INSMART

Integrative Smart City Planning

PROJECT BOOK

Findings and lessons learnt for European cities from the **INSMART** project:

A new methodology for smarter energy planning, tested in four EU cities

An EU-funded project under the FP7 Programme with 10 partners from 4 member states 2013 – 2017

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 314164

Contents

Introduction

All municipalities planning future developments in their cities will find the INSMART methodology developed by this project helpful in understanding present and future energy consumption patterns and resulting carbon emissions. This in turn will help them make smarter choices about the future of housing, public buildings and spaces, transport, the local economy and how to power them all more cleanly and efficiently.

INSMART has developed a sophisticated process to enable European cities to plan their future energy use more smartly. This has been tested with four cities in Greece, Italy, Portugal and the UK with the municipalities concerned and has been supported by a range of technical specialists from the four countries.

The process involves gathering local data then using it in state of the art computer modelling tools (for buildings and transport) to develop plausible future energy scenarios. The scenarios are tested and refined through a series of carefully weighted criteria are applied to ensure they are economically, environmentally and socially acceptable. The resulting weighted scenarios for each city are then run through the International Energy Agency's TIMES model to identify which scenario is the most effective overall at reducing energy consumption and emissions, generating more renewable energy and improving economic prospects and quality of life. Each municipality then uses its highest ranked scenario to develop an ambitious but realistic city-level energy action plan over the next decade.

Key to the process throughout is the involvement of informed local stakeholders in each city, who are invited to come together periodically to critically review the results at each stage and come to an agreement about the preferred next steps.

All the materials associated with INSMART are available on the project website including, conference information and presentations, articles published and all the deliverables, which are hyperlinked from the INSMART Project Deliverables page at the back.

Four European cities working in partnership towards a sustainable energy future

Funding

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FP7 was the EU's main instrument for funding research in Europe between 2007 and 2013 and supports research in selected priority areas bringing together our best talents from across Europe (researchers, industry and SMEs) to tackle the following areas:

Health; Food, Agriculture and Biotechnology; Information and Communication Technologies; Nano-sciences, Nano-technologies, Materials and new Production Technologies; Energy; Environment (including Climate Change); Transport (including Aeronautics); Socio-economic Sciences and Humanities; Space; Security.

FP7 is the predecessor to Horizon 2020

Project Duration - December 2013 to March 2017

Project Budget - 2,629,865 Euro

Consortium - 10 partners from 4 different member states

Glossary and Abbreviations

CO_2
Carbon Dioxide

DG
Distributed Generation

DER
Distributed Energy Sources

EIP – SCC
European Innovation Partnership on Smart Cities and Communities

ESCO
Energy Service Company

ESM
Energy System Model

FP7
7th Framework Programme for Research and Technological Development

GHG
Greenhouse Gas

GIS
Geographic Information System

ICT
Information and Communication Technologies

MCDA
Multi-Criteria Decision Analysis

MSW
Municipal Solid Waste

PM10s
Particulate Matter of fewer than 10 microns diameter; dust, dirt, smoke, soot and liquid droplets, deposited into the atmosphere by industry and transport

PV
Photovoltaic Solar Panels

RES
Renewable Energy Sources

RES-E
Renewable Energy Sources – Electricity

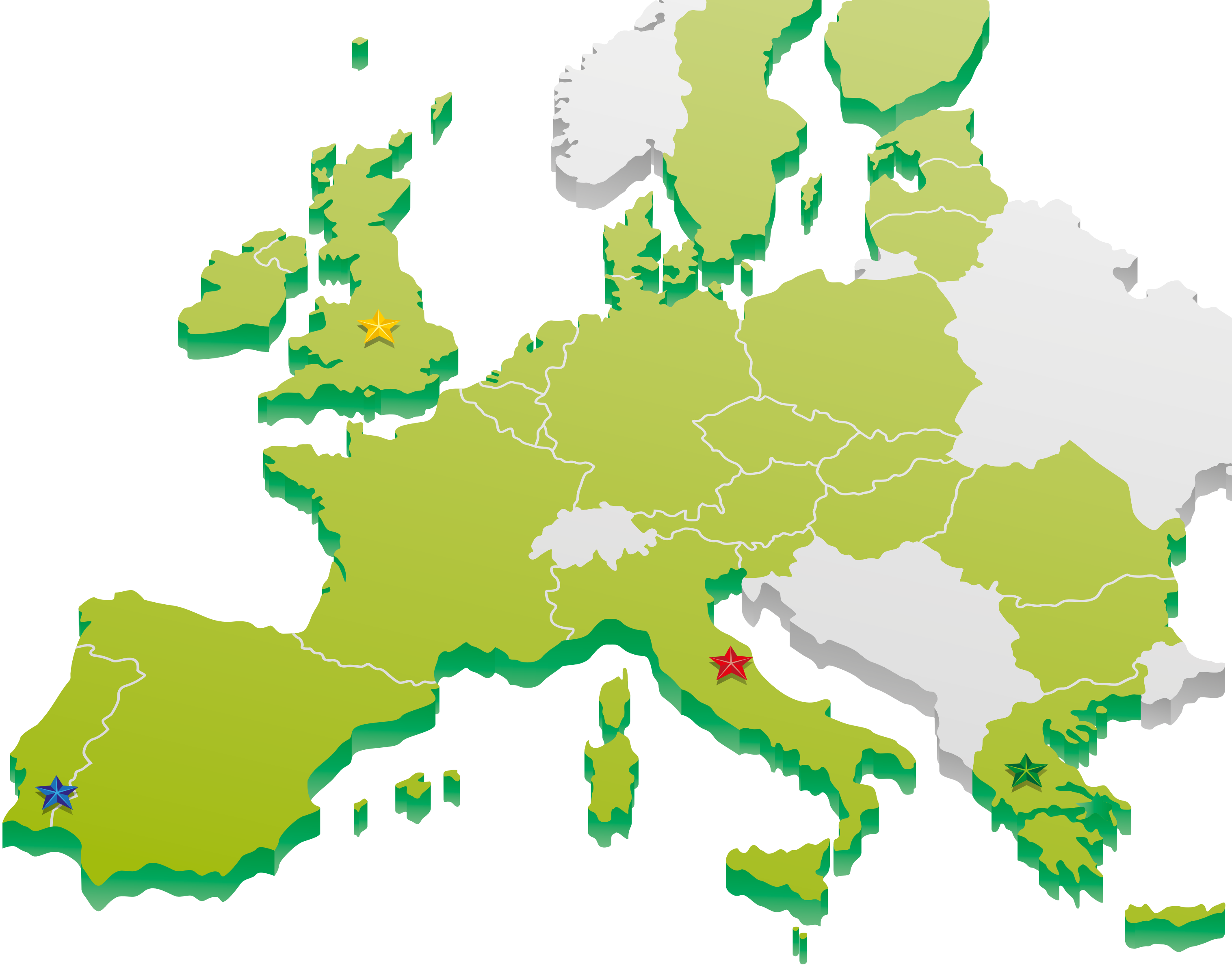
SEAP
Sustainable Energy Action Plan

TBM
Task Based Modelling

TIMES Model
The Integrated MARKAL-EFOM System model generator. This was developed by the International Energy Agency's Energy Technology Systems Analysis Program, an international community which uses long term energy scenarios to conduct in-depth energy and environmental analyses (Loulou et al, 2004).

TIMES reference

Loulou, R., Remme, U., Kanudia, A., Lehtila, A. and Goldstein, G., 2005, Documentation for the TIMES model - PART I, Energy Technology Systems Analysis Programme, [available: etsap.org/tools.htm]



The Consortium

Municipalities

- Trikala, Greece
- Évora, Portugal
- Cesena, Italy
- Nottingham, United Kingdom

Technical and academic partners

- Centre for Renewable Energy Sources and Saving (CRES) Greece
- EDP Distribuição Energia SA, Portugal
- Energy Engineering Economic Environment Systems Modeling and Analysis SRL (E4SMA), Italy
- Faculdade de Ciências e Tecnologia da Universidade NOVA de Lisboa (FCT), Portugal
- University of Nottingham (UoN), United Kingdom
- SYSTRA, United Kingdom

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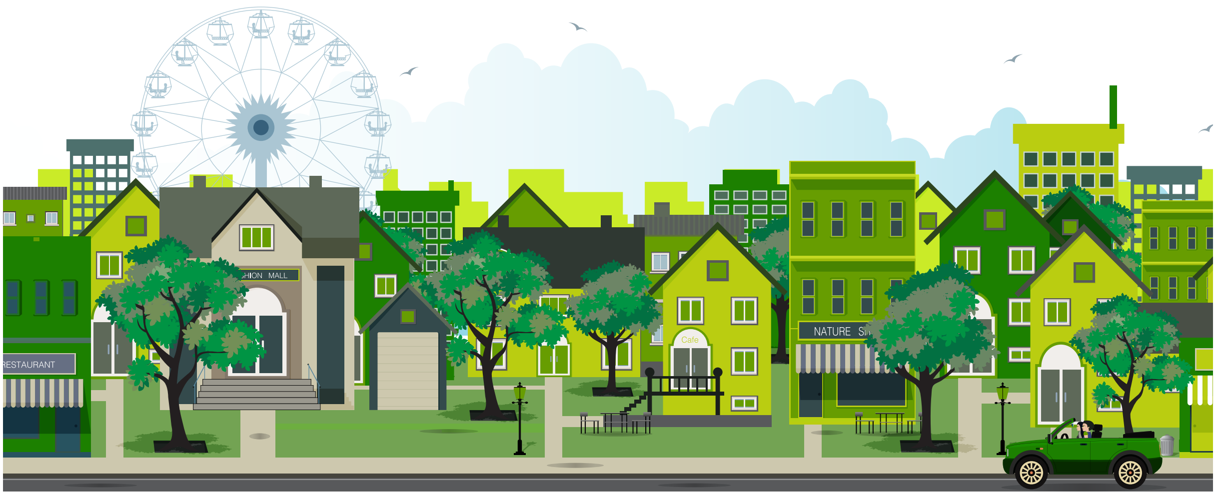
The common challenge of urban environments with respect to energy and climate

Europe is a highly urbanized continent where over 73% of the population live in cities, of which some two thirds live in urban settlements of less than 500 000 people[1]. The United Nations estimates that by 2050, the proportion of the European population living in cities will have risen to 80%. The UN also estimates that urban areas account for 60 to 80% of global energy consumption and around the same share of CO_2 emissions. In order to achieve the goal of the 2015 UN Paris Agreement on Climate Change to limit average global temperature rise to well under 2°c, concerted action will therefore be needed in cities to manage energy consumption and reduce greenhouse gas emissions overall.

