol Car Diesel Car Alternative Fuel Car LGV HGV Bus Moped Motorbike Train Tram Total Emissions outputs	Transportation
Public bus lines	Basic network				Transportation
School bus lines	Basic network				Transportation
Railway lines	Basic network				Transportation
Pavements	Basic network				Transportation