As more people move to cities, energy demand is expected to grow accordingly, along with demand for transport, so the scale of the challenge is increasing over time, whilst the need to substantially reduce energy and emissions grows ever more apparent. At the same time, many urban areas are already experiencing some of the impacts of climate change with more frequent and intense heatwaves and floods, where the most socially vulnerable are particularly at risk.[2]

Certain previous policy-led efforts to reduce emissions e.g. by supporting diesel engines in the transport sector, have had unintended consequences. The scale of harmful impacts of diesel particulate emissions on public health in urban areas is only now becoming clear through ongoing research.[3] Many EU cities are regularly breaching air pollution limits and the European Commission is in the process of taking action against certain member states, including Italy and the UK.[4]

Urban areas have a pivotal role to play in climate change mitigation, as they provide many opportunities for more efficient generation, distribution and use of energy. Innovation in energy is supported in many cities and is occurring across different economic sectors in response to a range of drivers.



[1] United Nations, Department of Economic and Social Affairs, Population Division (2014). World Urbanization Prospects: The 2014 Revision, Highlights (ST/ESA/SER.A/352). **https://esa.un.org/unpd/wup/publications/files/wup2014-highlights.Pdf Accessed 6th February 2017**

[2] Climate change, justice and vulnerability. Lindley, S., O'Neill, J., Kandeh, J., Lawson, N., Christian, R. And O'Neill, M. (2011) Joseph Rowntree Foundation, York. **http://www.climatejust.org.uk/resources/climate-change-justice-and-vulnerability**

[3] Royal College of Physicians/Royal College of Paediatrics and Child Health, Every Breath we take: the lifelong impact of air pollution, 2016. **https://www.rcplondon.ac.uk/projects/outputs/every-breath-we-take-lifelong-impact-air-pollution**

[4] European Commission press release, Feb 2017. **http://europa.eu/rapid/press-release_IP-17-238_en.htm**

Municipalities, local stakeholders and many citizens are increasingly aware of their role in helping to meet the demand for energy in a more efficient and sustainable manner that reduces their impact on the climate. Cities are places where both problems emerge and solutions are found. They provide fertile grounds for science and technology, for culture and innovation, for individual and collective creativity. Therefore, cities should act in planning their future development by taking into account common challenges on energy and climate: they must become "smart" and sustainable, and provide secure, affordable and climate-friendly energy solutions. Such an approach can help provide a transition to a lower carbon economy, improve the competitiveness of cities and improve the quality of life for citizens.

Tackling the energy and climate challenge in cities requires answering the following questions:

- How can we deliver a more sustainable energy system at the lowest cost?
- How can we provide the basis for unlocking the full potential of energy efficiency and large-scale integration of renewable energies in urban areas?
- How can we improve the cities' planning policy assessment, and the implementation of realistic Sustainable Energy Action Plans?

Project Insight

The INSMART project is contributing directly to these challenges, by providing a state of the art methodology for energy planning, using effective tools for data gathering, analysis and visualization.

2 The INSMART Solution

INSMART approaches the urban challenges of energy and climate by considering the city energy system as an integrated network of energy flows connecting energy providers with buildings, public spaces, transport and utilities, while taking into account spatial differentiation. Using a detailed characterisation of a local energy system, with simulation tools and the active participation of decision-makers and stakeholders is the cornerstone of the INSMART Integrated City Energy Planning Framework, as illustrated in Figure 1.

INSMART has paved the way towards the implementation of an optimum mix of measures, using multi-criteria decision anaysis (MCDA) involving different stakeholders from city planning bodies to private services in four European cities. The four cities involved, with specific and complex systems, got detailed insights about their own specific goals, through the application of the INSMART framework analysis.

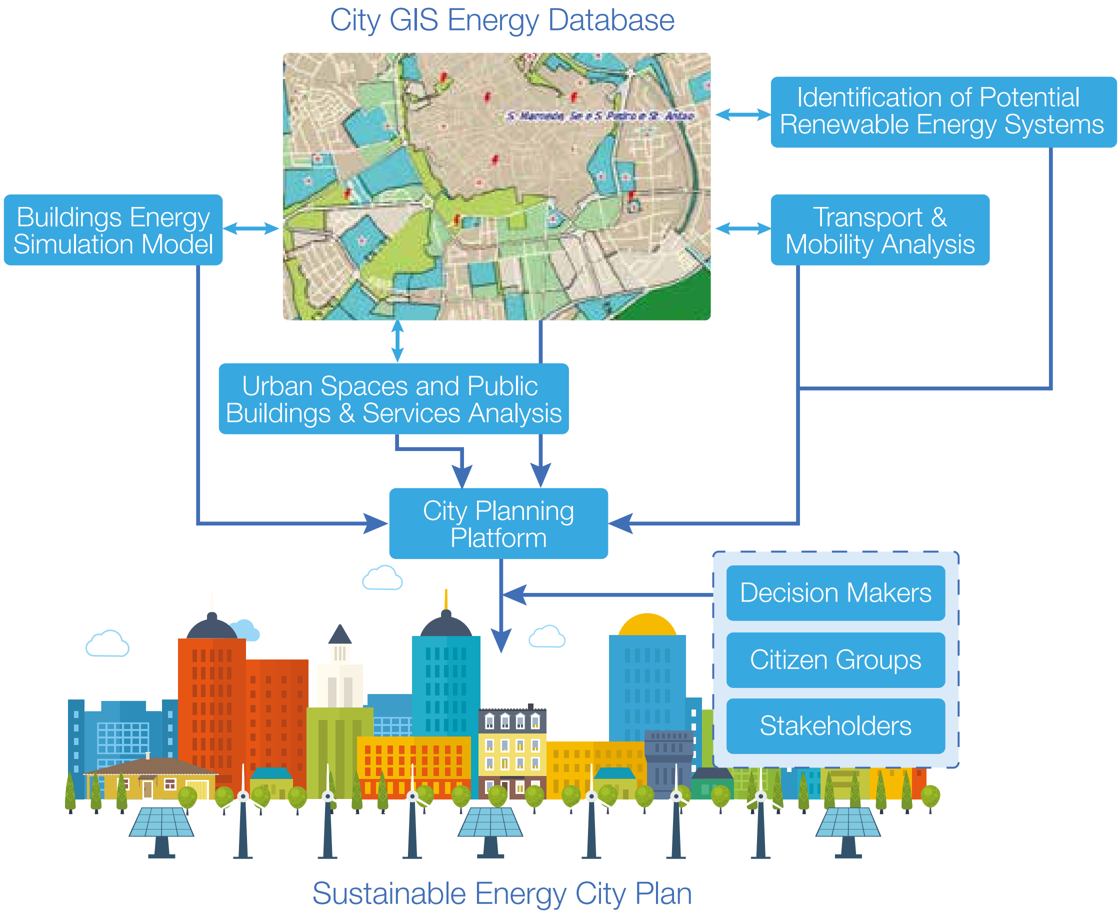


Figure 1: Integrated City Energy Planning Framework.

Project Insight

The INSMART overall objective is to identify the optimum mix of short, medium and long term measures for a sustainable energy future, addressing the efficiency of energy flows across various city sectors with regards to economic, environmental and social criteria.

The first step is to enhance the understanding of the existing city energy system, which is crucial to understanding the significance of, and interactions between, the different sectors in terms of energy use and potential for energy generation. The need for better appreciation of the energy flows is necessary for further analysis of the available technologies, measures and interventions to be undertaken. It also contributes to better integration between different municipality departments and improved governance for sustainable development.

Buildings and Transport are the two main energy-consuming sectors in cities, and these are handled in detail in the INSMART methodology:

- Field surveys and smart meters provide detailed data to characterise the existing building stock typologies.
- Door to door surveys provide data on the mobility needs of people in different city zones.
- Specialised simulation modelling tools highlight profiles of energy demand for buildings in alternative refurbishment scenarios, and shifts in the mobility patterns and transportation demand in alternative transport scenarios.
- Energy demand of municipal services, open spaces and public buildings are recorded.
- Energy related indicators from the city energy system are included in the city GIS energy database, used as a common tool for visualizing the existing energy systems and alternative energy futures for each city.
- The buildings and transport sectors, together with socio-economic characterization, guided the partition of the city into zones to tackle substantial spatial differentiation, to be further analysed.
- Renewable energy potential is estimated for solar PV, using data on adequate available land and rooftops, and solar irradiation.

A City Energy System Model (City-ESM, based on the TIMES model generator) is then calibrated with all the information collected. The City-ESM includes all the energy consuming and producing sectors within the city and is used for analysing alternative scenarios for the development of the city energy system in a medium-term horizon of around fifteen years. The definition of different possible scenarios and the selection of measures accordingly is a key step in the process, along with a participatory workshop approach that includes all the stakeholders in the city. A multi-criteria assessment that incorporates quantitative and qualitative criteria then provides the basis for the final ranking of measures.

The final outcome of this process is the development of a Sustainable Energy Action Plan for each city, to help make the case for action and pave the way towards the implementation of the measures. This requires detailed economic analysis of the mid-term prioritised measures, the identification of funding schemes and the definition of a realistic and applicable 5-10 year implementation plan that describes the necessary steps, resources required and monitoring procedures that should be applied.

Cesena (Italy)

A small town on a human scale with a valuable historic centre which needs a coherent urban future development

Location:	**Italy, Emilia Romagna Region**
Surface:	**250 km^2**
Population:	**96 758**

Rationale for using the INSMART methodology in Cesena

The Municipality of Cesena started a political process towards sustainability in 2009 by signing the Covenant of Mayors and developing a Sustainable Energy Action Plan accordingly. In 2016 the city joined the Mayors Adapt programme, making a new strong political commitment to climate adaptation through to 2030. Within this framework the city needs concrete planning tools which, starting from real life conditions in the local context, will support Cesena to plan in a truly integrated way. The INSMART method has allowed the city to prioritise sustainable future scenarios and to compare and asses them, not only in terms of energy but also in terms of local development, economic viability, aesthetic quality and creation of new jobs.

Paolo Lucchi – Mayor of Cesena

Évora (Portugal)

A middle-size city and district capital, which seeks to revitalise its historic centre, a UNESCO World Heritage Site.

Location:	**Portugal, Alentejo Region**
Surface:	**1 307 km^2**
Population:	**56 596**

Rationale for using the INSMART methodology in Évora

Évora is the first city in Portugal to have a massive implementation of smart meters with over 35,000 being installed, which opens the possibility of adjusting energy consumption to the real necessities and, fundamentally, to change the standards of energy consumption with a view to greater sustainability and efficiency. This is also accompanied by other municipal projects to adapt to climate change and the development of intelligent solutions, in line with Évora's commitment to the Covenant of Mayors to reduce its GHG emissions by 2020. With INSMART we could deepen this commitment! The project has helped us to better assess options for energy use in a more sustainable way, while improving the well-being of our citizens and the competitiveness of our businesses.

Carlos Pinto de Sá – Mayor of Évora

Trikala (Greece)

An historic and attractive city with a creative community, which aims to utilize technology in order to secure its sustainable future

Location:	**Greece, Region of Thessaly**
Surface:	**69 km^2**
Population:	**62 154**

Rationale for using the INSMART methodology in Trikala

Trikala was the first city in Greece to be given a smart city award in 2004 and this has evolved to a creative digital city since then. It signed the Covenant of Mayors for Climate & Energy objectives in 2010, to which it pays significant attention. In 2015 it expressed its willingness to become a highly energy efficient and intelligent city and responded to recent challenges like climate change with its 10-year strategic plan entitled "Trikala 2025: A Smart, Sufficient and Resilient City". All these considerations made the INSMART methodology essential for Trikala to adopt.

Dimitris Papastergiou – Mayor of Trikala

Nottingham (United Kingdom)

A medium size city and regional centre for the English East Midlands with a long history of municipal innovation in energy and transport

Location:	**United Kingdom, East Midlands Region**
Surface:	**75 km^2**
Population:	**314 300**

Rationale for using the INSMART methodology in Nottingham

Tackling fuel poverty and climate change are key commitments for Nottingham. The city has already beaten its 2020 climate change targets following ambitious programmes of work on domestic energy efficiency and improving green transport options. The INSMART project will enable Nottingham to build on these successes, to develop a strong evidence based strategy for the city and for the way energy is generated, distributed and used. The project has brought us a better understanding of Nottingham's energy generating potential and energy demand so that smart energy systems can be developed in the future to meet the city's growing demand for low carbon generation and reduced carbon emissions.

Councillor Alan Clark – Nottingham City Council Portfolio Holder for Energy and Sustainability

The INSMART Methology

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INSMART approaches the city energy system as an integrated network of energy flows connecting energy providers with buildings, public spaces, transport, and utilities, while taking into account spatial differentiation.

Four cities, in four different EU countries applied the INSMART Solution as follows.

2.1 Include all the local stakeholders in the planning process

INSMART is based on a participatory approach, incorporating a Multi-Criteria Decision Analysis (MCDA). All city stakeholders were invited to take part in the consultation process about alternative energy futures: the municipal authorities, commercial and professional associations, private companies and citizens.

Each stakeholder group contributed to the vision for the city's development in the next fifteen years, incorporating their own expectations and challenges, defining alternative scenarios, and giving input about options to be studied.

Once the alternative scenarios were formulated and assessed using the Energy System Model, the results were discussed with the stakeholder groups. The MCDA methodology was then applied to combine quantitative criteria (including reduction of CO_2 emissions, energy savings and financial effort for implementation) with qualitative criteria (local development, ease of implementation, aesthetic integration of interventions and improving life quality of inhabitants) to evaluate and rank the alternative options. The contribution of stakeholders was fostered through three sequential workshops:

1. Scenarios definition
2. Results discussion
3. Evaluation criteria definition and weighting, then ranking the city's energy measures

The participation of the city's stakeholders proved to be vital both to increase the awareness of the scientific terms on the city's specific challenges to be tackled by the modelling tools, and to the acceptance of the final ranking of options for the sustainable energy development of each city.

Project Insight

Active participation of municipal authorities, commercial and professional associations, private companies and citizens is key to the design of the future of a sustainable city's energy system.

Évora. Portugal

Trikala. Greece

Cesena. Italy

Nottingham. England

2.2 Model building energy consumption

The built environment is one of the primary sectors accounting for a large proportion of a city's energy consumption. The INSMART framework focuses primarily on each city's housing stock, modelled in detail using complex building simulation software. The non-residential stock is also included in the framework, though the level of detail is lower than for housing.

The INSMART housing model relies on the production of a representative typological sample of each city's housing stock and the extrapolation of this sample to predict the energy behaviour of the entire city housing stock. This involves the following steps:

- ✓ **Initial data collection** Identify what data and local knowledge already exists regarding each city's housing stock, for example, census records, spatial datasets, municipal records and national surveys.

- ✓ **Identify building typologies** Using available data, identify a set of building typologies, based on construction period and built form, to represent the city's housing stock (e.g. modern detached houses built after 1980 or historic terraced or row housing built before 1900). The choice of construction periods is determined by the diversity of the stock and the availability of data on building age. Each city's housing stock is classified into the appropriate typologies for each city zone. For example, in Évora 10 typologies were considered along the 4 city zones, while in Nottingham 16 typologies were required in the 20 city zones.

- ✓ **Detailed housing surveys** Conduct a survey of city households to collect the data required for the construction of energy models for each city's building typologies, based on a representative sample of each city's housing stock according to its distribution. For example, in Nottingham around 600 surveys were performed, and in Évora around 400. The surveys collected a wide range of information including details of the built structure (materials, insulation, internal floorplans, glazing), its occupants (age, income, employment status), heating/cooling systems presence and use, electrical appliances and lighting.

- ✓ **Detailed electricity use analysis** When smart meters data are available, they are highly valuable in understanding electricity use within each building typology. Due to its high temporal granularity, data from smart meters shows how energy is consumed over the course of a day and how this varies over the course of a year. This then helps to identify potential fuel poverty within certain types of housing and/or in particular areas of a city. This knowledge is important to calibrate the energy demand modelling and to guide the selection of measures while respecting the city's socio-economic features.

- ✓ **Energy demand modelling** Using the survey data, backed up by national or local housing data where applicable, create simulation models using building energy modelling software. EnergyPlus was used for the four INSMART cities but other similar software tools could also be used. Sensitivity analysis is performed to identify the variables that have a significant impact on energy demand.

- **Housing retrofit modelling** Identify potential retrofit options for each building typology. These include options for upgrades to heating/cooling systems, addition of insulation to walls, roofs or floors, draught-proofing measures or the addition of shading devices. The impact of each retrofit option is simulated using the building energy models.

- **Create a synthetic housing stock** Generate a synthetic housing stock for each city using the energy models developed for each typology. Variations in the housing stock are represented by changes to the significant building parameters (identified by the sensitivity analysis). For example, changes to heating system settings and the likelihood of insulation being present in the walls or roofs would lead to a synthetic stock that is representative of the actual stock using the results of the housing surveys. Total energy demand intensity (kWh/m^2) and a breakdown of energy demand by fuel type (e.g. gas, electricity) and use (e.g. heating/cooling, water, lighting, other) is recorded for each member of the synthetic stock.

The synthetic stock created is then extrapolated to the actual city housing stock using the spatial data available. The simulated total energy demand for a city's housing stock can then be calculated using the spatial data for the city. This is done by multiplying the synthetic stock energy intensity values by the actual floor area values for each building typology in the city.

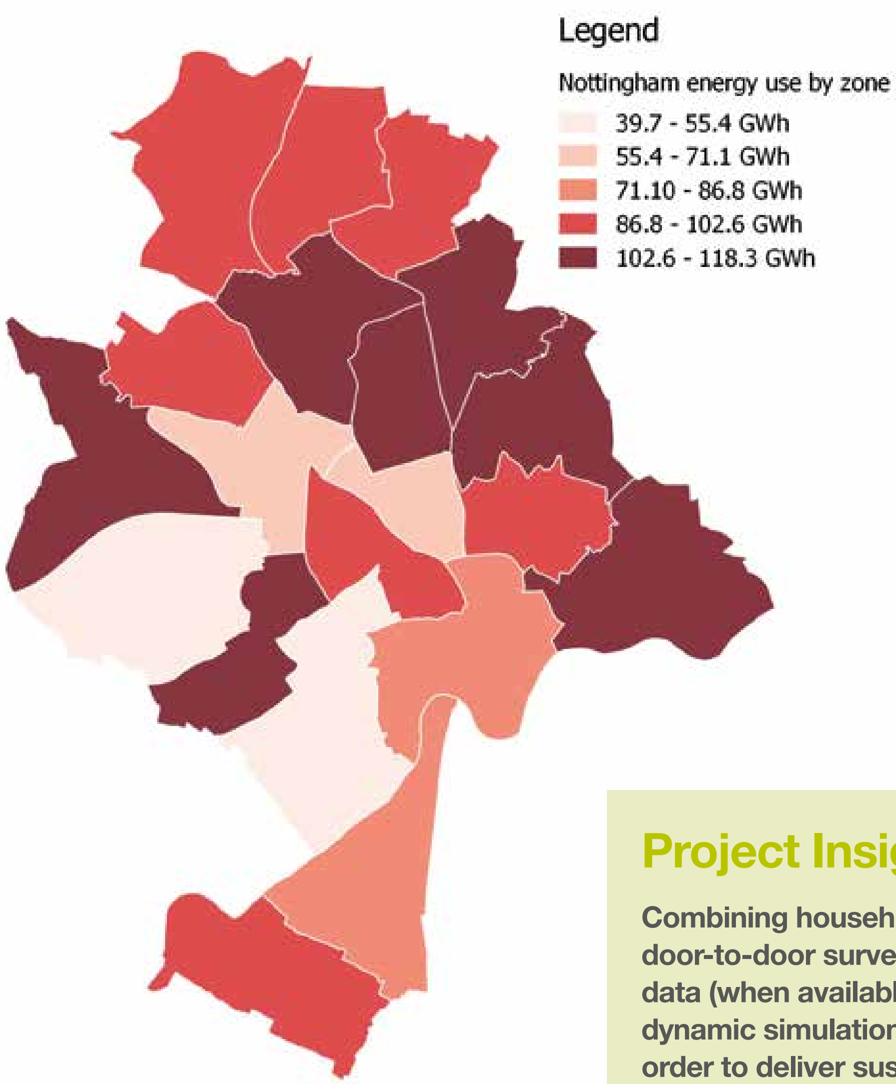

Figure 2. Map of simulated total energy demand for residential buildings in Nottingham

Project Insight

Combining household census data, door-to-door surveys, smart meter data (when available) and building dynamic simulation is essential in order to deliver sustainable options that take into account households' socio-economic status.

2.3 Analyse urban mobility needs

Transportation, be it public, private or freight, plays a major role in all cities, allowing, amongst other things, travel to work, delivery of goods and access to leisure activities. In the EU-28 region transport represents roughly a third of the total energy usage – the largest direct contribution of any sector[5] – and about a fifth of Greenhouse Gas (GHG) emissions[6]

Whilst energy usage from transport has been reducing in recent years, through a combination of improved efficiency of vehicles and the impacts of the economic recession, there is still much to do to reach EU targets to reduce transport emissions by 60% by 2050[7] . With this in mind, the importance of having a tool that enables the testing of various forecast scenarios, covering not just transport but also the impacts of land use and behavioural changes, becomes apparent.

The model developed as part of the INSMART project is an easy to use, but complex model, requiring minimal input data and computational time, but still providing sufficient sophistication to produce meaningful outputs for a variety of scenarios. The model includes processes for:

- ✓ **Trip Generation** from household numbers and floor space information for non-residential locations.
- ✓ **Modal Choice** between highway and public transport.
- ✓ **Route Choice** for both highway and public transport, allowing for the testing of new roads, traffic restrictions and new or altered service patterns and routes.
- ✓ **Splitting vehicular demand into detailed Fleet Types**, by vehicle and fuel type and Euroclass rating, to allow for detailed emissions calculation.
- ✓ **Fuel Consumption** calculations for the entire city, split by movements between city zones, plus the zone where the fuel is consumed.
- ✓ **Data on demand flows**, vehicle kilometres and key emissions such as CO_2, Hydrocarbons and PM10s is produced.

The modelling process was made up of three stages. The first was the creation of a Base Year model, representing the current energy usage situation in each city. Transport surveys were undertaken in each city (a minimum of 400 surveys was required) to assess the different trip-making purposes and patterns. The surveys were used to calibrate the models of observed mode shares and trip lengths. In addition, data was collected on each city's land use, public transport services, average distances and speeds and vehicle splits.

[5] EUROSTAT (2015). Consumption of Energy. May 2015. Available at: **http://ec.europa.eu/eurostat/statistics-explained/index.php/Consumption_of_energy. Accessed 28th January 2016**.

[6] EUROSTAT (2015). Sustainable development – transport. July 2015. Available at: **http://ec.europa.eu/eurostat/statistics-explained/index.php/Sustainable_development_-_transport. Accessed 28th January 2016**.

[7] EEA (2014). Focusing on environmental pressures from long-distance transport – TERM 2014: transport indicators tracking progress towards environmental targets in Europe. September 2016. Available at **http://www.eea.europa.eu/publications/term-report-2014. Accessed 28th January 2016**.

The second stage involved running the model forward to 2030, but with no additional scenarios included. This demonstrated the effect of changes in population and the vehicle fleet over time as people switched to more efficient vehicles and represented a ‘Do Nothing’ scenario to which all others could be compared. The combined impacts of improving vehicle efficiency and a changing population had differing effects in each city: for example, in Nottingham the projected increase in population cancels out any gains from vehicle efficiency, while the forecast decline in population in Évora and Trikala, whilst not desirable, led to an additional reduction in energy usage.

Finally, a wide range of forecast scenarios were run, providing changes in demand, energy usage and emissions compared to the ‘Do Nothing’ scenario.

Scenarios tested include:

Nottingham

- A variety of new tram routes
- Increased provision of electric buses

Évora

- Speed reductions around the historic centre
- City centre traffic restrictions

Trikala

- New cycling routes
- Ring road completion, moving goods vehicles away from the city centre

Cesena

- Two new tram routes
- Electric car share scheme

Whilst the model outputs can be analysed independently from the other aspects of the INSMART project, the true advantage of the project’s approach is the integration of all aspects of city energy usage. To facilitate this, the model is designed to provide inputs to both the GIS interface tool and the TIMES model for scenario testing.

Cesena. Italy

Évora. Portugal

Trikala. Greece

Nottingham. England

Project Insight

The mobility of people and goods makes the city a lively place but models and surveys are vital to find realistic ways to reduce its carbon footprint.

2.4 Deepen understanding of energy use in other sectors

The INSMART integrative planning approach includes the analysis of energy consumption beyond residential buildings and transport. The following sectors were also studied: municipality managed buildings, tertiary buildings, urban spaces, water and sewage systems, and the waste chain. Current energy consumption profiles for municipality managed buildings, tertiary buildings, public lighting, green areas & public fountains, municipal solid waste (MSW) collection and disposal, water supply and waste water collection and treatment were mapped. The future energy saving possibilities, both technological (e.g. improve efficiency of waste water treatment plants) and behavioural (e.g. impact of increasing MSW recycling rates) were assessed.

To complement this, a thorough analysis was also made on the energy supply side for each city, including district heating, as shown in Figure 3 for the case of Nottingham, and assessing potential for urban decentralised energy supply using renewable energy sources (RES). INSMART assessed each city's RES technical potential for photo voltaic (PV), solar thermal, small-scale hydropower, wind, geothermal and biogas, among others.

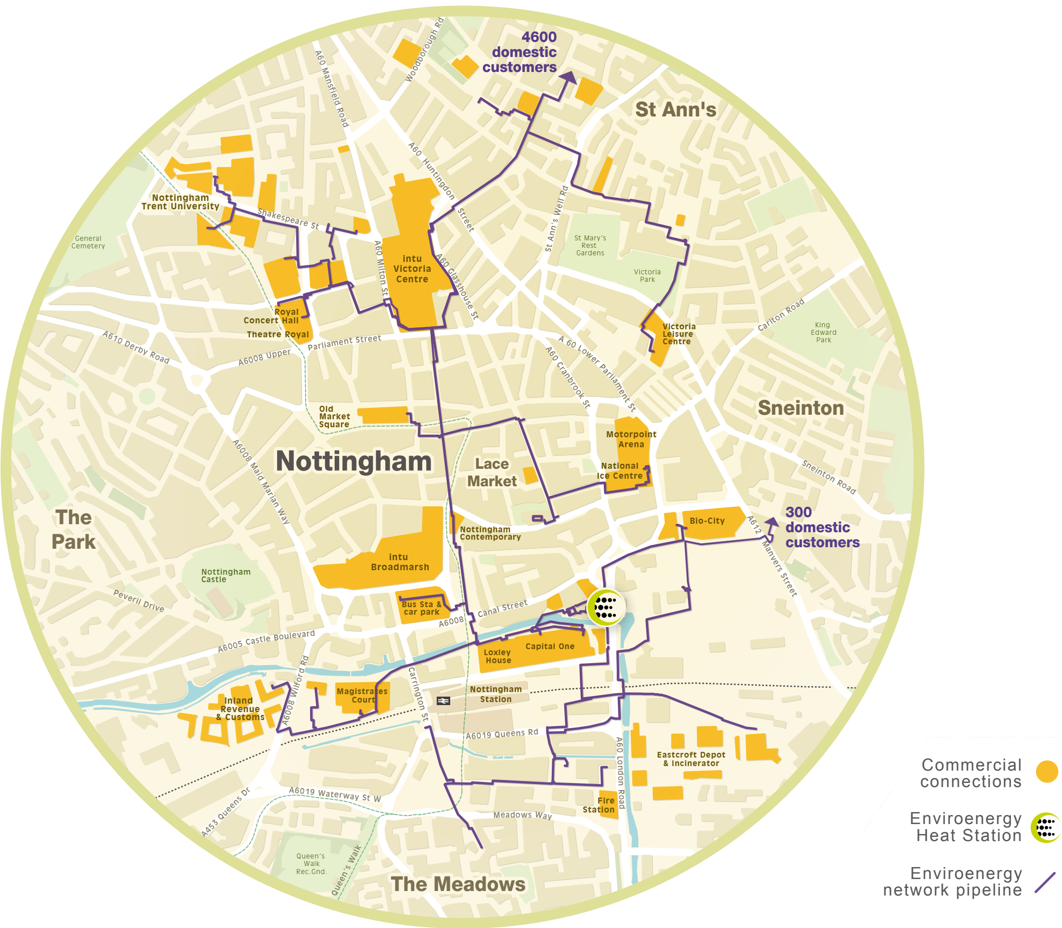

Figure 3 - District heating network for Nottingham

It was concluded that for the four partner cities, solar was the most important renewable energy resource and thus INSMART developed and implemented a methodology to assess the potential for installation of solar thermal panels and solar PV systems, both building integrated PV and utility scale PV (i.e.>1 MW). The methodology included a set of limitations to PV installation sites to be considered, such as spatial planning constraints, usually included in municipal policy documents (e.g. protected areas) for the case of utility-size potential (Figure 5) or the available suitable roof areas and angles in urban buildings for the case of rooftop potential. These limitations determine the extent of solar PV capacity to be installed, as well as the efficiency of electricity production (e.g. solar irradiation conditions for PV power productivity and thus the economic feasibility).

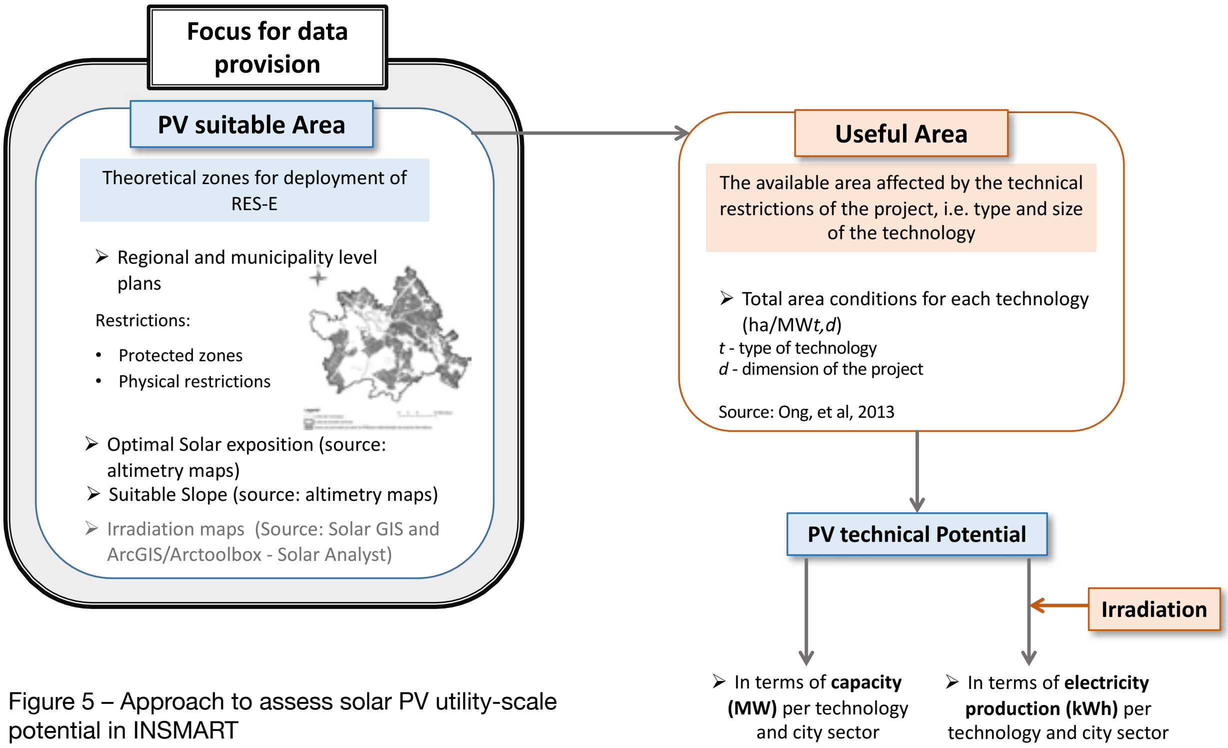

Figure 5 – Approach to assess solar PV utility-scale potential in INSMART

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Cities can provide meaningful amounts of renewable energy at affordable cost.

2.5 Use GIS technology to store and disseminate data

A Geographical Information System (GIS) can hold all ‘spatial’ and ‘spatial enabled’ information for each city. The City-GIS can then help to visualise all the energy indicators related to different sectors, to support decision making in selecting measures for sustainable city planning. Each city is divided in an appropriate number of city zones depending on the geographical characteristics, the buildings and mobility patterns, as well as the availability of data. The GIS presents:

- ✓ The 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
- ✓ The communication of energy information by publishing thematic energy maps for citizens, investors and planners in each city

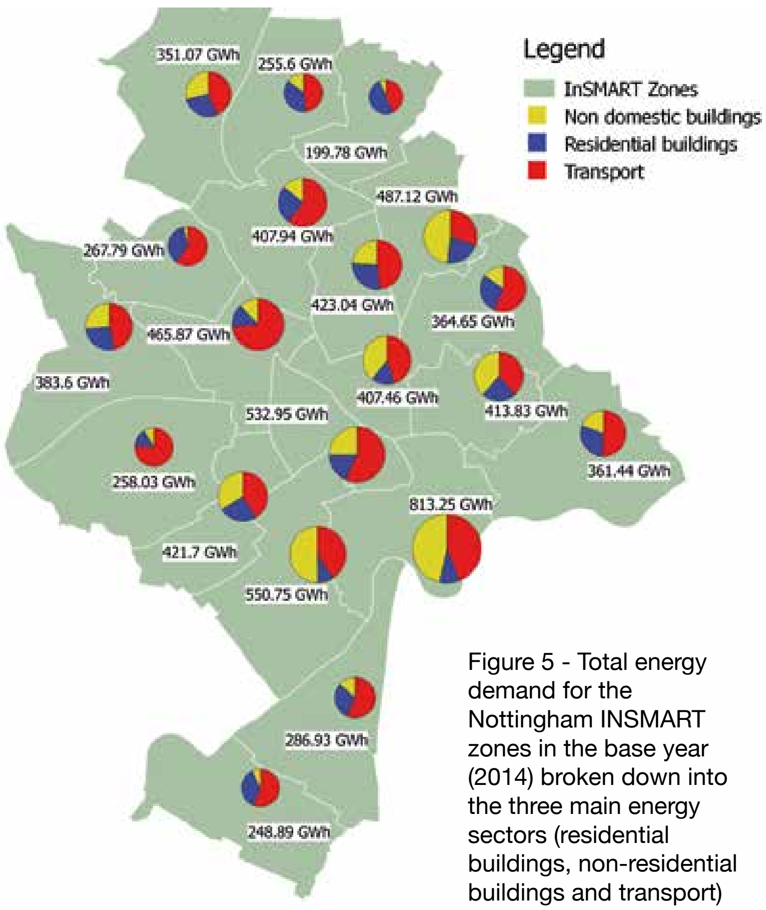


Figure 5 - Total energy demand for the Nottingham INSMART zones in the base year (2014) broken down into the three main energy sectors (residential buildings, non-residential buildings and transport)

Some of the insights that the GIS representation can provide include:

- ✓ The geographical representation of buildings’ energy demand can be used to identify regions of special interest (e.g. for district heating network expansion, expansion of natural gas networks, energy efficiency needs hotspots).
- ✓ The presentation of energy demand for transport identifies areas where high transport-related emissions appear, to be further targeted in more detailed analysis of alternative transport scenarios.
- ✓ The presentation of energy generation within the city (e.g. solar water heaters, solar PV panels) indicates areas that can operate at reduced demand from the electricity, heat or gas network.

Project Insight

Data availability and accessibility increases the awareness of all stakeholders to new and innovative sustainable energy options.

2.6 Implement 'Energy Systems Modelling' for integrated solutions

An integrated modelling tool is used to assess alternative plans (different actions or combinations of actions and measures over the energy system) towards the sustainable development of the cities, with a particular focus on the residential and transport sectors. The sophisticated energy system model is designed to be used as a test bed for exploring the evolution of different variables (both flows and technologies) in the energy system, at a city level and in smaller scale zones.

The structure of the city-model (Figure 6, below) makes explicit the representation of different building typologies (and of the refurbishment options), of the stock of appliances (e.g. boilers, lamps), and of the technology substitution (i.e. energy efficiency improvement, fuel switch) per each energy service demand (e.g. space heating and cooling, lighting, mobility). A "single agent" (household), placed in the dwelling and responsible for the investment decisions, demands a certain amount of "services" (e.g. space heating), that may be accomplished by selected cost-effective technologies (e.g. space heating, as listed in Figure 6, below).

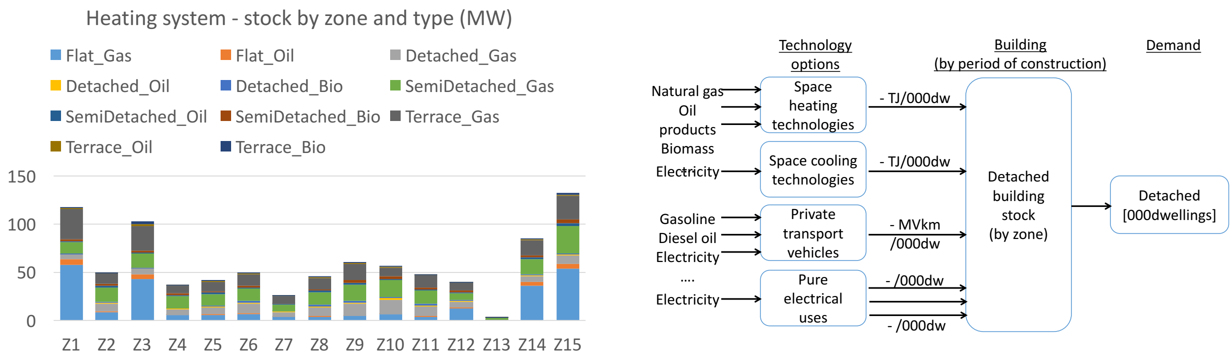
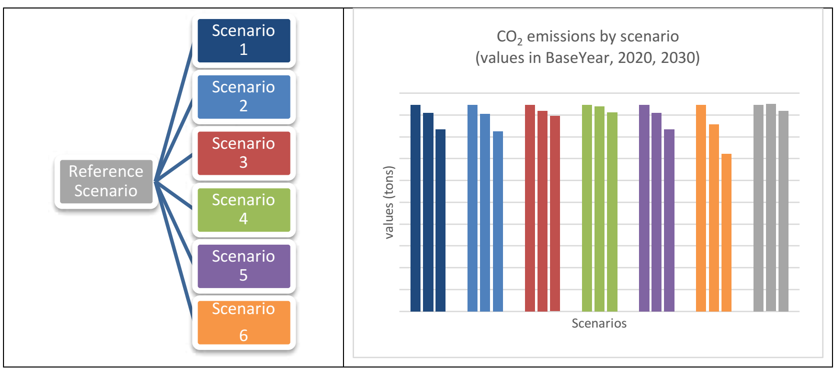


Figure 6 – Detailed representation of heating technologies (left), and scheme of the model (right).

A reference projection of the city energy system is calculated and then modified through a number of actions and measures aiming at representing alternative sustainable planning scenarios (Figure 7). The model returns the optimal (least-cost) energy and technology mix, together with the corresponding economic and environmental information, for each of the alternative scenarios. The benefits and trade-offs of the actions and measures can be evaluated by comparing the outputs of the integrated model among the different scenarios, and with respect to the reference scenario (no new policies) of the city energy system.



Project Insight

There are multiple configurations for a city's future energy pathway: integrated modelling tools assess which are the most promising.

Figure 7: Design of a number of scenarios (left), and dynamic responses of the model (right)

2.7 Deliver and disseminate concrete medium-term action plans

The prioritised measures identified through the MCDA with the stakeholders' participation over the modelling results, as described earlier, are used to formulate the cities' Sustainable Energy Action Plans.

In order that these plans are realistic, a pre-feasibility analysis of the economic viability of the near term measures is performed. Relevant funding schemes are identified and proposed and the relevant stakeholders (e.g. ESCOs, financial institutions) are made aware that applications may be forthcoming.

A detailed, realistic and applicable 10 year implementation plan that describes the necessary steps, required resources and monitoring procedures is then prepared for each city and is presented to all the city stakeholders.

Generic INSMART KPIs adapted by each city

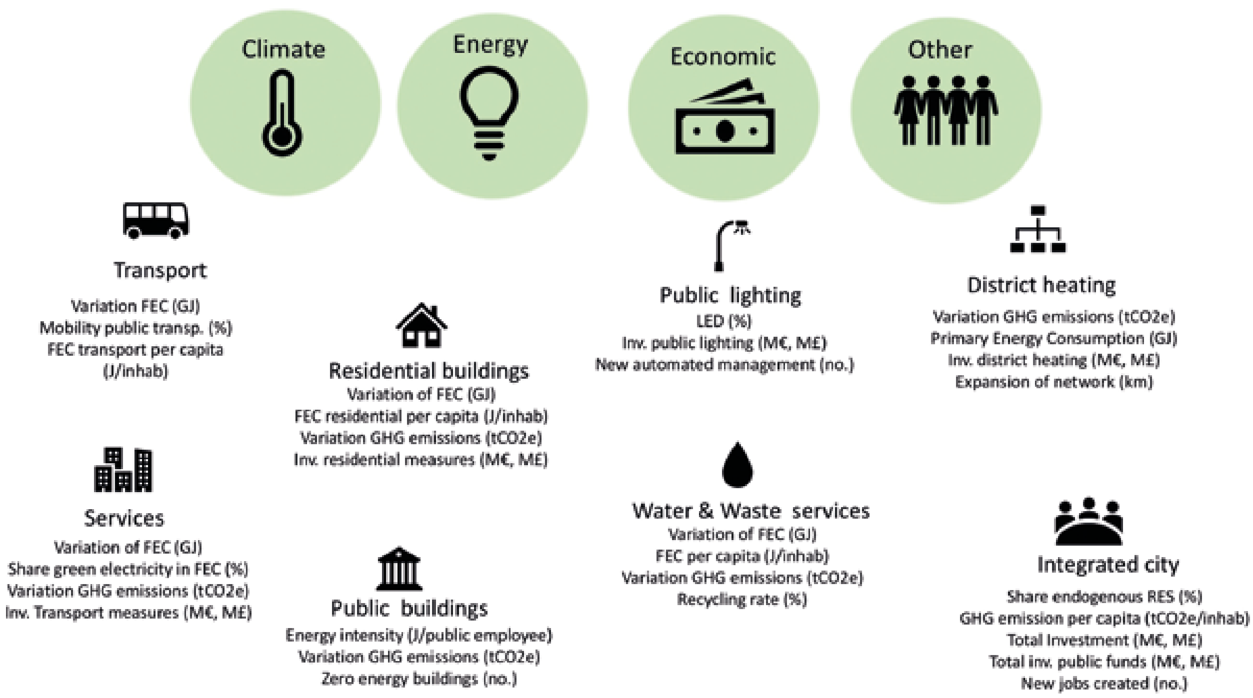


Figure 8: Examples of KPIs considered in INSMART and used in the Action Plans.

Project Insight

A detailed, realistic and applicable 10-year implementation plan, describing resources and monitoring requirements, is the best way to assure the city's future energy sustainability.

3

The INSMART Solution:

The experience of four European Cities

A doubly skilled team, with both scientific and municipal partners, fully implemented the INSMART solution for each of the four cities. The common methodology was adopted by all while retaining each city's own specific opportunities and challenges. Along the implementation process, a cross-fertilization among the four cities allowed the comparison of problems and solutions, in a continuous learning process, that proved effective for the conclusion of a technically robust and socially acceptable energy plan for each city.

The Four Cities

3.1 Cesena

ENERGY SYSTEM – Key results

Energy building consumption in 2013: 53.2 GJ /dwelling

Urban mobility needs in 2013: 89.85 GJ / dwelling

Energy use in city support sectors in 2013: 1.05 GJ / capita

CO_2 emissions in 2013 (direct emissions INSMART sectors): 3.71 t / capita

MID-TERM IMPLEMENTATION PLAN TO 2030

Measures to implement to promote Sustainable Energy (using the most-balanced energy scenario)

1. Residential buildings

Refurbishment of 25% of buildings currently with an energy rating equal or lower than class-E (over 130 kWh/m^2 year), to class-B (below 60 kWh/m^2 year).

How to achieve it by 2030 (key outcomes of the analysis):

- a) roof insulation in 8 600 dwellings.
- b) windows replacement in 5 800 dwellings.
- c) wall insulation of 5 150 dwellings.
- d) most cost-effective retrofit in “semi-detached” dwellings built before 1980.

2. Renewables

Increase by 30% (relative to 2013) the overall use of renewable energy for the production of decentralised heat and electricity in the city-system.

How to achieve this by 2030 using the key outcomes of the analysis:

- a) 5 300 kW of newly installed roof solar photovoltaic.
- b) 10 000 kW of newly installed solar water heaters.
- c) Extra investments are needed to supply extra CO_2-free energy into the system (e.g. production of 15 TJ from biogas plant).

3. Information campaigns

Strong “information campaigns” to support and inform citizens about objectives and opportunities for “rational” (energy-related) behaviour. Existing programs and services of “energy awareness” are maintained until the end of the horizon (2030), and a “new”, permanent, info-point aiming at providing information and recommendation to the community about energy-related investments, is opened by 2020.

Main Expected Achievements by 2030

Saved energy (with respect to the reference case): 135 TJ in Residential Buildings.

Reduction of CO_2 emissions from base year (direct emissions of the INSMART sectors): 31%, and from the reference year of the exiting SEAP (1995): 17%.

CO_2 emissions per capita covered by the analysis reduces to 3.2 in 2020 and to 2.5 in 2030 (t/capita).

Additional action (possible, to further enhance emissions reduction):

a. Completion of cycle paths (for a total of 16 km) along the main road network and within the so-called “areas 30”, to favour the use of bicycles in daily home-school and home-work trips.

b. Realization of “environmental” bike paths along the River Savio for cycling tourism (for a total of 87 km) and to connect areas of low population density.

The enhancement of the strategy (mid-term plan based on measures 1+2+3) with an extra measure (on transport) would be able to lower the emissions covered by the INSMART sectors by around 20% (based on values in 1995).

Additional Action Achievements by 2030

Extra saved energy (with respect to the reference case): 140TJ in Transport, (if the “enhanced” strategy is implemented).

Lessons Learnt or Key Innovations achieved with INSMART

The INSMART project helped the Municipality of Cesena to define improved standards and adopt best practices in order to simplify a complex path into one integrated path that is easier to follow.

The support and commitment of all involved areas inside City Hall is key to success. It is necessary not to impact their day-to-day work too much but at the same time, generate some value for the contribution they provide. Thanks to Cesena’s participation in other European sustainability projects, there is already good collaboration between different municipal sectors. Participation in the INSMART project has increased the awareness that only a multi-disciplinary team is able to identify and establish synergies, may avoid data and functions overlaps, and contributes to better design of policies and instruments.

The multi-model approach used in the project has provided a rationale for involving a multi-disciplinary team. By including all the relevant sectors and views in the same storyline at the outset, the response (the minimization of the whole energy system costs coupled with a ranking analysis) delivered by the methodology has ensured “effectiveness” and “integration”. Furthermore, the multi-criteria analysis, through the involvement of key public and private stakeholders and public authorities at city level, paved the way to convergence around, and support for, the selected solutions.

This approach will be used to provide a screening and update of the already available Sustainable Energy Action Plan (SEAP), as well as to develop the new Sustainable Energy and Climate Action Plan (SECAP) of Cesena, resulting in a high expectation of success for its implementation and achievement of realistic targets.

The Four Cities

3.2 Évora

ENERGY SYSTEM – Key results

Energy building consumption in 2013: 16.73 GJ /dwelling

Urban mobility needs in 2013: 38.21 TJ / dwelling

Energy use in other sectors in 2013: 1.83 GJ / capita

CO_2 emissions in 2013: 3.71 t / capita

MID-TERM IMPLEMENTATION PLAN TO 2030

Measures to implement to promote Sustainable Energy

1. **Public lighting:**
   - a) 100% of luminaires using LED in 2030 (from baseline of 0.4% of public lighting in 2014).
2. **Residential buildings**
   - a) Review existing municipal programs for private building renovation in the historic centre and provide access to credit schemes for residential owners towards passive energy efficiency measures in the building envelope.
3. **Transport and Mobility:**
   - a) Increase bike lanes: short-term implementation of 7km Bacelo-PITE bike lane, combined with making available public bicycles.
   - b) Double parking fees in historic centre from 2020 onwards.
   - c) Restriction of traffic to the Acropolis at the historic centre from 2020 onwards, except for residents and merchants.
   - d) Reduce traffic speed in most of the residential area outside the historic centre, to 30km/h, from 2020 onwards.
   - e) Increase car parking areas in the historic centre with 3 parking lots with a total of 500 parking spaces for non-residents, from 2020 onwards.
   - f) Add 300 more street parking places in the historic centre for residents from 2020 onwards.
   - g) Negotiate with bus company to change fleet to buses running exclusively on biofuels, from 2030 onwards.
   - h) Negotiate with bus company to review the conditions of the concession, in order to increase the frequency of public transport between the train station and the Industrial Aeronautic Area.
4. **Waste:**
   - a) Increase the share of urban waste collected for recycling up to 35% from 2020 onwards making use of information campaigns (currently, the goal is 24% by 2020).
   - b) Install computer management of waste collection operated by the municipal services.
   - c) Reduce waste produced per capita by 20% from 2013 to 2020 making use of information campaigns.

5. **Municipal buildings and fleet:**

a. Study in detail the available options to reduce energy consumption in buildings, and vehicles directly managed by the municipality

Main Expected Achievements by 2030

Saved energy in 2030 compared to a Baseline scenario: 5,918 GJ in Residential Buildings 37,285 GJ in Transport (savings in transport varies if biodiesel buses measure is considered)

Share of Renewable Energy in Final Energy Consumption 2013 and 2030: 15-20% (second value in 2030 assuming the implementation of 100% biodiesel buses)

Reduction of CO_2 emissions from base-year: 21-22%

Variation in CO_2 emissions per capita from base-year: 7% lower

Lessons Learnt or Key Innovations achieved with INSMART

Innovation in the city's energy system knowledge

- Improved knowledge on energy consumption, in particular for electricity consumption in the residential sector, supported by an in-depth analysis of smart meter data. As a spin-off to this it was possible to:
  - characterize fuel poor consumers.
  - identify complementarities between potential PV generated electricity and daily consumption profiles of end-users in commercial, residential and industry sectors.
- Detailed characterization of the residential building stock, through building typologies and in-depth assessment of its energy saving potential.
- Detailed mapping of solar thermal and solar PV technical potential (first city in Portugal with this information).
- Mobility analysis, including for major infrastructure planned (the new ring road or shopping malls) and modelling of impact of transport-related measures.

Innovation in the city's energy system planning

- Involving external stakeholders in the energy planning process of the city whereas before only municipal staff were doing this task. This clearly promoted synergies, by considering new perspectives on visioning the future of the municipality and increased awareness of energy planning.
- Thinking ahead about energy consumption in Évora as an "integrated urban energy system" highlighted new priorities instead of those traditionally taken under municipal management, which is a challenge for a new generation of local energy policies.
- The use of methods such as MCDA and engaging different groups of external stakeholders enabled convergence around a set of sustainable energy measures that are both scientifically sound and socially acceptable for the future of the municipality.

The Four Cities

3.3 Trikala

ENERGY SYSTEM – Key results

Energy building consumption in 2012: 58.42 GJ /dwelling

Urban mobility needs in 2012: 54.08 GJ / dwelling

Energy use other support sectors in 2012: 1.45 GJ / capita

CO_2 emissions in 2012: 1.12 t / capita

MID-TERM IMPLEMENTATION PLAN TO 2030

Measures to implement to promote Sustainable Energy

1. **Public lighting:**
   a. Replace all existing sodium lamps in street lighting with LED by 2030.
2. **Buildings**
   a. Connect 80% of the buildings within the municipality (residential and non-residential buildings) to the natural gas network by 2030
3. **Transport and Mobility:**
   a. Increase cycle lanes by 2.8kms in the next 3 years and by an extra 10km by 2025.
   b. Construct a new ring road around the city by 2020 which will lead to a reduction of transport demand through the city centre and a corresponding decrease in fuel consumption and emissions.
   c. Provide incentives for the promotion of electric and hybrid cars in the city including free parking in the city centre for these cars and an increase in the cost of access to the city centre for conventional cars.
   d. Replace existing municipal small vehicles by electric cars by 2025 and replace all heavy duty municipal vehicles by Euro 6 vehicles by 2030.
   e. Implement a programme for the development of green spaces in all city squares and open spaces, to help reduce cooling demand in nearby buildings by 5% by 2030.
4. **Waste:**
   a. Interventions in the municipal sewage treatment plant by 2020 to reduce energy consumption by 25%.
5. **Municipal buildings and fleet:**
   a. Refurbishment of all municipal buildings (following the example of the first sixteen buildings that will be refurbished in the next five years) leading to the reduction of heating and cooling loads and the improvement of lighting installations (reduction of energy consumption and improvement of comfort levels).

Main Expected Achievements by 2030

Saved energy: 51,098 GJ/year in Residential Buildings, 7,540 GJ/year in Transport

Reduction of CO_2 emissions from base year only with the measures above: 9%

Variation in CO_2 emissions per capita from base year: 15% lower

Lessons Learnt or Key Innovations achieved with INSMART

Several useful outcomes have resulted from Trikala's participation in the INSMART project. The primary benefit has been how the INSMART model has calculated a baseline for the urban energy system in 2012, and demonstrated how local activities impact on energy demand. In this respect, the municipality realized that each intervention that it undertakes has an energy "footprint", which has to be estimated, especially under the lens of the policies that the municipality has signed and is obliged to respect (i.e. the Covenant of Mayors).

Another important outcome concerns the evolution of the local energy system. Even in the current

economic environment the city continues to grow steadily and energy demand increases and its estimation for 2030 is extremely useful to the local political leadership. In this respect, the INSMART project demonstrated how the energy system can be affected by policy making and the estimated outcomes can be compared with the baseline. This comparison showed the municipality that the interventions it plans should be reviewed for their impacts on energy. For instance, project results showed that although public buildings' energy and public lighting upgrades return important energy savings, the outcome at a city level is limited overall and hence the wider community has to be encouraged to follow suit.

Finally, the city realised that improving the urban energy system requires the participation of all local stakeholders and for their opinions to be taken into account. All the stakeholders benefitted from their involvement in this innovative approach and similar debates will be held whenever further energy planning occurs in Trikala.

In conclusion the city of Trikala gained extremely useful knowledge from its participation in the INSMART project. The municipality plans to undertake initiatives in order to disseminate these outcomes to other cities, both via the Greek cities' community (KEDE) and through several coalitions in which Trikala is a participant.

The Four Cities

3.4 Nottingham

ENERGY SYSTEM – Key results

Energy building consumption in 2014: 49.95 GJ /dwelling

Urban mobility needs in 2014: 80.06 GJ / dwelling

Energy use in other sectors in 2014: 0.42 GJ / capita

CO_2 emissions in 2014: 3.6 t / capita

MID-TERM IMPLEMENTATION PLAN TO 2030

Measures to implement to promote Sustainable Energy

1. Residential buildings

a. Support local householders to reduce their energy use by installing insulation (cavity wall and loft) in all the suitable uninsulated properties in the city.

b. Set up a programme to assist residents in increasing the energy efficiency of their homes through the implementation of basic draught-proofing measures to reduce heat loss.

c. Promote the development of zero/low carbon housing for all new residential developments in the city

2. Transport and Mobility

a. Carry out major upgrades to the city's cycle network and implement a range of other measures designed to inspire residents to switch from motor vehicles to cycling as their primary mode of local transport.

b. Support a shift to electric and low carbon vehicles in the city by 2030. This will be achieved through a combination of improved infrastructure (a greatly expanded charging network), incentive schemes to support a switch to electric vehicles, highway priority routes for electric vehicles and the introduction of a city centre low carbon zone.

c. Double the price of car parking in the city centre (by 2030) to reduce congestion, improve air quality and provide funding for other transport improvements.

d. Convert the city's bus fleet to electric vehicles and improve highway infrastructure in the south of the city to facilitate faster journeys by public transport.

3. Energy

a. Upgrade the city's district heating network to enable a major expansion of residential and commercial customers.

b. Encourage the setting up of combined heat and power generators for local communities using biomass burners at suitable locations.

c. Install large scale solar energy generation at municipal sites such as schools, leisure centres and car parks.

Main Expected Achievements by 2030

Saved energy:	**Residential Buildings - 650 TJ**
	Transport - 3,000 TJ City only
	4,400 TJ Travel to work area

Reduction of CO_2 emissions from base year: 21.17%

Variation in CO_2 emissions per capita from base year: 28.51% lower

Lessons Learnt or Key Innovations achieved with INSMART

- The UK national datasets relating to energy from buildings are not accurately reflective of energy used. The INSMART surveys and datasets have provided more robust energy use data which is more reflective of the energy use within the domestic sector.
- INSMART has demonstrated that Nottingham City Council's strategic direction on energy and transport is sustainable and robust.
- In terms of the privately rented housing sector, then there is considerable investment required in relatively simple insulation measures. This is a gap as there is no UK funding currently available for private rented accommodation.
- A further study of non-residential energy use is required, as there are various unknown factors and hence further scope for improvement. The two main data sources, such as national datasets, and CIBSE benchmarks, provide completely different sets of results in energy used, which makes planning for future energy in the non-domestic sector difficult.
- The multi criteria decision analysis (MCDA) tool provides a good process for decision making between multiple scenarios.
- The biggest potential CO_2 reduction comes from reduced car use.
- Understanding who the local stakeholders are and finding out their views has been helpful in planning Nottingham's sustainable energy future and has provided a basis for future partnership working.
- Having a comprehensive understanding of Nottingham's building typologies and making this available via GIS mapping will greatly assist Nottingham in its future plans.

4 The Contribution from the INSMART Technical Partners

CRES is the Greek national centre for Renewable Energy Sources and Energy Saving. Its main goal is the promotion and support of related activities taking into consideration the environmental impacts of energy supply and use. CRES has special knowledge and experience in analysis of building stock and urban spaces as well as in identification of supply potential from RES and other distributed resources. Moreover, it conducts planning scenarios and action plans for the Greek state, providing feasible solutions for the achievement of national targets.

For CRES, INSMART offered the opportunity to apply these advanced planning methodologies on a local / city level.

The University of Nottingham (UoN) is ranked 75th in the world and in the top 1% of Universities internationally by the latest (2016) QS World University Rankings. UoN is a major international centre for energy research, with a reputation for excellence across a broad range of research and technology-based activities. Research into the sustainability of cities in one of UoN's research priority areas.

The InSMART programme represents a significant step forward in this field and is also part of ongoing efforts to forge stronger research links between the university and the city of Nottingham.

SYSTRA provides advice on transport, environment and other policy areas to central, regional and local government, agencies, developers, operators and financiers throughout Europe. They offer support on complex issues concerning the location and movement of people and have significant experience in the development of transport strategies aimed at minimising energy consumption and the effects on the environment.

For the INSMART project SYSTRA assessed the energy and carbon implications of the transport networks of the four cities and provided advice on initiatives to minimise the energy usage of travel across a wide range of scenarios.

EDP Distribuição smart grid project-InovGrid is the example of a new paradigm in the management and operation of distribution networks and customer relations. For the consumer, the ability to understand their consumption patterns and act before this information, both in terms of energy efficiency measures and behavior, is something completely new. It demonstrates that a properly developed integration tool can facilitate the integration of DG, resulting in a more efficient use of energy and a reduction in CO2 emissions, without compromising security or quality of service.

InovGrid and INSMART have set a clear path for the integration on a European scale, of renewable and DER in electricity distribution networks with participation from end-users.

Faculdade de Ciências e Tecnologia da Universidade NOVA de Lisboa (FCT) Faculdade de Ciências e Tecnologia da Universidade NOVA de Lisboa (FCT) is one of the most prestigious Portuguese public schools of science and engineering. CENSE research centre is devoted to interdisciplinary research in environmental sciences and engineering with extensive experience on research and policy support using energy-environment modelling towards sustainable low-carbon energy systems.

Within INSMART, FCT mapped the energy consumption of the city's support systems, developed the approach to assess the cities RES potential, and implemented INSMART in Évora. The innovative combination of tools complemented FCT's modelling expertise and its skills in the context of developing local sustainable energy pathways.

E4SMA ltd provides consulting services in the areas of energy planning, policy and environment. The main area of expertise is in supporting the creation and use of energy / environmental / economic models, or ad-hoc tools and methodologies, for medium-long term analysis helping energy decision makers to evaluate a range of challenges at different geographic scales.

Within INSMART, E4SMA supported the design of an innovative and replicable modelling framework to explore and compare multiple future energy-environmental scenarios of an urban system, and the application of the integrated energy decision support system to the project cities.

DEYAT is the Water Utility Provider for Trikala. They participated in this project on behalf of the city of Trikala. DEYAT has special knowledge and extensive capacity in ensuring water efficiency for the Municipality of Trikala and in adopting innovative technology. DEYAT adopted the INSMART energy model to measure and evaluate the energy consumption of its systems and collaborated with the local stakeholders in evaluating and prioritising energy efficiency policies for the city of Trikala for 2030.

Conclusions

Over the last three years, four cities and six technical partners worked together on the INSMART project in order to develop and test a new methodology for sustainable energy planning for municipalities in European cities.

The methodology offers cities an integrated and participatory process to examine all the energy consumption sectors together with potential local energy generation options and come up with a smart development plan for energy that is supported by all stakeholders.

The methodology is described here and in more detail on the INSMART website and is freely available to use in any city by the municipality and its local stakeholders. It can be integrated into the process of developing a Sustainable Energy Action Plan or a Sustainable Energy and Climate Action Plan by municipalities participating in the Covenant of Mayors for Climate and Energy and offers the advantage of concrete scientific approaches in local energy planning[1].

The INSMART project tools, experiences and achievements may facilitate and support the deployment of local sustainable solutions and decision-making in cities across Europe, contributing to the realisation of the EU's energy and climate goals.

InSmart methodology makes use of a well-orchestrated set of tools to identify the optimum mix of short, medium and long term measures for a sustainable energy future, addressing the efficiency of energy flows across various city sectors with regards to economic, environmental and social criteria and paving the way towards actual implementation of priority actions and a more sustainable city planning. Each city´s energy system was analyzed through surveys, models, smart meters data analysis, using a Geographic Information System energy database, and options for the future were assessed and evaluated by local stakeholders through multi-criteria methods supporting a local energy planning process.

[1] The introduced methodology has been accepted by the International Telecommunications Union (ITU) Study Group 5 (ITU-T SG5), which works on the development of a standard for Environment and circular economy and it has planned to incorporate it in its standard with the title "A Standardized Process for Energy Efficiency Policy Making at cities level" on May, 2017.

INSMART
Integrative Smart City Planning

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